Vld CRDI
for Kodiak

Environmental Assessment of the Alaskan Continental Shelf

Final Reports of Principal Investigators
Volume 13. Biological Studies

U.S. DEPARTMENT OF COMMERCE
National Oceanic & Atmospheric Administration
Office of Marine Pollution Assessment

U.S. DEPARTMENT OF INTERIOR
Bureau of Land Management

October 1981

Environmental Assessment of the Alaskan Continental Shelf

Final Reports of Principal Investigators
Volume 13. Biological Studies

U.S. DEPARTMENT OF COMMERCE
National Oceanic & Atmospheric Administration
Office of Marine Pollution Assessment

U.S. DEPARTMENT OF INTERIOR
Bureau of Land Management

October 1981

The facts, conclusions and issues appearing in these reports are based on interim results of an Alaskan environmental studies program managed by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) of the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce, and primarily funded by the Bureau of Land Management (BLM), U.S. Department of Interior, through interagency agreement.

DISCLAIMER

Mention of a commercial company or product does not constitute an endorsement by National Oceanic and Atmospheric Administration. Use for publicity or advertising purposes of information from this publication concerning proprietary products or the tests of such products is not authorized.

TABLE OF CONTENTS
Volume 13 - Biological Studies

RU	PI/Agency	Title	Page
332	McCain, B.B. et al. -Northwest and Alaska Marine Fisheries Center Seattle, WA	Determine the Frequency and Pathology of Marine Fish Diseases in the Bering Sea, Gulf of Alaska, Norton Sound, and Chukchi Sea	001
359	Horner, Rita A. Private Consultant Seattle, WA	Beaufort Sea Plankton Studies	065
423	Ainley, D.G. et al. -Pt. Reyes Bird Observatory Stinson Beach, CA	Influence of Petroleum on Egg Formation and Embyronic Development in Seabirds	315
551	Dunn, J.R. et al. -Northwest and Alaska Marine Fisheries Center Seattle, WA	Seasonal Composition and Food Web Relationships of Marine Organisms in the Nearshore Zone- Including Components of the Ichthyoplankton, Meroplankton, and Holoplankton	357
551	Kendall, A.W. et al. -Northwest and Alaska Marine Fisheries Center Seattle, WA	Taxonomic Composition, Seasonal Distribution, and Abundance of Ichthyoplankton in the Nearshore Zone of the Kodiak Archipelago, Alaska	777

DETERMINE THE FREQUENCY AND PATHOLOGY OF MARINE FISH DISEASES IN THE BERING SEA, GULF OF ALASKA, NORTON SOUND, AND CHUKCHI SEA -

by

Bruce B. McCain*
Harold O. Hodgins*
Albert K. Sparks*
William D. Gronlund*
Mark S. Myers*

Submitted as a Final Report
for Contract #R7120817
Research Unit #332
OUTER CONTINENTAL SHELF ENERGY ASSESSMENT PROGRAM
Sponsored by
U.S. Department of the Interior
Bureau of Land Management

January, 1980

* Principal Investigators, Environmental Conservation Division, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard East, Seattle, Washington 98112

TABLE OF CONTENTS

Page

I. SUMMARY OF OBJECTIVES, CONCLUSION, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT------------------------ 4

A. SUMMARY OF OBJECTIVES------------------------------------ 4

B. SUMMARY OF CONCLUSIONS----------------------------------- 4

C. IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT--- 4

II. INTRODUCTION--- 4

A. GENERAL NATURE AND SCOPE OF STUDY------------------------ 4

B. SPECIFIC OBJECTIVES------------------------------------- 5

C. RELEVANCE TO PROBLEMS OF PETROLEUM DEVELOPMENT------------ 5

III. CURRENT STATE OF KNOWLEDGE------------------------------ 5

IV. STUDY AREA-- 6

V. SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION------------ 6

VI. RESULTS--- 7

A. DESCRIPTIONS OF FISH DESEASES---------------------------- 8

1. <u>Pseudobranchial Tumors of Gadids</u>---------------------- 8

2. <u>Skin Ulcers of Pacific Cod</u>---------------------------- 9

3. <u>Epidermal Papillomas of Pleuronectids</u>----------------- 10

4. <u>Lymphocystis of Yellowfin Sole</u>------------------------ 11

5. <u>Epithelioid Tumors of Pacific Ocean Perch</u>-------------- 12

6. <u>Parasitic Infestations</u>-------------------------------- 13

B. INVERTEBRATE DISEASES----------------------------------- 13

1. <u>Norton Sound/Chukchi Sea</u>------------------------------ 13

2. <u>Kodiak Island</u>-- 14

VII. DISCUSSION--- 14

A. BERING SEA-- 14

TABLE OF CONTENTS
(Cont.)

		Page
	B. NORTON SOUND/CHUKCHI SEA	15
	C. GULF OF ALASKA	16
VIII.	GENERAL CONCLUSIONS	17
IX.	NEEDS FOR FURTHER STUDY	17
X.	REFERENCES USED	18
XI.	LIST OF TABLES	20
	FIGURES	27

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

A. SUMMARY OF OBJECTIVES

The overall objectives are to determine the frequency and pathology of marine animal diseases in the Bering Sea and Gulf of Alaska (GOA).

B. SUMMARY OF CONCLUSIONS

Of the approximately 60 species of fish (representing 130,000 individuals) examined in the Bering Sea, Chukchi Sea, Norton Sound, and GOA, only nine species had pathological conditions. Of the seven types of pathological conditions found, three were tumorous growths, three were lesions presumably caused by microorganisms and one was a parasitic infestation. Invertebrates were examined for pathological conditions in only two areas, the Norton Sound/ Chukchi Sea area (25,000 animals) and the Kodiak Island region of the GOA (3,000 animals). In the Norton/Chukchi Sea area, of the approximately 35 invertebrate species examined, 10 had detectable abnormalities, whereas only five of 45 invertebrate species examined in the GOA had detectable pathological conditions. Six of the conditions observed were parasitic infestations, two were fungal infections, and the remaining two conditions were of unknown etiology.

The types of pathological conditions detected in marine animals in Alaskan waters during this study were generally chronic conditions, for example, tumorous growths and parasitic infestations. Animals with such disorders would be expected to live longer than animals affected by acute diseases. Therefore, the types of pathological conditions described here probably represent only a portion of the abnormalities in marine animal populations in Alaskan waters, and the prevalences of disease in species of these areas is predictably higher than was observed.

C. IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

These field studies have increased our knowledge of the health status of demersal species near Alaska's outer continental shelf (OCS). Therefore, in the aftermath of possible incidents of petroleum-related contamination of Alaska's OCS, the finding of high frequencies of diseased fish and invertebrates alone will not be sufficient to demonstrate that harmful effects have occurred.
In addition, information has been gained concerning those marine species that have relatively high or low incidences of disease and which diseases seem most closely correlated or least closely correlated with man's activities.

II. INTRODUCTION

A. GENERAL NATURE AND SCOPE OF STUDY

The purpose of this investigation was to obtain baseline data on the prevalence, distribution, and characteristics of diseases presently existing in fish and invertebrates in the Bering, Beaufort, and Chukchi Seas, Norton Sound, and GOA. This effort required both field and laboratory activities. Field activities were performed in cooperation with the Resource Assessment and Conservation Engineering Division (RACE), Northwest and Alaska Fisheries Center (NWAFC), Seattle, Washington (OCSEAP R.U. #175) or Alaska Department of Fish and Game (ADFG) (OCSEAP R.U. #552).

Animals captured by these agencies as part of other environmental assessment studies were examined for externally visible pathological conditions. The biological and pathological characteristics of each affected animal were determined.

B. SPECIFIC OBJECTIVES

The specific objectives of this investigation were: (1) determine the nature and frequency of each major type of pathological condition in demersal fishes and invertebrates in the sampling area; (2) establish the geographical distribution of each disease; (3) define the histopathological features of each disease by examining tissues from surface lesions and associated major internal organs and blood, using procedures designed for light and/or electron microscopy; (4) isolate disease-associated microorganisms from surface lesions and internal tissues, use taxonomic tests to identify them, and determine if any microorganism is disease specific; and (5) compare the size, weight, age, and sex of diseased animals with those of normal-appearing animals of the same species.

C. RELEVANCE TO PROBLEMS OF PETROLEUM DEVELOPMENT

The research described in this report is relevant in two main ways to understanding the effects of petroleum development on the marine animals in the waters of Alaska's OCS regions. The most important contribution is to provide data on the present health of demersal fishes and invertebrates prior to the time when possible environmental impacts of oil drilling occur, so that future effects of oil exploration on marine animals can be assessed. Also, knowledge of the possible causes of pathological abnormalities in demersal animals will provide a clearer understanding of the ways in which exposure of an organism to oil could directly or indirectly affect the frequency and distribution of pathological conditions.

III. CURRENT STATE OF KNOWLEDGE

Very little was known concerning the health status of marine fish and invertebrates in Alaskan waters prior to our OCSEAP-supported investigations initiated in 1975. Turner (1886) reported observing skin tumors (probably epidermal papillomas) on starry flounder (*Platichthys stellatus*) and Arctic flounder (*Liopsetta glacialis*) in the Aleutian Islands. In the early 1960's, Levings (1967) observed epidermal papillomas on approximately 10% of the rock sole captured in Bristol Bay and the western Gulf of Alaska. In some cases, these skin tumors were seen to cover almost 50% of the body surface.

Published accounts of abnormalities in Alaskan invertebrates include a report by Sparks and Pereyra (1966) which described shrimp of the family Hippolytidae parasitized by an isopod. Van Hyning and Scarborough (1973) isolated fungi from tanner crabs (*Chionoecetes* sp.) having "black mat" disease, a condition consisting of a tar-like covering on the exoskeleton. Another important Alaskan crab, the king crab (*Paralithodes* sp.), was reported by Bright et al. (1960) to have a condition known as "rust disease," which caused a darkening and softening of the exoskeleton. Although chitin-destroying bacteria were found associated with "rust disease," the cause is not yet known.

IV. STUDY AREA

Five main geographical areas of Alaskan waters were investigated. The latitude and longitude boundaries of these study areas, and the figures in this report in which each area is depicted are as follows:

	N. Latitude	W. Longitude
A. Bering Sea (Fig. 6)	-54°41' to 58°46'	168°38' to 174°32'
B. Chukchi Sea (Fig. 33)	-65°46' to 68°18'	168°48' to 162°2'
C. Norton Sound (Fig. 33)	-63°4' to 65°32'	171°51' to 161°15'
D. Gulf of Alaska (Fig. 5)	-58°21' to 56°34'	149°4' to 152°32'
E. Kodiak Island (Fig. 20)	-56°40' to 58°15'	152°15' to 154°18'

V. SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION

The sampling and data collection were carried out on the following vessels: NOAA Ship Miller Freeman; Polish research ship Professor Siedlecki; U of W FRI research vessel Commando; and the ADFG charter vessel Yankee Clipper. The characteristics of the ships, sampling gear, and methodology used aboard these platforms are outlined in Table 1. Also included is a summary of the time and location of sampling for each vessel. Demersal fish and epibenthic invertebrates were sorted according to species, and subsamples were examined for externally visible pathological conditions and, when feasible, for readily recognizable internal disorders. The following information was recorded for each haul in the Haul Data Sheet: haul number, date, number of animals examined of each species, sex, the type of pathological condition for each species and often each sex.

Animals with apparently abnormal conditions were processed while still alive or freshly dead. Each animal was assigned a specimen number and the following information was recorded on the Individual Data Sheet: species, sex, dimensions (length for fish), weight, method of age determination (otolith or scale, applicable to fish only), pathological condition, and location and size of the condition(s).

Photographs were taken of representative and unusual pathological conditions. Fish samples were preserved in 10% formalin with phosphate-buffered saline and invertebrates were kept in a 10% formalin and seawater solution. Specimens were also preserved in a special fixative for electron microscopy (Hawkes 1974). Small numbers of invertebrates lacking external lesions were routinely collected for examination of microscopic lesions of internal organs. In some cases, tissue was frozen at -20°C or in liquid nitrogen (-196°C) for later microbiological procedures. Bacteria or fungi inside lesions, tumors, and internal organs were isolated by cauterizing the surface of the tissue to be sampled, opening the tissue with a sterile scalpel, removing an inoculum with a sterile loop, and streaking the inoculum in petri dishes containing bacteriological medium. Media used included Ordal's Seawater Cytophaga Agar (OSCA), brain-heart infusion agar (Difco*, dissolved in seawater), or potato dextrose agar with penicillin and streptomycin. In addition to streaking the inoculum onto agar media, a portion of some inocula was spread onto a glass microscope slide and Gram stained. Representative colonies growing on the culture media were purified by restreaking, stored in tubes containing OSCA, and returned to the laboratory for further tests.

Laboratory activities involved processing the specimens and data obtained in the field. Tissue specimens from animals with the main pathological conditions to be examined histologically were matched with the photographic colored slides showing the gross appearance of the lesions.

Tissues to be examined by light microscopy for histopathology were embedded in paraffin, sectioned with a microtome, and the sections were stained by a variety of methods, including hematoxylin and eosin, Oil-Red-O, Sudan black and Masson's trichrome. Microscopic examination of sections from diseased tissue and major organs allows for determination of abnormalities of tissue structure, the types of cells involved, and the presence or absence of intracellular or extracellular microorganisms.

Tissue was to be examined electron microscopically, which had been previously preserved in 2% glutaraldehyde, and was treated with osmium tetroxide, dehydrated in absolute ethanol, embedded in Spurr's Low Viscosity Epoxy Resin and sectioned on a MT2B Dupon-Sorvall microtome. Sections were examined with either a Ziess EM95 or an AEI-EM801 electron microscope. Examination of tissue in this manner allows detection of intracellular damage, identification of disease-specific cells, and observation of virus particles.

Modified procedures were used for histological examination of crabs. Individuals selected for necropsy were rapidly bled by removal of all legs; portions of the carapace were removed to expose the underlying soft parts; and small random samples of the following organs of tissues excised and fixed in Helly's or Davidson's Fixative: gill, hepatopancreas, ovary or testis and vas deferens, epidermis, heart, bladder, hemopoetic tissue, cardiac stomach, esophagus, anterior and posterior caecum, pyloric stomach, midgut and ampulla, antennal gland, mandibular organ, brain, and thoracic ganglion. The entire eye stalk was also removed as were affected portions of the carapace of some crabs with the underlying epidermis still attached; these were fixed in Helly's and subsequently decalcified in Davidson's Fixative. The tissues were dehydrated and embedded by standard methods, sectioned at 6-10 um, and stained with the following: Harris-Modified Hematoxylin and Eosin (H & E), Grocott's Method for Fungi (GMS) and, in some instances, Gridley's Fungus Stain.

Bacterial isolates were characterized using standard taxonomic criteria, such as cell morphology, colony color and morphology, oxidase activity, behavior in oxidation-fermentation media, and motility.

Scales and otoliths from diseased fish were examined and age determinations were made. This data was added to the information contained on the Individual Data Sheet.

VI. RESULTS

Over 130,000 demersal fish and 28,000 epibenthic invertebrates have been examined from the continental shelf of Alaska for externally visible pathological conditions. Of the 60 species of fish examined, only nine were found with recognizable abnormalities (Table 2). The fish species found to be free of detectable abnormalities are listed in Table 3. Of the seven types of pathological condi-

* Mention of commercial products is for information only and does not constitue endorsement by the U.S. Department of Commerce.

tions found, three were tumors, three were lesions presumably caused by microorganisms and one was a parasitic infestation.

Invertebrates were examined for pathological conditions in only two areas, the Norton Sound/Chukchi Sea area (25,000 animals) and the Kodiak Island region of the Gulf of Alaska (3,000 animals). In the Norton-Chukchi area, of the approximately 35 species examined, 25 were free of detectable abnormalities (Table 4). Only five of 45 species examined in the Gulf of Alaska had detectable pathological conditions. The observed pathological conditions are listed in Table 5. Six of the conditions involved parasitic infestations, two were fungal infections, and the remaining two conditions were of unknown etiology.

A. DESCRIPTIONS OF FISH DISEASES

1. Pseudobranchial Tumors of Gadids

The gross appearance of the cod (*Gadus macrocephalus*) tumors was described by McCain et al. (1978a) and Wellings et al. (1977). Briefly, they ranged in color from yellow, to pink, to brown. They were oval-shaped, smooth-surfaced, extended into the pharyngeal cavity, and ranged in size from just larger than the normal pseudobranch to 50 x 30 x 20 mm (Fig. 1). With one possible exception, all of the tumors were bilateral and both were usually the same size. The tumors often had necrotic areas on the surface, and normal-appearing pseudobranchial tissue was located on the surface or in the interior of each tumor.

The histopathological properties of the pseudobranchial tumors have been described previously (Alpers et al. 1977a). Briefly, they included the separation of normal-appearing pseudobranchial tissue from the tumor tissue by a connective tissue capsule and the presence of cells known as X-cells (Fig. 2). These cells are also found in other marine fish tumors, and they will be discussed later. In one cod with bilateral tumors, another similar tumor was found attached to a gill filament. This tumor was oval, cream-colored, and about 4 mm in diameter (Fig. 3). The tumors had a similar cell organization, composed mainly of X-cells, except no pseudobranchial tissue was associated with the gill tumor.

The overall prevalence of pseudobranchial tumors of Pacific cod in the GOA was 2.5% (range 1.0 to 50.0%)(Table 6). The condition did not appear to be related to sex, as was shown by the male:female ratio of 1.3:1. The age of tumor-bearing fish was from 1 to 4 years, and 69% of them were 2 or 3 years (Fig. 4). Pacific cod with tumors were distributed in a broad geographical area of the western GOA near Kodiak Island the Kenai Peninsula (Fig. 5). This broad distribution is reflected in the finding that 41% of the hauls in which Pacific cod were captured had tumor-bearing cod. The geographical distribution of this condition does not seem to be depth related.

In the Bering Sea 8.7% of the cod had pseudobranchial tumors (Table 2). Tumor-bearing cod were most common in the south central portion of the sampling area (Fig. 6). Both the frequency of catches with tumor-bearing cod and the proportion of affected individuals decreased to the northwest. Cod were not captured in the eastern portion of the sampling. The range of the disease frequencies in hauls containing cod with tumors was 1.1 to 73.3%.

Analyses of the biological characteristics of tumor-bearing cod from the Bering Sea showed that about the same number of males had tumors as did females. The relative age composition for cod with tumors was different from that of normal cod ("normal" in this case and for the other species described in this report means those apparently healthy animals captured, speciated, sexed, measured, and when possible aged during 1975 or 1976 by RACE and EC Divisions of the NMFS, NWAFC in the study area). Normal cod ranged in age from one to five years, while no tumor-bearing cod were less than two years. In addition, tumor-bearing cod were about 25% shorter than normal cod of the same age.

Small numbers of juvenile Pacific cod were captured at inshore stations off Kodiak Island and none of these had detectable diseases. This species was not captured in the Norton Sound or Chukchi Sea.

The pollock (Theragra chalcogramma) pseudobranchial tumors and the cod tumors were grossly similar in color, shape, and texture (McCain et al. 1979) (Fig. 7). However, the pollock tumors were often less protruding, tending to extend up into the roof of the pharynx, and ten pollock had unilateral tumors. Also, one pollock was found to have a secondary tumor on the outside of the operculum which had originated from an invasive pseudobranchial tumor. In general, these tumors were smaller than cod tumors with dimensions ranging up to 35 x 20 x 10 mm.

The microscopic anatomy of these tumors was very much like that described for the same condition in Pacific cod (Alpers et al. 1977a) with the following exceptions: (1) granulomas common to Pacific cod tumors were not seen in pollock tumors; (2) the fibrous stroma of the pollock tumors was populated with numerous melanophores, while melanophores were seldom observed in the stroma of Pacific cod tumors; and (3) the pollock tumors usually had a marked infiltration of macrophages and lymphocytes, this was not the case in the Pacific cod tumors.

For catches from the Bering Sea 1.7% of the pollock had pseudobranchial tumors. Tumor-bearing pollock were distributed in the Bering Sea in a pattern very similar to that of cod with tumors (Fig. 8), with the widest distribution and highest frequency in the south central area. Of the hauls where pollock were captured, 45% contained pollock with tumors, and the disease frequency in these latter hauls was from 0.6 to 13.2%.

The geographical distribution of this condition was generally confined to the western portions of the GOA near Kodiak Island and the Kenai Peninsula (Fig. 9). Only one trawl in the central region of the Gulf produced tumor-bearing pollock, and none were found in the eastern region. The prevalence of this condition in individual hauls ranged from 0.3 to 14.3% with an average frequency of 0.7% (Table 2). The disease was not depth-related. The sex ratio was 2.8:1, males to females. Of those tumor-bearing pollock aged, most were 2 years old (34 out of 38), with the ages ranging up to 10 years (Fig. 4).

The age and sex composition of tumor-bearing pollock differed sharply from similar data for normal pollock. No tumors were detected in fish less than two years of age and only occasionally in those over five years. About twice as many male pollock between the ages of two and five had tumors as did females of the same age. Also, after age six there was a marked decline in the relative abundance of normal males as opposed to females. The growth rate of pollock with tumors was apparently depressed in that they were 15% shorter than their normal cohorts (McCain et al. 1979).

No pollock were captured in samples from the bays of Kodiak Island. Small numbers of disease-free juvenile pollock were captured in the Chukchi Sea and Norton Sound.

2. Skin Ulcers of Pacific Cod

Two main types of skin lesions were observed on Pacific cod: an ulcer (Fig. 10) and a ring-shaped lesion (Fig. 11) (McCain et al. 1979). Ring-shaped lesions were found only in the Bering Sea and the ulcers were found in both the Bering Sea and the GOA. The ulcers were roughly circular, ranged in size from approximately 1 to

50 mm in diameter, and were either pale white or red (hemorrhagic) with a dark pigment concentrated in the margin of the surrounding epidermis. Between one and forty ulcers were observed on each affected fish. The ring-shaped lesions were characterized by a 5 to 20 mm wide, cream-colored strip, sometimes having hemorrhagic foci, surrounding a normal-appearing circular patch of epidermis. These lesions were about 10 to 50 mm in diameter. The number of ring-shaped lesions per diseased fish ranged from one to five.

Histological examination of the skin ulcers revealed that in most cases the epidermis was absent from the center of the lesion. Less often, portions of the dermis had also been destroyed. The white covering over some ulcers was composed of residual necrotic epidermis. The periphery of the lesions was hyperemic, hemorrhagic, and contained numerous inflammatory cells (lymphocytes and macrophages) and areas of fibrosis (Fig. 12). High concentrations of microorganisms were not observed histologically in the ulcers (McCain et al. 1979). However, ulcers from five different cod yielded Pseudomonas-like bacteria, sometimes in pure culture, which so far, have proven to be essentially taxonomically identical.

The histological properties of the ring-like lesions were described by McCain et al. 1979. Briefly, the epidermis and the stratum spongiosum (a component of the dermis directly beneath the epidermis) were the only parts of the skin obviously affected by this condition. The appearance of normal cod is shown in Figure 13. Cod epidermis normally contains mucous cells and large cystic structures of unknown function (Bullock and Roberts 1974). In the epidermis of fish affected with the lesion were large cyst-like bodies, about four times the size of a normal mucous cell, which contained a very basophilic center surrounded by an eosinophilic margin (Fig. 14). Preliminary electron-microscopic examination of these large cyst-like bodies has demonstrated the presence of herpesvirus-like particles.

In the Gulf of Alaska 18 of 2,097 (0.9%) of the Pacific cod had skin ulcers (Table 2). Skin ulcers were found in only 5 of 61 (8%) hauls in which cod were captured, and these hauls tended to be in the north-central portion of the GOA (Fig. 15). The male to female ratio of 0.8:1 suggests that this condition is not sex-related. The age of diseased Pacific cod ranged from 1 to 5, with 61% being 2 or 3 years of age (Fig. 4).

Cod in the Bering Sea had a frequency of 1.6% with ulcers or ring-shaped lesions. Diseased cod were found primarily in the south central area with 5% of the fish being affected (Fig. 16). There were no indications of sex, size, and age preference in these conditions.

3. Epidermal Papillomas of Pleuronectids

The epidermal papillomas of rock sole (*Lepidopsetta bilineata*) from the Bering Sea grossly and histologically resembled similar tumors described for several species of pleuronectids along the western coast of North America (McCain et al. 1978; Brooks et al. 1969; Wellings et al. 1976). The tumors ranged in size from 3 x 3 x 2 mm to 100 x 70 x 10 mm. They were brown to black and elevated, with a papillary architecture (Fig. 17). The tumors were located randomly on the body surface, and frequently a tumor extended to both sides of a fish with both sides being mirror images of each other. No metastases were identified.

Examination of sections of epidermal papillomas demonstrated the typical papillary structure of the thickened layer of epidermal cells supported by a branching fibrovascular stroma (Fig. 18). X-cells were observed in both the stromal and epidermal areas. Typical X-cells are characterized as being larger than normal epidermal cells, and having a pale nucleus, a large intense nucleolus, and granular cytoplasm.

Electron microscopic examination of X-cells showed that the cytoplasm contained numerous vesicular bodies. The nucleus contained a large nucleolus, and the chromatin-like material was evenly dispersed around the nucleus. This was in contrast to the normal-appearing cells in the tumors which had generally even-staining cytoplasm, and a nucleus with chromatin condensed around the periphery of the nuclear membrane.

Tumor-bearing rock sole were found almost exclusively in the south central part part of the Bering Sea (Fig. 19) and had an overall frequency of 1.3%. Similarly affected fish were found only at one station in the Gulf of Alaska, however many of the juvenile rock sole caught in the bays near Kodiak Island had tumors (Table 2). In the bays of Kodiak Island (Fig.20), the earliest recognizable stage of these skin tumors was found on young (1-5 years) rock sole. Known as angioepithelial nodules (AEN), these early lesions were hemispherical, cream-to-brown, smooth-surfaced, sessile lesions (Fig. 21). The microscopic structure of the AENs were the same as those described below for flathead sole. Table 6 shows the number and frequency of diseased rock sole for each of the areas studied. Figure 22 shows the distribution of rock sole with tumors in the GOA. The highest frequencies were at the shallowest stations and were for the youngest fish.

The gross appearance of the epidermal papillomas on flathead sole (Fig. 23) differed slightly from that of the rock sole tumors. Three basic types of flathead sole tumors were observed: (a) the typical epidermal papilloma, (b) a tumor type identified as an AEN (Wellings et al. 1976) which is known to be the progenitor of the epidermal papillomas (Fig. 24), and (c) an unclassified form of an epidermal papilloma that has not been previously described. This latter tumor was similar in texture and appearance to an epidermal papilloma, except that this tumor was black rather than brown and more loosely attached to the underlying dermis. The appearance and histopathological characteristics of this tumor suggest that it was an epidermal papilloma in the process of regression.

The microscopic anatomy of the epidermal papillomas and AENs of flathead sole was similar to that previously reported by Wellings et al. (1976) for similar tumors found in other pleuronectids. The unclassified tumor differed from the above tumors by having signs of a pronounced inflammatory host response. The stroma of the tumor contained numerous pleomorphic melanophores, macrophages, lymphocytes, and eosinophilic granular cells. A high percentage of cells (Wellings et al. 1976) near the surface of the tumors were degenerated; the X-cells in typical epidermal papillomas were very seldom necrotic.

Catches in the GOA containing adult tumor-bearing flathead sole were limited to a small geographical area east of Kodiak Island (Fig. 25). Six of 49 hauls in which flathead sole were captured had tumor-bearing flathead sole. The overall prevalence was 0.4% (10/2439) with a frequency range for individual hauls of 1.7 to 16.7% (Table 2). The ages of tumor-bearing fish were evenly distributed between 4 and 11 yr (Fig. 4).

Catches of flathead sole in the inshore areas near Kodiak Island less than 20 fathoms had tumor frequencies of 4.5% and the fish were predominantly 1 to 2 years old.

4. Lymphocystis of Yellowfin Sole

Lymphocystis (a virus-caused disease) of yellowfin sole (*Limanda aspera*) was characterized by the presence of variously shaped and colored growths on fins and body surfaces (Fig. 26). These growths, ranging in size from 1 mm in diameter to 20 x 10 x 5 mm, were of three basic types: (1) single or clusters of translucent, round bodies about 1 mm in diameter, (2) small red sacs on the ends of fin rays, and (3) red to gray amorphous growths. All these types had in common the presence of small round bodies, which, as will be mentioned below, were hypertrophied fish cells. Fin erosion was associated with about 10% of the cases where lymphocystis growths were on the fins (Fig. 26). Most growths were found on the "blind" side of the fish.

The histological properties of lymphocystis growths have been extensively described elsewhere (Alpers et al. 1977b, McCain et al. 1978, Russell 1974, Templeman 1965). The growths on yellowfin sole contained hypertrophied cells about 0.1 to 1.5 mm in diameter. These cells contained cytoplasmic inclusion bodies which were composed of hexagonal virions about 200 nm in diameter (Fig. 27).

In the Bering Sea, 2.8% of the yellowfin sole examined had this condition. Diseased yellowfin sole found in almost all of the catches in the south central Bering Sea, and 10% of the animals in this region were affected (Fig. 28). Adjacent areas had only two samples out of 24 with this condition and the occurrence was less than 1%. About the same number of males as females had this disease. The age composition of normal yellowfin sole of both sexes was bimodal, having peaks of abundance at six and eight years. Diseased fish had an age composition closely paralleling that of the normal population. This condition was not found in yellowfin sole from the Gulf of Alaska, Kodiak Island, or the Norton Sound and Chukchi Sea.

5. Epithelioid Tumors of Pacific Ocean Perch

Epithelioid tumors of Pacific ocean perch were located on membranes associated with gills and on body surfaces. The epithelial tumors appeared as multiple raised nodules and/or flat, spreading growths of dull red to pink. A variety of anatomical structures were found with these tumors, including: (1) the translucent membrane on the body surface between the cleithrum and the posterior holobranch of the gills (2) the membrane on the underside of the opercula (Fig. 29); (3) the gill rakers, rays, and filaments (Fig. 30); (4) the body surface sometimes associated with the pectoral, pelvic, caudal and anal fins; and (5) several structures (anterior esophagus, various epithelial membranes) of the buccal cavity as a result of spreading from the above-mentioned primary tumor sites.

Although the histological characteristic of the Pacific ocean perch tumors have many similarities to the previously mentioned X-cell tumors (pseudobranchial tumors of Pacific cod and pollock, and skin tumors of rock sole and flathead sole), there are several important differences; the most dramatic of which was the commonly observed invasiveness of the Pacific ocean perch tumors. Several tumors contained areas on their periphery in which X-cells had spread into connective and/or epithelial tissues (Fig. 31). In addition, secondary tumors or metastases with no connection with primary tumors were found.

Another characteristic of Pacific ocean perch tumors seldom observed in the other X-cell tumors was a mononuclear infiltrate composed mainly of lymphocytes which was present to a variable degree in most tumors. Normally the infiltrate was diffuse and mild, but dense foci were occasionally noted. Pacific ocean perch tumors were generally more vascular. The stroma surrounding the nests of tumor cells was collagenous and contained numerous capillaries, vesicles, and arterioles.

Electron microscopic examination of several different types of Pacific ocean perch epithelioid tumors has demonstrated that these tumors are composed of X-cells morphologically very similar to X-cells found in the epidermal papillomas of pleuronectids (Brooks et al. 1969) and the pseudobranchial tumors of Pacific cod (Alpers et al. 1977a).

Tumor-bearing Pacific ocean perch were in 7 of 36 Pacific ocean perch-containing hauls which were taken along the northwestern to northeastern periphery of the GOA (Fig. 32). The prevalence ranged from 0.2 to 21.0%, with an overall average of 0.6% (Table 2). No relationship between the depth of a haul and the frequency of tumor-bearing Pacific ocean perch was observed. Also, males and females had similar tumor frequencies, as was suggested by the ratio of tumor-bearing males to females of 0.9:1.0. Only Pacific ocean perch 8 years or older had detectable tumors, the maximum age was 17 years (Fig. 4). This condition was not detected in Sebastes from the Bering Sea.

6. Parasitic Infestations

Trematode metacercarial cysts were observed in the skin of Pacific herring (Clupea harengus pallasi), toothed smelt (Osmerus mordax dentrex), and saffron cod (Eleginus gracilis) in the Norton Sound/Chukchi Sea, and in the rock sole from the bays of Kodiak Island. The cysts in fish from the Norton Sound/Chukchi Sea were black (Fig. 33) due to aggregations of surrounding melanin-containing cells, cells, and white cysts in rock sole (Fig. 34) from the other area were due to the presence of a fibrotic capsule of host response tissues. In the case of the black cysts, the encysted larval trematode was probably a Cryptocolyle sp. There were no indications that these conditions affected one sex or age group differentially. Table 2 shows the overall numbers and frequency of these conditions.

The geographical distribution of these parasitic conditions are shown in Figures 35 to 37. This was the only potentially pathological condition found in the Norton Sound/Chukchi Sea.

B. INVERTEBRATE DISEASES

1. Norton Sound/Chukchi Sea

In the Norton/Chukchi area, the affected species, associated conditions, and population frequency of each condition were as follows: Sclerocrangon boreas (crangonid shrimp), leech eggs on the host's pleopods, 41.7%; Leptasterias sp. (sea star), parasitic gastropods (snail), 11.3%; Leptasterias polaris (sea star), parasitic gastropods, 4.8%; Pagurus capillatus (hermit crab), rhizocephalan (barnacle) parasite, 5.7%; Argis lar (crangonid shrimp), bopyrid (isopod) parasite, 1.2%; Hyas coarctatus alutacueus (spider crab), darkened exoskeleton suspected to be melanization, 7.1%; Argis lar, pale and enlarged eggs, 2.7% (Table 5).

The leech eggs on S. boreas were found in greatest proportion southeast of St. Lawrence Island (Figure 38). The condition was also prevalent in central and eastern Norton Sound where it occurred in 11 of 16 stations. Incidence of this condition within a haul ranged from 9.6% to 100.0%. The leech eggs were circular, about 1 mm in diameter, and peppered the pleopods; but if the surface area was crowded, they were found on the ventral abdomen and/or on egg clutches (Figure 39). Of the affected S. boreas of known sex, 88.3% were female. Almost three-quarters (73.1%) of these were gravid, 14.5% were maturing, 11.2% had spawned, and 1.2% were sexually undeveloped.

The sea stars Leptasterias polaris and Leptasteria sp. carried parasitic gastropods internally in 24 of 49 stations for the former and 17 of 29 stations for the latter, with a range of 0.1% to 75.0% and 1.2% to 37.8% in a haul, respectively. The greatest frequency in Leptasterias polaris occurred near the entrance to Kotzebue Sound; for Leptasterias sp. the highest proportion was found in central Norton Sound (Figure 40 and 41). The adult gastropod, a bright orange, bean-shaped protuberance, varied in size from approximately 1 mm to 27 mm in length, the larger ones distending the ossicles/epidermis of the sea stars (Figures 42 and 43). As many as 25 were found in one host, in the central disc as well as in the rays. Identification as a gastropod was affirmed by the presence of shelled veliger larvae within the parent's body mass (Figure 44).

The parasites seemed to show some preference in location in Leptasteris polaris. A total of 77.3% of the gastropods showed oral orientation; that is, the "proboscis" connecting the parasite inside the sea star with sea water usually passed through the epidermis on the oral side (near the substrate) of the host. Aboral orientation occurred in 15.9% of the cases observed and lateral orientation, along the sides of the rays, was found 6.8% of the time. There seems to be no difference in infestation among the rays selected for parasitism although incidence in the central disc was lowest. Within a single ray the parasites occurred on a gradient, increasing as they approached the central disc; 20.2% were found distally on the rays, 30.6% were midway, and 40.9% occurred proximal to the "body". Markedly fewer (8.3%) were noted at disc/ray junctions.

Rhizocephalan (barnacle) parasites were noted on the abdomens of hermit crabs, primarily Pagurus capillatus in 27 of 43 stations involved. The highest proportion in one haul occurred in the northeastern part of the study area; frequency extended from 2.0% to 50.0%.

Argis lar carried bopyrid parasites under the carapace in 23 of 132 stations. The greatest proportion in a haul occurred in southern Norton Sound, and frequency ranged from 0.5% to 88.9%. This parasite was most common in stations less than 25 meters in depth (19 of 63) in Norton Sound and Kotzebue Sound.

Darkened and/or eroded exoskeleton was noticed in Hyad coarctatus alutaceus from 12 of 26 stations, with highest frequency in the southeast Chukchi Sea. Of these crabs, 5.3% to 50.0% were affected in a haul. Since fouling was usually heavy on these animals, it is assumed that this conditon, probably melanization, was a result of prolonged periods between molting or its termination altogether.

Argis lar from 17 of 132 stations investigated also carried discolored (necrotic) eggs. Shrimp with such eggs ranged in frequency from 1.2% to 90.0%. These enlarged, pale eggs were seen only in the Chukchi Sea/Kotzebue areas, with highest incidence in Kotzebue Sound (Figure 45).

2. Kodiak Island

Fungal infections of snow crab (Chionecetes bairdi) and shrimp (Crangon dalli) were both found in the bays of Kodiak Island (Table 5). The condition of snow crab, commonly known as "black mat disease" (Figure 46 and 47), was recently described by Sparks and Hibbits (1979). The eggs of C. dalli were infected by a phycomycete tentatively identified as a Lagenidium sp. The fungal hyphae invade the eggs and cause death.

VII. DISCUSSION

A. BERING SEA

Both the prevalence and distribution of three diseases: pseudobranchial tumors of cod, lymphocystis of yellowfin sole, and skin tumors of rock sole found by us in the Bering Sea in 1976 (McCain et al. 1979) were very similar to those we found in 1975 (McCain et al. 1978). The 1976 incidences for each of the above diseases were slightly higher by 1.3, 0.7, and 0.3%, respectively. In both years, the distributions of tumor-bearing cod and yellowfin sole with lymphocystis were almost identical. Rock sole with tumors in 1975 appeared to be distributed in significantly different patterns from those found in 1976; however, this deviation may be explained by differences in the locations of sampling stations. Also, as will be discussed below, the stations sampled in 1975 and 1976 which had the highest frequencies of tumor-bearing rock sole were also the shallowest.

The causes of all but possibly three of the pathological conditions of demersal fishes found near the OCS of the Bering Sea are not known. The exceptions are lymphocystis of yellowfin sole, which is caused by a virus, the apparently bacterially-caused skin ulcers of cod and the ring-shaped skin lesions of cod which had electron-microscopically detectable herpes-like virus particles. Cod and pollock pseudobranchial tumors (probably carcinomas) and epidermal papillomas of rock sole are neoplasms of unknown cause(s).

An interesting observation in our study was the uneven distribution of three of the five diseases. Yellowfin sole with lymphocystis, rock sole with epidermal papillomas and Pacific cod with skin lesions were most prevalent in the southeastern Bering Sea near Unimak Island.

Diseased yellowfin sole were often part of massive schools which are frequently found in this area of the Bering Sea during the spring (Fandeev 1970). The inevitable close contact between fishes in such schools may facilitate virus transmission.

As mentioned earlier, the two stations near Unimak Island with the highest frequencies of rock sole with epidermal papillomas were also the two shallowest stations of the cruise. Previous studies of pleuronectids with epidermal papillomas have shown that young flatfish between six months and two years of age most often have tumors (Miller and Wellings 1971; Angell et al. 1975). Young rock sole are initially found near the beaches and move into deeper water as they grow older (Clemens and Wilby 1961). Our observations and those of Levings (1967) demonstrated that tumors on older fish can spread over as much as 50% of the body surface, including the head region. Extensive tumors and other possible tumor-related factors very likely caused older affected fish to die. Therefore, it is not surprising that the shallow stations would have yielded the most tumor-bearing rock sole.

B. NORTON SOUND/CHUKCHI SEA

The most striking aspect of our investigations of the baseline health status of marine animals in Norton Sound and Chukchi Sea has been the low frequency of pathological conditions in these areas. Tumors and tumor-like lesions observed in fish of the eastern Bering Sea have been totally absent in fish from these areas. Parasitic conditions seem to be the most prevalent and severe conditions encountered. Parasitism may be an indicator of general health in that an animal that has been weakened by other factors may be more susceptible to parasitic infestation.

The reasons for the lack of recognizable pathological conditions in fish in the Norton/Chukchi area are not clear. Conditions found in the nearby Bering Sea included pseudobranchial tumors of cod and pollock, skin tumors of rock sole, and the virus-caused lymphocystis of yellowfin sole. The total absence of cod and rock sole and the small numbers of pollock in the study area are explanations for some of the differences between the two areas. However, since yellowfin sole were present in sufficient numbers to detect lymphocystis, it appears likely that in this case, the virus or vector responsible for virus transmission is not present in the Norton/Chukchi area.

Other disease-causing factors may be in the Norton/Chukchi area at reduced levels compared in the Bering Sea. For example, pseudobranchial tumors are presently known to be in three species of gadids: Pacific cod, pollock, and Atlantic cod (*Gadus morhua*). It is possible that all gadids are susceptible to this disease; nevertheless, over 10,000 saffron cod and 2,952 Arctic cod (*Boreogadus saida*) were examined in the Norton/Chukchi area and no tumors were found. Either the hypothesis concerning the universal susceptibility of gadids to these tumors is not valid, or the saffron and Arctic cod we examined were not exposed to the tumor-inducing factor. Marine animals capable of transmitting an infectious agent which may enter this area may not come in close enough contact with other fish for transmission to occur.

It is difficult to assess at this time the pathological effects of the "black spot" disease on the Pacific herring, toothed smelt, and saffron cod. Cryptocotyle lingua, a trematode that has metacercariae very similar in appearance to the trematode we found in the above species, has been reported to cause "black spot" conditions in cod (G. callarias), plaice (Pleuronectes platessa), and herring (Clupea harengus) in the Atlantic Ocean (Sindermann 1970). Cercariae of C. lingua have been experimentally shown to blind and kill immature herring. Nevertheless, the species examined in the Norton/Chukchi area with the "black spot" condition did not appear to be adversely affected.

Although parasitism was observed in five species of invertebrates in the Norton/Chukchi area, the impact of these conditions on the health of their respective hosts is not clear. The affected animals did not grossly appear to be adversely affected. Nevertheless, due to the complexities of marine invertebrate behavior, any interference by parasites with normal activities could impair feeding, predator-prey, or reproductive functions.

C. GULF OF ALASKA

Several aspects of the geographical distribution, prevalence, age, sex, and pathology of the diseased fish from the GOA warrant further discussion. Fish with five of the six pathological conditions (tumors of Pacific ocean perch were the exception) were largely captured in the northwestern periphery of the GOA. The following reasons may independently or collectively account for this observation: (1) disease frequency may be related to fish density, and more areas with high fish densities may be in the northwestern GOA; (2) since four of the five conditions were found in even higher prevalences in the Bering Sea, some diseased fish may have migrated into the GOA from the north; (3) the bottom sediment types in the northwestern GOA may contribute to disease induction; and (4) infectious agents may be in higher concentrations in the northwestern GOA.

Three diseases, pseudobranchial tumors of Pacific cod and pollock and the skin ulcers of Pacific cod, appear to largely affect fish less than five years of age. On the other hand, mainly older (over eight years) Pacific ocean perch had tumors. The reasons for this apparent age specificity are not clear. One likely explanation is that sampling bias caused by sampling techniques and/or the life histories of the affected fish permit only certain age groups to be captured. For example, Pacific ocean perch can be captured with an age range of 8 to 21 years or 2 to 15 years depending upon the mesh size of the trawls and the sampling lcoation (Major and Shippen 1970).

The type of epidermal tumor found on rock sole appeared to be age dependent. Epidermal papillomas were found only on adult (older than two years) rock sole in the GOA and the Bering Sea. However, the earliest form of the tumor, the AEN, was observed on juvenile rock sole found in the bays of Kodiak Island where the youngest rock sole (one year or less) in Alaskan waters were captured. As a result, the earliest form of the tumor was observed, the AEN.

The overall average frequency of diseases in the GOA was relatively low, with only pseudobranchial tumors of Pacific cod having a frequency of over 1.0%. In the Bering Sea, for example, average disease frequencies ranged from 1.3 to 8.7%, as compared to 0.2 to 2.5% in the GOA. Nevertheless, in the GOA, each of the fish diseases, with the exception of the rock sole skin tumors, had frequencies of between 14 and 50% in certain hauls. Thus, unexplained disease "hot spots" may exist in the GOA. Although the frequencies of cod and pollock with pseudobranchial tumors and of rock sole with epidermal papillomas were somewhat lower in the GOA than in the Bering Sea, the existence of these pathological conditions over a wide geographical area of Alaskan marine waters has been established.

The "black mat disease" of snow crab found in the bays of Kodiak Island is a fungal disease which appears to be harmful to this species (Sparks and Hibbits, 1979). The adverse affects are suggested by microscopic observations of penetration of the exoskeleton by fungal hyphae in internal organs such as the heart.

VIII. GENERAL CONCLUSIONS

Of the six major diseases of fish characterized during this study, four had a restricted range of geographical distribution. Lymphocystis of yellowfin sole and skin lesions of Pacific cod were essentially found in the Bering Sea; "black spot" disease of Pacific herring, toothed smelt, and saffron cod was found only in the Norton/Chukchi area; and the epithelioid opercular tumors of Pacific ocean perch were only observed in the GOA. Pseudobranchial tumors of cod and pollock and epidermal papillomas of rock sole and/or flathead sole, the remaining two diseases, were found in both the Bering Sea and GOA.

Three of the four major pathological conditions involving six species of fish were tumors with a possibly common etiology. The three types of tumors, epidermal papillomas of pleuronectids, pseudobranchial tumors of gadids, and epithelioid tumors of *Sebastes* sp., all contained morphologically identical, tumor-specific cells known as X-cells. The origin of X-cells is not known; although they could be virally or chemically transformed host cells, or single-cell parasites.

Lymphocystis growths from yellowfin sole contained typical-appearing lymphocystis virus, which suggests that, if this virus is similar to other lymphocystis virus isolates, this disease is infectious. If this is true, then host defense mechanisms probably play an important role in disease transmission. Therefore, environmental stress (i.e., high temperature, pollution) which affect the disease defenses could increase the frequency of lymphocystis in yellowfin sole.

The types of pathological abnormalities so far detected in the demersal fish populations of Alaska are mostly chronic conditions. Chronic disease is the main type of disease one would expect to find in fish captured by the existing sampling methods. This is because fish with chronic disorders live longer than fish affected with acute diseases. Acutely diseased fish, such as those infected with virulent bacteria or viruses, would be removed much more rapidly from the population; either from the direct affects of the disease, or by predators. Therefore, the fish diseases described in this report very probably represent only a portion of the diseases by which demersal fishes are affected.

IX. NEEDS FOR FURTHER STUDY

Investigations of the health status of demersal fishes in Alaskan marine waters are very complementary to resource assessment studies. Marine animals captured and examined for population studies can also be examined for pathological conditions with only a small increase in time and personnel. Thus, as long as OCSEAP-supported resource assessment programs are carried out in Alaskan waters, it would seem to be in OCSEAP's best interest to continue marine animal disease studies.

X. REFERENCES USED

Alpers, C.E., B.B. McCain, M.S. Meyers, S.R. Wellings, M. Poore, J. Bagshaw, and C.J. Dawe.
1977a. Pathological anatomy of pseudobranch tumors in Pacific cod. Gadus macroephalus. J. Natl. Cancer Inst. 54:377-98.

Alpers, C.E., B.B. McCain, M.S. Meyers, and S.R. Wellings.
1977b. Lymphocystis disease in yellowfin sole (Limanda aspera) in the Bering Sea. J. Fish Res. Board Can. 34:611-6.

Angell, C.L., B.S. Miller, and S.R. Wellings.
1975. Epizoology of tumors in a population of juvenile English sole (Parophrys vetulus) from Puget Sound, Washington. J. Fish. Res. Board Can. 32:1723-1732.

Bright, D.B., F.E. Durham, and J.W. Knudsen (1960). King crab investigations of Cook Inlet, Alaska. Unpublished report.

Brooks, R.E., G.E. McArn, and S.R. Wellings.
1969. Ultrastructural observations on an unidentified cell type found in epidermal tumors of flounders. J. Natl. Cancer Inst. 43:97-100.

Bullock, A.M., and R.J. Roberts.
1974. The dermatology of marine teleost fish. I. The normal integument. Oceangr. Mr. Biol. Ann. Rev. 13:383-411.

Clemens, W.A., and G.U. Wilby.
1961. Fishes of the Pacific coast of Canada. Fish. Res. Board Can. Bull. 68, 443 p.

Fandeev, N.S.
1970. The fishery and biological characteristics of yellowfin sole in the eastern part of the Bering Sea. Tr. Vses. Nanchno-issled. Inst. Morsk, Rzbu. Oceanogr. 58:121-138.

Hawkes, J.W.
1974. The structure of fish skin. I. General organization. Cell Tissue Res. 149:147-58.

Levings, C.D.
1967. A comparison of the growth rates of the rock sole, Lepidopsetta bilineata Ayres, in Northeast Pacific waters. Fish. Res. Board Can. Tech. Rep. No. 36, 43 p.

Major, R.L. and H.H. Shippen.
1970. Synopsis of biological data on Pacific ocean perch. Sebastodes alutus. FAO Species Synopsis No. 79. NOAA, NMFS, Washington D.C. 38 pp.

McCain, B.B., S.R. Wellings, C.E. Alpers, M.S. Myers, and W.D. Gronlund.
1978. The frequency, distribution, and pathology of three diseases of demersal fishes in the Bering Sea. J. Fish. Biol. 12:267-276.

McCain, B.B., W.D. Gronlund, M.S. Myers, and S.R. Wellings.
1979. Tumours and microbial diseases of marine fishes in Alaskan waters. J. Fish Diseases 2:111-130.

Miller, B.S. and S.R. Wellings.
1971. Epizootiology of tumors on flathead sole (Hippoglossoides elassodon) in East Sound, Orcas Island, Washington. Trans. Am. Fish. Soc. 100:247-266.

Russell, P.H.
1974. Lymphocystis in wild plaice Pleuronectes platessa (L.), and flounder, Platichthys flesus (L.), in British coastal waters: A histopathological and serological study, J. Fish Biol. 6, 771-778.

Sinderman, C.J.
1970. Principal diseases of marine fish and shellfish. Academic Press, New York. 369 p.

Sparks, A.K. and W.T. Pereyra
1966. Benthic invertebrates of the southeastern Chukchi Sea, pp. 817-838. In: N.J. Wilimovsky and J.N. Wolfe (eds.), Environment of Cape Thompson region, Alaska. U.S. Atomic Energy Comm., Wash., D.C.

Templeman, W.
1965. Lymphocystis disease in American plaice of the Eastern Grand Bank. J. Fish. Res. Bd. Canada 22, 1345-1356.

Turner, L.M.
1886. Results of investigations made chiefly in the Yukon District and the Aleutian Islands. In: Contributions to the natural history of Alaska, U.S. Army.

Van Hyning, J.M and A.M. Scarborough.
1973. Identification of fungal encrustation on the shell of the snow crab (Chionoecetes bairdi). J. Fish Res. Board Can. 30:1738-9.

Wellings, S.R., R.G. Chuinard, and R.A. Cooper.
1967. Ultrastructure studies of noraml skin and epidermal papillomas of the flathead sole. Zeitschrift fur Zellfors-chung 78, 370-387.

Wellings, S.R., B.B. McCain, and B.S. Miller.
1976. Epidermal papillomas in pleuronectidae of Puget Sound, Washington. Prog. Exp. Tumor Res. 20:55-74.

Wellings, S.R., C.E. Alpers, B.B. McCain, and M.S. Myers.
1977. Fish diseases of the Bering Sea. Annals N.Y. Acad. Sci. 298: 290-304.

XI. LIST OF TABLES

Page

Table 1. Vessel and sampling gear characteristics and sampling schedules used in collection of specimens---------------

Table 2. Prevalence of the major pathological coditions of fish in Alaskan waters---

Table 3. Fish species captured in the Bering Sea (B), Gulf of Alaska (G), Norton Sound (N) and Chukshi Sea (C) in which no detectable pathological conditions were identified--

Table 4. Major invertebrate species exhibiting no significant detectable pathological conditions (including paratitism) in the Norton Sound (N), Chukshi Sea (C), and Gulf of Alaska (G)---

Table 5. The principal pathological conditions found on bottom-dwelling invertebrates from the Norton Sound/Chukchi Sea area, and the Kodiak Island area of the GOA----------

TABLE 1. Vessel and sampling gear characteristics and sampling schedules used in collection of specimens

Vessel name	Vessel description	Size (m)	Trawl gear type	Sampling times	Area sampled
R/V MILLER FREEMAN	NOAA	68	Eastern otter	Summer-Fall, 1975	Bering Sea
"				Spring, Summer, 1976	Bering Sea
"				Fall, Winter, 1976	GOA
"				Fall, 1977	Chukchi Sea, Norton Sound
PROFESSOR SIEDLECKI	Polish	100	Eastern otter	Summer, 1977	GOA
COMMANDO	Charter (Univ. Washington)	28	Eastern otter	Spring, Summer, 1978	Kodiak Island
YANKEE CLIPPER	Charter (private)	18	Shrimp	Spring, Summer, 1978	Kodiak Island

Table 2. Prevalence of the major pathological conditions of fish in Alaskan waters

Species	Condition	Bering Sea		Gulf of Alaska		Chukchi Sea, Norton Sound		Inshore Kodiak Island	
		No. examined	No. & % affected	No. examined	No. & % affected	No. examined	No. & % affected	No. examined	No. & % affected
Pacific cod *Gadus macrocephalus*	Pseudobranchial tumor	4,654	403 8.7	2,097	51 2.4	0	0 0	--	--
Pacific cod *Gadus macrocephalus*	Skin ulcer	4,654	73 1.6	2,097	18 0.9	0	0 0	--	--
Walleye pollock *Theragra chalcogramma*	Pseuobranchial tumor	9,173	156 1.7	5,541	38 0.7	270	0 0	--	--
Pacific ocean perch *Sebastes alutus*	Gill tumor	149	0 0	2,466	16 0.7	0	0 0	0	0 0
Rock sole *Lepidopsetta bilineata*	Epidermal tumor	6,440	87 1.3	1,945	3 0.2	0	0 0	2,917	197 6.8
Flathead sole *Hippoglossoides elassodon*	Epidermal tumor	2,977	0 0	2,439	10 0.4	0	0 0	693	31 4.5
Yellowfin sole *Limanda aspera*	Lymphocystis	8,036	228 2.8	0	0 0	3,279	0 0	0	0 0

Table 2. - continued.

Species	Condition	Bering Sea		Gulf of Alaska		Chukshi Sea, Norton Sound		Inshore Kodiak Island	
		No. examined	No. & % affected	No. examined	No. & % affected	No. examined	No. & % affected	No. examined	No. & % affected
Pacific herring *Clupea harengus pallasi*	Trematode cysts	175	0 0	0	0 0	2,027	92 4.5	0	0 0
Toothed smelt *Osmerus mordax dentax*	Trematode cysts	20	0 0	9	0 0	3,772	146 3.9	0	0 0
Saffron cod *Eleginus gracilis*	Trematode cysts	0	0 0	0	0 0	10,826	91 0.8	0	0 0

TABLE 3. Fish species captured in the Bering Sea (B), Gulf of Alaska (G), Norton Sound (N) and Chukchi Sea (C) in which no detectable pathological conditions were identified

Agonus acipenseris (Sturgeon poacher)	B,N,C	Microstomus pacificus (Dover sole)	B,G
Anoplopoma fimbria (Black cod, sablefish)	B,G	*Myoxocephalus jack	B
Atheresthes stomias (Arrowtooth flounder)	B,G	Myoxocephalus polyacanthocephalus (Great sculpin)	B,G
*Bathymaster signatus (Searcher)	G	Myoxocephalus sp.	B,N,C
Boreogadus saida (Arctic cod)	N,C	*Osmerus mordax dentex (Rainbow smelt)	B,G
*Careproctus sp. (Snailfish)	B	*Parophrys vetulus (English sole)	G
Clupea harengus pallasi (Pacific herring)	B	Platichthys stellatus (Starry flounder)	B,C,N,G
Dasycottus setiger (Spinyhead sculpin)	B,G	*Pleurogrammas monopterygius (Atka mackerel)	G
*Eleginus gracilis (Saffron cod)	B	Pleuronectes quadrituberculatus (Alaska plaice)	B,C,N,G
Glyptocephalus zachirus (Rex sole)	G	*Raja kincaidi (Black skate)	G
Gymnocanthus galeatus (Armorhead sculpin)	G	Reinhardtius hippoglossoides (Greenland turbot)	B
*Hemilepidotus hemilepidotus (Red Irish lord)	B	Sebastes aleutianus (Rougheye rockfish)	G
Hemilepidotus jordani (Yellow Irish lord)	G	Sebastes alutus (Pacific Ocean perch)	B
*Hexagrammos decagrammos (Kelp greenling)	G	Sebastes brevispinus (Silvergrey rockfish)	G
*Hexagrammos stelleri (White spotted greenling)	G	Sebastes ciliatus (Dusky rockfish)	G
Hippoglossoides elassodon (Flathead sole)	B	Sebastes flavidus (Yellowtail rockfish)	G
Hippoglossoides robustus (Bering flounder)	N,C	Sebastes polyspinus (Northern rockfish)	G
Hippoglossus stenolepsis (Pacific halibut)	B,G	Sebastes variegatus (Harlequin rockfish)	G
Limanda aspera (Yellowfin sole)	N,C	Sebastolobus alascanus (Shortpsine thorneyhead)	G
Limanda proboscidea (Longhead dab)	B,N,C	*Squalus acanthias (Dogfish)	B
Liopsetta glacialis (Arctic flounder)	N,C	Theragra chalcogramma (Walleye pollock)	N,C
Liparids (5 species) (Snailfish)	N,C	*Trichodon trichondon (Pacific sandfish)	B
*Lumpenus sagitta (Snake prickleback)	B	*Triglops forfacata (Scissortail sculpin)	G
Lycodes palearis (Wattled eelpout)	B	*Triglops macellus (Roughspine sculpin)	G
*Malacacottus kincaidi (Blackfin sculpin)	G	*Triglops pingeli (Ribbed sculpin)	G
Mallotus villosus (Capelin)	B,N,C	*Zaprora silenus (Prowfish)	G
Microgadus proximus (Tomcod)	G		

* Less than 50 specimens were examined for each of these species.

TABLE 4. Major invertebrate species exhibiting no significant detectable pathological conditions (including parasitism) in the Norton Sound (N), Chukchi Sea (C), and Gulf of Alaska (G)

1. CRABS	*Chionecetes opilio* (Tanner crab) N, C
	Paralithodes camtschatica (Red king crab) N, C, G
	Telmessus cheiragonus (Telmessus horse crab (N, C, G
	**Cancer magister* (Dungeness crab) G
	**Pugettia* sp. G
	**Lophopanopeus bellus* G
2. HERMIT CRABS	**Humilaria kennerlyii* G
	**Pagurus tenuimanus* G
	**Pagurus splendescens* G
	Pagurus trigonocheirus N, C
	Labidochirus splendescens N, C
3. SHRIMPS	*Pandalus borealis* (Pink shrimp) G
	Pandalus goniuris (Humpy shrimp) N, C
	**Pandalus* sp. G
	Crangon dalli N, C
	Crangon sp. G
4. MOLLUSCS	**Chlamys* sp. (Scallop) G
	**Cyclocardia* sp. G
	**Fusitriton oregonensis* G
	**Astarte alaskensis* G
	**Polinices pallida* G
	**Macoma* sp. (or *Tellina* sp.) G
	**Solariella obscura* G
	Strongylocentrotus drobachiensis (Green sea urchin) N, C
5. ECHINODERMS	
6. 16 OTHER MINOR SPECIES	

* Indicates less than 50 specimens of each species were examined.

TABLE 5. The principal pathological conditions found on bottom-dwelling invertebrates from the Norton Sound/Chukchi Sea area, and the Kodiak Island area of the GOA

Common name Species	Area	Disease	Frequency (%)
CRAB			
Chionoecetes bairdi	GOA	Fungal infection of carapace	7.0
Pagurus alaskensis	GOA	Rhizocephalan parasite	5.3
P. capillatus	Norton/Chukchi	Rhizocephalan parasite	5.7
P. dalli	GOA	Isopod parasite	12.4
Hyas coarctatus alutaceus	Norton/Chukchi	Darkened/eroded exoskeleton	7.1
SHRIMP			
Crangon dalli	GOA	Fungus infection of eggs	12.3
Sclerocrangon boreas	Norton/Chukchi	Leech eggs on exoskeleton	42.2
Argis lar	Norton/Chukchi	Pale, enlarged eggs	2.7
Argis lar	Norton/Chukchi	Isopod parasite	1.3
SEA STAR			
Leptasterias polaris	Norton/Chukchi	Parasitic gastropod infestation	4.8

Figure 1. Bilateral pseudobranchial tumors (T) in the pharynx of the Pacific Cod.

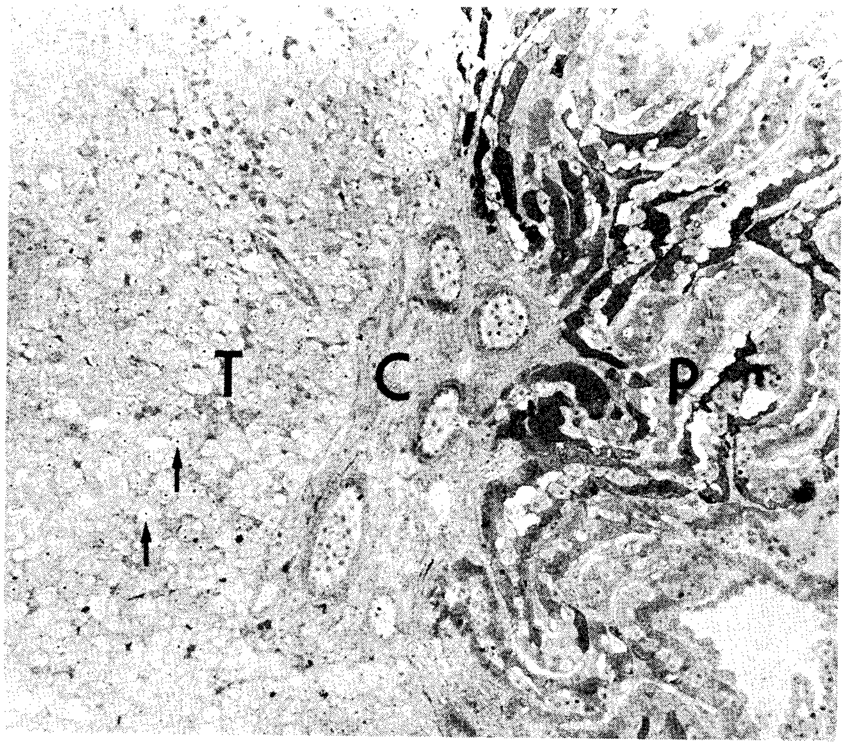


Figure 2. A section of a pseudobranchial tumor from a Pacific cod. Normal appearing pseudobranchial tissue (P) is separated from the tumor tissue (T) by a connective tissue capsule (C). Typical X-cells are identified by arrows. (Toluidine Blue, X230).

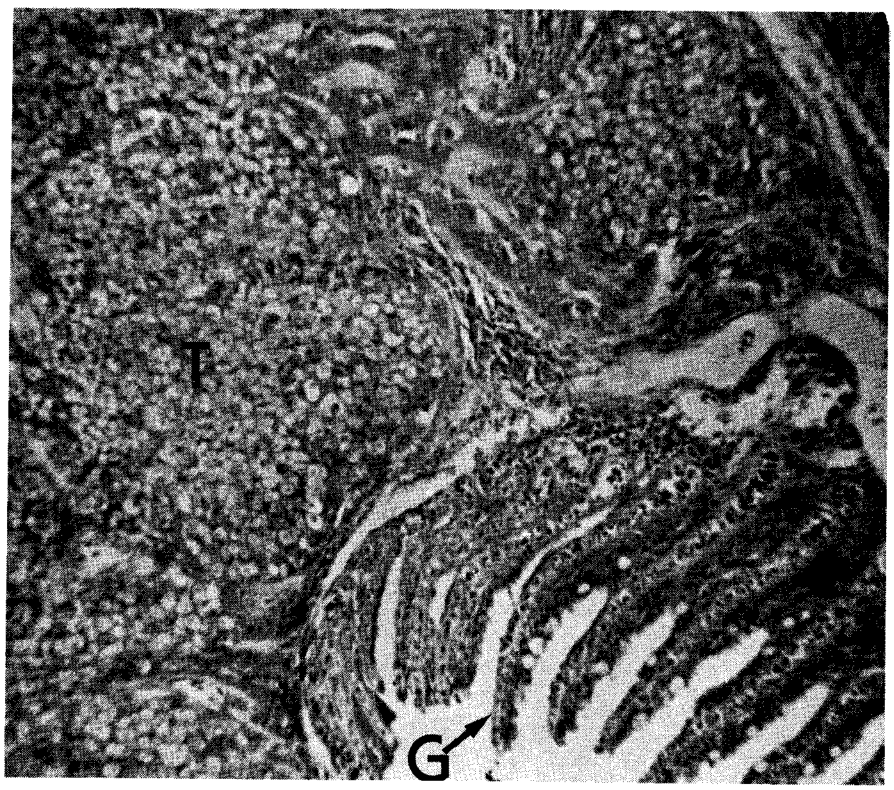


Figure 3. Section of a secondary pseudobranchial tumor (T) attached to the gill filament (G) of a Pacific Cod. (Hematoxylin and Eosin,X450).

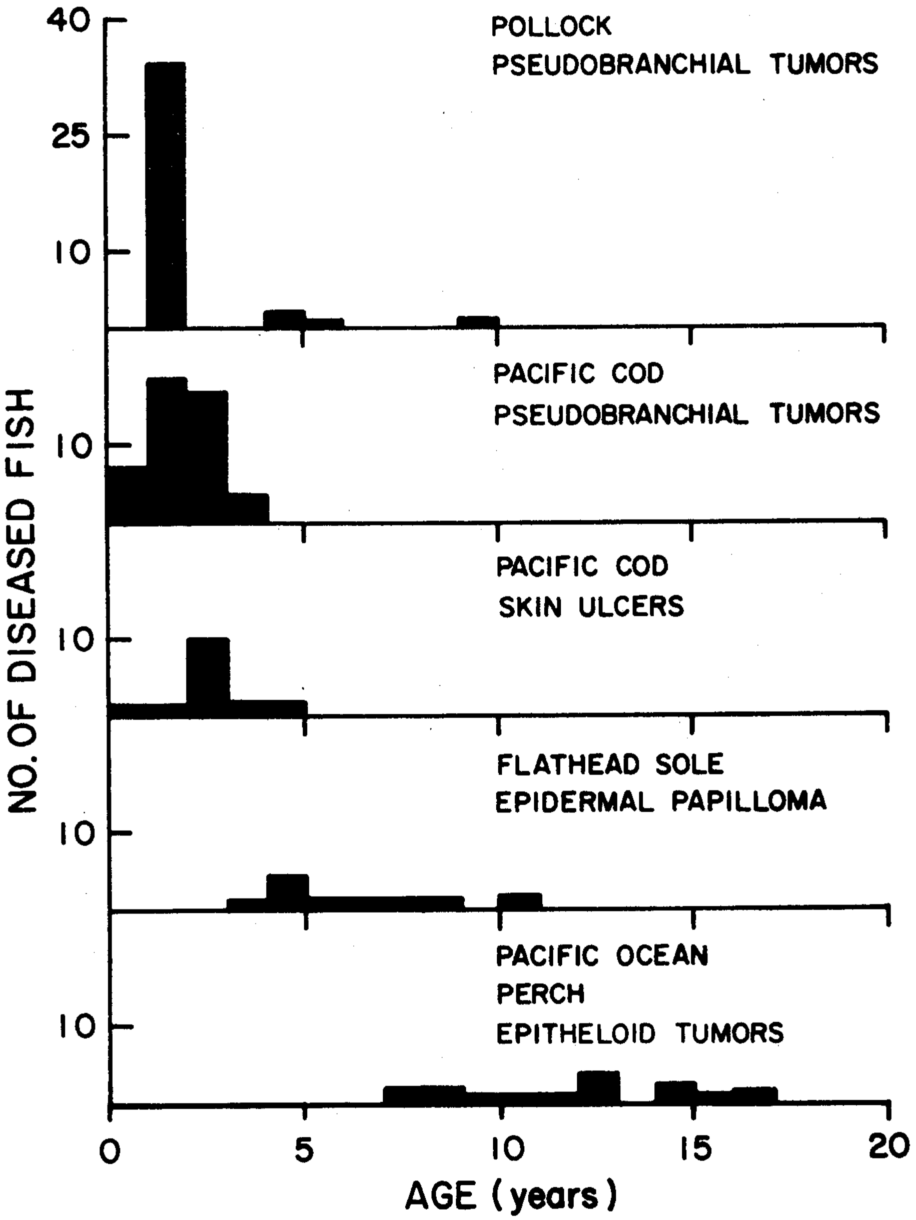


Figure 4. Age frequencies for five pathological conditions found in the GOA.

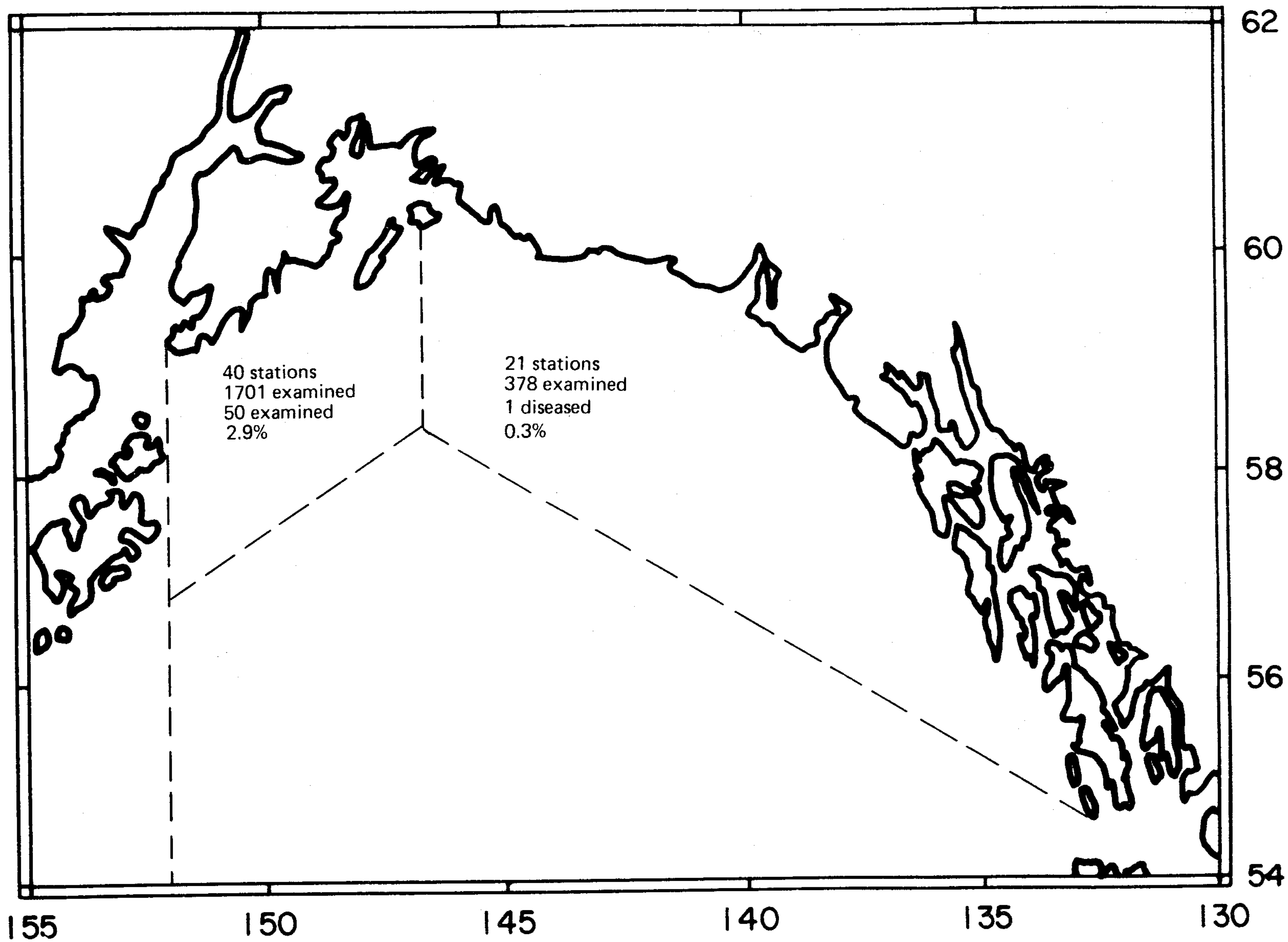


Figure 5. The general distribution and frequencies of Pacific cod with pseudobranchial tumors in three areas of the GOA.

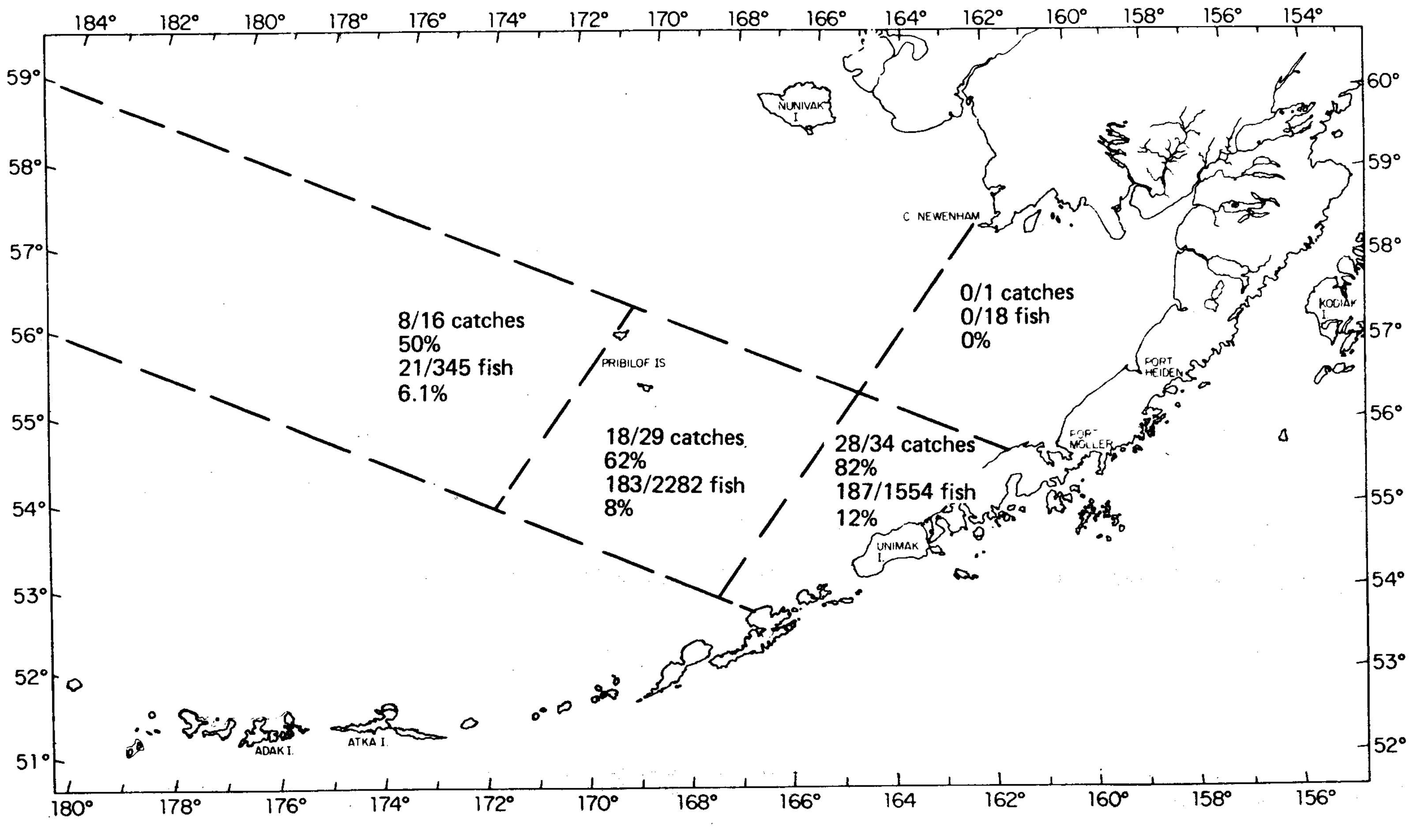


Figure 6. The general distribution and frequencies of cod with pseudobranchial tumors in four areas of the Bering Sea.

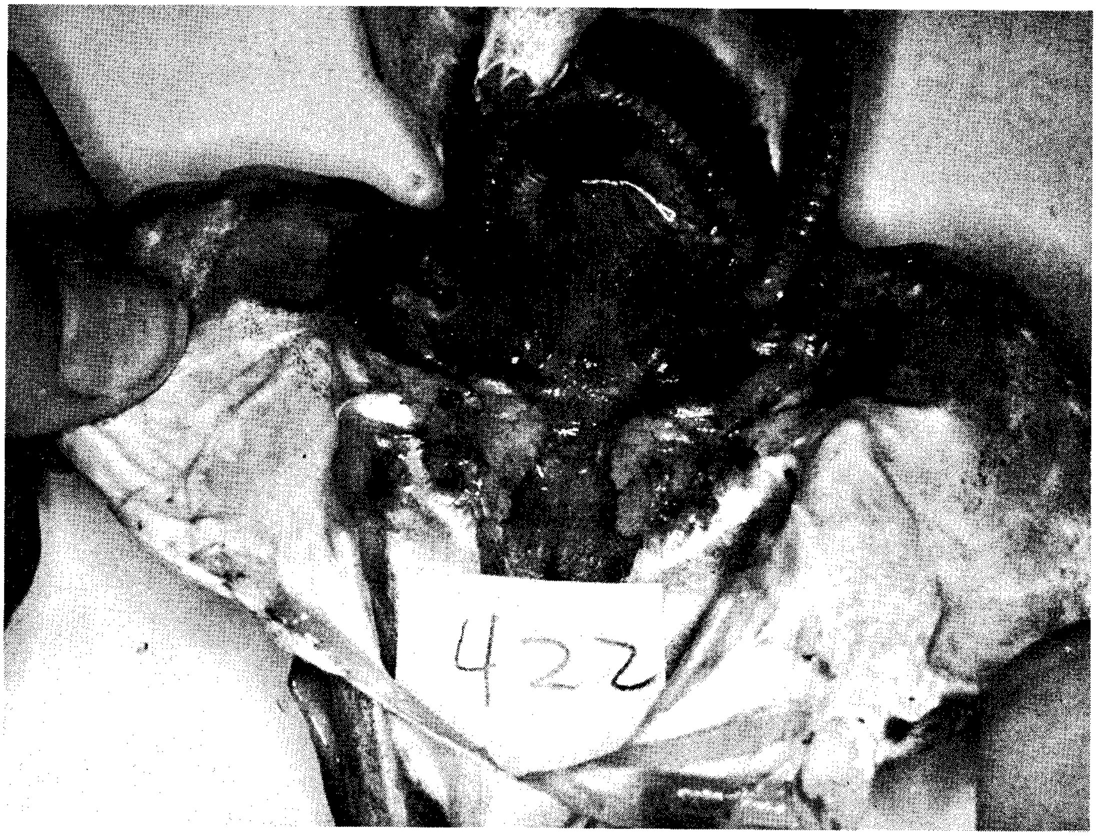


Figure 7. Bilateral pseudobranchial tumors (just above card) in the pharyngeal fossae of a Walleye pollock.

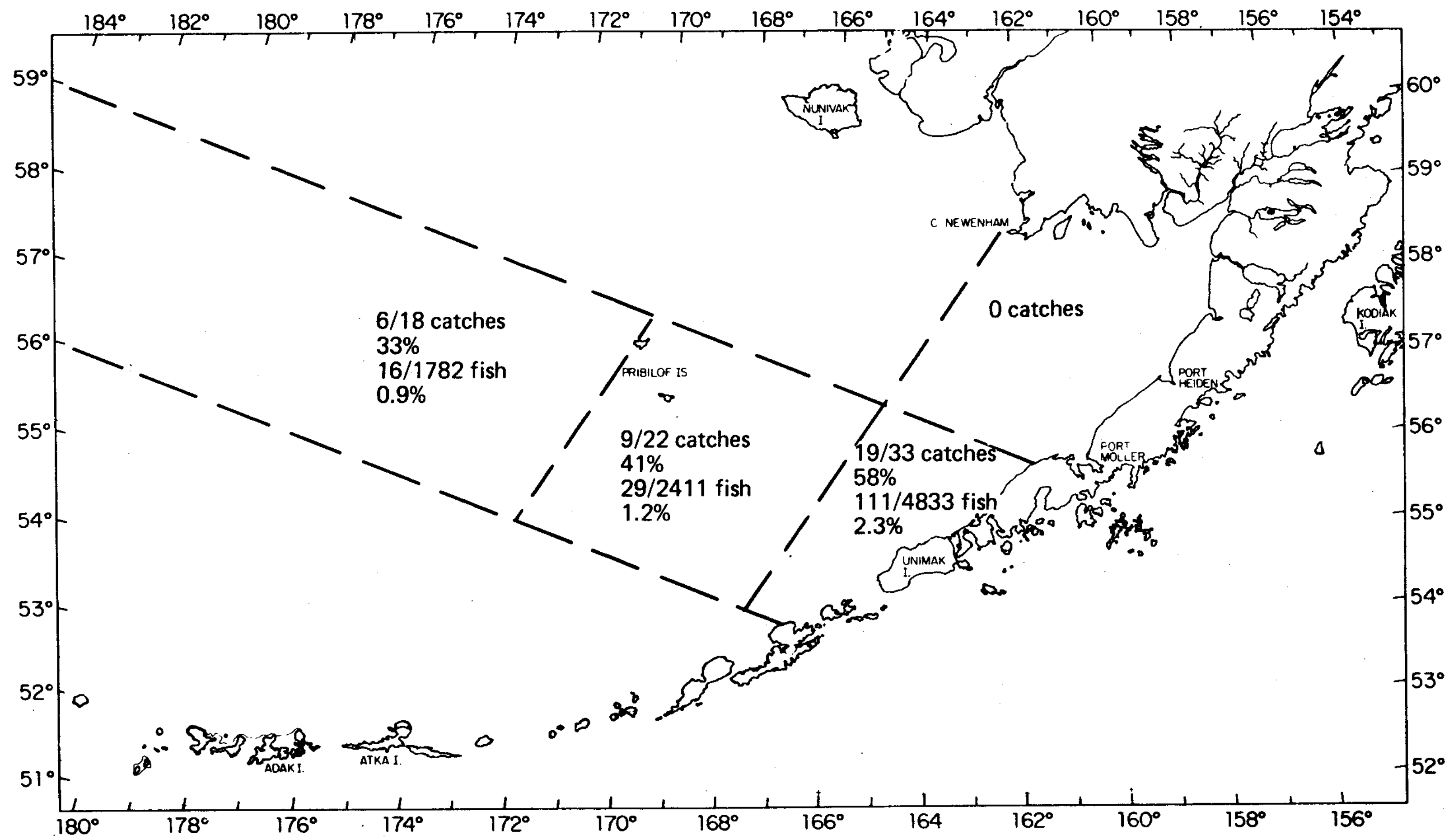


Figure 8. The general distribution and frequencies of pollock with pseudobranchial tumors in four areas of the Bering Sea.

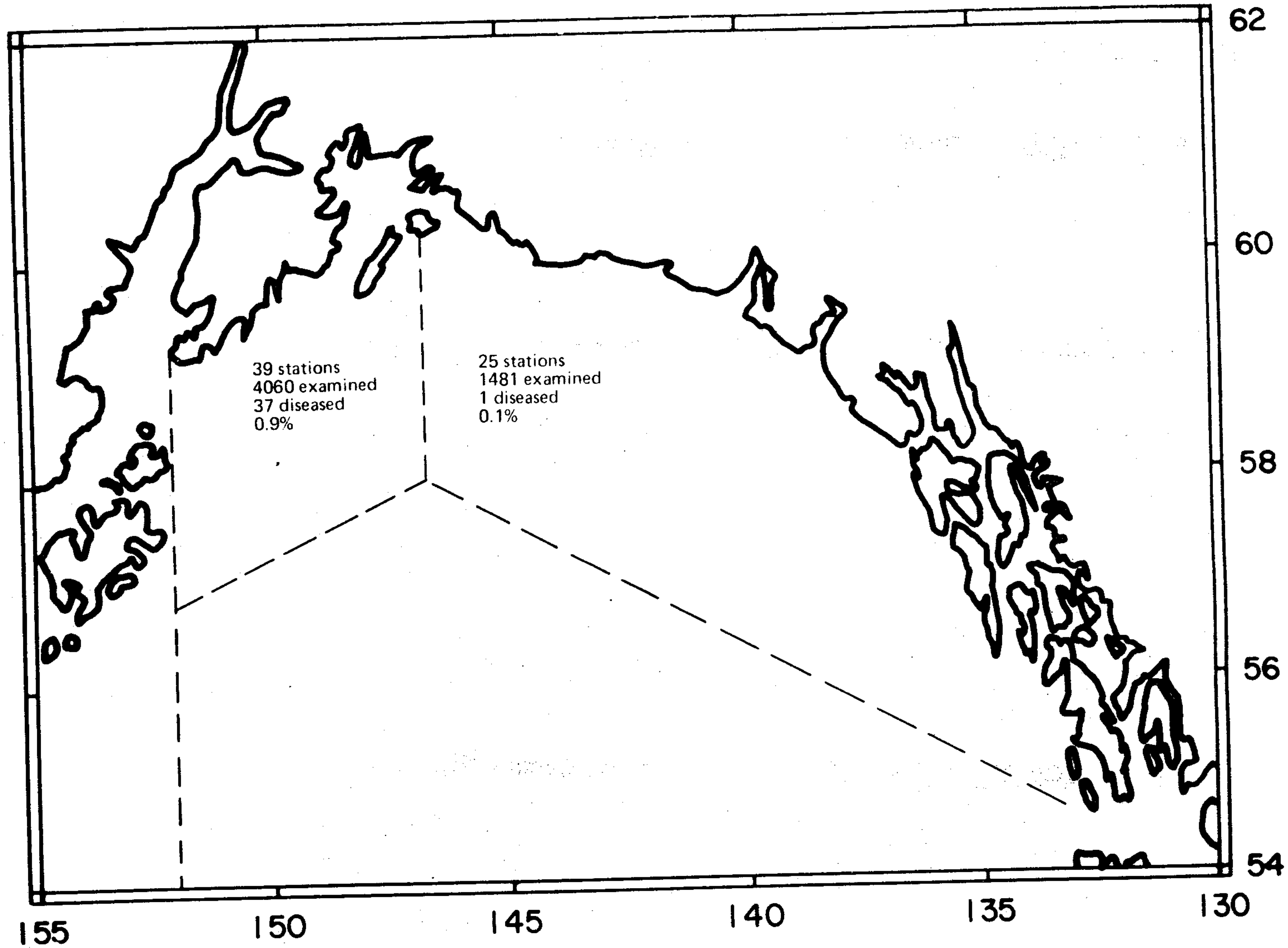


Figure 9. The general distribution and frequencies of pollock with pseudobranchial tumors in two areas of the GOA.

Figure 10. Skin ulcers on the ventrolateral surface of a Pacific cod.

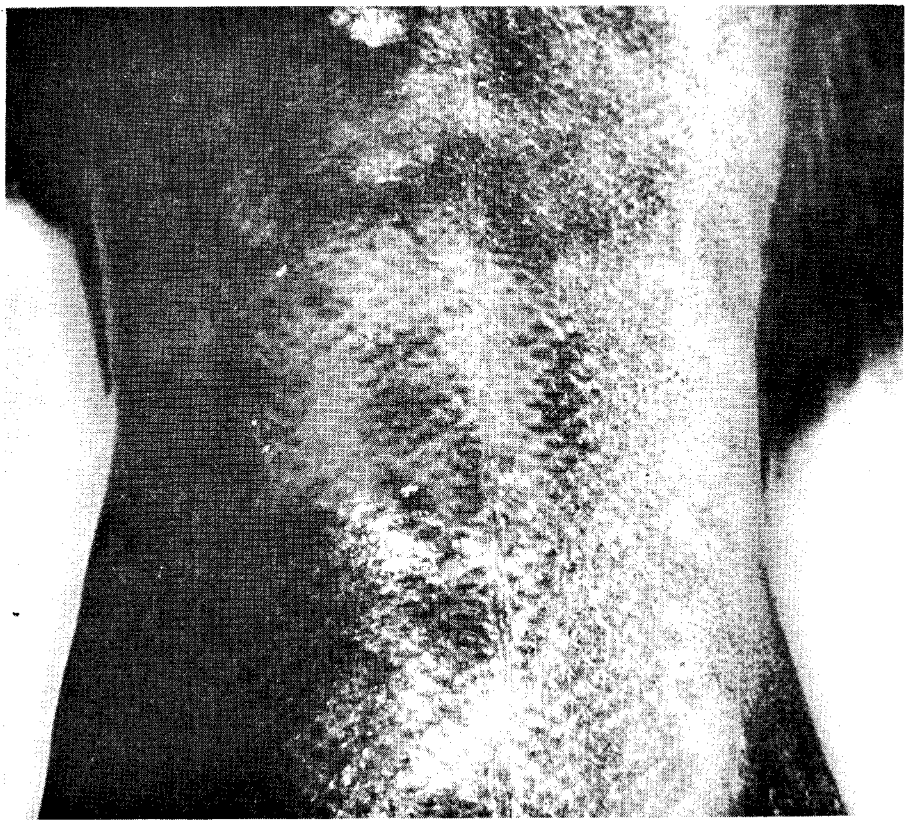


Figure 11. A ring-like lesion near the caudal region of a Pacific cod.

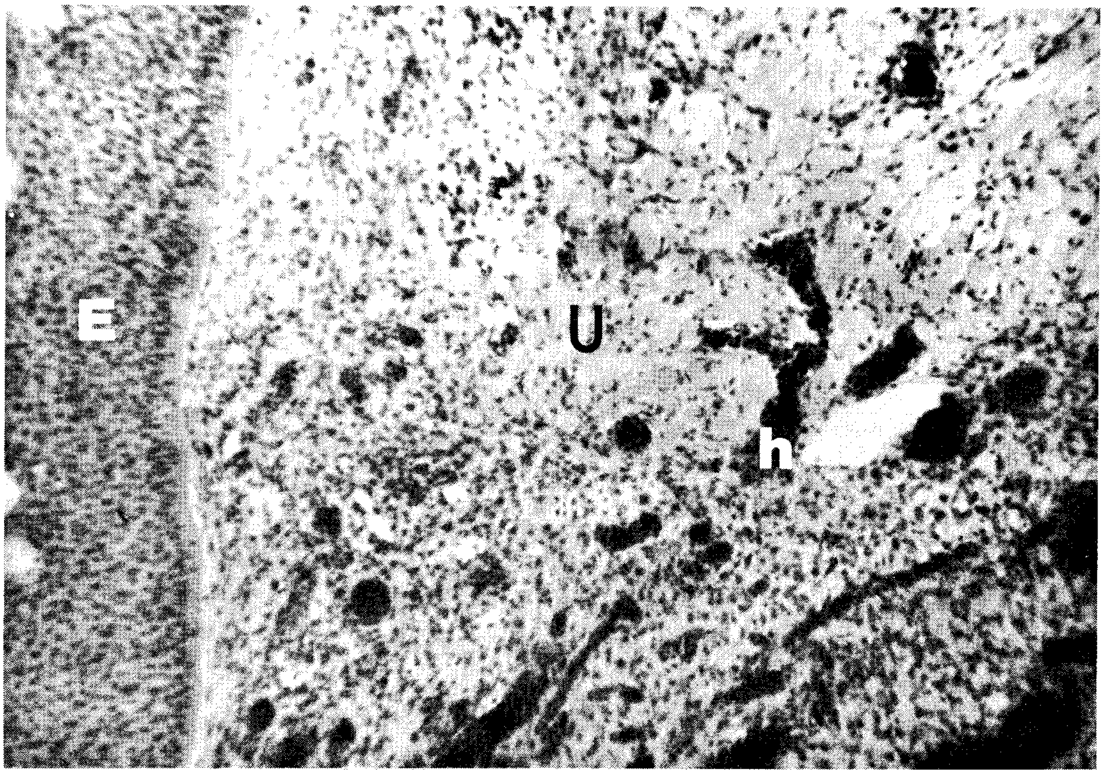


Figure 12. Section of a skin ulcer on a Pacific cod. Normal appearing epidermis (E) is to the left, the ulcerated area (U) is to the bottom, and the dermis surrounding the ulcer has extensive hyperemia (h). (Hematoxylin and Eosin, X250).

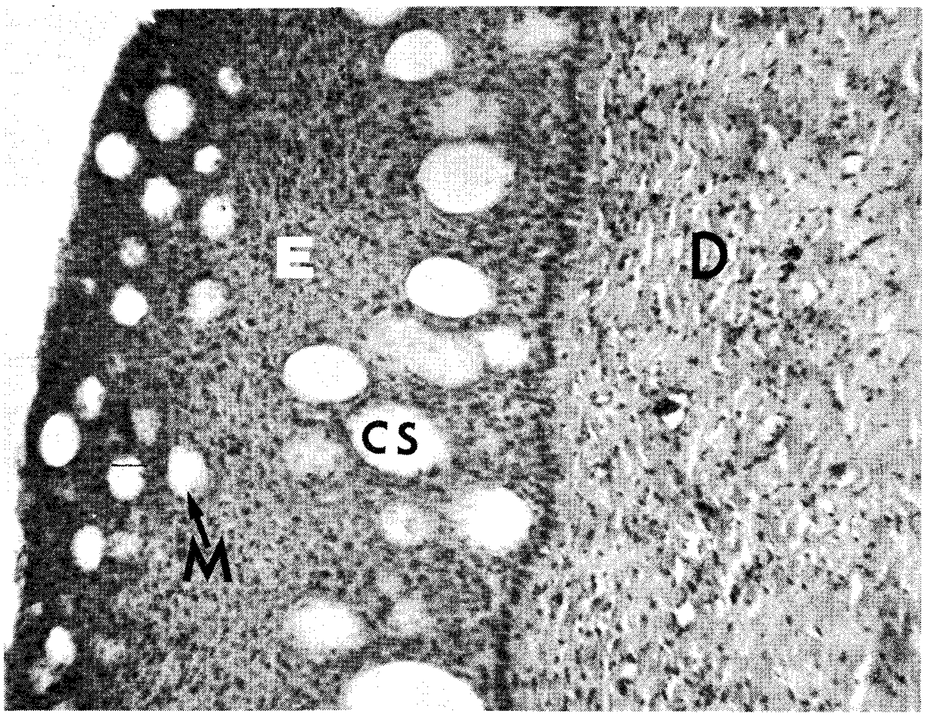


Figure 13. Section of normal skin from a Pacific cod showing epidermis (E) containing mucous cells (M) and large cystic structures (CS). The normal-appearing dermis (D) is also present. (Hematoxylin and Eosin, X250).

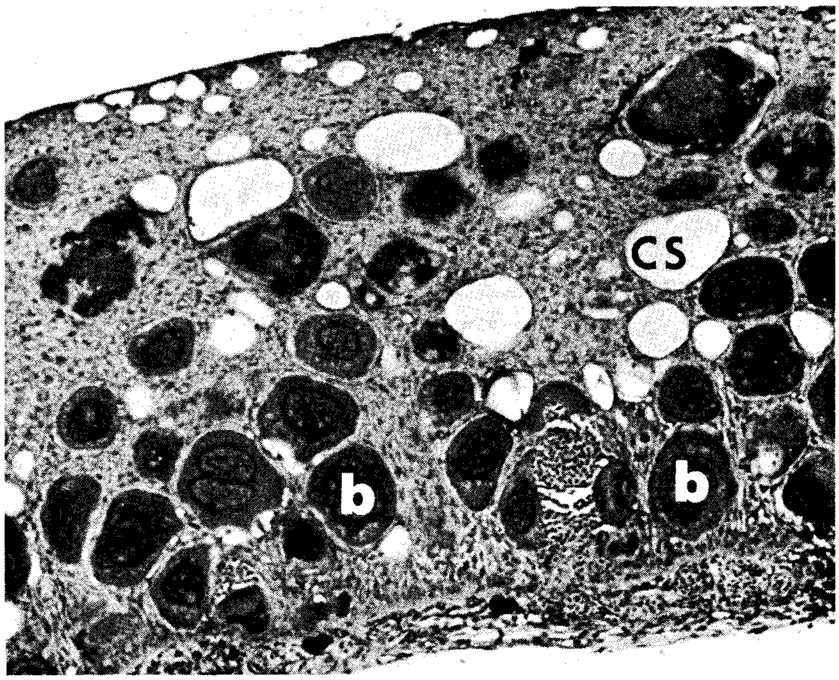


Figure 14. Section of a ring-shaped skin lesion from a Pacific cod demonstrating the basophilic bodies (b) and large cystic structures (cs) in the epidermis. (Hematoxylin and Eosin, X100)

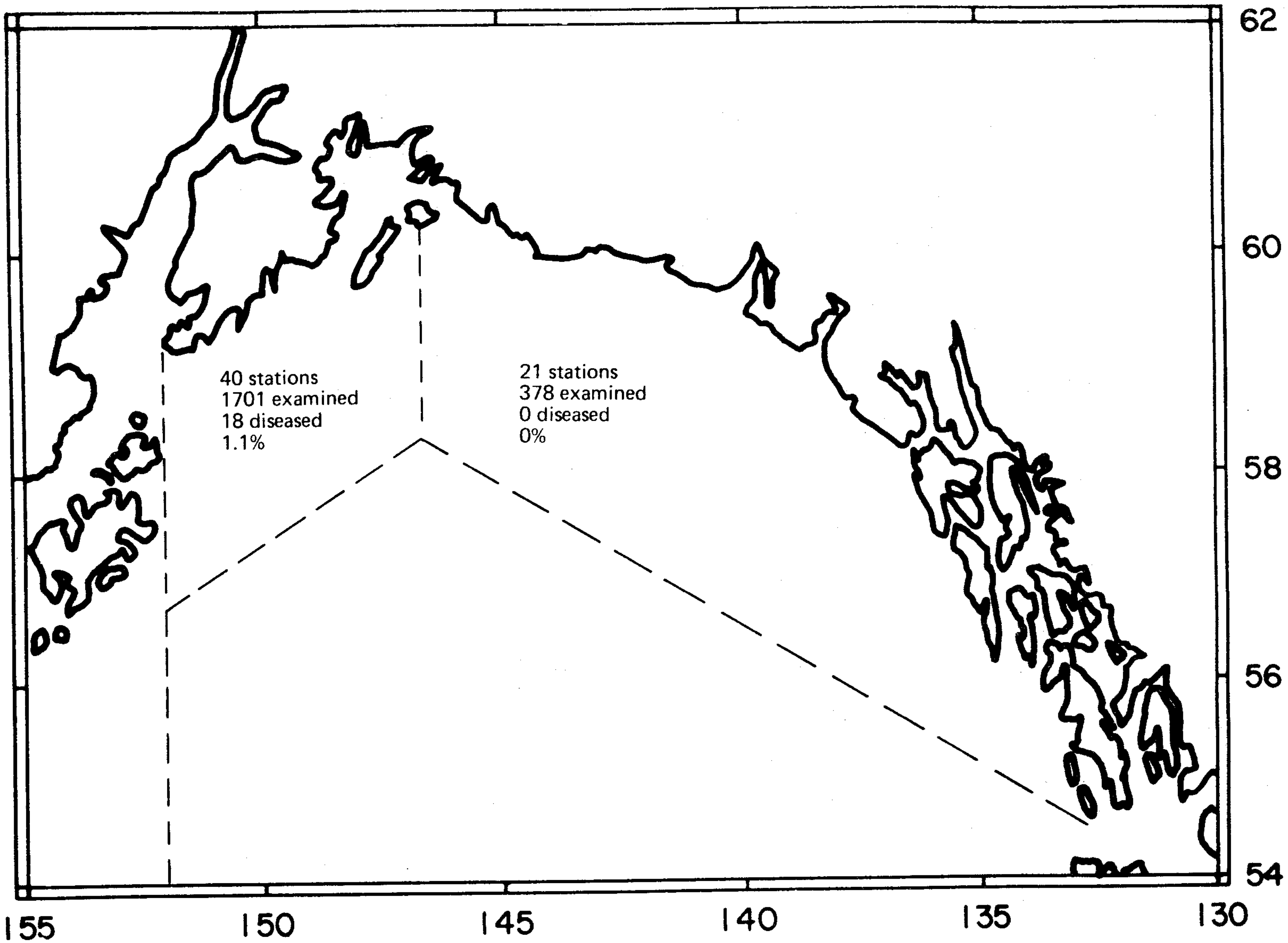


Figure 15. The general distribution and frequencies of Pacific cod with skin ulcers in two areas of the GOA.

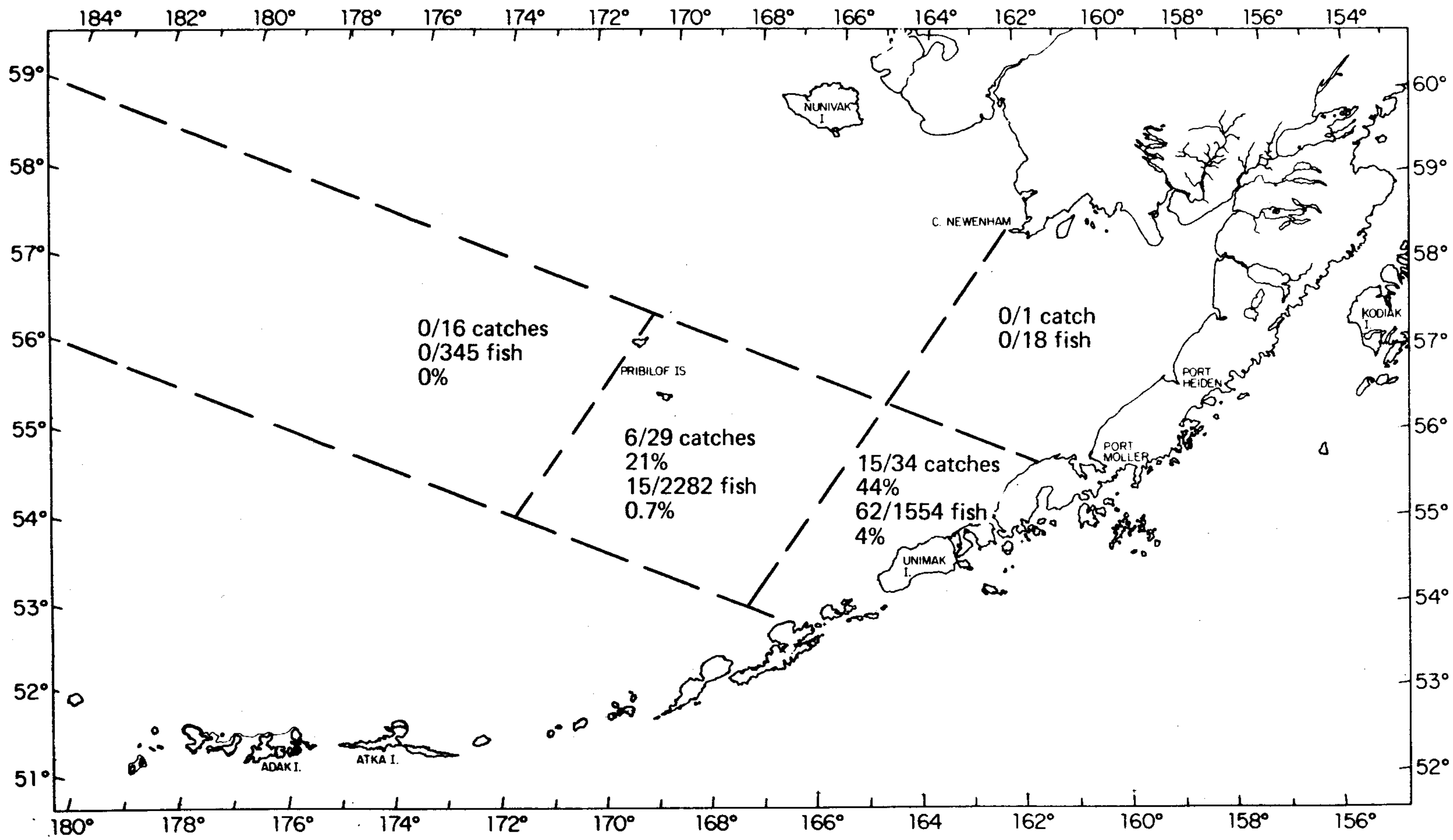


Figure 16. The general distribution and frequencies of Pacific cod with skin lesions in four areas of the Bering Sea.

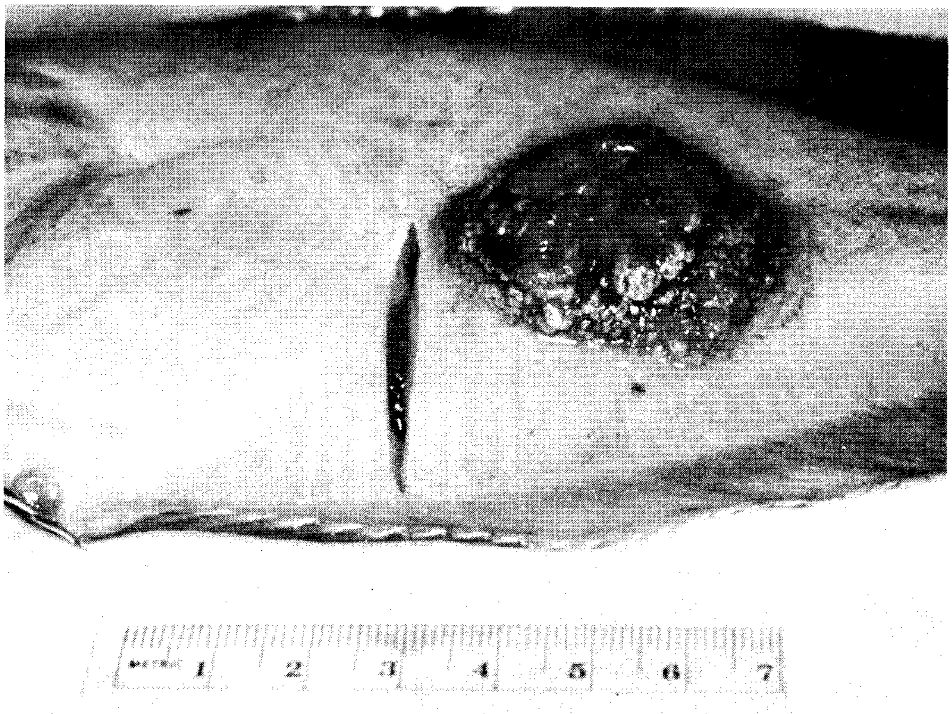


Figure 17. Rock sole with an epidermal papilloma on its "blind" side.

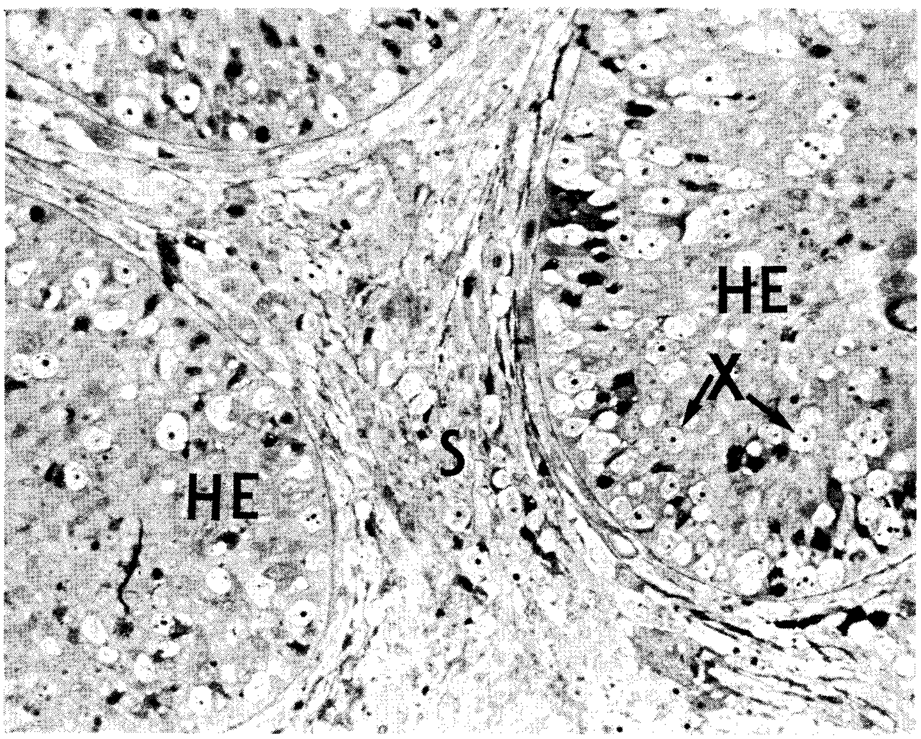
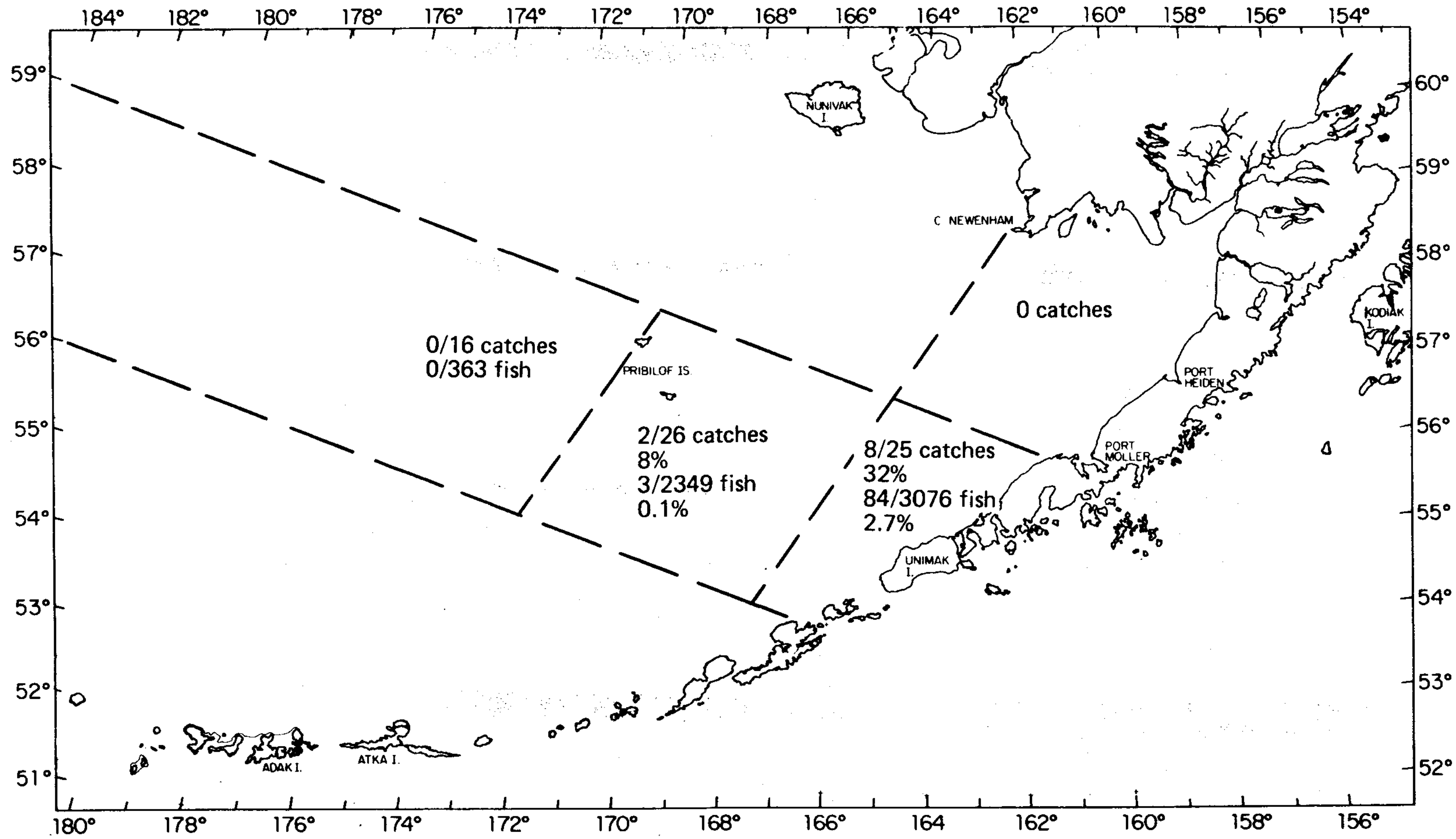


Figure 18. Section of an epidermal papilloma from a rock sole. Fibrovascular stroma (S) extends up through hyperplastic epithelium (HE); both areas contain X-cells characterized by their large size, pale nucleus and large, intensely stained nucleolus. (Richardson's Stain, X100)



ution and frequencies of rock sole with epidermal
areas of the Bering Sea.

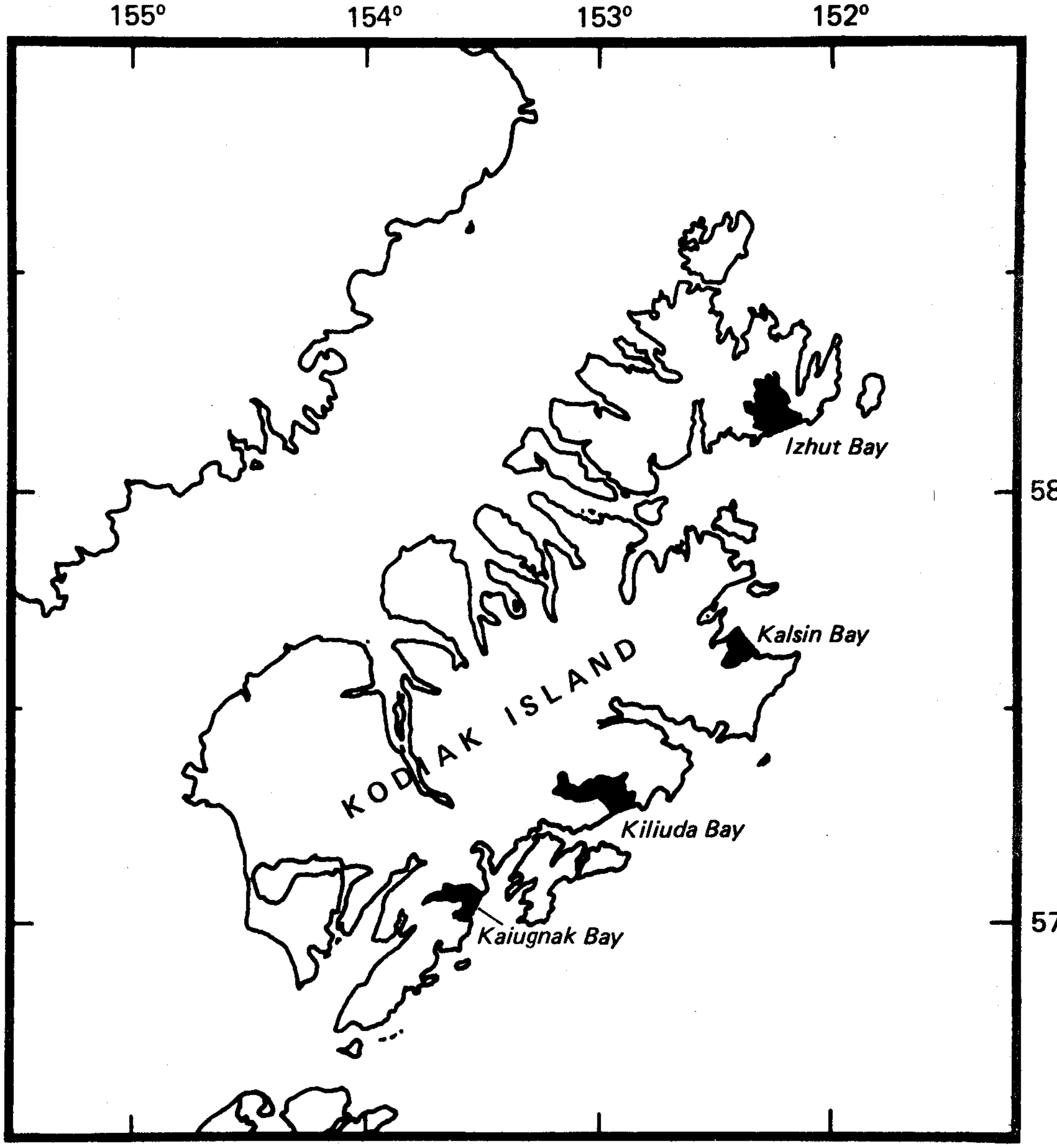


Figure 20. Map depicting bays sampled (dark areas) on Kodiak Island.

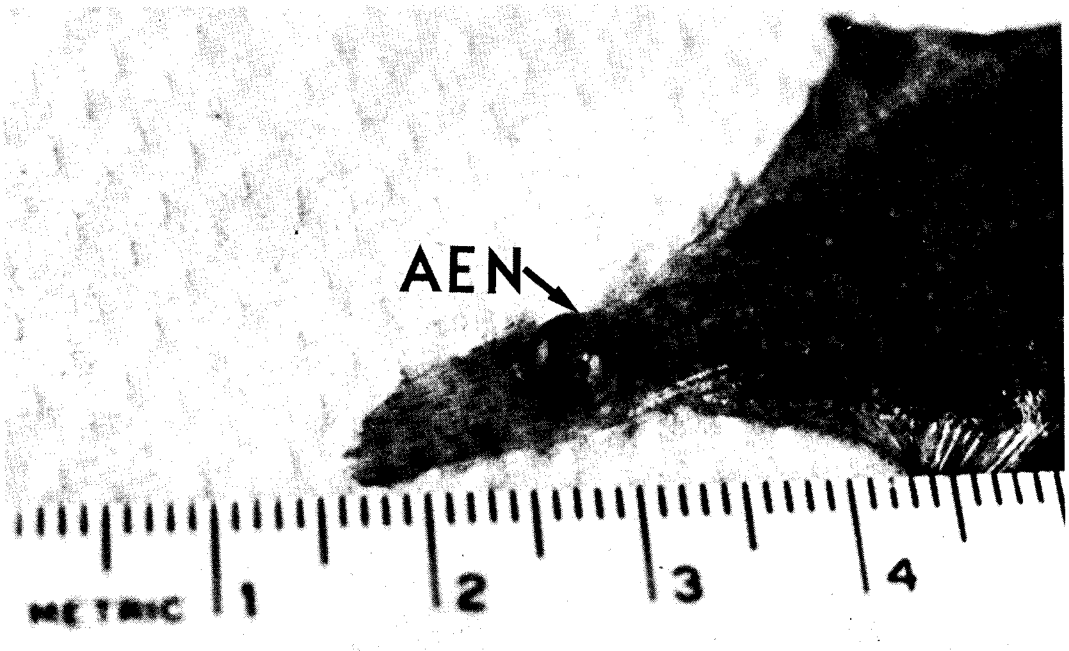


Figure 21. Young rock sole with an angioepithelial nodule (AEN) near the caudal fin.

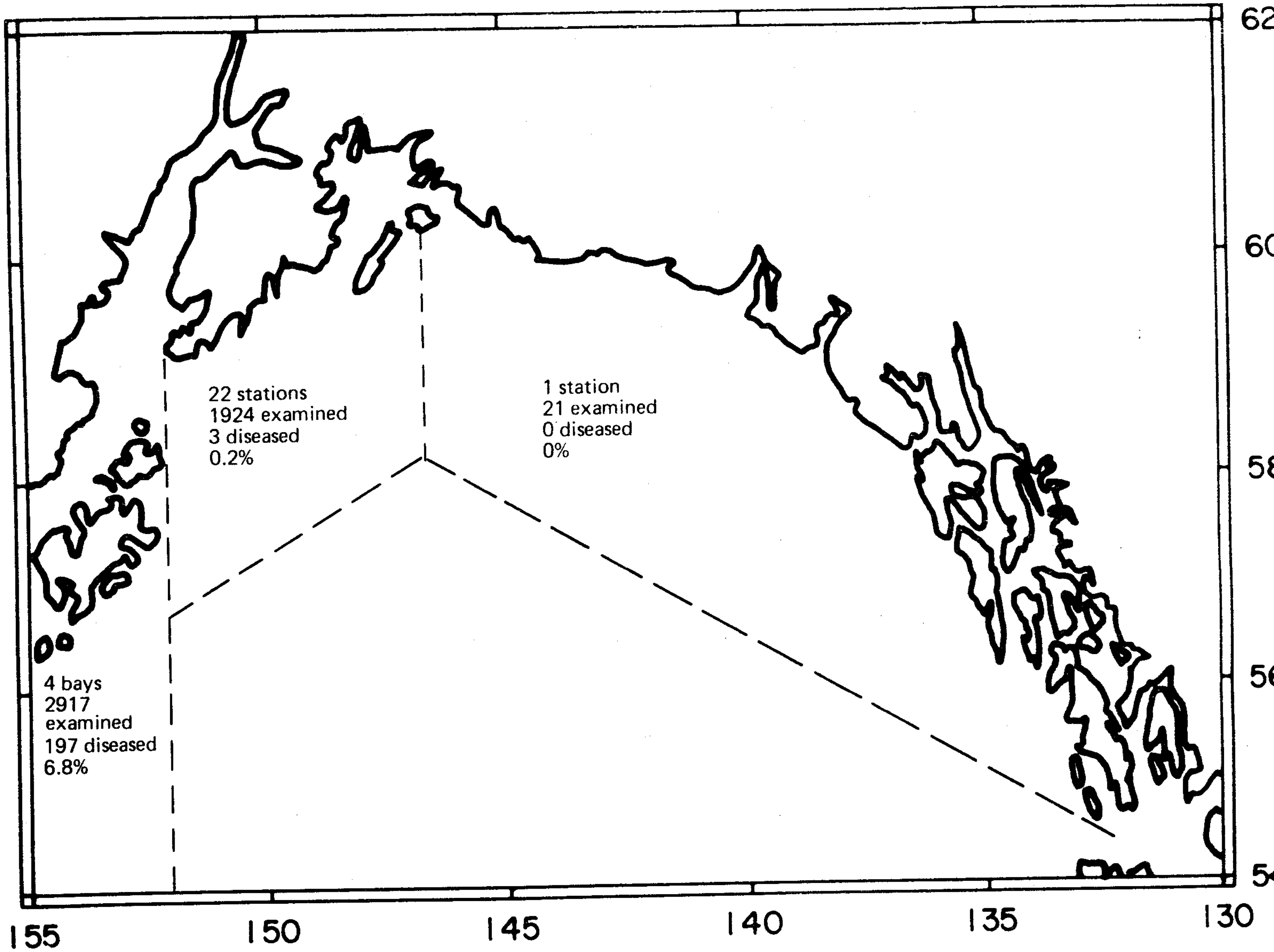


Figure 22. The general distribution and frequencies of rock sole with epidermal papillomas in the bays of Kodiak Island (the most easterly area) and in the offshore waters of the GOA.

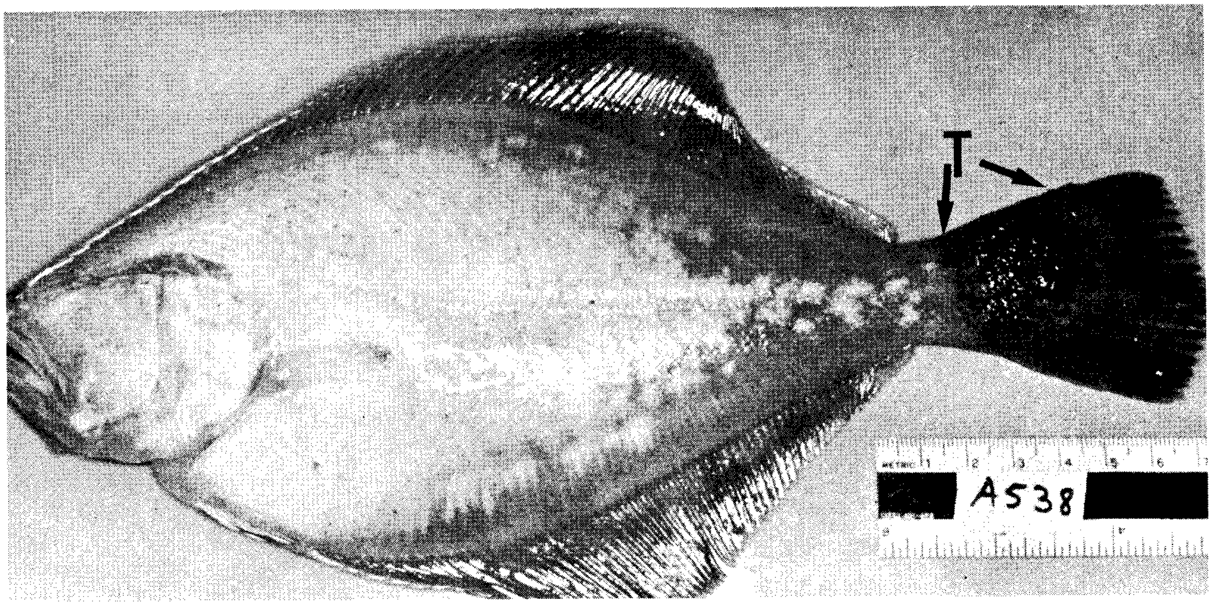


Figure 23. A flathead sole with an epidermal papilloma (T) on the "blind" side of the caudal region.

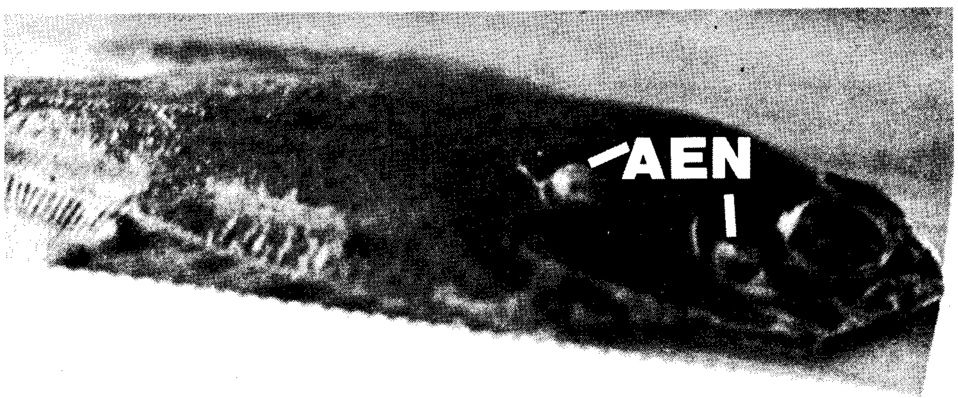


Figure 24. A young flathead sole with two angioepithelial nodules (AEN), one on the abdomen and one on the head.

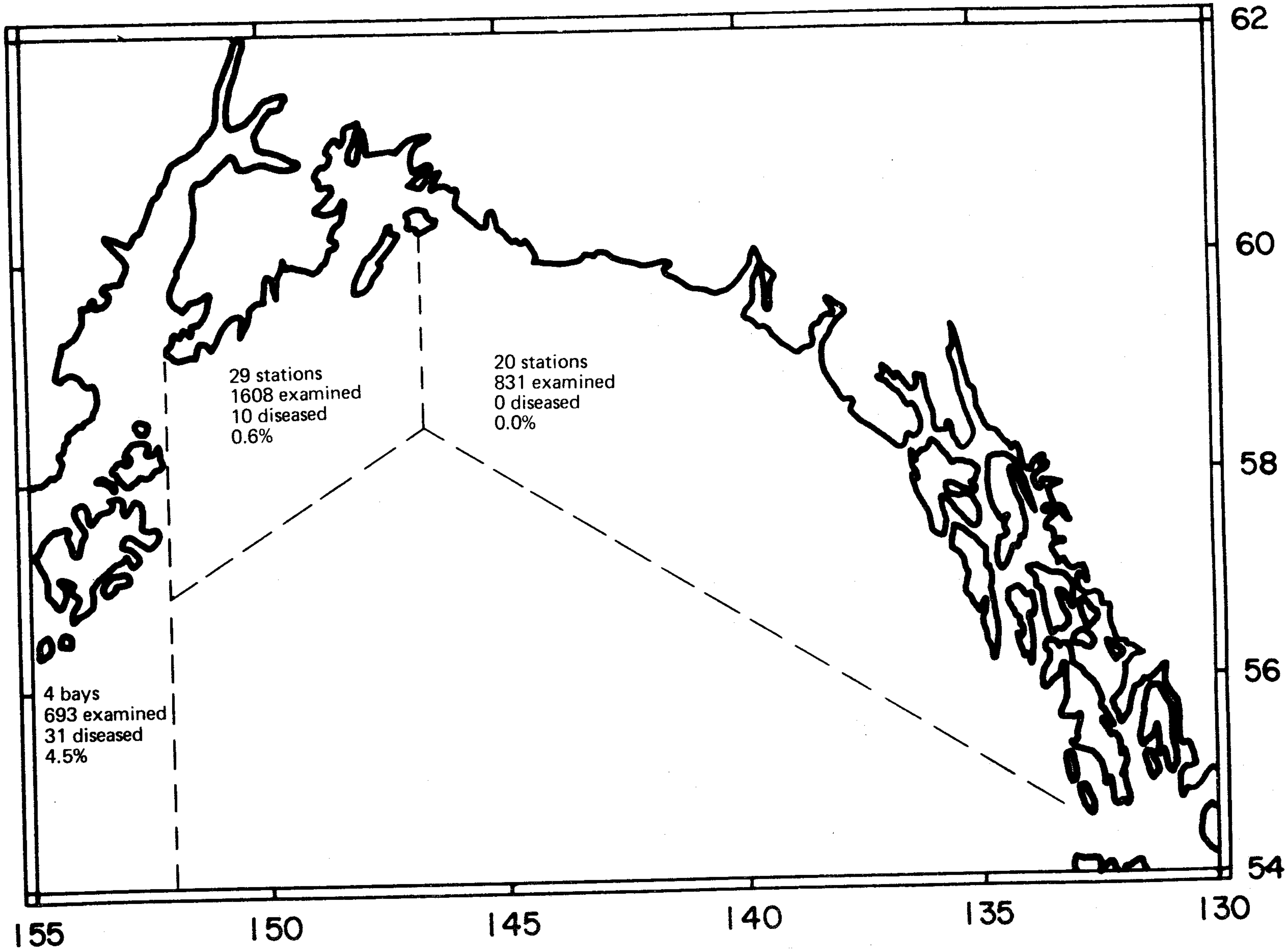


Figure 25. The general distribution and frequencies of flathead with epidermal papillomas in the bays of Kodiak Island (the most easterly area) and in the offshore waters of the GOA.

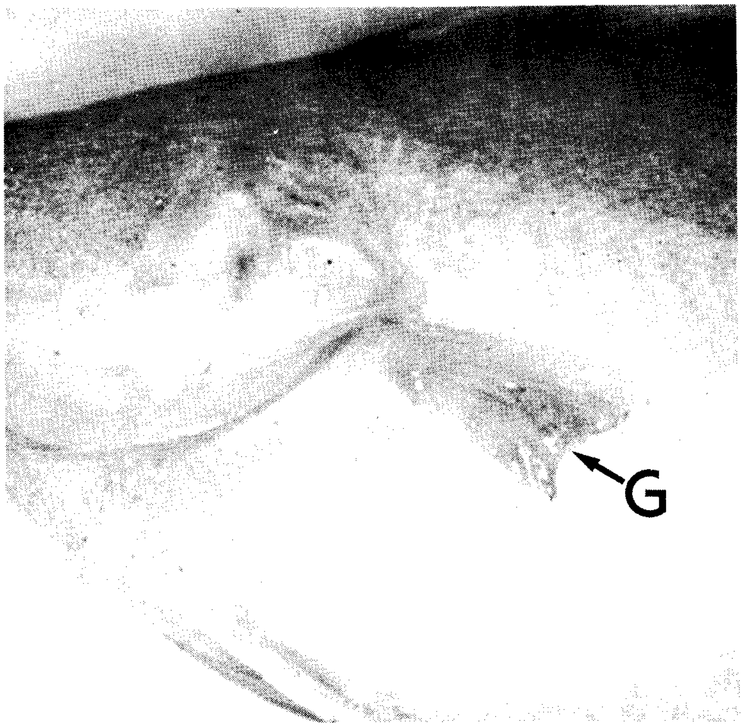


Figure 26. Lymphocystis growth (G) on the "blind side" pectoral fin of a yellowfin sole. The distal end of the fin is eroded.

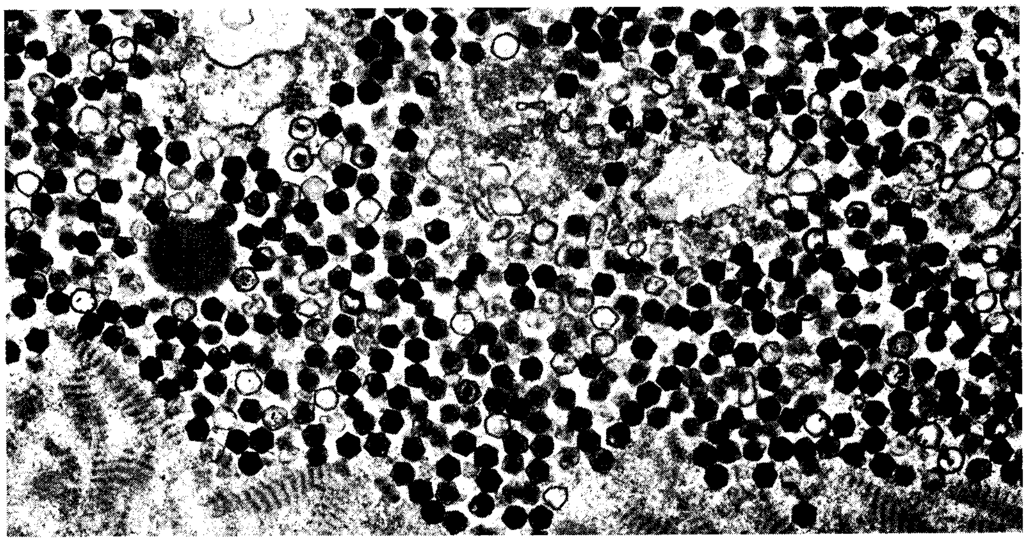


Figure 27. Electron micrograph of an inclusion body of a lymphocystis cell containing the hexagonal virions about 200 nm in diameter. (X 16,000).

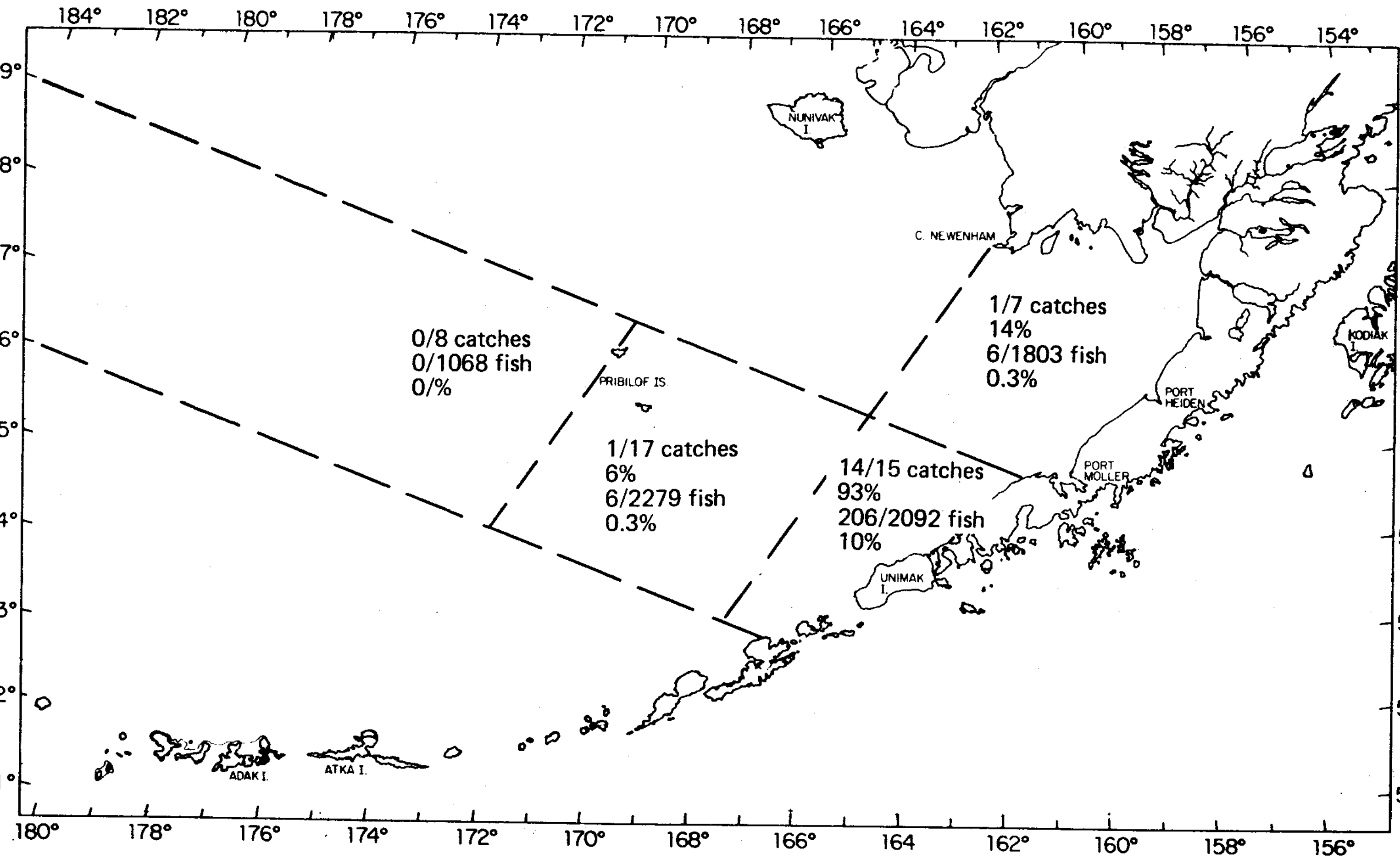


Figure 28. The general distribution and frequencies of yellowfin sole with lymphocystis in four areas of the Bering Sea.

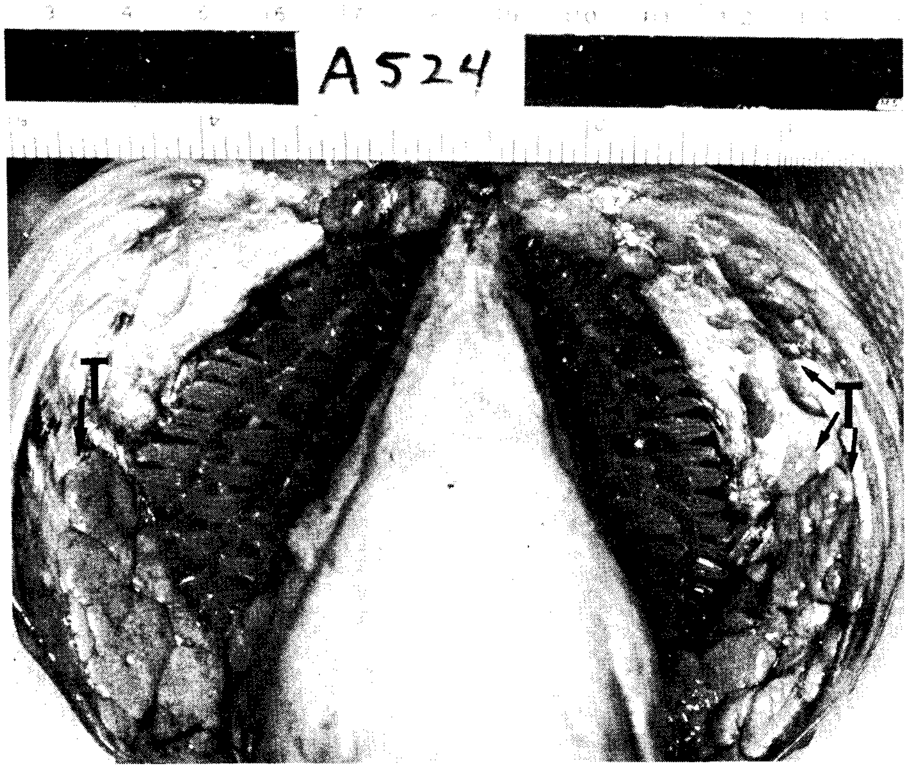


Figure 29. Epithelioid tumors (T) on the membrane on the underside of the operculum of a POP.

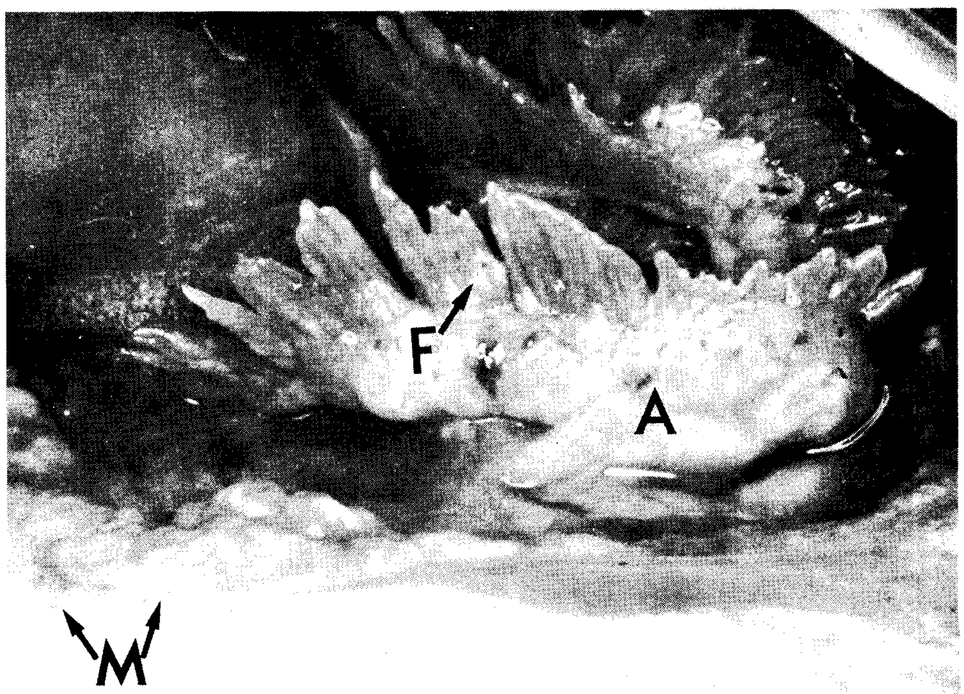


Figure 30. The ventral view of the gill cavity of a POP with extensive epithelioid tumors of the membrane between the posterior holobranch and cleithrum (M) and of the arch (A) and filaments (F) of the posterior holobranch.

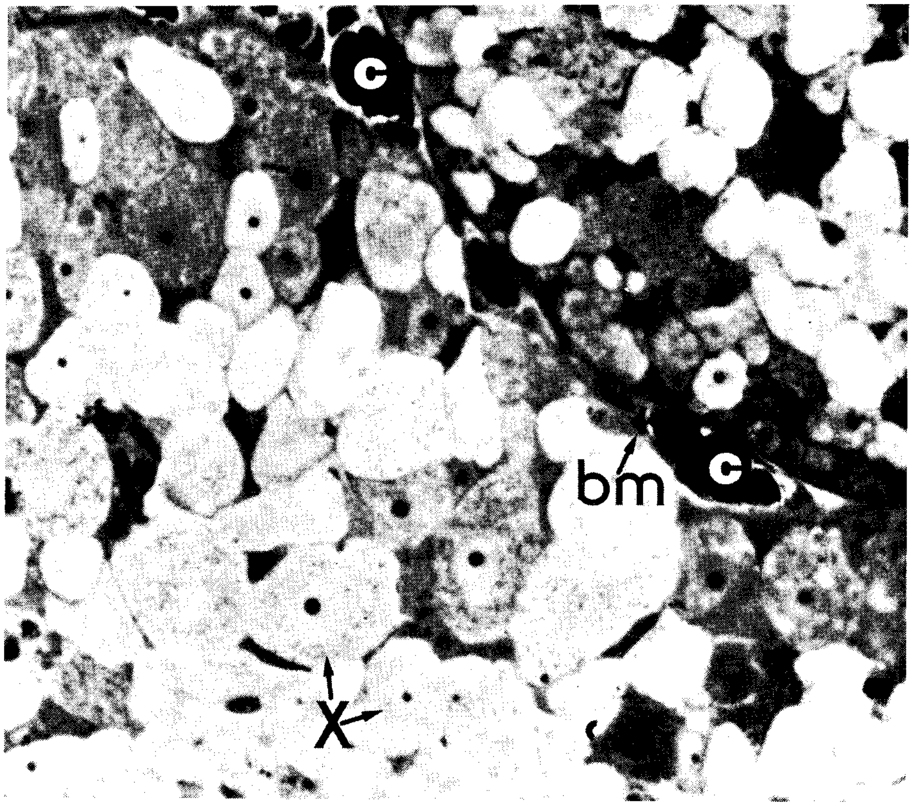


Figure 31. Light micrograph of a epithelioid tumor from the opercular membrane of a POP. X-cells (X) have a variably granular cytoplasm and some are in a state of degeneration. Basement membranes (bm) of X-cells nests are separated by a thin stroma containing capillaries (c). (Richardson's Stain, X780).

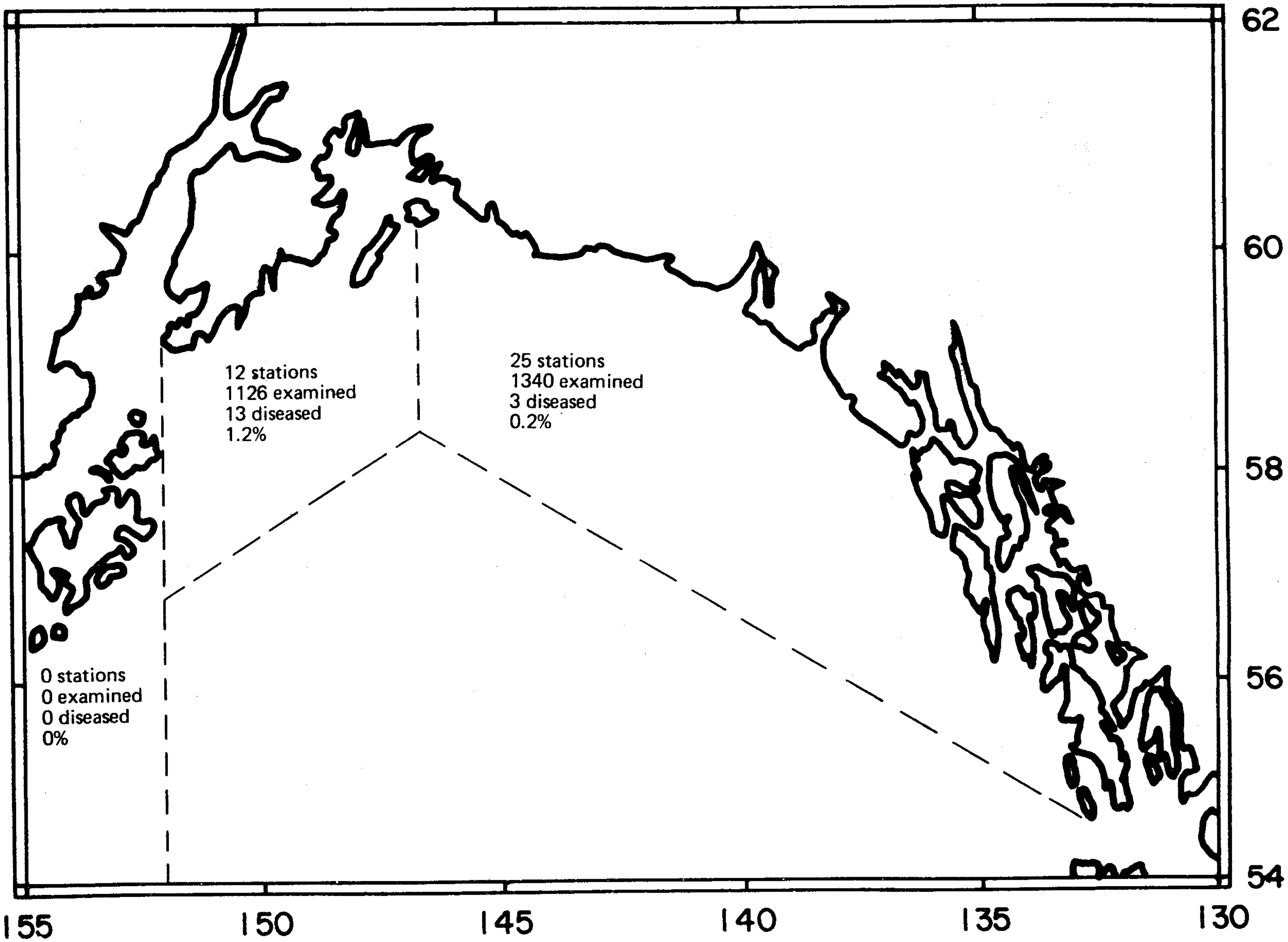


Figure 32. The general distribution and frequencies of POP with epithelioid tumors in two areas of the GOA.

Figure 33. Saffron cod from Norton Sound/Chukchi Sea area with "black spots" in its skin.

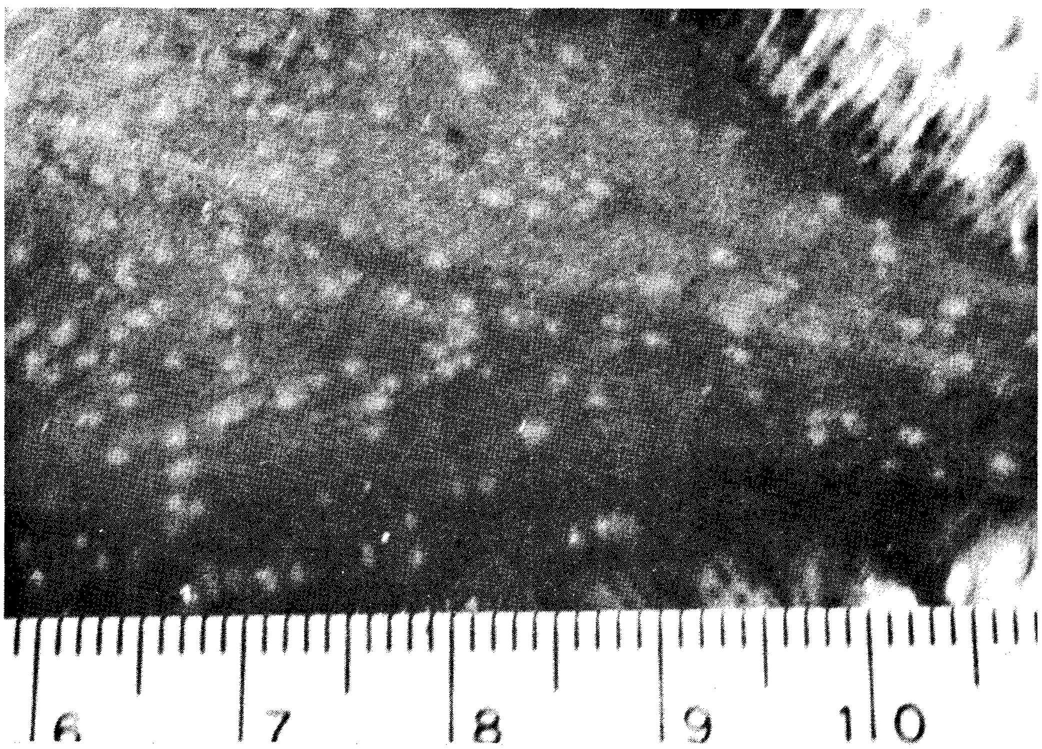


Figure 34. Rock sole from Kodiak Island with "white spots" in the "blind-side" skin.

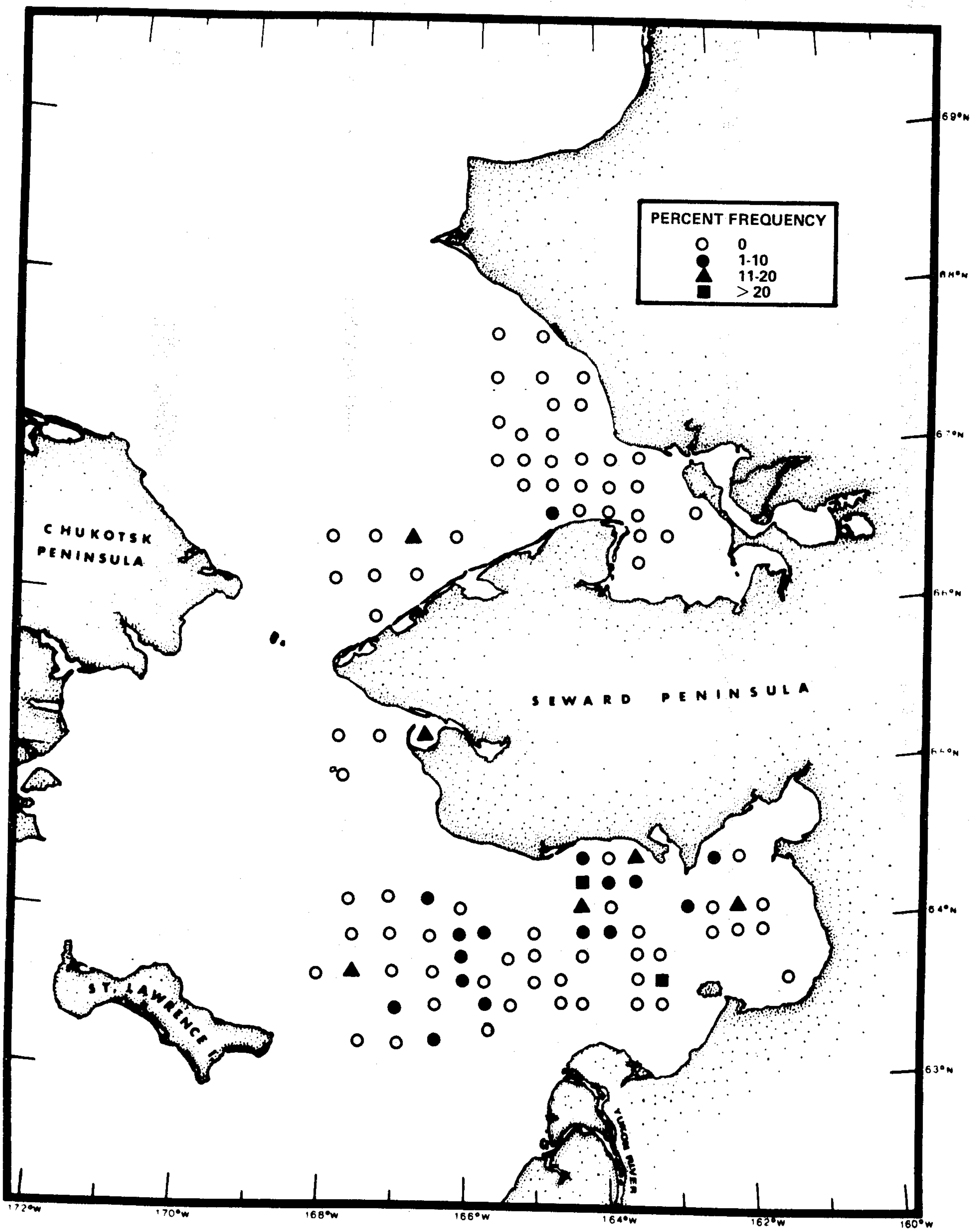


Figure 35. The geographical distribution of smelt with "black spot" disease in the Norton Sound and Chukchi Sea areas.

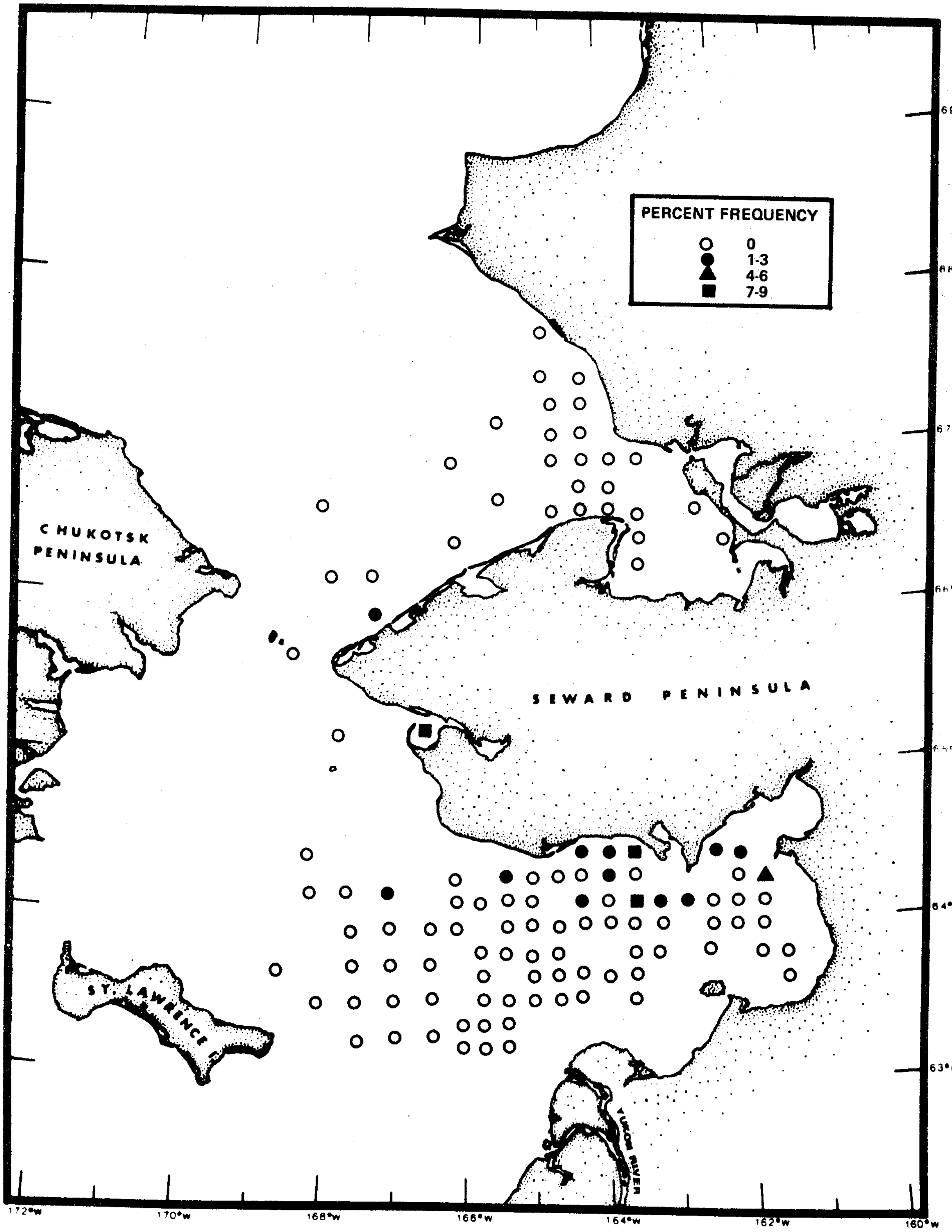


Figure 36. The geographical distribution of saffron cod with "black spot" disease in the Norton Sound and Chukchi Sea areas.

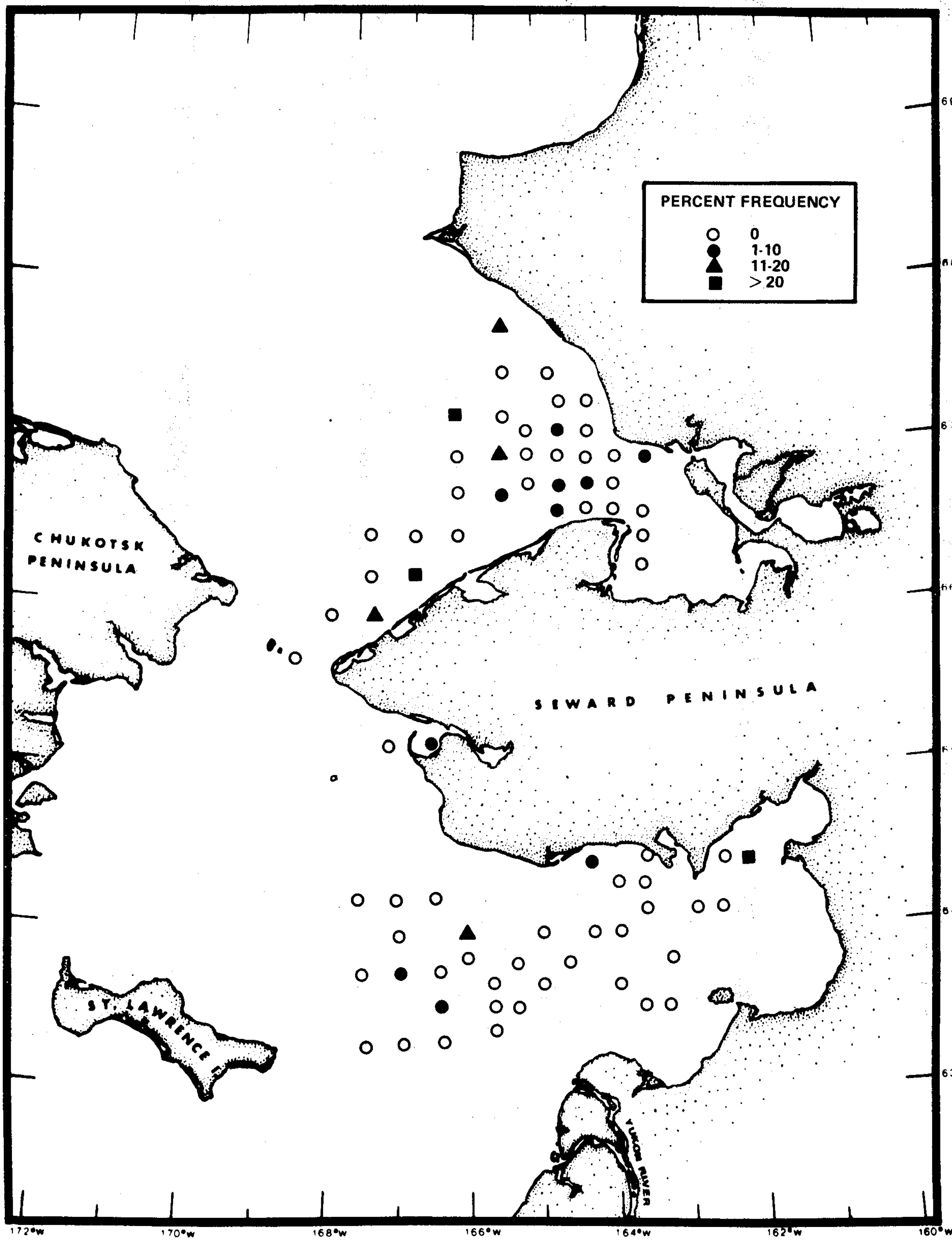


Figure 37. The geographical distribution of herring with "black spot" disease in the Norton Sound and Chukchi Sea areas.

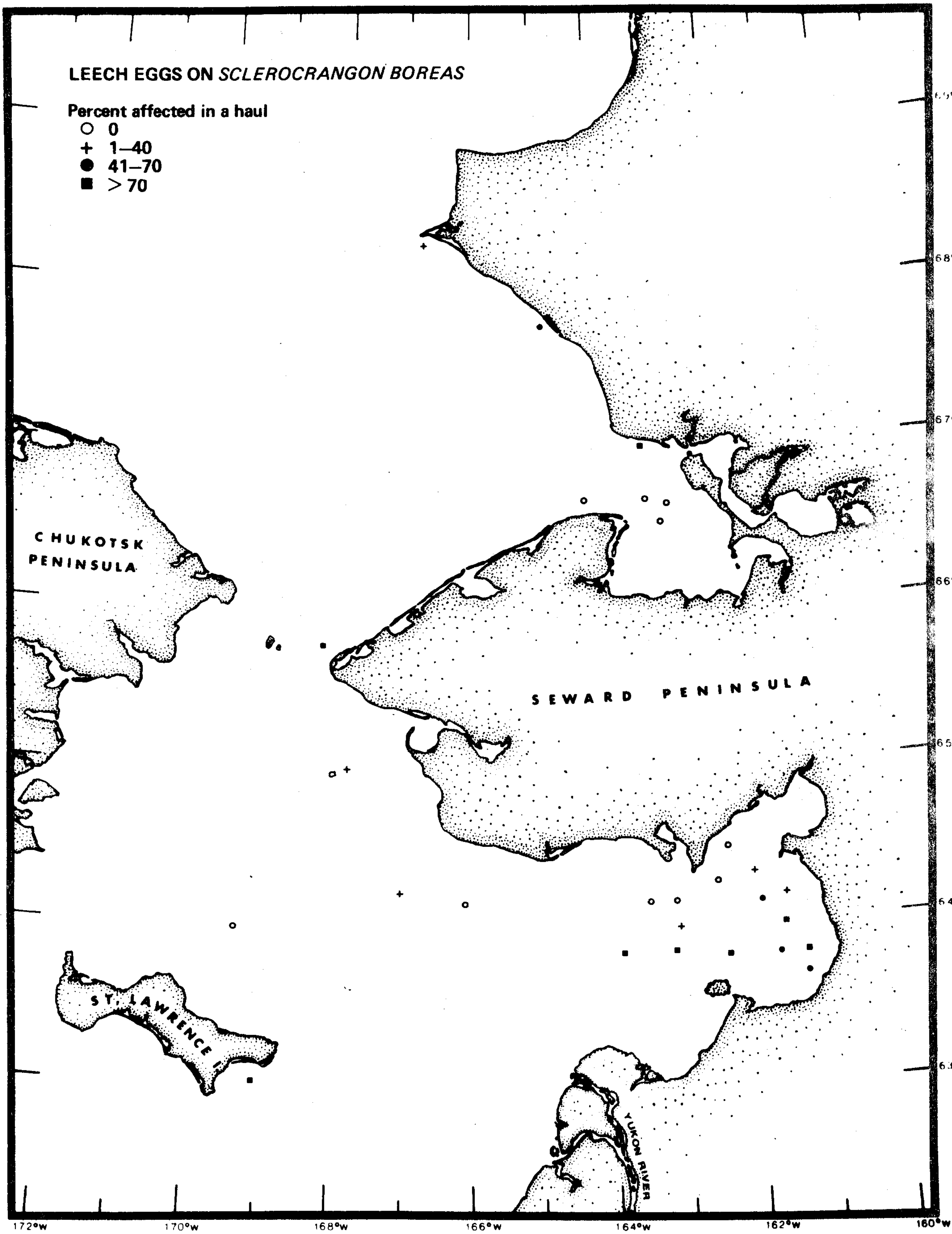


Figure 38. The geographical distribution of S. boreas with leech eggs in the Norton Sound and Chukchi Sea areas.

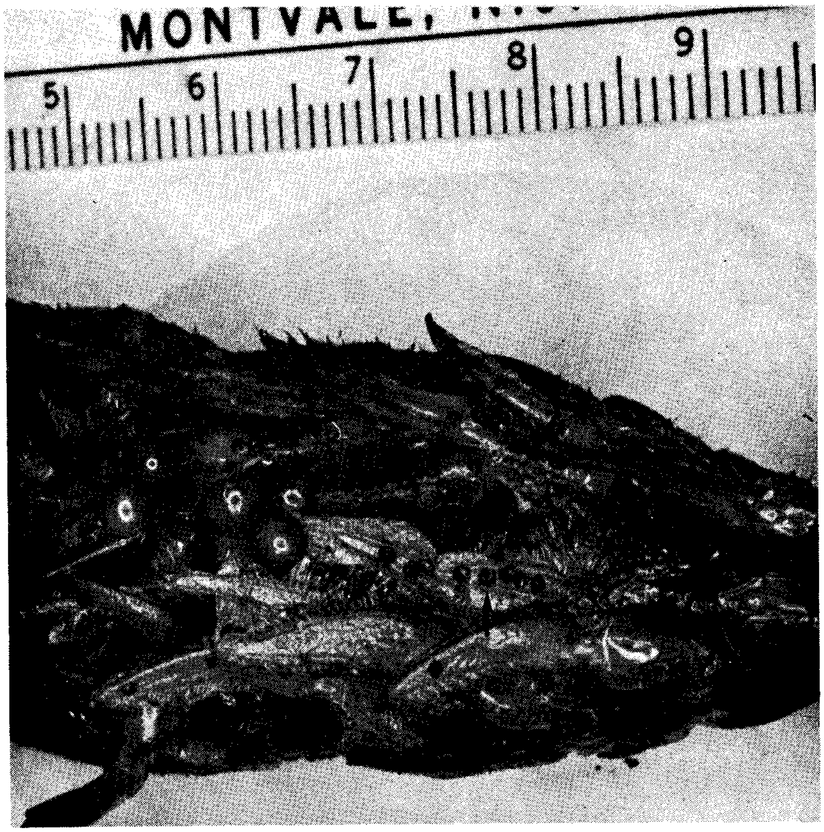


Figure 39. A S. boreas with leech eggs (arrows) on its pleopods.

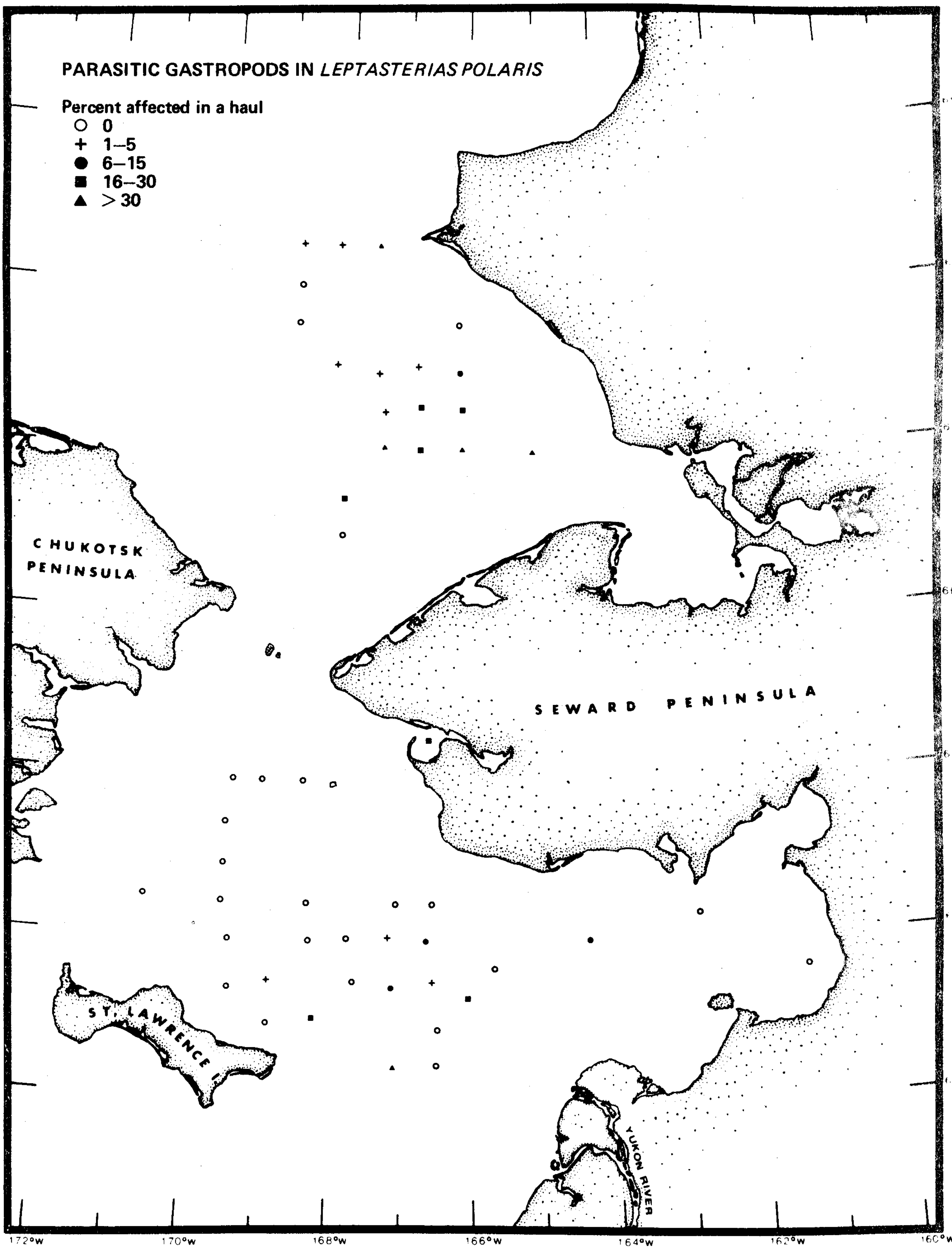


Figure 40. The geographical distribution of L. polaris with parasitic gastropods in the Norton Sound and Chukchi Sea areas.

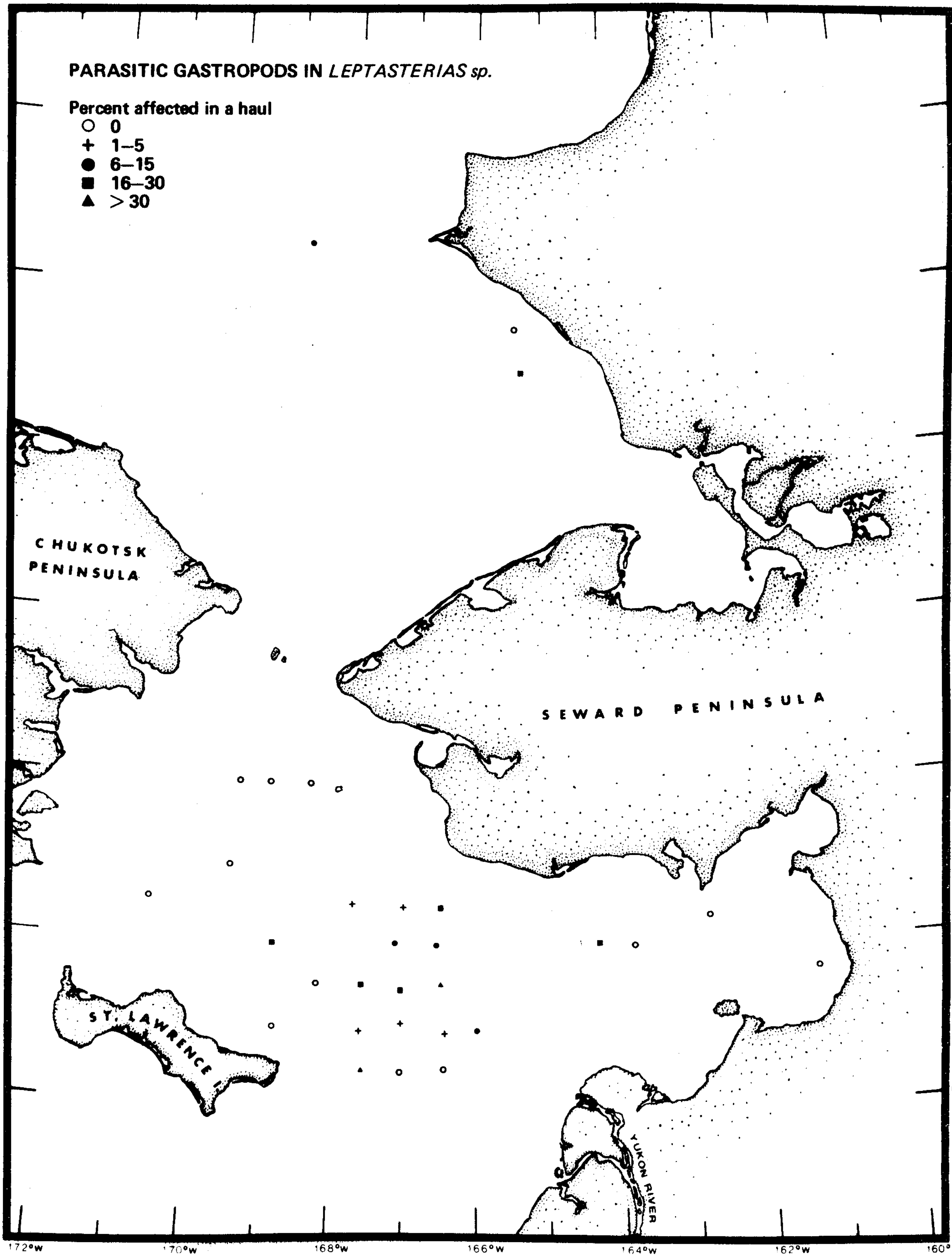


Figure 41. The geographical distribution of Leptasterias sp. with parasitic gastropods in the Norton Sound/Chukchi Sea areas.

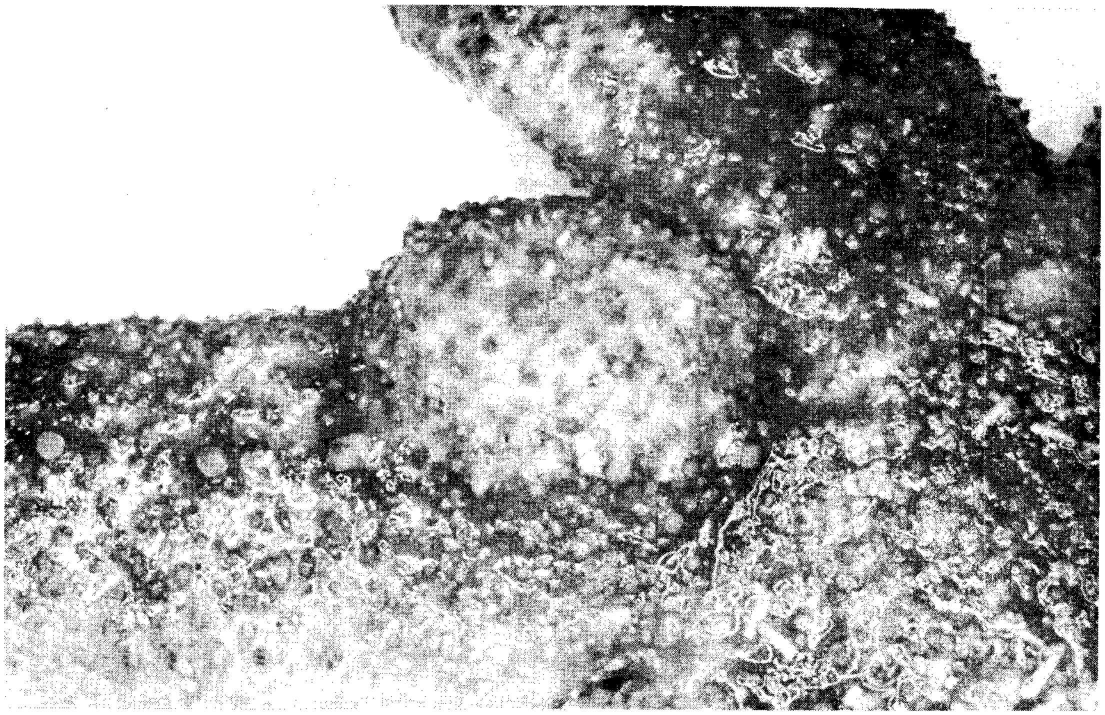


Figure 42. The upper surface of a *L. polaris* with a protuberance caused by an adult gastropod.

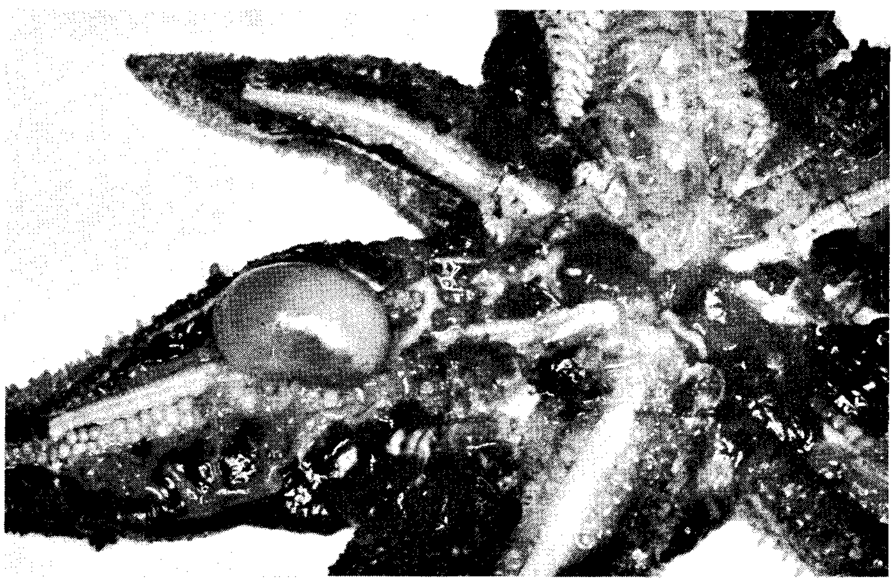


Figure 43. Similar to figure 42, except the rays have been cut open revealing one "bean-shaped" adult gastropod.

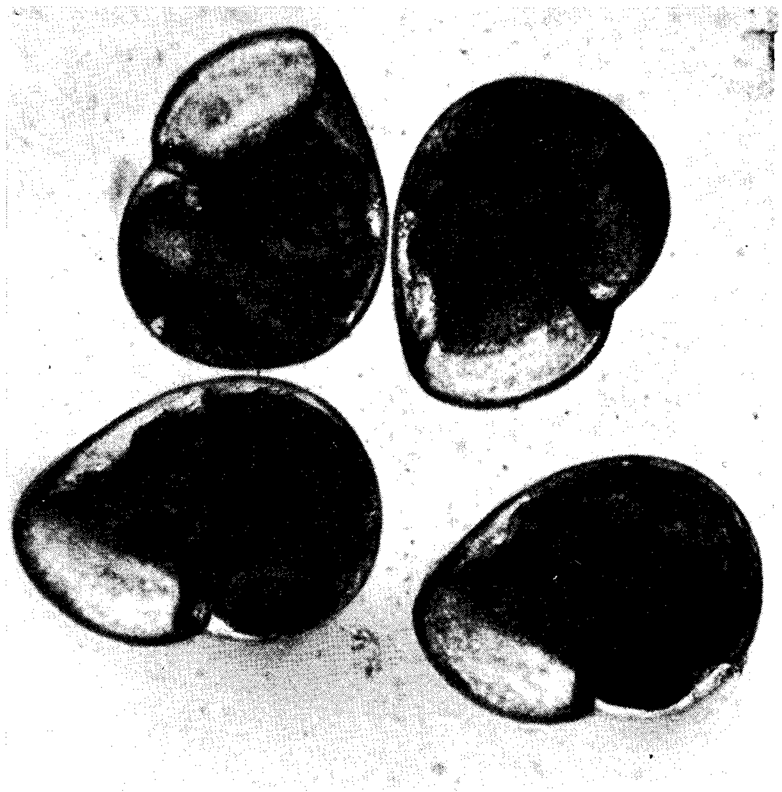


Figure 44. A low-power magnification of shelled veliger larvae excised from the body of an adult gastropod.

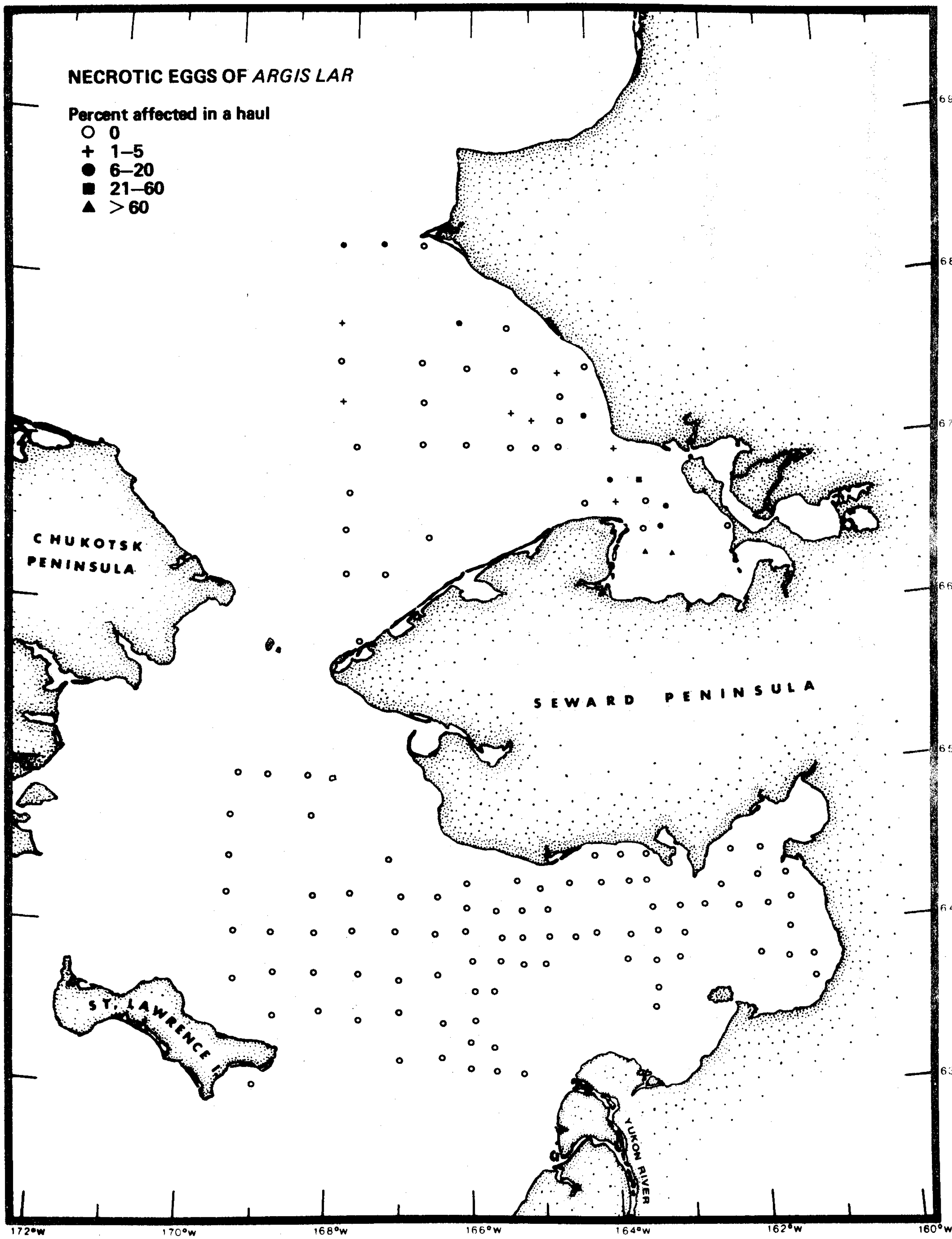


Figure 45. The geographical distribution of Argis lar with necrotic eggs from the Norton Sound and Chukchi Sea areas.

Figure 46. A tanner crab with heavy encrustation of the "black mat" disease.

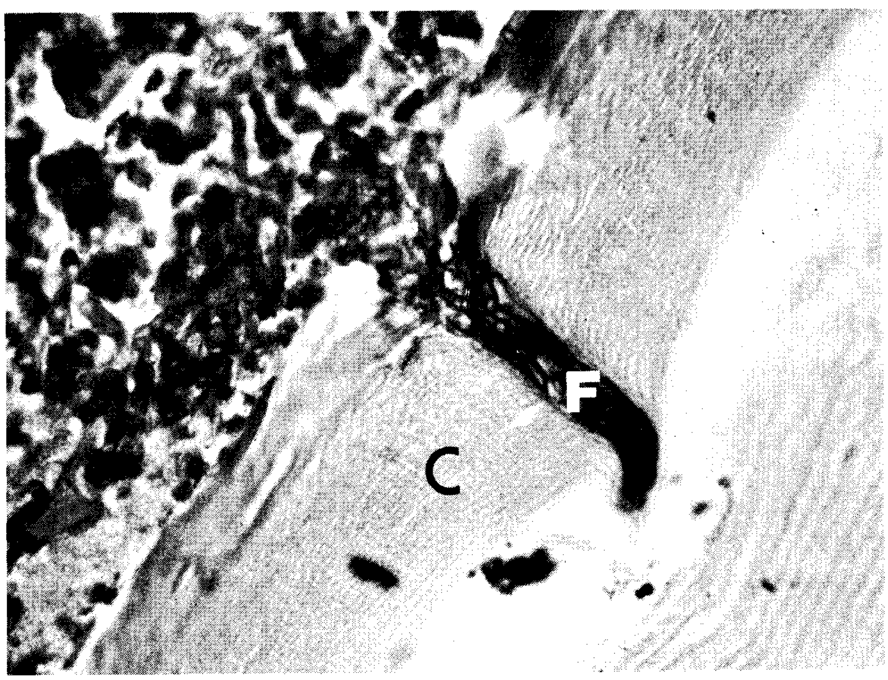


Figure 47. Fungal hyphae (F) penetrating the chitinous covering of the carapace (C). (Grocotts Stain, X620).

Final Report

Beaufort Sea Icebreaker Studies

Contract #: 03-78-B01-6
Research Unit #: 359
Reporting Period: 1976-1978

Beaufort Sea Plankton Studies

Rita A. Horner

1 February 1981

Table of Contents

List of Tables.. 68

List of Figures... 69

I. Summary of objectives, conclusions and implications with respect to OCS oil and gas development................................. 70

II. Introduction.. 71
A. General nature and scope of the study........................ 71
B. Specific objectives..
C. Relevance to problems of petroleum development............... 80
D. Acknowledgements... 80

III. Current state of knowledge................................. 80
A. Physical oceanography.. 80
B. Chemical oceanography: nutrients............................. 81
C. Plankton... 83
1. Zooplankton.. 83
2. Phytoplankton.. 83

IV. Study area.. 86

V. Sources, methods, and rationale of data collection and sample analysis... 86
A. Sample collection.. 86
1. Zooplankton... 86
a. WEBSEC-72... 86
b. OCSEAP 1976-1978.. 87
2. Phytoplankton... 87
a. WEBSEC-73 and CGC *Staten Island* 1974....................... 87
b. OCSEAP 1976-1978.. 88
3. Salinity.. 88
4. Temperature... 88
5. Secchi disc... 88
B. Sample analysis.. 89
1. Zooplankton... 89
a. WEBSEC-72... 89
b. OCSEAP 1976-1978.. 89
2. Phytoplankton... 93
a. WEBSEC-73... 93
1. Standing stock... 93
2. Plant pigments... 93
b. CGC *Staten Island* 1974..................................... 94
1. Standing stock... 94
2. Plant pigments... 94
c. OCSEAP 1976-1978.. 94
1. Standing stock... 94
2. Plant pigments... 95
3. Primary productivity.. 95
3. Temperature... 96
4. Salinity.. 96

VI. Results.. 96
A. Hydrography.. 96
B. Plankton... 141
1. Zooplankton.. 141
Coelenterata.. 141
Ctenophora.. 188
Annelida.. 188
Mollusca.. 188
Arthropoda - Ostracoda...................................... 189
Arthropoda - Copepoda....................................... 189
Arthropoda - Cirripedia..................................... 190
Arthropoda - Mysidacea...................................... 190
Arthropoda - Cumacea.. 191
Arthropoda - Cladocera...................................... 191
Arthropoda - Amphipoda...................................... 191
Arthropoda - Euphausicea.................................... 192
Arthropoda - Decapoda....................................... 193
Echinodermata... 193
Chaetognatha.. 193
Chordata - Larvacea... 194
Chordata - Pisces... 194
Other organisms... 194
2. Phytoplankton.. 195

VII. Discussion... 241

VIII. References cited...................................... 248

Appendix I.. 259

List of Tables

1. Number and kinds of samples collected/analyzed by cruise in the Beaufort Sea, 1972-1978..79 79

2. References used to identify zooplankton from the Beaufort Sea, WEBSEC-72 samples..90 90

3. References used to identify zooplankton from the Beaufort Sea, OCSEAP 1976-1978 samples..91 91

4. Station locations, temperature, salinity, chlorophyll *a* concentrations, and total number of phytoplankton cells per liter for stations taken in the Beaufort Sea, 28 Jul - 12 Aug 1973, CGC *Glacier*........... 97

5. Station locations, temperature, salinity, and chlorophyll *a* concentrations for stations taken in the Beaufort Sea, 19 Aug - 5 Sep 1974, CGC *Staten Island*.. 108

6. Station locations, temperature, salinity, chlorophyll *a* and phaeopigment concentrations, and primary productivity for stations taken in the Beaufort Sea, 17 Aug - 2 Sep 1976, CGC *Glacier*............. 115

7. Station locations, temperature, salinity, ice cover, chlorophyll *a* and phaeopigment concentrations, and primary productivity for stations taken in the Beaufort Sea, 7 Aug - 5 Sep 1977, CGC *Glacier*........... 119

8. Station locations, temperature, salinity, ice cover, chlorophyll *a* and phaeopigment concentrations, and primary productivity for stations taken in the Beaufort Sea, 15 Aug - 15 Sep 1978, CGC *Northwind*....... 131

9. Zooplankton species present in the Beaufort Sea, 1972 and 1976-1978..... 182

10. List of phytoplankton species found in the Beaufort Sea........ 196

11. Percent *Chaetoceros* species, all other diatoms, flagellates, and dinoflagellates at depth of greatest carbon uptake, 17 Aug - 2 Sep 1976..... 218

12. Percent *Chaetoceros* species, all other diatoms, flagellates, and dinoflagellates at depth of greatest carbon uptake, 7 Aug - 5 Sep 1977...... 228

13. Percent *Chaetoceros* species, all other diatoms, flagellates, and dinoflagellates at depth of greatest carbon uptake, 15 Aug - 15 Sea 1978.... 240

14. List of hydrozoan names based on Kramp (1961) and Naumov (1960)......... 243

List of Figures

1. Locations where samples were collected in the Beaufort Sea...... 72

2. Locations where zooplankton samples were collected during WEBSEC-72, CGC *Glacier*, 4 Aug - 5 Sep 1972.................................. 73

3. Locations where phytoplankton samples were collected during WEBSEC-73, CGC *Glacier*, 28 Jul - 12 Aug 1973.............................. 74

4. Locations where phytoplankton samples were collected in 1974, CGC *Staten Island*, 19 Aug - 5 Sep 1974.............................. 75

5. OCSEAP station locations where phytoplankton and zooplankton were collected, CGC *Glacier*, 18 Aug - 2 Sep 1976.................... 76

6. OCSEAP station locations where phytoplankton and zooplankton were collected, CGC *Glacier*, 7 Aug - 5 Sep 1977..................... 77

7. OCSEAP station locations where phytoplankton and zooplankton were collected, CGC *Northwind*, 15 Aug - 15 Sep 1978................. 78

8. Depth profiles of temperature-salinity and chlorophyll *a*-phytoplankton cells per liter in the Beaufort Sea, 28 Jul - 12 Aug 1973....... 142

9. Depth profiles of temperature-salinity and chlorophyll *a* concentrations in the Beaufort Sea, 19 Aug - 5 Sep 1974...................... 153

10. Depth profiles of temperature-salinity and chlorophyll *a*-^{14}C assimilation in the Beaufort Sea, 17 Aug - 2 Sep 1976.................. 159

11. Depth profiles of temperature-salinity and chlorophyll *a*-^{14}C assimilation in the Beaufort Sea, 7 Aug - 5 Sep 1977................... 163

12. Depth profiles of temperature salinity and chlorophyll *a*-^{14}C assimilation in the Beaufort Sea, August-September 1978................. 173

13. Percentage of phytoplankton by major category by depth for each station CGC *Glacier*, 28 Jul - 12 Aug 1973.............................. 199

14. Percentage of phytoplankton by major category by depth for each station CGC *Glacier* 1976.. 213

15. Percentage of phytoplankton by major category by depth for each station CGC *Glacier* 1977.. 220

16. Percentage of phytoplankton by major category by depth for each station CGC *Northwind* 1978.. 229

I. Summary of objectives, conclusions, and implications with respect to OCS oil and gas development.

The objectives of this project have been to determine the seasonal density distribution and environmental requirements of phytoplankton, zooplankton, and ichthyoplankton and to determine seasonal indices of phytoplankton production. In addition, this project was to summarize existing literature and identify archived samples.

These objectives have generally been met, although some seasonal information is still missing. Data from winter and spring collected in Stefansson Sound will be presented in the winter studies synthesis (RU 359, April 1981). Information on the plankton communities farther offshore in winter, spring, and early summer is still missing mainly because of the difficulties in working in the Beaufort Sea reagion during these seasons.

The summary of existing literature was presented in English and Horner (1977) and has been updated in more recent OCSEAP reports from RU 359. A number of archived samples were identified and the analysis of some of these is reported here.

Conclusions from these studies are:

Zooplankton

1. Distribution is influenced by hydrography with:
   a. species occurring throughout the Arctic Ocean,
   b. species occurring primarily in higher temperature, less saline coastal areas,
   c. species that are expatriates from the Bering Sea occurring in intrusions of Bering Sea water.
2. Meroplanktonic larvae of benthic species are present with their distribution limited primarily to the wide, shallow shelf area of the western Beaufort Sea.
3. Distribution of species is patchy, partly depending on ice conditions, but also a function of our sampling gear, *e. g.*, we did not sample amphipods nearly as effectively as seals did.
4. Concentrations of animals that could be identified acoustically were not present, although they have been reported farther offshore (T-3).

Phytoplankton

1. Distributions are widespread, although some species are associated primarily with ice or Bering Sea water.
2. Microflagellates are more abundant in surface waters and diatoms are more abundant at depth.
3. Standing stock and primary production are variable and patchy, partly depending on ice, and thus, light, conditions; annual productivity varied two-threefold over the three years (1976-78) of this study.
4. Highest chlorophyll *a* and primary productivity generally occurred at depth where diatoms were most abundant; lowest chlorophyll *a*

and primary productivity occurred where microflagellates were most abundant.

The general consensus appears to be that the pelagic environment is the first to be impacted by an oil spill, but apparently recovers quickly. However, recovery will depend to some extent, on the time of year, the zooplankton life cycle stages that are present, and the amount of actual contact with the oil. There may be changes in the species composition of the phytoplankton community from diatoms to microflagellates which will affect the herbivorous zooplankton that may prefer the larger particle size of the diatoms. This situation has been suggested from large container experiments (CEPEX).

While it is generally assumed that the pelagic community will recover more quickly than the benthic or nearshore communities, this might not be true in the Arctic where growth is slow and breeding cycles are extended and where degradation of oil is slow.

II. Introduction

A. General nature and scope of the study

The purpose of this project was to provide basic seasonal information on the organisms in the Beaufort Sea that are at the lower end of the trophic system. These organisms, the phytoplankton and zooplankton, are the primary producers and primary and secondary consumers in the ecosystem, and, as such, provide food for all higher trophic levels including fish, birds, and mammals. Knowledge of the species present, their abundance and distribution throughout the year, and the levels of primary production is necessary to understand their relationships within the ecosystem.

Samples were collected during icebreaker cruises in 1972, 1973, 1974, 1976, 1977, and 1978 (Fig. 1). The 1972 and 1973 cruises were sponsored by the U.S. Coast Guard as part of the WEBSEC (Western Beaufort Sea Ecological Cruises) program. Zooplankton samples from 1972 (Fig. 2) were collected by Dr. Bruce Wing, National Marine Fisheries Services, Auke Bay Laboratory. Phytoplankton sample collection and analysis in 1973 (Fig. 3) was funded by the Office of Naval Research, Code 461. The 1974 phytoplankton collections (Fig. 4) were also funded by ONR. The 1976-1978 cruises (figs. 5-7) were sponsored by BLM/NOAA as part of the OCSEAP project. Data are reported here from non-OCSEAP sponsored cruises because one of our objectives was to identify and report on archived samples.

Samples collected included phytoplankton standing stock, plant pigments, primary productivity, zooplankton standing stock and acoustic assessment, temperature, and salinity, although not all kinds of information was collected from all cruises (Table 1).

The data reported here provide basic background information about the plankton populations in the Beaufort Sea in August and September. Data from other times of the year from most areas of the Beaufort Sea are still generally unavailable, although some winter-spring information from the nearshore area will be included in the final winter studies report for

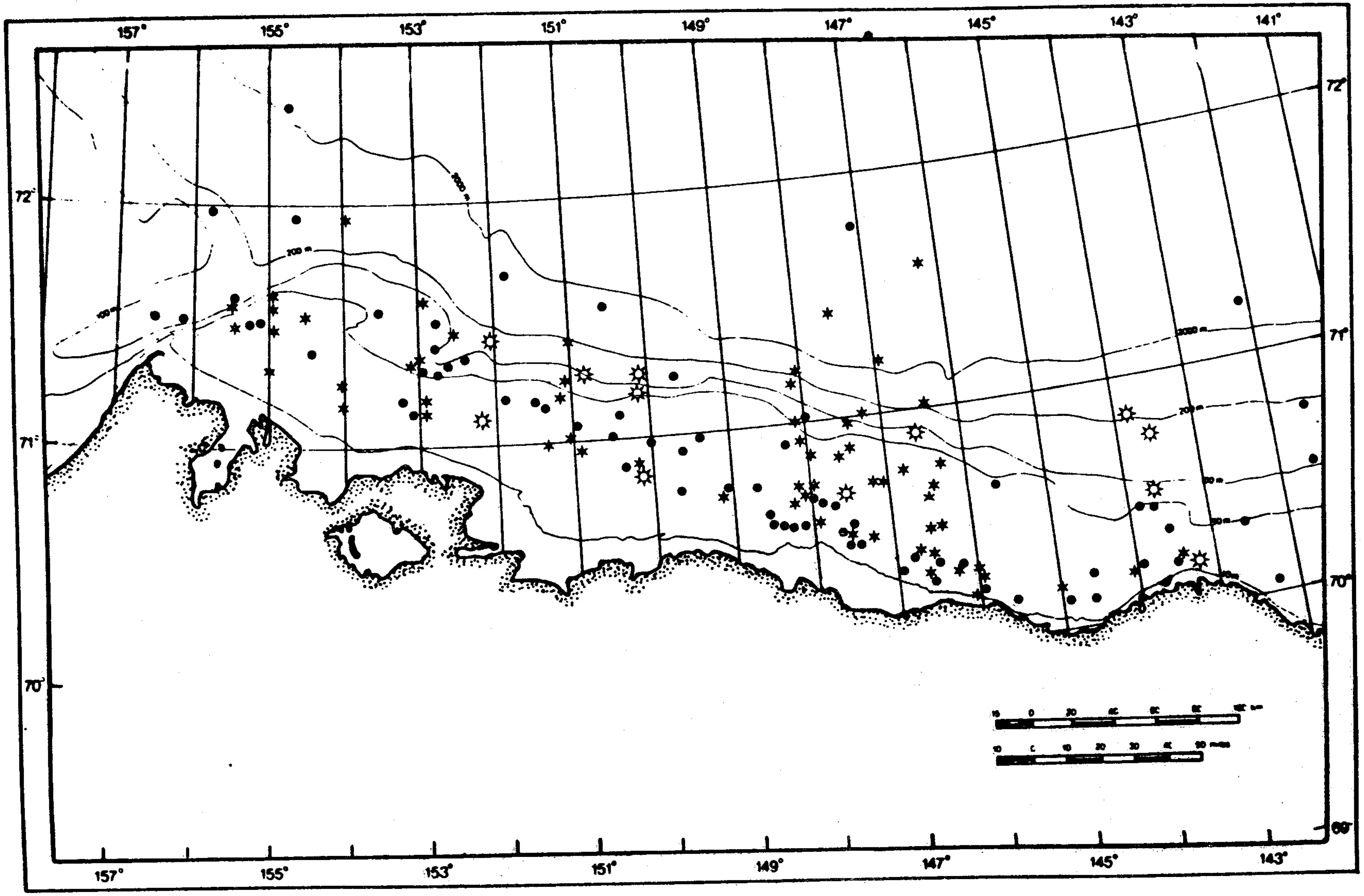


Fig. 1. Locations where samples were collected in the Beaufort Sea. A few OCSEAP stations located north and east of the mape area have been omitted. ✡ = zooplankton samples only (1972); * = phytoplankton samples only (1973, 1974); ● = phytoplankton and zooplankton samples (1976, 1977, 1978).

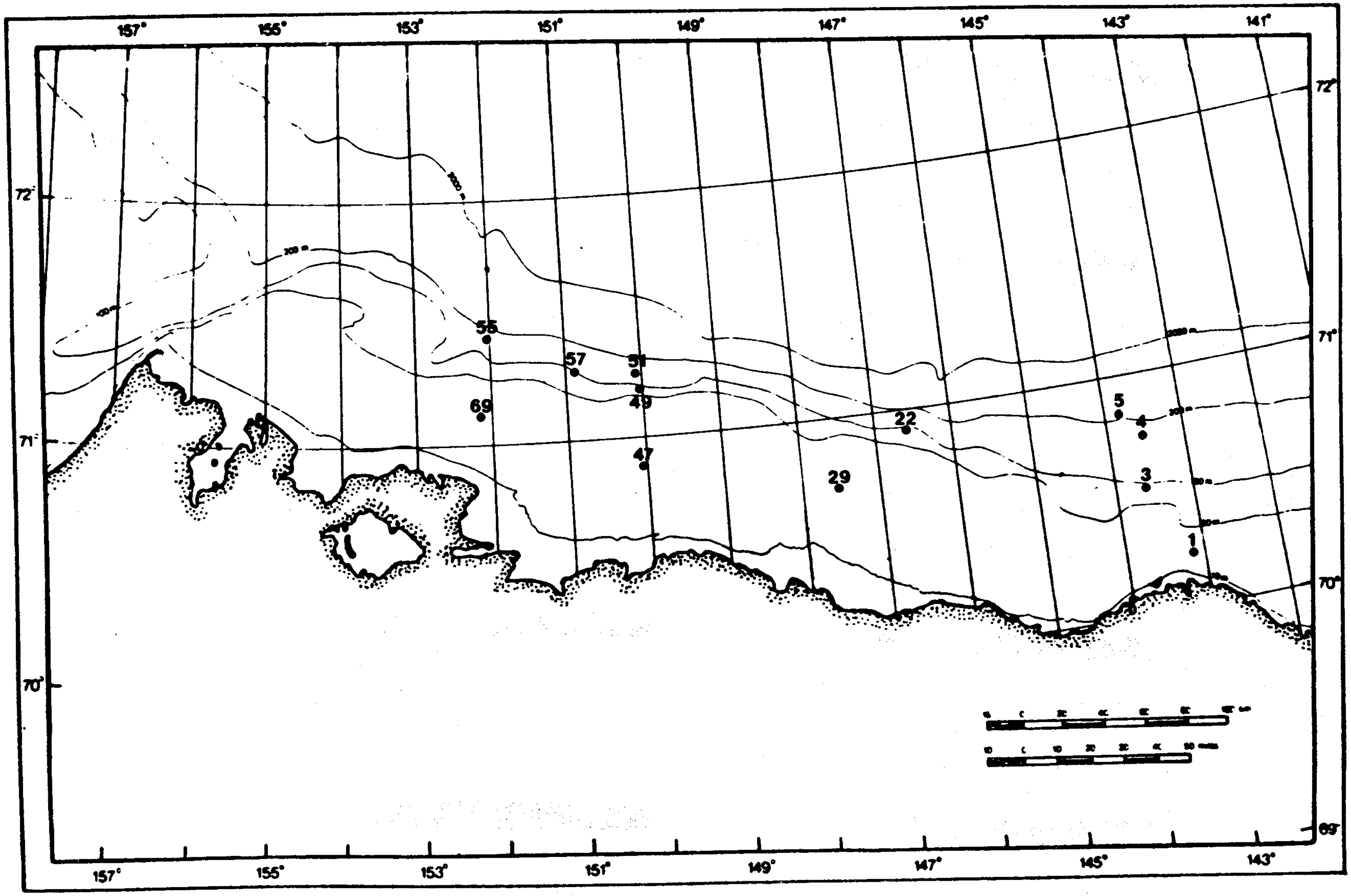


Fig. 2. Locations where zooplankton samples were collected during WEBSEC-72, CGC *Glacier*, 4 Aug - 5 Sep 1972.

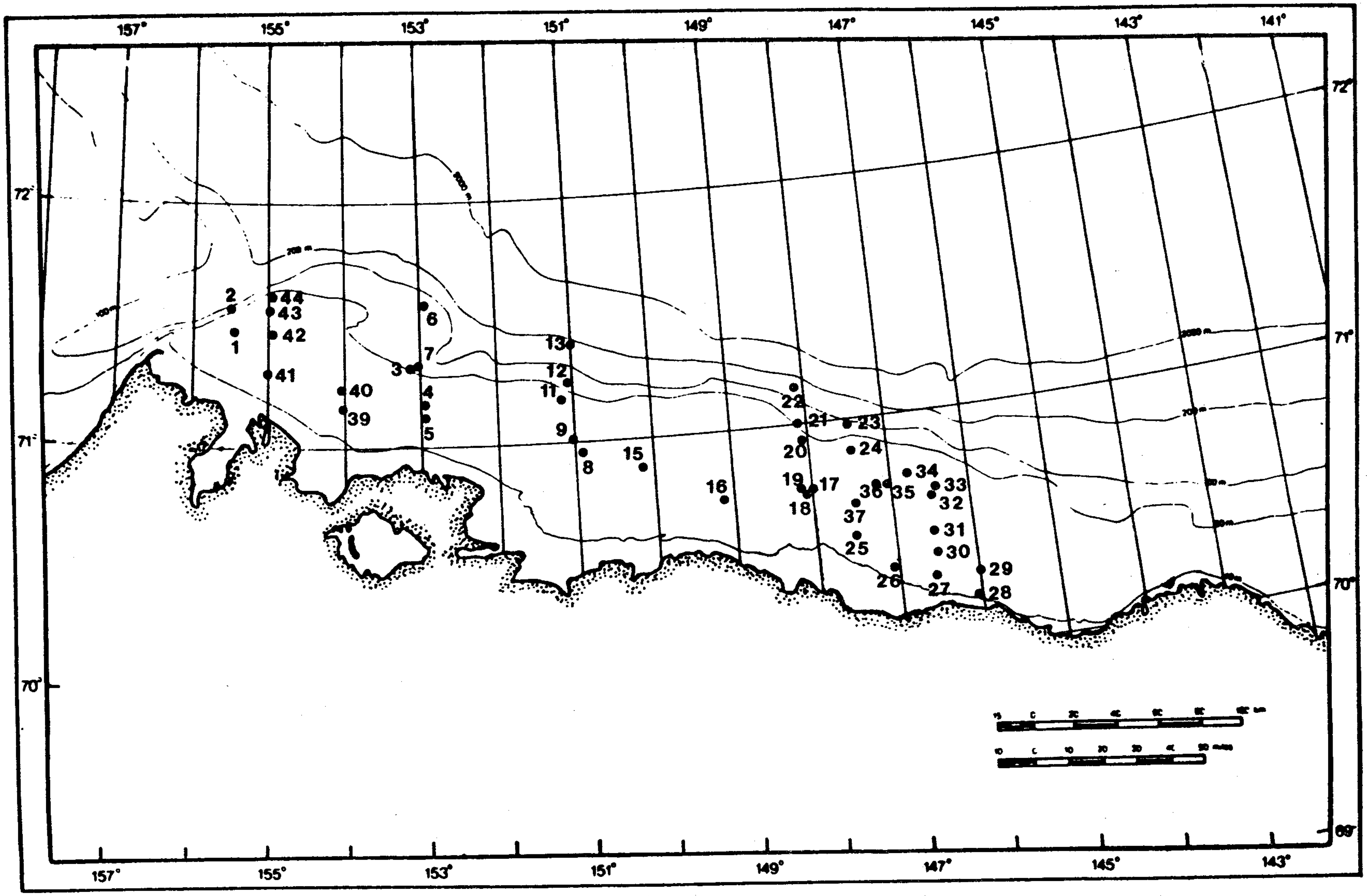


Fig. 3. Locations where phytoplankton samples were collected during WEBSEC-73, CGC *Glacier*, 28 Jul - 12 Aug 1973.

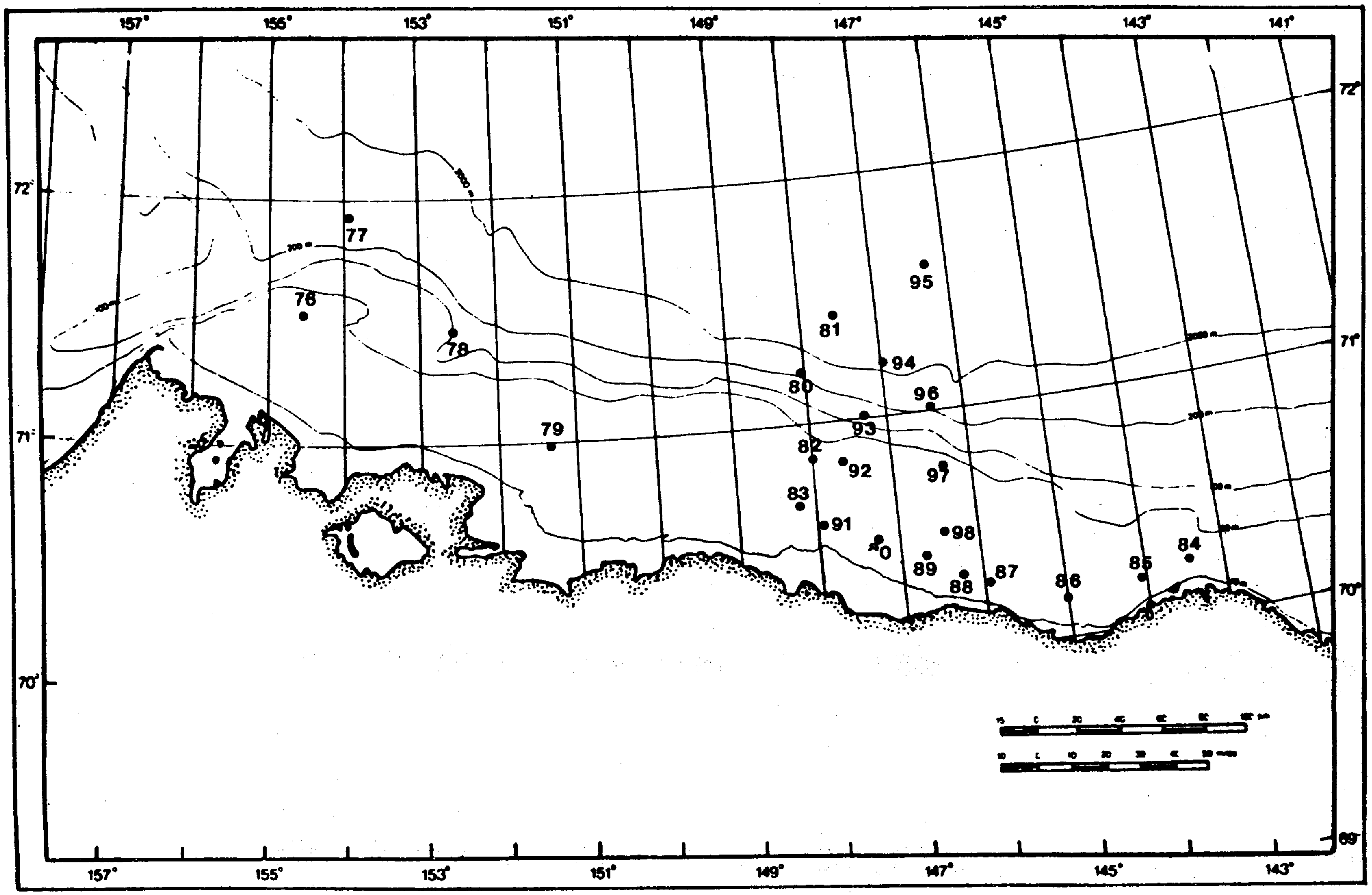


Fig. 4. Locations where phytoplankton samples were collected in 1974, CGC *Staten Island*, 19 Aug - 5 Sep 1974.

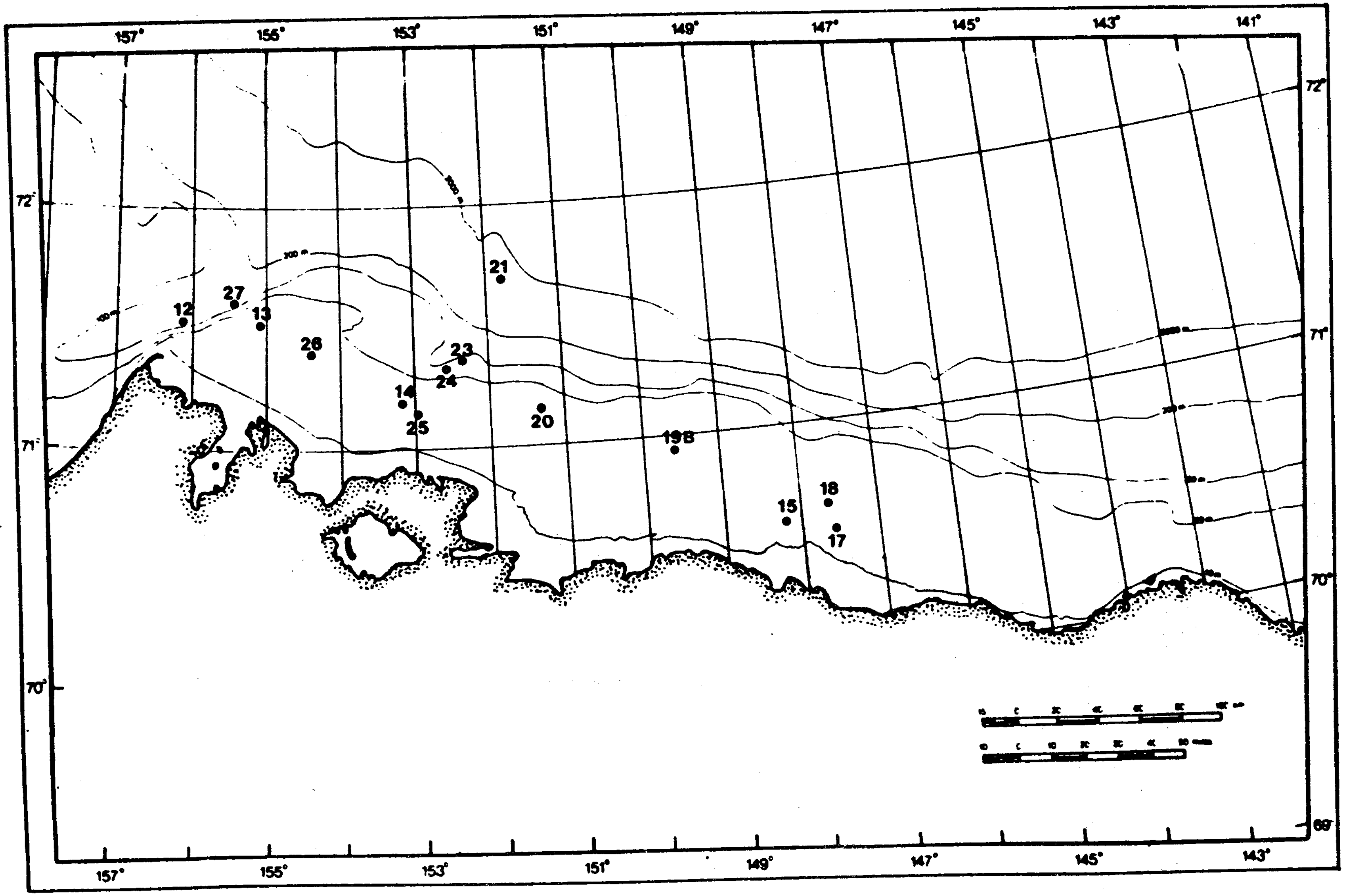


Fig. 5. OCSEAP station locations where phytoplankton and zooplankton were collected, CGC *Glacier*, 18 Aug – 2 Sep 1976.

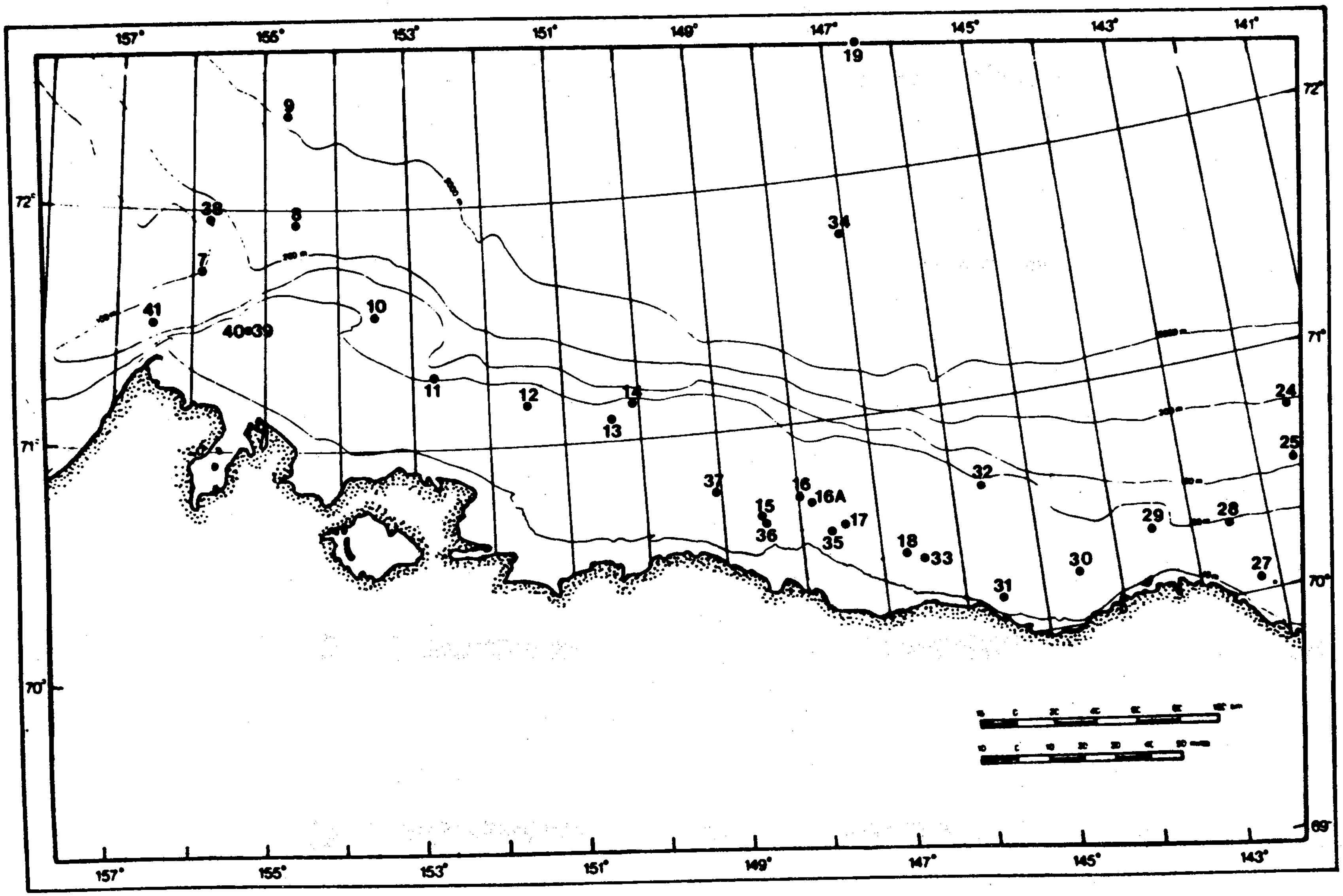


Fig. 6. OCSEAP station locations where phytoplankton and zooplankton were collected, CGC *Glacier*, 7 Aug - 5 Sep 1977.

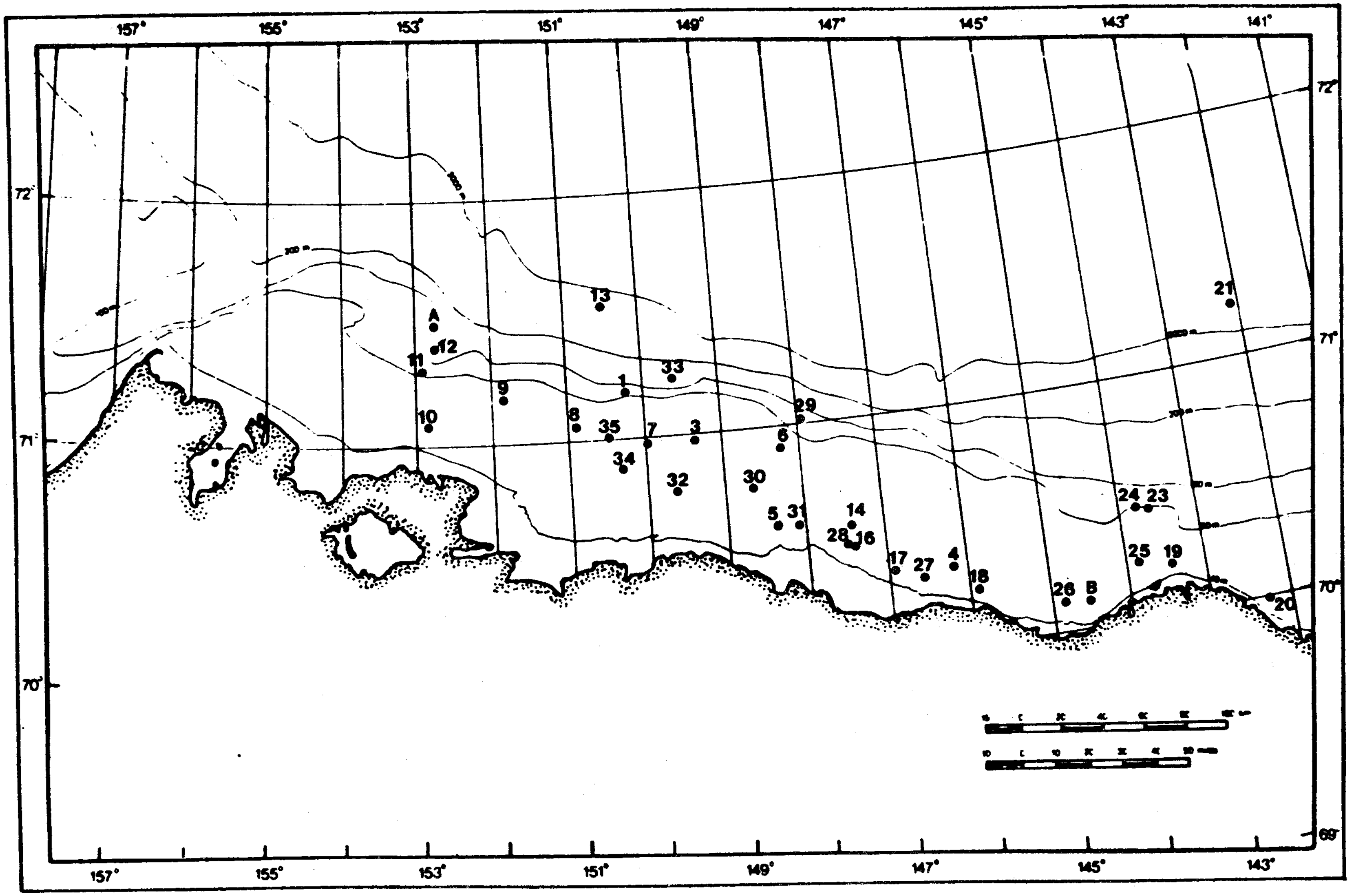


Fig. 7. OCSEAP station locations where phytoplankton and zooplankton were collected, CGC *Northwind*, 15 Aug - 15 Sep 1978.

Table 1. Number and kinds of samples collected/analyzed by cruise in the Beaufort Sea, 1972-1978. Blanks indicate data not taken.

Data Type						
Number Collected/ Number Analyzed	Date					
	1972	1973	1974	1976	1977	1978
Number of Stations		41	23	14	42	30
Zooplankton						
Standing stock	/12			36/32	38/36	34/32
Phytoplankton						
Standing stock		263/260	180/0	87/43	334/193	241/210
Plant pigments		263/263	180/180	87/87	334/334	241/241
Prim prod				82/82	167/167	241/241
Temperature		255/255	175/175	88/88	333/333	241/241
Salinity		261/261	181/181	89/89	331/331	242/242
Secchi disc					28	28

Stefansson Sound (April 1981).

B. Specific objectives

The specific objectives of this project have been to determine the seasonal density distribution and environmental requirements of phytoplankton, zooplankton, and ichthyoplankton; to determine seasonal indices of phytoplankton production; to summarize existing literature; and to identify and report on archived samples.

C. Relevance to problems of petroleum development

Basic background information on standing stock, species composition, distribution, and productivity of plankton communities in the western Beaufort Sea was generally not available before OCSEAP studies. Lease sales have been held in some areas, and additional areas are being considered for possible sales in the near future. Phytoplankton, as the primary producer in the marine environment, forms the base of the food web. Phytoplankton, together with zooplankton that are the primary and secondary consumers, provide food for all higher trophic levels. The effects of industrial development on the planktonic community are generally not known, however, disruptions in this community could affect the entire marine ecosystem through trophic interactions.

D. Acknowledgements

Many individuals have provided support for this project. Tom Kaperak provided field assistance during the 1976-1978 icebreaker cruises, analyzed zooplankton samples from the 1977 and 1978 cruises, and helped to process data. He was also responsible for writing most of the zooplankton results and discussion sections of this report. Kevin Wyman analyzed zooplankton samples from the 1976 cruise. Melanie Tyler sorted zooplankton samples and helped with plant pigment analyses from 1977. Marc Weinstein helped analyze zooplankton samples from 1977. Leanne Stahl identified fish eggs and larvae from all cruises. David Murphy analyzed the zooplankton samples from WEBSEC-72 and processed the data. Gayle Heron identified copepods from 1976-1978. Jerry Hornof helped with data processing and did the computer plots of temperature, salinity, chlorophyll *a*, and primary productivity, and the phytoplankton kite diagrams.

Last, but not least, Captain J. J. Dirschel and the men of CGC *Glacier* and Captain R. R. Garrett and the men of CGC *Northwind* did a superb job of providing ship support during the cruises.

III. Current state of knowledge

A. Physical oceanography

Circulation in the southern Beaufort Sea in summer has been described by several investigators. Johnson (1956) was apparently the first to suggest an eastward flow of Bering Sea water around Point Barrow into the Beaufort Sea. His observations were based on zooplankton samples in which he found species common in the Bering Sea at stations in the Beaufort Sea.

Paquette and Bourke (1974) followed a warm current northward from Bering Strait to Point Barrow and eastward to 152°W near the Colville River delta in July and August 1971. This warm current was located about 50-75 km seaward in the Beaufort Sea with the warm core near the bottom at 30-50 m near the shelfbreak.

In August and September 1971, Hufford (1973) traced a warm layer from 154°30'W to 143°42'W. This layer, 10-60 m thick, extended from the 25 m bottom contour to at least 71°40'N with the core paralleling the edge of the shelf. The temperature ranged from 0.1-3.0°C. Salinity ranged from 30.0-32.0 ‰, and along with oxygen and nutrient concentrations, was similar to the surrounding seawater. All available data for the southern Beaufort Sea were analyzed and the warm water layer was found to be present during the summer in 10 of 16 years (Hufford 1973).

Mountain (1974) concluded that two types of circulation occurred on the shelf, the dominant type being the eastward flow of Bering Sea water that is apparently driven by momentum possessed before it reaches the shelf. The second type is the westward flow associated with upwelling and driven by easterly winds. This second type has not been observed often and perhaps occurs only in the eastern region.

Hufford (1974a) described upwelling near 145°W at a depth of 125 m along the continental slope and up onto the shelf. Nutrient concentrations were 3-15 times higher in this area than farther west. The upwelling was caused by easterly winds transporting surface water offshore and being replaced by deep water.

Farther east, O'Rourke (1974) reviewed the physical oceanography of the eastern Beaufort Sea where the main water masses are the same as those of the Arctic Ocean.

B. Chemical oceanography: nutrients

Inorganic nutrient levels in the surface waters of the Beaufort Sea undergo marked seasonal fluctuations. During the summer, nitrate and phosphate drop to very low or undetectable levels, and the system is considered to be strongly nitrogen limited. This results from high phytoplankton utilization and limited vertical mixing due to high water column stability which develops in response to ice melt and increased insolation (Hufford *et al.* 1974; Aagaard 1977). In the winter when stratification breaks down, nutrient concentrations increase to relatively high levels as a result of increased vertical mixing and regeneration at a time when plant utilization is low.

Schell (1974) has documented the regeneration of nitrogenous nutrients beneath the winter ice cover in shallow, nearshore and estuarine areas. This suggests the possibility that a substantial fraction of the nitrate in arctic coastal waters may be regenerated *in situ* during the winter months rather than deriving from offshore, deep water sources. It is suspected however, that much of the nutrients regenerated in coastal waters may be transported offshore by thermohaline convective processes during winter (November-March).

Winter nutrient levels near Point Barrow have been reported to range up to 1.7 μg at ℓ^{-1} phosphate, 9.2 μg at ℓ^{-1} nitrate plus nitrite, and 35 μg at ℓ^{-1} silicate (Matheke 1973). Similar values have been reported by Horner *et al.* (1974) for Stefansson Sound. The same authors reported summer levels ranging from 0-0.9 μg at ℓ^{-1} phosphate, 0-2.7 μg at ℓ^{-1} nitrate, and 5-28 μg at ℓ^{-1} silicate.

Upwelling has been documented by Hufford (1974a) along the eastern portion of the shelf and may be a major source of nutrients to the euphotic zone in this region. As a result of local easterly winds, nutrient-rich water from 100-200 m depth is upwelled and advected westward over the mid-portion of the shelf. Observed as far east as Barter Island (144°W), upwelling is largely limited by the amount of open water on which the wind may act. The rather persistent ice cover in the western shelf area may be responsible for the lack of observed upwelling in that region.

Strong onshore-offshore nutrient gradients are often apparent during summer, due largely to the influence of river runoff. Hufford (1974b) found that in the area between Point Barrow and Barter Island, nitrates decreased from 1.5 μg at ℓ^{-1} nearshore to very low or not detectable levels near the shelfbreak. At the same time he found that river discharge in the area contained 3-15 times the amount of nitrates found in the coastal surface layer. Silicates followed a similar pattern decreasing from 10 μg at ℓ^{-1} near the mouth of the Colville River, to less than 2 μg at ℓ^{-1} 100 km offshore. Phosphates deviated strongly from this pattern, being low or not detectable nearshore and increasing to 0.8 μg at ℓ^{-1} near the shelf-break. This pattern reflects the high input of nitrates and silicates by river water and the relative lack of phosphates (Codispoti and Richards 1968; Grainger 1974). River flow is seasonal however, and the majority of nutrient input from rivers occurs during spring breakup (Hamilton *et al.* 1974).

Farther to the east in the Canadian Arctic, the Mackenzie River has a substantial impact on the southern Beaufort Sea. Approximately half of the freshwater runoff to the Beaufort Sea flows through this river. The plume generally flows eastward along the coast and is deflected north and westward near Amundsen Gulf to mix with waters of the Beaufort Gyre (O'Rourke 1974). Grainger (1974) found the highest surface nutrients immediately off the river mouths, with concentrations decreasing seaward. With the exception of silicate, nutrients were much higher in the surrounding sea where the river discharges than in the river proper. These high nutrient concentrations may be largely attributed to the estuarine circulation typical of many large rivers (Redfield *et al.* 1963). In this type of circulation, a subsurface countercurrent forms to replace water entrained in the surface flow, causing nutrient concentrations to increase upstream relative to the motion of the surface layer. In addition, Griffiths *et al.* (1978) found microbial activity to be very high in the plumes of major rivers and nearshore sediments of the North Slope. Decomposition of river-borne detritus must be a major source of nutrients to the nearshore environment.

C. Plankton

1. Zooplankton

The first major collections of zooplankton from the Beaufort Sea were made during the Canadian Arctic Expedition, 1913-1918. Taxonomic studies on the ctenophores and hydromedusae (Bigelow 1920), copepods (Willey 1920), amphipods (Shoemaker 1920), and schizopod crustaceans (Schmitt 1919) indicated that copepods were the dominant organisms.

Johnson (1956) demonstrated for the first time the presence of Bering Sea water in the Beaufort Sea based on the distribution of zooplankton collected in 1950 and 1951. Hydromedusae from the same samples were described by Hand and Kan (1961), including breeding ranges and the influence of hydrography on species distribution.

Zooplankton from the vicinity of Point Barrow have been studied by MacGinitie (1955), Johnson (1958), and Redburn (1974). MacGinitie (1955), concerned mainly with benthic invertebrates, included a limited discussion of zooplankton based on relative abundances and reproductive periods, while Johnson (1958) described the qualitative and quantitative composition of the inshore zooplankton community for one month in summer.

Redburn (1974) described the zooplankton community in terms of species abundance and composition, life cycles, and relationship to the hydrographic regime. Copepods were the major constituents of the community, including some expatriate species from the Bering Sea, another indication of Bering Sea water at Barrow. MacGinitie (1955) and Redburn (1974) reported a lag time of about two weeks between the peak periods of phytoplankton and zooplankton standing stocks leading to an unbalanced state.

Cooney and Crane (1972) reported on the zooplankton of the Harrison Bay-Simpson Lagoon area. They found absolute faunal abundance to be greater in areas outside the barrier islands than in the lagoons, but species composition was similar. Crane (1974) used these data to discuss distribution patterns and biology of an isopod, *Mesidotea entomon* (L.)[1] and a mysid, *Mysis oculata*.

Horner *et al.* (1974) found evidence for three zooplankton communities near Prudhoe Bay. The inshore, or Prudhoe Bay, community was holoplanktonic in nature and had the lowest species diversity. A more diverse community, located between the mainland shore and the Midway Islands, consisted primarily of copepods, with some meroplanktonic larvae also present. The third zooplankton community, found seaward of the Midway Islands, was the most diverse and contained holoplanktonic and meroplanktonic elements; copepods remained numerically dominant, but decapod and barnacle larve were also numerous.

---

[1] OCSEAP lists this animal as *Saduria entomon* (L.)

Zooplankton from the southern Beaufort Sea have been reported by Grainger (1975) and Grainger and Grohe (1975), while Percy and Mullin (1975) discussed the effects of crude oil on Arctic marine invertebrates. Grainger (1975) reported at least 92 species for the area between Herschel Island and the Eskimo Lakes region with distributions in the area related to salinity-temperature barriers. Inshore stations had the greatest number of organisms, but few species. Stations off the Tuktoyaktuk Peninsula supported mixed populations of estuarine and more offshore species. Deep stations farther offshore had low standing stocks, but high species diversity.

Grainger and Grohe (1975) cataloged collections made in the southern Beaufort Sea from 1951-1975, listing collection data, species present, and abundance.

Most of the organisms studied by Percy and Mullin (1975) were benthic species, but the hydrozoan, *Halitholus cirratus*, the sculpin, *Myoxocephalus quadricornis*, and the important copepod, *Calanus hyperboreus*, were tested. *Calanus hyperboreus* was resistant to all oils tested and was also resistant to crude oil dispersions. *Halitholus cirratus* was much less tolerant of the various oils tested, and little or no mortality occurred in light and medium dispersions of any oils. The fry of *M. quadricornis* were very sensitive to seawater dispersions of Norman Wells crude oil.

Busdosh and Atlas (1971) found that amphipods that come in contact with oil slicks have little chance for survival. These authors pointed out that oil trapped under ice would be especially toxic to those animals that feed on the underside of the ice, *i.e.*, on the ice algae community, while oil slicks in shallow, nearshore areas would affect both pelagic and benthic amphipods.

2. Phytoplankton

The earliest collections of diatoms from the Beaufort Sea were made during the Canadian Arctic Expedition, 1913-1918, but mostly benthic species were found (Mann 1925). Extensive studies of phytoplankton populations and production have been primarily near Barrow (MacGinitie 1955; Bursa 1963; Horner 1969, 1972); Harrison Bay (Alexander 1974); and Prudhoe Bay (Coyle 1974; Horner *et al.* 1974).

MacGinitie (1955) listed diatoms as "circular", "spiny", "spicule", "iridescent", and "chain" types and recorded their relative abundance during the year. Bursa (1963) was able to distinguish six separate ecological niches, each containing a well-defined population. He reported that inshore waters extending up to three miles offshore were not favorable for phytoplankton growth because of rapidly changing temperature and salinity and large amounts of detritus.

Horner (1969, 1972) reported a bimodal annual cycle with a spring maximum in June and early July before ice breakup and a fall maximum in August-September. Most of her samples were collected within three miles of shore, and only for a short period during ice breakup was low salinity unfavorable for phytoplankton growth. Detritus was more common in the fall after winds caused thorough mixing in the shallow, nearshore area.

Primary productivity, chlorophyll *a*, and biomass data have been reported for the phytoplankton community in the Colville River system, including Harrison Bay and Simpson Lagoon (Alexander 1974). Highest primary productivity occurred in deeper, more saline water during August. The relatively high rates may be partly due to nutrient-rich water from the Colville River system. Species composition of the community varied with depth and season, but many of the cells were less than 10 µm in diameter.

Coyle (1974) and Horner *et al.* (1974) described the Prudhoe Bay phytoplankton community in terms of primary productivity, standing stock, species composition, and spatial variability along with local hydrographic conditions. Three major phytoplankton communities were present during the open water season: 1) a pennate diatom community in the bay shortly after ice breakup; 2) a pelagic diatom community in deeper, more saline water outside the bay; and 3) a flagellate community in brackish surface water. Nutrient concentrations were highest in winter and early spring with nitrate being rapidly depleted during spring and probably limiting growth in summer.

Studies on phytoplankton standing stock and species composition, chlorophyll *a*, primary productivity, and oil toxicity have been done in the southern Beaufort Sea as part of the Canadian Beaufort Sea Project (Adams 1975; Grainger 1975; Foy and Hsiao 1976; Hsiao 1976; Hsiao *et al.* 1977). Adams (1975), reporting the results of a controlled winter oil spill experiment, found slightly enhanced ^{14}C uptake and a greater abundance and variety of genera in the oil contaminated samples (but also see discussion).

The biology of the southern Beaufort Sea has been shown to be dependent on both Mackenzie River and offshore marine influences (Grainger 1975). Nitrate is probably the factor limiting phytoplankton production outside the Mackenzie River plume, while within the plume, light is the major factor. Annual primary productivity is low in all areas, but especially in the river plume. Grainger (1975) believes that pollutants would spread rapidly through the system because of the two-layered structure of the estuarine system. Food chains are short, therefore each link is relatively more important and perhaps more vulnerable.

Phytoplankton standing stock, primary productivity, and sensitivity to oil data are presented by Foy and Hsiao (1976), Hsiao (1976) and Hsiao *et al.* (1977). Standing stock and *in situ* primary productivity decreased with increasing distance from shore and the Mackenzie River. The phytoplankton community, composed primarily of diatoms and flagellates, had diatoms dominating in coastal waters and flagellates offshore. Their studies on the effects of crude oil on primary productivity showed that production varied with the species composition of the sample, type and concentration of the oil, methods of preparation of oil-seawater mixtures, and duration of exposure.

The literature on ice algae studies has not been included here, but will be presented in the winter studies report (April 1981); for reviews see Horner (1976, 1977); Alexander (1980).

IV. Study area

The study area has been the Beaufort Sea seaward from the 20 m isobath and extending from Point Barrow (156°30'W) to Demarcation Point (141°W) (Figs. 1-7). Four stations located near 73°N in 1977 and two stations located near 69°45'N and 141°30'W in 1977 and 1978 are not shown on the maps because of limitations of the official OCSEAP map projections. These stations are included in the data tables.

For the 1976 OCSEAP cruise, we planned to concentrate on three transects: Pitt Point, Prudhoe Bay, and Barter Island. These transects were to be coordinated with the physical oceanographic studies, including current meter arrays, that were to be done in the same areas. Heavy ice east of Prudhoe Bay prevented our sampling of the Barter Island transect.

In 1977, the three transects were to be repeated with additional work east of Prudhoe Bay where little sampling had previously been done. Microbiologists were particularly interested in the eastern area. Relatively light ice conditions enabled us to sample in all areas.

Trophic interactions were the major interest during the 1978 cruise. Major study areas were to be the ice remnant region off Harrison Bay; off the Canning River; and off Prudhoe Bay where concentrations of seals were expected. The Pitt Point transect was to be repeated because of its long-term interest for RU 6. Marine mammal investigators were forced to end their studies early because of equipment failures; ice prevented ornithologists from running uninterrupted transects; and finally, the cruise was terminated 10 days early because of *Northwind*'s mechanical problems.

V. Sources, methods, and rationale of data collection and sample analysis

A. Sample collection

1. Zooplankton

a. WEBSEC-72 (CGC *Glacier*)

Samples were collected with 0.5 and 1.0 m diameter ring nets with mesh size of 570 μm and with a 1.8 m Isaacs-Kidd mid-water trawl with a mesh size at the mouth of 38 mm (Wing and Barr 1977). The 0.5 and 1.0 m ring nets were lowered at 60 m per min to 3-4 m from the bottom and vertically hauled to the surface at 40 m per min. The Isaacs-Kidd mid-water trawl was towed horizontally at a predetermined depth estimated from the wire angle and amount of wire out, for 30 min at 3-4 kt.

b. OCSEAP 1976-1978 (CGC *Glacier*, CGC *Northwind*)

Samples were collected with 60 cm diameter bongo nets with mesh sizes of 335 and 500 μm, 0.75 m diameter ring nets with mesh size of 308 μm, and a 4 m^2 umbrella net with mesh size of 220 μm.

Bongo nets were used when enough open water was present. A TSK flowmeter (InterOcean Systems, San Diego, CA.) was mounted in the mouth of each net to determine the amount of water filtered; a bathykymograph was attached to the center of the net frame to help determine sample depth in 1976 and 1977, but not in 1978. Weights, approximately 35-45 kgm, were attached to the center of the net frame. The bongo tows were double oblique with deployment at *ca.* 50 m per min; a 30 sec soaking period at depth, and retrievel at *ca.* 20 m per min. Sampling depth varied with water depth, but the net was usually placed as close to the bottom as possible.

The ring net, used when the ship was in heavy concentrations of ice in 1976, was lowered to a predetermined depth, usually 10 or 20 m, at *ca.* 50 m per min, soaked for 10 sec, and vertically hauled to the surface at *ca.* 20 m per min. Two or more tows were made at each station depending on water depth.

The umbrella net was used in 1977 when the ship was in heavy concentrations of ice or stopped on station for long periods of time. This net, designed to fall open after it is in the water beneath the ice, was lowered to a depth near the bottom, allowed to stabilize for 30 sec, and was then hauled vertically to the surface. The net was closed by a messenger *ca.* 2 m below the ice surface to facilitate handling when bringing the net up through the ice.

All nets were washed down with seawater so that animals caught on the nets would be washed into the collecting cups. The samples were concentrated in the net collection cups by gently swirling the cup to remove excess water. All samples were put in labeled jars, usually 250 or 500 ml, and preserved with 37% formaldehyde buffered with sodium acetate and/or sodium borate.

Acoustic surveys were conducted in 1976 and 1977 using a Ross 200A Fine Line Echosounder system operating at a frequency of 105 kHz. A 10° transducer mounted in a 0.6 m V-fin depressor was lowered to just beneath the water surface when the ship was stopped on station. The incoming signal was recorded on a paper chart and on magnetic tape for later analysis.

2. Phytoplankton

a. WEBSEC-73 (CGC *Glacier*) and CGC *Staten Island* 1974

Phytoplankton standing stock and chlorophyll *a* samples were collected at standard depths throughout the water column using 5 ℓ Niskin bottles (General Oceanics, Inc., Miami, FL.). Some of each water sample was poured into 250 ml glass jars and preserved with *ca.*

5 ml 4% formaldehyde buffered with sodium acetate for the standing stock sample.

Water for chlorophyll analysis was filtered through 47 mm, 0.45 μm Millipore filters. A small amount of a saturated solution of $MgCO_3$ was added near the end of the filtration. The filters were folded into quarters, placed in labeled coin envelopes, and frozen.

b. OCSEAP 1976-1978 (CGC *Glacier*, CGC *Northwind*)

Samples were collected at standard depths throughout the water column using 5 ℓ Niskin bottles. Subsamples were taken for salinity, standing stock, primary productivity, and plant pigment determinations. Standing stock samples were preserved in 250 ml glass jars with 5-10 ml 4% formaldehyde buffered with sodium acetate.

Primary productivity measurements were made in 60 ml reagent bottles with 2 light and 1 dark bottle used for each depth. Two ml $NaH^{14}CO_3$, about 5 μci ^{14}C, were added to each bottle, aluminum foil was wrapped around the dark bottles, and the samples were incubated in a laboratory sink under a bank of cool white fluorescent lights. Light levels were measured at the beginning and end of the incubation period with a Gossen Super Pilot photographic light meter. Low temperature in the sink was maintained by continuously running seawater and was monitored throughout the incubation period. After a 3-4 hr incubation period, the samples were filtered onto 25 mm, 0.45 μm Millipore filters, rinsed with 5 ml 0.01 N HCl and 5 ml filtered seawater, and placed in scintillation vials.

Water for plant pigment determinations was filtered through 47 mm, 0.45 μm Millipore filters. Two drops of saturated $MgCO_3$ solution were added near the end of the filtration and the filter tower was rinsed with filtered seawater. The filters were folded into quarters, placed in labeled glassine envelopes, and frozen.

3. Salinity

Salinity samples were stored in tightly closed 250 ml polyethylene bottles. Samples were analyzed about once a week.

4. Temperature

Temperatures were taken with deep sea reversing thermometers attached to the Niskin bottles. Thermometers were read within an hour of being brought to the surface.

5. Secchi disc

Secchi disc depths were determined at most stations using a 30 cm diameter Secchi disc lowered on a handline. This was always done from the same site on the ship with two observers determining the depth at which the Secci disc was no longer visible.

B. Sample analysis

1. Zooplankton

a. WEBSEC-72 (CGC *Glacier*)

Samples were poured onto a 209 μm mesh screen, rinsed with tap water, and allowed to stand in tap water during sorting to remove the formaldehyde preservative. Larger samples were split into. subsamples with a Folsom plankton splitter (McEwan *et al.* 1954). The subsamples were successively sorted until at least 100 specimens of each taxon were removed. Only a fraction of each sample was sorted for abundant species, while the whole sample was sorted for rare species. After sorting and identification, the samples and voucher specimens were returned to buffered formaldehyde.

Identifications were made using dichotomous keys and by comparison with descriptions and illustrations in the literature (Table 2).

The number of animals per 1000 m^3 was calculated using:

1) $$V\ (m^3) = \text{haul length (m)} \times \text{mouth area } (m^2)$$

2) $$\text{Number animals } (1000\ m_3) = \frac{(A)(1000)}{V} \times 2^n$$

where n is the number of times the sample was split; A is the number of animals counted; and V is the volume of water filtered (m^3).

Voucher specimens were kept for all taxonomic categories. These have been submitted to the California Academy of Sciences in keeping with OCSEAP procedures.

b. OCSEAP 1976-1978 (CGC *Glacier*, CGC *Northwind*)

Zooplankton samples collected in 1976 with 0.75 m ring nets and 335 and 500 μm mesh bongo nets, in 1977 with 500 μm mesh bongo nets and 220 μm mesh umbrella nets, and in 1978 with 500 μm mesh bongo nets have been analyzed. Large and rare organisms, including amphipods, euphausids, shrimp, and fish eggs and larvae, were first sorted from the whole sample. The remaining sample was split in a Folsom plankton splitter (McEwan *et al.* 1954). Subsamples were successively sorted until at least 100 specimens of each taxon were counted and identified. A few samples contained large numbers of several different taxonomic categories and these samples were split before any organisms were removed. The organisms were counted and identified using dissecting microscopes. References used to identify zooplankton are listed in Table 3.

The number of animals per 1000 m^3 was calculated using the equations:

Table 2. References used to identify zooplankton from the Beaufort Sea, WEBSEC-72 samples.

General
- Barnes, R. D. 1974
- Smith, D. L. 1977
- Wing, B. L. 1974

Coelenterata
- Hartlaub, C. 1933
- Naumov, D. V. 1960
- Shirley, D. W., and Y. M. Leung 1970
- Totton, A. K. 1965

Mollusca
- Leung, Y. M. 1971

Ostracoda
- Leung, Y. M. 1972c

Amphipoda
- Barnard, J. L. 1969
- Bousfield, E. L. 1979
- Gurjanova, E. 1951
- Sars, G. O. 1895
- Sars, G. O. 1900a
- Tencati, J. R. 1970

Euphausiacea and Mysidacea
- Banner, A. H. 1948a
- Banner, A. H. 1948b
- Banner, A. H. 1950
- Leung, Y. M. 1970a
- Leung, Y. M. 1972b
- Sars, G. O. 1870
- Zimmer, C. 1933

Decapoda
- Hart, J. F. L. 1960
- Haynes, E. B. 1973
- Haynes, E. B. 1978

Chaetognatha
- Dawson, J. K. 1971

Larvacea
- Leung, Y. M. 1972a
- Lohmann, H. 1933

Table 3. References used to identify zooplankton from the Beaufort Sea, OCSEAP 1976-1978 samples.

Coelenterata	
	Naumov, D. V. 1960
	Shirley, D. W., and Y. M. Leung 1970
Ctenophora	
	Leung, Y. M. 1970b
Mollusca - Pteropoda	
	Leung, Y. M. 1971
Ostracoda	
	Leung, Y. M. 1972c
	Sars, G. O. 1928
Copepoda	
	Jaschnov, W. A. 1948
	Johnson, M. W. 1963
	Sars, G. O. 1900b
	Tidmarsh, G. W. 1973
	Vidal, J. 1971
Cirripedia	
	Smith, R. I., and J. T. Carlton 1975
Mysidacea	
	Leung, Y. M. 1972b
Cumacea	
	Smith, R. I., and J. T. Carlton 1975
Amphipoda	
	Bernard, J. L. 1969
	Gurjanova, E. 1951
	Sars, G. O. 1895
	Tencati, J. R. 1970
Euphausiacea	
	Lebour, M. V. 1926
	Leung, Y. M. 1970a
Decapoda	
	English, T. S. 1976
Chaetognatha	
	Dawson, J. K. 1971
Larvacea	
	Leung, Y. M. 1972a

Table 3. (cont.)

Pisces
Blackburn, J. E. 1973
Ehrenbaum, E. H. 1909
Gorbunova, N. N. 1954
Rass, T. S. 1949

3) $$\text{Number animals } (1000 \text{ m}^3) = \frac{(A)(1000)}{V} \times 2^n$$

where A is the number of specimens counted in the subsample; V is the volume of water filtered (m^3); and n is the number of times the sample was split.

For the 0.75 m ring net, the volume of water filtered was calculated from:

4) $$V\ (m^3) = \pi r^2 \times D$$

where V is the volume of water filtered; r is the radius of the net ring; and D is the depth of tow.

For the 60 cm diameter bongo net, the volume of water filtered was calculated from:

5) $V\ (m^3)$ = mouth area net frame x meters/revolution x revolutions

where V is the volume of water filtered; meters/revolution is taken from the flowmeter calibration curve; and revolutions is taken from the flowmeter.

2. Phytoplankton

a. WEBSEC-73 (CGC *Glacier*)

1. Standing stock

Standing stock samples were analyzed using an inverted microscope technique (Utermöhl 1931). A Zeiss phase contrast inverted microscope and Zeiss 5 and 50 ml counting chambers were used. Large, rare organisms (> 100 μm) were counted at 125 x magnification in 50 ml chambers, while small, abundant organisms (< 100 μm) were counted at 500 x magnification in 5 ml chambers. One-half of the 50 ml chamber and one fourth of the 5 ml chamber was counted.

The number of cells per liter was calculated by multiplying the number of cells counted in the 50 ml chamber by 40 and the number of cells counted in the 5 ml chamber by 800.

2. Plant pigments

Chlorophyll *a* concentrations were determined using trichromatic methods (Strickland and Parsons 1968). The filters were ground in *ca*. 12 ml 90% acetone and centrifuged three times for a total of 30 min. The supernatant liquid was made up to 14.5 ml with 90% acetone and poured into 5 cm path length spectrophotometric cells. The extinction was measured against a cell containing a blank Millipore filter ground in 90% acetone and centrifuged like the samples. Readings were made at 7500, 6630, 6450, and 6300 Å using a Beckman DU-2 spectrophotometer.

Chlorophyll *a* concentrations were calculated using SCOR/UNESCO equations (Unesco 1966) after the 7500 Å blank reading was subtracted from the extinction readings at 6630, 6450, and 6300 Å.

$$6)\quad \text{Chl } a \text{ (mg m}^{-3}) = \frac{11.64E_{6630} - 2.16E_{6450} + 0.10E_{6300}}{\text{light path (cm)}} \times \frac{\text{vol extract (ml)}}{\text{vol filtered } (\ell)}$$

where light path is the length of the spectrophotometric cell (always 5 cm for these samples); vol extract is the volume of the acetone extracted pigment, usually 14.5 ml; vol filtered is the volume of water filtered for the sample, usually 1 ℓ.

Phaeopigment concentrations were not determined for these samples.

b. CGC *Staten Island* 1974

1. Standing stock

Standing stock samples have not been analyzed for this cruise (Table 1).

2. Plant pigments

Chlorophyll *a* concentrations were determined using trichromatic methods (Strickland and Parsons 1968). The filters were ground in *ca*. 12 ml 90% acetone and centrifuged three times for a total of 30 min. The supernatant liquid was made up to 14.5 ml with 90% acetone. Extinction was measured in 5 cm path length spectrophotometer cells at 7500, 6630, 6450, and 6300 Å using a Beckman DU-2 spectrophotometer. The blank was a new Millipore filter ground in 90% acetone and treated like a sample.

Chlorophyll *a* concentrations were calculated using SCOR/UNESCO equations (Unesco 1966). The extinction at 7500 Å was first subtracted from the extinctions at 6630, 6450, and 6300 Å then equation 6 above was followed. However, the volume of water filtered for these samples was usually 2 ℓ.

Phaeopigment concentrations were not determined.

c. OCSEAP 1976-1978 (CGC *Glacier*, CGC *Northwind*)

1. Standing stock

Standing stock samples were analyzed using an inverted microscope technique (Utermöhl 1931). A Zeiss phase contrast inverted microscope and Zeiss 5 and 50 ml counting chambers were used. Large, rare organisms (> 100 μm) were counted at 125 x magnification in 50 ml chambers, while small, abundant organisms (< 100 μm) were counted at 312 x magnification in 5 ml chambers. One-tenth of the 5 ml chamber and one-fifth of the 50 ml chamber was counted.

The number of cells per liter was calculated by multiplying the number of cells counted in the 50 ml chamber by 500 and the number of cells counted in the 5 ml chamber by 2000.

2. Plant pigments

Chlorophyll *a* and phaeopigment concentrations were determined using a fluorometric technique (Strickland and Parsons 1968). The filters were ground in *ca.* 10 ml 90% acetone for *ca.* three min and centrifuged three times for a total of 30 min. The extract was analyzed with a Turner Model 111 fluorometer using 90% acetone as a blank.

Chlorophyll *a* and phaeopigments were calculated using the equations:

$$\text{7)} \qquad \text{Chl } a \text{ (mg m}^{-3}\text{)} = \frac{\dfrac{F_o/F_{a_{max}}}{(F_o/F_{a_{max}})-1}(K_x)(F_o - F_a)}{\text{vol filtered}}$$

$$\text{8)} \qquad \text{Phaeo (mg m}^{-3}\text{)} = \frac{\dfrac{F_o/F_{a_{max}}}{(F_o/F_{a_{max}})-1}(K_x)\ F_o(F_a/F_{a_{max}}) - F_a}{\text{vol filtered}}$$

where F_o is the fluorometer reading before acidification; F_a is the fluorometer reading after acidification; K is the fluorometer door calibration factor; $F_o/F_{a_{max}}$ is the acid ratio; vol filtered is the volume of sample filtered.

3. Primary productivity

Radioactive uptake was measured using liquid scintillation techniques in a Packard Tri-Carb Scintillation spectrometer using Aquasol (New England Nuclear, Boston, MA.) as the scintillation cocktail. Ten ml of Aquasol were added to filters in the scintillation vials and shaken. The vials were placed in the spectrometer and counted for 50,000 counts or 50 min. All counts were normalized to 50 min.

Carbon uptake was calculated using the equation:

$$\text{9)} \qquad \text{Ps (mg C m}^{-3}\text{ hr}^{-1}\text{)} = \frac{(L - D) \times W \times 1.05}{R \times T}$$

where L is the light bottle disintegrations per min; D is the dark bottle disintegrations per min; W is the carbonate carbon present in the water column; 1.05 is the isotope factor for ^{14}C; R is the activity of the ^{14}C added to each sample; T is the incubation time (Strickland and Parsons 1968).

3. Temperature

a. WEBSEC-73 (CGC *Glacier*), CGC *Staten Island* 1974

Temperatures were provided by the U.S. Coast Guard Oceanographic Unit, Washington, D. C.

b. OCSEAP 1976-1978 (CGC *Glacier*, CGC *Northwind*)

Thermometer readings were corrected using calibration factors provided by the U.S. Coast Guard Oceanographic Unit and following the procedures outlined in the U.S. Naval Oceanographic Office Publ. 607 (1968).

4. Salinity

Salinity samples were analyzed onboard ship using a Beckman RS-7A induction salinometer. Standard seawater (National Institute of Oceanography, Wormley, England) was used to calibrate the machine at the beginning and end of a run and after 30-40 samples if more than that were being analyzed at one time.

Salinity was determined from the conductivity ratio readings using conversion tables provided in the salinometer manual.

VI. Results

A. Hydrography

Ice conditions during the summers when sampling was done were extremely variable. In 1973, severe ice conditions in late July in the vicinity of Point Barrow prevented the icebreaker from entering the Beaufort Sea for several days. Later, ice or fog prevented some sampling. Ice conditions in 1974 were particularly heavy in the area from *ca*. 146°-148°W, while ice conditions in the southern (Canadian) Beaufort Sea were the worst in 20 years (Herlinveaux and de Lange Boom 1975). In 1976 and 1977, heavy ice in the vicinity of Point Barrow kept OCSEAP investigators onboard CGC *Glacier* in the Chukchi Sea for several days. Heavy ice east of Prudhoe Bay in 1976 kept us from a proposed transect off Barter Island. Once into the Beaufort Sea in 1977, ice conditions were relatively light except at a few stations well offshore and in the area between 147°-148°W. Of particular interest in 1978 were the ice remnant areas off Harrison Bay and Prudhoe Bay, and the possible upwelling area off Barter Island. Heavy ice was present off Harrison and Prudhoe bays and east to *ca*. 146°W.

In all years, at stations where heavy ice was present there was a layer of low salinity water about 5 m thick at the surface. This was especially true at stations east of Harrison Bay in 1973 and 1974; at nearly all stations in 1976; and at only a few stations in 1977 and 1978.

Temperature and salinity data for all cruises, except WEBSEC-72, are given in Tables 4-8; vertical profiles of temperature-salinity and chloro-

Table 4. Station locations, temperature, salinity, chlorophyll *a* concentrations, and total number of phytoplankton cells per liter for stations taken in the Beaufort Sea, 28 Jul-12 Aug 1973, CGC *Glacier*.

Sta	Date	Latitude (N)	Longitude (W)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/°°	Chl *a* (mg m^{-3})	No. cells per liter
1	28 Jul	71°28'	155°26'	22	000	3.12	26.38	1.28	158400
					005	2.59	28.57	1.42	184800
					010	1.55	29.92	1.67	279600
					015	0.11	31.04	1.56	124000
					020	-0.03	31.39	1.22	114400
2	29 Jul	71°34'	155°30'	64	000	0.41	28.33	1.27	200800
					005	0.61	29.75	1.08	145600
					010	1.01	30.36	1.00	120000
					015	1.58	30.64		137600
					020	1.62	30.73	1.10	155200
					030	1.51	30.95		237200
					040	1.93	31.15	1.40	146400
					050	1.72	31.67	1.57	250400
					060	1.22	31.75	2.35	280800
3	29 Jul	71°20.6'	153°07.5'	65	000	-0.47	20.26	1.20	264800
					005	-1.12	29.13	1.79	292800
					010	-1.29	29.20	1.51	327400
					015	-1.14	30.18	3.00	340800
					020	-0.99	31.07	4.59	333600
					030	-1.02	31.83	3.75	454400
					040	-1.03	32.01	5.12	936000
					050	-0.97	32.06	4.32	744000
					060	-0.72	32.12	4.62	476000
4	30 Jul	71°11'	152°59'	22	000	-0.53	19.14	1.64	196800
					005	-0.59	29.34	1.20	128800

Table 4. (cont.)

Sta	Date	Latitude (N)	Longitude (W)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/oo	Chl a (mg m^{-3})	No. cells per liter
					010	-1.26	29.62	1.42	136000
					015	-0.92	30.69	5.52	493600
					020	-0.86	31.54	3.02	104000
5	30 Jul	71°07.5'	152°59'	24	000	0.35	13.40	1.45	339200
					005	-1.09	29.15	1.12	217600
					010	-1.43	30.89	1.54	200800
					015	-1.58	30.65	4.13	310400
					020	-1.59	30.66	4.08	343200
6	30 Jul	71°35'	152°59'	123	000	-1.01	28.43	0.62	142400
					005	-1.34	29.38	0.66	52000
					010	-1.44	29.42	0.63	165600
					015	-1.27	29.45	0.57	112800
					020	-1.24	30.11	0.95	174400
					030	-1.12	31.22	4.30	299200
					040	-1.67	31.77	3.52	396000
					050	-1.64	32.04	4.26	700000
					075	-1.39	32.16	3.17	389200
					100		32.34	3.52	328000
					120	-1.70	32.85	2.82	130400
7	31 Jul	71°20'	153°05'	80	000	-0.78	19.56	1.44	214400
					005	-1.30	29.15	2.20	354600
					010	-1.41	29.36	1.65	398800
					015	-1.25	30.22	1.08	89600
					020	-1.15	31.38	3.53	397600
					030	-1.02	31.92	5.38	812800
					040	-0.40	32.04	5.28	870400
					050	-0.56	32.09	2.35	396000

Table 4. (cont.)

Sta	Date	Latitude (N)	Longitude (W)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/°°	Chl *a* (mg m^{-3})	No. cells per liter
					075	-1.27	32.19	3.55	415200
8	01 Aug	70°55.9'	150°55'	25	000	1.47	14.25	0.76	278400
					005	-0.30	27.42	1.50	528800
					010	-1.36	29.75	2.34	801600
					015	-1.36	30.09	3.16	1404800
					020	-1.31	30.62	8.30	1368000
9	01 Aug	71°02'	151°00'	21	000	1.07	11.73	0.67	227200
					005	-1.39	29.34	0.55	125600
					010	-1.41	30.07	1.63	1130400
					015	-1.41	30.64	7.64	325600
					019	-1.52	30.70	8.77	1222600
11	01 Aug	71°11'	151°16'	25	000	-0.21	8.48	1.57	328400
					005	-0.89	28.84	0.88	160800
					010	-1.32	30.69	1.63	260000
					015	-1.23	30.95	2.46	192800
					020	-1.27	31.16	2.07	140800
12	01 Aug	71°16'	151°04'	95	000	-0.30	15.36	0.95	265600
					005	-1.35	29.33	0.66	163200
					010	-1.48	29.64	0.45	100800
					015	-1.42	29.89	0.42	129600
					020	-1.38	30.33	0.79	176000
					030	-1.41	31.22	3.20	524400
					040	-1.32	32.03	3.01	313600
					050	-0.94	32.13	2.89	345400
					075	-1.00	32.13	2.66	390400
					090	-1.01	32.14	2.36	314400

Table 4. (cont.)

Sta	Date	Latitude (N)	Longitude (W)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl a (mg m^{-3})	No. cells per liter
13	02 Aug	71°23'	151°00'	951	000	-0.25	9.89	1.61	600800
					005	-0.95	29.19	0.74	141600
					010	-1.39	30.10	0.63	155200
					015	-1.38	30.47	0.95	176000
					020	-1.32	30.77	0.75	196000
					030	-1.51	31.14	1.53	210400
					040	-1.47	31.54	3.93	599600
					050	-1.46	31.88	4.58	530400
					075	-1.46	32.27	4.31	545600
					100	-1.20	32.28	2.99	471200
					200	-1.61	32.89	0.94	
					300	0.21	34.73	0.16	
					400	0.43	34.84	0.10	
15	02 Aug	70°51'	150°10'	24	000	1.07	18.10	0.27	770400
					005	-1.20	29.15	2.05	734400
					010	-1.47	30.17	6.30	4266400
					015	-1.32	30.66	6.51	1426400
					020	-1.27	30.70	7.84	1924800
16	02 Aug	70°42.5'	149°10.5'	18	000	6.29	14.15	1.80	262400
					005	-0.41	26.79	1.39	760000
					010	-1.47	29.84	2.99	616000
					015	-1.45	30.20	2.26	490400
17	02 Aug	70°42'	148°00'	24	000	4.14	12.44	0.79	748800
					005	-0.41	26.65	0.77	1061600
					010	-1.41	29.45	3.26	2739600
					015	-1.28	29.65	3.22	425000
					020	-1.18	29.68	4.28	576100

Table 4. (cont.)

Sta	Date	Latitude (N)	Longitude (W)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/oo	Chl a (mg m^{-3})	No. cells per liter
18	03 Aug	70°41'	148°07'	34	000	3.86	13.96	1.15	357100
					005	0.94	25.71	0.87	846800
					010	-1.31	29.95	1.66	1678400
					015	-1.32	30.35	2.20	2042800
					020	-1.31	30.53	3.63	1000000
					030	-1.54	30.56	4.12	3173200
19	04 Aug	70°42'	148°10'	32	000	3.31	14.41	0.89	162400
					005	-0.75	28.74	0.31	96800
					010	-1.46	29.97	0.77	1056000
					015	-1.31	30.32	0.94	969200
					020	-1.16	30.70	1.12	966400
					030		31.10	2.99	2326400
20	04 Aug	70°56'	148°10'	44	000	2.82	14.62	0.79	126400
					004		14.67	0.56	144000
					009	-1.40	29.62	0.60	1075200
					014	-1.34	29.74	0.63	1042400
					019	-1.39	30.35	0.83	1600800
					029	-1.40	31.36	2.53	1058400
					039	-1.47	31.53	3.38	1162400
21	04 Aug	71°02'	148°12'	54	000	1.49	11.57	0.87	146000
					004	-1.31	28.76	0.63	139200
					009	-1.36	29.60	0.47	179200
					014	-1.37	30.08	0.54	331200
					019	-1.38	30.37	0.95	759600
					029	-1.26		3.21	876800
					039	-1.35	31.82	3.25	1160000
					049	-1.35	31.91	4.53	1643600

Table 4. (cont.)

Sta	Date	Latitude (N)	Longitude (W)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/oo	Chl a (mg m^{-3})	No. cells per liter
22	04 Aug	71°09'	148°09'	391	000	0.55	9.25	0.78	154000
					005	-0.88	29.09	0.65	818400
					010	-1.31	29.64	0.63	705600
					015	-1.32	29.84	0.76	656800
					020	-1.33	30.12	0.82	920000
					030	-1.40	31.30	0.76	390400
					040	-1.45	31.73	1.96	349200
					050	-1.49	31.94	1.38	369600
					075	-1.33	32.17	3.59	539200
					100	-1.19	32.38	2.18	373600
					200	-1.44	33.05	0.58	53600
					300	0.22	34.76	0.19	17600
23	05 Aug	70°57'	147°30'	50	000	0.16	4.63	0.82	294400
					005	-1.05	28.93	0.28	550400
					010	-1.20	29.06	0.43	502400
					015	-1.12	29.65	0.48	616000
					020	-1.22	30.65	0.55	324800
					030	-1.33	31.41	0.88	646400
					040	-1.40	31.86	1.19	332000
					050	-1.42	31.89	1.22	222400
24	05 Aug	70°52'	147°30'	44	000	1.26	10.43	0.65	196400
					005	-1.20	29.38	0.63	678400
					010	-1.27	29.55	0.70	786400
					015	-1.31	29.99	0.98	1275200
					020	-1.36	31.01	1.54	690400
					030	-1.45	31.27	1.81	709600
					040	-1.41	31.62	2.17	428800

Table 4. (cont.)

Sta	Date	Latitude (N)	Longitude (W)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/∘∘	Chl *a* (mg m^{-3})	No. cells per liter
25	05 Aug	70°32'	147°30'	30	000	4.37	14.41	0.61	125600
					005	-1.03	28.42	0.57	162400
					010	-1.24	29.79	2.52	1471200
					015	-1.29	29.92	2.57	832400
					020	-1.24	30.04	2.77	797600
26	05 Aug	70°23.4'	147°06.9'	21	000	2.54	13.55	0.71	127200
					005	-0.82	27.75	0.91	132400
					010	-1.29	28.25	0.94	120800
					015	-1.50	29.94	3.55	1346400
27	05 Aug	70°19'	146°33'	22	000	1.91	17.75	0.99	286400
					005	0.25	24.32	0.98	184800
					010	-1.22	30.03	4.09	2059200
					015	-1.37	30.26	2.94	838400
					020	-1.55	30.29	2.94	797600
28	06 Aug	70°13'	146°01'	24	000	2.15	15.65	1.11	342400
					005	-1.21	29.50	3.31	936800
					010	-1.44	30.16	3.45	880800
					015	-1.51	30.38	2.85	449600
					020	-1.49	30.34	2.37	62800
29	06 Aug	70°21'	146°00'	24	000	0.56	10.10	0.79	289600
					005	-0.92	27.56	1.33	148000
					010	-1.22	29.52	1.72	580000
					015	-1.36	30.23	1.80	547200
					020	-1.37	30.64	1.80	474400

Table 4. (cont.)

Sta	Date	Latitude (N)	Longitude (W)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/°°	Chl *a* (mg m^{-3})	No. cells per liter
30	06 Aug	70°24.2'	146°31'	24	000	1.00	12.53	0.92	321600
					005	-1.04	27.81	0.93	181600
					010	-1.40	29.25	1.12	200800
					015	-1.42	30.03	2.03	262400
					020	-1.48	30.69	2.04	660800
31	06 Aug	70°31.7'	146°31'	38	000	0.20	4.66	1.21	225600
					005	-1.37	29.14	1.26	355600
					010	-1.44	29.87	1.39	316000
					015	-1.39	30.11	1.34	415200
					020	-1.51	30.77	1.98	260800
					030	-1.56	31.04	1.86	207200
32	06 Aug	70°39'	146°31'	33	000	0.83	11.40	1.15	168800
					005	-0.95	27.82	1.12	203200
					010	-1.12	29.63	1.02	366400
					015	-1.19	30.09	1.21	861600
					020	-1.16	30.98	1.25	669600
					030	-1.28	31.78	1.97	364000
33	06 Aug	70°40'	146°29'	45	000	0.70	11.45	1.09	178400
					005	-1.20	29.03	1.04	385600
					010	-1.19	29.28	1.31	288000
					015	-1.19	29.78	1.07	367200
					020	-1.20	30.18	1.13	772000
					030	-1.27	31.63	2.99	1147200
					040	-1.34	31.84	1.59	216800
34	06 Aug	70°44'	146°45'	36	000	1.00	11.97	1.53	72000
					005	-0.87	28.02	1.05	345600

Table 4. (cont.)

Sta	Date	Latitude (N)	Longitude (W)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl a (mg m^{-3})	No. cells per liter
					010	-1.30	29.43	0.48	357600
					015	-1.32	29.74	0.52	620800
					020	-1.36	30.76	0.72	552800
					030	-1.36	31.63	1.97	811200
35	06 Aug	70°42'	147°04'	44	000	1.32	12.01	0.54	164800
					004	-0.12	26.65	0.44	252000
					009	-1.26	29.20	0.52	396000
					014	-1.32		0.59	566400
					019	-1.31	30.28	0.55	303200
					029	-1.35	31.72	1.24	296800
					039	-1.37	31.75	1.72	445600
36	06 Aug	70°42'	147°10'	36	000	1.60	12.61	0.31	126400
					005	-0.22	27.33	0.45	77600
					010	-1.27	29.39	0.66	371200
					015	-1.28	29.90	0.75	372000
					020	-1.28	30.94	1.00	494400
					030	-1.41	31.42	1.81	396800
37	06 Aug	70°39'	147°33'	27	000		13.74	0.46	68000
					005		29.64	1.04	273800
					010		29.98	0.72	309600
					015		30.44	1.03	248800
					020		30.70	1.21	507200
39	11 Aug	71°09'	154°03'	18	000	0.02	28.24	1.05	166400
					005	-0.25	28.61	1.03	232200
					010	-0.95	29.74	1.63	170400
					015	-0.84	29.93	1.86	108000

Table 4. (cont.)

Sta	Date	Latitude (N)	Longitude (W)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})	No. cells per liter
40	11 Aug	71°15'	154°05'	24	000	-0.02	27.21	0.78	138400
					005	-0.21	27.79	0.81	155200
					010	0.02	28.39	0.77	130400
					015	0.59	30.08	0.61	82400
					020	0.65	30.08	0.70	102400
41	11 Aug	71°19'	155°00'	15	000	2.62	27.67	0.60	203200
					005	2.70	27.77	0.88	137600
					010	-0.28	29.32	1.33	193600
					013	-0.37	29.87	0.91	186400
42	12 Aug	71°28'	154°55'	20	000	4.65	28.66	0.76	121600
					005	3.98	28.65	1.55	169600
					010	3.35	28.77	1.44	117600
					015	1.91	29.16	0.99	116000
					020	1.50	29.35	0.72	155200
43	12 Aug	71°33'	155°00'	33	000	4.32	28.84	0.91	144800
					005	4.56	29.08	1.42	100000
					010	4.52	29.38	1.07	119200
					015	4.14	29.73	1.00	116000
					020	4.06	29.78	0.91	112000
					030	3.30	30.16	0.96	166400
44	12 Aug	71°36'	154°57'	58	000	3.68	29.87	1.57	126400
					005	3.57	30.14	1.33	133600
					010	3.59	30.15	1.24	257600
					015	3.63	30.16	1.34	168000
					020	3.59	30.16	1.29	117600
					030	2.92	30.39	1.42	89600

Table 4. (cont.)

Sta	Date	Latitude (N)	Longitude (W)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/∘∘	Chl *a* ($mg\ m^{-3}$)	No. cells per liter
					040	2.66	30.59	1.81	138400
					050	2.42	30.69	1.90	195200

Table 5. Station locations, temperature, salinity, and chlorophyll *a* concentrations for stations taken in the Beaufort Sea, 19 Aug–5 Sep 1974, CGC *Staten Island*.

Sta	Date	Time (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/∘∘	Chl *a* ($mg\ m^{-3}$)
76	19 Aug	0116	71°32.9'	154°33.5'	1	34	000	2.08	21.46	0.69
							005	2.30	27.59	0.82
							010	3.29	28.41	0.83
							015	3.41	28.64	0.56
							020	3.22	28.88	0.42
							025	3.28	29.10	0.39
77	19 Aug	0452	71°56.9'	153°56'	2	416	000	1.41	26.07	0.84
							005	2.68	28.55	0.49
							010	4.23	29.75	0.83
							015	2.10	29.76	0.79
							020	-0.49	30.92	0.57
							025	-1.06	31.27	2.87
							030	-0.18	31.08	1.69
							040	-0.63	31.81	1.62
							050	0.06	32.09	1.27
							075	-0.74	32.41	1.93
							100	-0.94	32.49	2.20
							150	-1.15	33.33	0.91
78	19 Aug	1110	71°27'	152°35'	1	68	000	2.07	24.21	2.06
							005	1.91	27.07	0.74
							010	3.66	28.67	0.74
							015	3.25	28.98	0.81
							020	1.74	29.41	0.98
							025	1.87	30.49	0.63
							030	3.00	30.90	0.74
							040	2.70	31.11	0.65
							050	2.14	31.30	0.62

Table 5. (cont.)

Sta	Date	Time (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})
79	20 Aug	0020	70°59'	151°23.3'	2	21	000	1.42	13.79	0.63
							005	-0.30	27.22	1.08
							010	-0.66	30.01	0.74
							015	-1.13	31.44	4.25
80	21 Aug	1509	71°13'	148°06'	7	800	000	-0.32	15.06	0.70
							005	-0.84	26.80	0.46
							010	-0.94	27.16	0.56
							015	-0.67	28.81	0.57
							020	-0.87	29.29	0.53
							025	-1.03	29.57	0.53
							030	-1.12	29.89	0.50
							040	-1.07	31.16	1.38
							050	-1.08	31.64	0.63
							075	-1.27	32.19	0.44
							100	-1.32	32.50	0.52
							150	-1.33	33.21	0.52
81	22 Aug		71°25.8'	147°33.7'	8	2565	000	No sample		
							005	-0.48	27.02	0.59
							010	-0.76	27.33	0.77
							015	-0.79	28.77	0.65
							020	-0.98	29.70	0.52
							025	-1.06	30.02	0.47
							030	-1.20	30.23	0.44
							040	-1.16	30.69	0.53
							050	-1.27	31.11	0.72
							075	-1.05	32.09	0.31
							100	-1.19	32.49	0.23
							150	-1.13	33.12	0.18

Table 5. (cont.)

Sta	Date	Time (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl a (mg m^{-3})
82	22 Aug		70°52'	148°00'	7	40	000	0.10	5.31	0.61
							005	-0.73	29.05	0.27
							010	-0.95	29.24	0.22
							015	-0.94	29.90	0.30
							020	-1.04	31.25	0.79
							030	-1.12	31.82	0.49
83	22 Aug		70°39'	148°14'	8	27	000	0.24	6.76	1.09
							005	-1.00	28.88	1.43
							010	-1.16	29.97	1.62
							015	-1.10	30.43	1.56
							020	-1.16	30.90	2.14
84	1 Sep		70°15.1'	143°26'	3	30	000	1.91	8.22	0.76
							005	-0.93	29.17	2.42
							010	-1.24	30.34	7.24
							015	-1.24	31.07	3.66
							020	-1.33	31.20	1.48
							025	-1.33	31.20	2.02
85	1 Sep		70°13.8'	144°06.6'	2	30	000		10.05	0.98
							005	-0.83	29.52	2.46
							010	-1.21	30.65	2.11
							015	-1.19	31.16	1.74
							020	-1.27	31.16	1.61
							025	-1.26	31.04	1.91
86	2 Sep		70°12.5'	145°00'	1	27	000	2.55	10.42	
							005	-0.86	29.33	2.09
							010	-1.15	30.29	4.97

Table 5. (cont.)

Sta	Date	Time (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})
							015	-1.16	31.01	1.84
							020	-1.25	31.04	2.05
							025	-1.23	31.06	1.88
87	2 Sep		70°17.5'	145°55'	1	31	000	1.53	12.49	0.55
							005	-0.92	30.03	1.83
							010	-1.19	30.05	2.00
							015	-1.18	30.97	1.01
							020	-1.25	31.07	0.92
							025	-1.25	31.08	1.00
88	2 Sep		70°21.4'	146°18'	5	27	000	0.38	6.58	1.43
							005	-0.90	29.33	0.99
							010	-1.10	30.26	1.12
							015	-1.11	30.47	2.38
							020	-1.21	30.99	1.00
							025	-1.21	31.00	1.02
89	2 Sep		70°24'	146°42'	3	26	000	0.80	6.75	0.98
							005	-1.21	29.67	1.86
							010	-1.19	30.45	2.84
							015	-1.27	30.97	2.46
							020	-1.26	31.05	1.98
90	3 Sep		70°30.6'	147°17.7'	3	27	000	1.05	8.01	1.17
							005	-0.91	29.28	1.29
							010	-1.09	29.80	1.50
							015	-1.05	30.23	1.67
							020	-1.14	30.68	1.10

Table 5. (cont.)

Sta	Date	Time (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/°°	Chl *a* (mg m^{-3})
91	3 Sep		70°35'	147°52'	2	24	000	0.84	7.03	0.63
							005	-0.86	29.13	0.59
							010	-1.11	29.83	0.59
							015	-1.12	30.51	1.09
							020	-1.19	30.95	0.85
92	3 Sep		70°46.1'	147°39.0'	7	42	000	0.65	3.05	0.62
							005	-0.74	27.91	0.31
							010	-0.73	28.85	0.43
							015	-0.75	29.41	0.22
							020	-0.92	29.83	0.18
							025	-0.93	30.81	0.24
							030	-1.09	30.54	0.21
							040	-1.13	31.62	0.76
93	3 Sep		71°00.5'	147°19.4'	7	325	000	-1.03	26.40	0.43
							005	-0.94	27.04	0.36
							010	-0.92	27.67	0.41
							015	-0.78	29.46	0.23
							020	0.28	29.97	0.28
							025	1.51	30.91	0.32
							030	-0.65	30.47	0.30
							040	1.04	31.06	0.24
							050	-0.22	31.31	0.56
							075	-0.02	31.52	0.60
							100	-1.10	31.99	0.46
							150	-1.20	32.71	0.47
94	3 Sep		71°14'	146°59'	7	2020	000	-1.01	26.54	0.43
							005	-0.71	26.93	0.52

Table 5. (cont.)

Sta	Date	Time (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl a (mg m^{-3})
							010	-0.81	27.98	0.53
							015	-0.72	29.20	0.66
							020	-0.54	29.68	0.52
							025	-1.10	30.24	0.57
							030		30.39	0.45
							040	-1.10	30.99	0.63
							050	-1.17	31.63	0.49
							075	-1.25	32.09	0.41
							100	-1.24	32.35	0.37
							150	-1.40	33.03	0.37
95	4 Sep		71°35.5'	146°27.6'	7	3023	000	-0.15	13.49	0.54
							005	-0.62	26.68	0.50
							010	-0.79	27.09	0.42
							015	-0.50	29.10	0.51
							020	-0.76	29.49	0.50
							025	-0.78	29.84	0.44
							030		29.90	0.52
							040	-1.07	30.69	0.54
							050	-1.12	31.42	0.47
							075	-1.00	32.16	0.27
							100	-1.12	32.52	0.30
							150	-1.05	33.19	0.24
96	5 Sep		71°03'	146°25'	4	1052	000		21.63	0.61
							005	-0.99	26.88	0.33
							010	-1.12	26.98	0.31
							015	-0.97	27.18	0.26
							020	-0.82	29.23	0.40
							025	-0.94	29.58	0.40

Table 5. (cont.)

Sta	Date	Time (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/∘∘	Chl a (mg m^{-3})
							030	-1.07	29.67	0.42
							040	-1.10	30.57	0.41
							050	-1.15	31.31	0.37
							075	-1.02	32.17	0.17
							100	-1.16	32.52	0.03
							150	-1.10	33.18	0.16
97	5 Sep		70°47'	146°25'	7	53	000	-0.01	9.37	0.60
							005	-1.00	27.94	0.21
							010	-0.98	29.01	0.15
							015	-1.03	28.88	0.23
							020	-0.88	29.49	0.17
							025		30.34	0.22
							030	-1.19	31.59	0.21
							040	-1.27	31.77	0.26
							050	-1.25	31.77	0.28
98	5 Sep		70°30.4'	146°23.5'	1	35	000	-0.32	20.55	0.96
							005	-0.75	26.48	2.08
							010		29.43	1.43
							015	-1.07	29.97	0.85
							020	-1.13	30.43	0.38
							025	-1.10	31.61	1.68

Table 6. Station locations, temperature, salinity, chlorophyll *a* and phaeopigment concentrations, and primary productivity for stations taken in the Beaufort Sea, 17 Aug-2 Sep 1976, CGC *Glacier*.

Sta	Date	Time (GMT)	Latitude (N)	Longitude (W)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
12	17 Aug	1545	71°31.5'	156°09.0'	139	000	3.23	29.09	0.31	0.04	0.15
						005	3.23	29.06	0.27	0.02	0.20
						010	3.46	29.25	0.31	0.04	0.16
						015	2.54	29.64	0.54	0.23	0.45
						025	-0.72	31.88	0.56	0.19	0.45
						050	-1.33	32.67	3.10	0.25	2.81
						075	-1.29	32.69	2.90	0.40	1.75
						100	-1.34	32.74	2.60	0.37	1.81
13	18 Aug	1555	71°31.0'	155°05.0'	31	000	1.03	15.35	0.62	0.09	0.36
						005	2.54	28.22	0.49	0.10	0.52
						010	2.82	29.44	0.59	0.13	0.43
						015	2.53	29.63	0.51	0.08	0.54
						020	2.09	29.90	0.54	0.10	0.54
						025	0.72	30.56	0.47	0.10	0.62
14	21 Aug	0100	71°11.0'	153°09.0'	25	000	1.78	7.84	0.29	0.06	0.16
						005	-0.80	27.72	0.81	0.02	0.55
						010	-0.67	29.67	0.18	0.06	0.07
						015	-0.67	31.29	0.15	0.11	0.09
						020	-0.87	31.46	0.12	0.12	0.07
15	24 Aug	0053	70°36.0'	148°12.0'	16	000	-0.21	10.04	0.32	0.03	0.22
						005	-0.91	28.48	5.07	0.18	4.36
						010	-1.41	28.23	5.20	0.08	3.94
						015	-1.43	30.32	5.38	0.14	4.20
16	No hydrographic data										

Table 6. (cont.)

Sta	Date	Time (GMT)	Latitude (N)	Longitude (W)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/oo	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
17	26 Aug	0518	70°32.0'	147°33.0'	25	000	-1.34	6.02	0.48	0.06	0.19
						005	-1.56	28.88	3.22	0.51	4.33
						010	-1.48	30.06	3.80	0.25	5.98
						015	-1.54	30.72	2.93	0.36	3.40
						020	0.67	31.72	1.64	0.18	1.67
18	26 Aug	1808	70°39.0'	147°37.0'	25	000	0.33	5.05	0.36	0.05	0.09
						005	-0.84	25.90	2.00	0.08	2.36
						010	-1.56	29.70	3.36	0.34	3.95
						015	-1.60	30.21	3.08	0.21	3.37
19B	27 Aug	0900	70°57.0'	149°33.0'	30	000	0.43	7.64	0.43	0.08	0.34
						005	-1.15	24.63	0.71	0.07	0.45
						010	-1.12	30.01	0.38	0.07	0.14
						015	-1.16	31.44	0.23	0.13	0.18
						020	-1.01	30.43	0.32	0.21	0.04
						025	-1.05	31.62	0.20	0.15	0.12
20	28 Aug	2327	71°08.0'	151°19.0'	34	000		19.05	0.30	0.03	0.10
						005	0.78	22.81	1.76	0.06	0.86
						010	-1.36	32.25	3.90	0.75	2.45
						015	-0.57	30.73	0.50	0.12	0.47
21	30 Aug (cast 3)	0035	71°43.0'	151°47.0'	1700	000	0.28	10.18	0.18	0.03	0.10
						005	-0.98	25.63	0.48	0.10	0.36
						010	-1.02	28.06	0.65	0.02	0.49
						015	-0.96	29.54	0.53	0.04	0.38
						020	0.54	30.04	0.74	0.10	0.72
						025	0.53	30.58	0.63	0.03	0.38
21	29 Aug (cast 2)	2355				030		30.85	0.22	0.03	0.13
						040	-0.12	31.33	0.25	0.10	0.17

Table 6. (cont.)

Sta	Date	Time (GMT)	Latitude (N)	Longitude (W)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl a (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
						050	-0.77	32.04	0.24	0.18	0.13
						060	-1.19	32.44	0.39	0.26	
						075	-1.30	32.62	0.39	0.25	0.12
						100	-1.49	32.74	0.62	0.20	0.32
21	29 Aug	2300				500	0.33		no sample		
	(cast 1)					510	0.34	34.79	0.11	0.14	
						700	0.05	34.84	0.35	0.30	
						800	-0.04	34.84	0.09	0.11	
						900	-0.09	34.85	0.19	0.30	
						1000	-0.18	34.85	0.18	0.28	
23	31 Aug	0112	71°22.0'	152°20.0'	75	000	0.54	15.71	0.54	0.04	0.23
						005	1.45	25.52	0.67	0.08	0.32
						010	1.91	27.43	0.83	0.06	0.60
						015	2.67	28.84	1.98	0.83	0.76
						020	0.92	30.98	0.41	0.09	0.32
						025	0.52	31.25	0.38	0.11	0.27
						030	1.33	24.05	0.73	0.14	0.36
						040	2.34	28.34	1.00	0.06	0.97
						050	-0.12	31.10	0.36	0.12	0.25
						060	-0.66	31.59	0.27	0.13	0.17
						075	-0.94	32.22	0.77	0.35	0.55
24	31 Aug	1715	71°19.0'	152°32.0'	52	000	0.27	17.36	0.58	0.07	0.23
						005	1.68	25.83	0.75	0.09	0.42
						010	3.18	27.87	0.89	0.12	0.58
						015	2.78	28.55	1.03	0.09	0.77
						020	2.32	29.42	0.74	0.06	0.53
						025	1.91	30.09	0.49	0.05	0.36

Table 6. (cont.)

Sta	Date	Time (GMT)	Latitude (N)	Longitude (W)	Sonic Depth (m)	Sample Depth (m)	Temp (°C)	S°/∘∘	Chl a (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
						030	2.05	30.60	0.34	0.07	0.22
						045	-0.30	31.47	0.46	0.16	0.21
25	1 Sep	1625	71°08.0'	152°57.0'	22	000	1.79	20.47	0.19	0.03	0.12
						005	-0.26	26.24	0.47	0.07	0.35
						010	-0.41	28.99	2.20	0.60	2.25
						015	0.30	30.09	1.08	0.14	0.73
26	2 Sep	1420	71°23.0'	154°21.0'	30	000	1.15	17.40	0.22	0.03	0.06
						005		25.27	0.44	0.08	0.29
						010	2.95	27.55	0.69	0.10	0.38
						015	2.73	28.77	0.62	0.09	0.48
						020	2.15	29.15	0.66	0.09	0.37
						025	2.13	29.38	0.36	0.06	0.17
27	2 Sep	2158	71°36.0'	155°32.0'	171	000	0.14	8.35	1.00	0.20	0.30
						005	2.31	25.79	0.54	0.05	0.32
						010	2.12	27.73	0.46	0.05	0.34
						015	-0.67	28.48	0.53	0.04	0.30
						020	-1.34	31.05	1.28	0.01	1.24
						025	0.23	31.92	0.69	0.12	0.36
						030	0.19	32.00	0.51	0.15	0.33

Table 7. Station locations, temperature, salinity, ice cover, chlorophyll *a* and phaeopigment concentrations, and primary productivity for stations taken in the Beaufort Sea, 7 Aug-5 Sep 1977, CGC *Glacier*.

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/oo	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
4	4 Aug	71°25'	164°00'	1	42	8	000	-0.14	27.14	0.15	0.04	0.11
							005	1.36	30.50	0.11	0.21	0.09
							010	-0.47	31.77	0.40	0.15	0.29
							015	-1.43	32.32	0.10	0.35	0.06
							020	-1.53	32.49	7.58		4.52
							025	-1.70	32.82	22.94		7.96
							030	-1.70	33.18	9.08	0.22	1.84
							045	-1.74	33.45	0.69	0.16	0.49
5	6 Aug	71°12'	158°22'	1	107	9	000	1.20	24.26	0.27	0.03	0.08
							010	3.89	31.32	0.10	0.22	0.09
							020	-0.09	31.97	0.34	0.13	0.34
							030	-1.63	32.78	18.80		3.08
							045	-1.62	32.92	15.45		4.20
							060	-1.64	32.86	14.34	0.19	3.63
							075	-1.65	32.87	15.17	0.48	3.79
							100	-1.70	32.92			3.75
6	6 Aug	71°25'	156°56'	1	112	11	000	2.81	29.38	0.22	0.02	0.16
							010	2.83	30.64	0.20	0.09	0.21
							020	0.13	32.36	0.61	0.27	0.48
							030	-0.21	32.46	0.94	0.25	0.51
							045	1.69	32.47	1.53	0.43	0.55
							060	-0.60	32.49	1.37	0.39	0.56
							075	-0.72	32.51	1.85	0.27	0.68
							100	-1.38	32.69	3.80	0.61	1.25
7	7 Aug	71°46'	155°51'	1	123	16	000	0.27	27.94	0.22	0.18	0.05
							010	-0.79	30.85	0.15	0.02	0.08

Table 7. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/°°	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
							020	-0.97	31.19	0.11	0.04	0.02
							030	-1.41	31.55	0.74		0.24
							045	-1.29	32.04	1.48	0.20	1.02
							060	-1.26	32.44	1.85	0.01	0.59
							075	-1.08	32.95	1.78	0.20	0.63
							100	-1.61	33.20	1.04	0.19	0.32
8	9 Aug	71°57'	154°33'	1	183	1	000	1.12	28.22	0.16	0.10	0.09
							010	1.12	29.27	0.18	0.02	0.11
							020	-0.33	30.27	0.25	0.08	0.25
							030	0.85	31.58	0.33	0.12	0.30
							045	-0.50	32.54	0.42	0.47	0.66
							060	-1.24	33.01	0.98	0.20	0.36
							075	-1.29	33.13	0.10	0.04	0.41
							100	-1.66	33.43	0.45	0.14	0.15
							125	-1.50	33.77	0.24	0.15	0.23
							150	-0.95	34.20	0.09	0.69	
							175	0.05	34.70	0.22	0.15	0.12
9	10 Aug	72°24'	154°37'	8	2196		000	-0.73	25.20	0.17	0.13	0.14
							010	-0.63				
							020	0.95	31.80	0.14	0.19	0.23
							030	-1.38	32.29	0.10	0.04	0.04
							045	3.34	32.90	0.19	0.09	0.13
							060	2.34	32.86	0.19	0.16	0.16
							075	1.68	32.92	0.08	0.31	0.18
							100	0.16	33.01	0.24	0.16	0.22
10	10 Aug	71°35'	153°29'	1	51		000	1.24	29.45	0.19	0.29	0.25
							010	1.02	29.58	0.14	0.48	0.32

Table 7. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/oo	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
							020	3.90	31.95	0.59		0.56
							025	5.19	32.24	0.50	0.03	0.50
							030	5.06	32.33	0.75	0.05	0.63
							035	4.81	32.48	0.62	0.02	0.46
							040	5.02	32.58	0.43	0.03	0.36
							045	3.39	32.62	0.19	0.11	0.26
11	11 Aug	71°18'	152°43'	0	55		000	1.39	29.39	2.12	0.03	0.74
							010	1.35	29.41	0.83	1.25	0.85
							015	1.33	29.45	1.85	0.04	1.37
							020	0.77	30.68	0.12	0.01	2.26
							025	0.83	31.99	1.35	0.05	0.82
							035	1.77	32.57	0.23	0.20	0.24
							045	2.57	32.77	0.18	0.16	0.08
							050	1.15	32.78	0.70	0.24	0.34
12	12 Aug	71°10'	151°30'	0	24		000	-0.71	28.80	2.42	0.28	1.89
							005	-0.81	29.35	3.75	0.01	1.75
							010	-1.23	31.18	4.40	0.09	2.65
							015	-1.30	32.84	1.70	0.36	1.03
							020	-1.28	32.87	2.02	0.47	1.07
13	13 Aug	71°05'	150°23'	1	29		000	-1.00	30.29	1.78	0.25	0.99
							005	-1.06	30.35	1.85	0.24	1.20
							010	-1.03	30.31	1.77	0.20	1.37
							015	-1.48	32.67	0.55	0.10	0.56
							020	-1.29	32.81	0.42	0.26	0.28
							025	-1.40	32.82	0.45	0.16	0.29

Table 7. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl a (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
14	14 Aug	71°10'	150°04'	4	44	7	000	-0.85	30.95	1.66	0.39	1.22
							005	-1.00	31.32	3.12	0.14	1.83
							010	-0.97	31.71	2.15		3.21
							015	-1.13	31.96	1.99		1.78
							020	-1.45	32.24	0.61	0.10	0.41
							025	-1.49	32.33	0.16	0.16	0.11
							030	-1.49	32.54	0.21	0.06	0.07
							040	-1.53	32.86	0.28	0.10	0.20
15	15 Aug	70°38'	148°28'	0-1	22		000	0.05	31.25	2.59	1.34	2.75
							003	-0.69	31.80	3.50	0.11	2.97
							006	-0.74	31.83	4.14		4.12
							009	-0.94	31.90	5.29		3.81
							012	-0.84	32.13	2.12	1.14	2.57
							015	-1.23	32.13	2.29	1.76	1.51
							018	-1.24	32.13	2.71		1.43
16	17 Aug	70°42'	147°59'	3	31		000	0.19	31.03	3.49	0.16	
							005	-0.47	31.97	9.99		
							010	-0.98	32.31	1.17	0.13	
							015	-1.12	32.42	1.19	0.16	
							020	-0.98	32.47	1.41	0.11	
							025	-1.21	32.46	1.38	0.02	
16A	17 Aug	70°40'	147°48'	2	32	4	000	-0.39	30.44	3.40	0.35	
							005	-0.43	32.18	7.77	0.08	
							010	-0.65	32.39	3.19	0.50	
							015	-1.02	32.41	2.44	0.08	
							020	-1.09	32.43	1.83	0.35	

Table 7. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
							025	-1.12	32.42	2.25	0.02	
							030	-1.17	32.42	1.83	0.15	
17	18 Aug	70°33'	147°24'	2-3	27	4	000	-0.15	31.48	7.26	0.18	4.13
							003	-0.16	31.51	8.74		3.94
							006	-0.28	31.55	7.26		5.82
							009	-0.47	31.61	6.32	0.41	4.99
							012	-0.50	31.65	6.12	1.22	7.08
							015	-0.64	31.85	7.52		7.35
							020	-0.78	31.98	4.66		6.42
							025	-0.97	32.09	5.00		5.12
18	18 Aug	70°25'	146°41'	0	31		000	0.90	32.06	2.96	0.39	2.19
							003	0.86	32.06	4.27	0.68	2.06
							006	0.88	32.06	2.45	0.55	2.18
							009	0.82	32.06	3.91	1.13	2.54
							012	0.90	32.06	3.06	0.51	2.57
							015	1.02	32.06	2.70	0.85	1.85
							020	-0.72	32.38	4.69	0.20	3.65
							025	-0.74	32.40	7.57	5.64	3.45
19	19 Aug	70°32'	146°30'	0	3660	30	000	-0.97	26.66	0.14	0.13	
							010	-0.94	28.10	0.05	0.05	
							020	-1.24	30.98	0.07	0.05	
							030	-1.45	31.63	0.10	0.07	
							045	-1.33	31.91	0.05	0.32	
							060	-0.79	32.24	0.06	0.11	
							075	-1.42	32.52	0.05	0.05	
							100	-1.50	32.83	0.02	0.04	
							200	-0.77	34.27	0.02	0.03	

Table 7. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl a (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
							400	0.47	34.88	0.02	0.02	
							500	0.45	34.90	0.02	0.04	
							600	-0.29	34.91	0.04	0.04	
							700	-0.23	34.91		0.09	
							800	0.03	34.92	0.01	0.02	
							900	-0.04	34.92	0.02	0.03	
							1000	-0.15	34.93	0.01	0.01	
20	21 Aug	72°46'	146°23'	8	3568	42	000	1.35	5.02	0.08	0.02	
							010	-0.85	29.76	0.04	0.01	
							020	-1.19	30.71	0.04	0.02	
							030	-1.43	31.45	0.06	0.04	
							045	-1.35	31.74	0.15	0.08	
							060	-1.48	32.10	0.08	0.11	
							075	-1.44	32.44	0.05	0.05	
							100	-1.47	32.76	0.01	0.03	
21	22 Aug	72°47'	146°34'	1	3568	14	000	1.41	24.42	0.11	0.05	
							010	2.15	26.30	0.10	0.06	
							020	-1.14	30.60	0.05	0.03	
							030	-1.42	31.54	0.08	0.03	
							045	-1.50	31.88	0.10	0.10	
							060	-1.44	32.18	0.09	0.06	
							075	-1.42	32.37	0.03	0.04	
							100	-1.50	32.81	0.01	0.03	
22	23 Aug	72°57'	143°20'	4	3292	21	000	2.13	17.72	0.23	0.11	
							010	-0.48	27.01	0.06	0.04	
							020	-0.87	30.93	0.08	0.03	
							030	-1.26	31.82	0.07	0.03	

Table 7. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/∘∘	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
							045	-1.17	31.82	0.09	0.05	
							060	-1.48	32.17	0.05	0.10	
							075	-1.47	32.42	0.03	0.04	
							100	-1.45	32.78	0.02	0.02	
23	23 Aug	72°54'	142°08'	5	3531	21	000	3.34	21.22	0.17	0.13	
							010	1.16	29.20	0.06	0.01	
							020	-0.65	31.17	0.05	0.07	
							035	-1.45	31.71	0.05	0.06	
							050	-1.59	31.95	0.04	0.09	
							075	-1.59	32.43	0.03	0.06	
							100	-1.46	32.76	0.01	0.04	
							3400	-0.28	34.98			
24	25 Aug	70°45'	141°28'	0	1189	12	000	2.59	30.50	0.09	0.06	
							010	2.39	30.54	0.07	0.08	
							020	-1.10	31.65	0.21	0.08	
							030	-1.49	31.92	1.48	0.09	
							045	-1.59	32.18	0.54	0.25	
							060	-1.56	32.43	0.11	0.10	
							075	-1.51	32.63	0.12	0.07	
							100	-1.50	32.95	0.05	0.05	
25	25 Aug	70°32'	141°32'	0	406	20	000	2.02	30.92	0.25	0.07	
							010	-0.14	31.44	0.50		
							020	-0.73	31.96	5.74	1.20	
							030	-1.04	32.15	2.42	0.23	
							045	-0.85	32.40	1.34	0.11	
							060	-1.43	32.72	0.94	0.19	
							075	-1.48	32.81	0.80	0.21	
							100	-1.49	32.86	0.84	0.19	

Table 7. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})	Phaeo	Prim Prod (mg C m^{-3} hr^{-1})
26	26 Aug	69°49'	141°31'	0	28	5	000	2.38	32.52	10.40		8.20
							003	2.36	32.53	8.72		9.72
							006	2.41	32.52	13.59		10.35
							009	2.37	32.53	10.40		8.56
							012	2.33	32.52	18.84		8.30
							015	2.36	32.53	12.76		8.59
							020	0.36	32.76	3.06	0.06	1.71
							025	-0.18	32.79	1.55	0.36	1.40
27	26 Aug	70°04'	142°14'	0	35	4	000	1.27	32.24	5.06	0.21	2.82
							003	1.23	32.34	6.08		2.10
							006	1.26	32.34	4.59		2.93
							009	1.20	32.34	5.82		2.17
							012	1.19	32.34	7.00		2.53
							015	1.21	32.34	4.62		1.86
							020	0.20	32.45	6.84		1.98
							030	-0.33	32.50	8.90	0.68	1.85
28	27 Aug	70°19'	142°32'	0	49	13	000	1.47	31.22	0.57	0.03	
							005	1.45	31.23	0.44	0.05	
							010	1.47	31.21	0.41		
							015	0.93	32.09	1.58	0.25	
							020	0.55	32.35	4.93		
							025	-1.03	32.56	2.09		
							030	-1.08	32.56	4.24	0.34	
							045	-1.20	32.59	4.43	2.03	
29	28 Aug	70°21'	143°29'	0	38		000	1.47	31.71	0.76	0.10	0.25
							005	1.45	31.76	0.74		0.25
							010	1.38	32.03	1.26	0.01	0.80

Table 7. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/∘∘	Chl a (mg m^{-3})	Phaeo	Prim Prod (mg C m^{-3} hr^{-1})
							015	1.61	32.16	1.44		0.53
							020	1.15	32.19	2.39	0.06	1.05
							025	-0.64	32.46	11.03	2.21	5.17
							030	-0.61	32.46	10.40	3.64	4.52
							035	-0.62	32.46	4.77	2.24	4.58
30	28 Aug	70°14'	144°28'	0	28	11	000	1.37	32.13	0.32	0.23	0.19
							003	1.36	32.13	0.30	0.20	0.36
							006	1.42	32.14	0.37	0.23	0.17
							009	1.36	32.14	0.48	0.05	0.25
							012	1.33	32.21	0.30	0.16	0.22
							015	1.35	32.14	0.29	0.19	0.18
							020	-0.76	32.37	4.82	1.75	4.86
							025	-0.80	32.38	13.08	1.47	3.94
31	29 Aug	70°10'	145°32'	0	20	5	000	1.04	31.39	0.64	0.17	0.31
							003	1.07	31.39	0.45	0.23	0.26
							006	1.09	31.42	0.51	0.13	0.28
							009	1.09	31.52	0.46	0.15	1.44
							012	1.07	31.61	0.29	0.22	0.25
							015	1.30	31.68	0.30	0.30	0.25
							018	1.36	31.71	0.35	0.31	0.37
32	30 Aug	70°39'	145°34'	0	51	10	000	2.08	29.62	0.10	0.06	
							005	2.08	29.62	0.06	0.09	
							010	2.08	29.65	0.11	0.03	
							015	1.28	31.67	0.21	0.01	
							020	0.56	31.89	0.26	0.13	
							025	-0.84	32.14	5.74		
							030	-0.83	32.29	8.31		
							045	-1.45	32.59	4.20	1.34	

Table 7. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/∘∘	Chl a (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
33	30 Aug	70°23'	146°26'	2	28		000	-0.20	29.82	0.96	0.01	
							003	0.12	30.24	1.02		
							006	0.12	30.86	0.81	0.34	
							009	-0.07	31.40	1.53	0.38	
							012	-0.21	31.40	2.30	0.31	
							015	-0.46	31.55	3.06	1.33	
							020	-0.69	31.63	5.17	0.55	
							025	-0.73	31.64	7.34	1.19	
34	31 Aug	71°46'	147°02'	0	54	24	000	1.04	28.02	0.36	0.08	
							005	1.75	28.99	0.17	0.05	
							010	0.70	29.90	0.20	0.03	
							015	0.59	29.91	0.17	0.05	
							020	0.19	30.54	0.29	0.03	
							025	-1.08	31.46	0.23	0.06	
							030	-1.19	31.55	0.30	0.02	
							045	0.12	32.24	0.55	0.46	
35	1 Sep	70°32'	147°35'	3-4	18	5	000	0.55	29.89	0.81	0.17	
							003	0.75	30.00	0.49	0.05	
							006	0.53	30.17	1.31	0.40	
							009	0.27	30.23	1.59	0.24	
							012	0.15	32.67	2.35	0.61	
							015	0.04	30.99	3.25	1.03	
36	1 Sep	70°36'	148°26'	1	22		000	0.66	28.78	0.60	0.04	0.15
							003	1.17	28.87	0.78		
							006	0.90	28.91	0.40	0.03	0.18
							009	0.40	30.07	0.61		0.20
							012	0.21	30.81	0.72	0.22	0.35

Table 7. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/∘∘	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
							015	-0.26	31.22	3.98	0.17	1.73
							018	-0.27	31.22	3.28	1.22	2.21
37	2 Sep	70°45'	149°03'	3	27	11	000	0.67	28.45	0.17	0.42	
							003	0.36	28.78	0.48	0.06	
							006	-0.13	29.79	0.21	0.19	
							009	-0.15	30.04	0.33	0.18	
							012	-0.50	30.47	0.40	0.14	
							015	-1.06	31.29	1.29	0.14	
							018	-1.43	31.83	14.54	1.38	
38	4 Sep	71°58'	155°43'	0	150		000	5.96	29.17	0.21	0.29	
							010	6.21	29.23	0.21	0.14	
							020	-1.16	31.70	0.16	0.24	
							030	-1.38	31.93	0.04	0.11	
							040	-1.40	32.10	0.05	0.08	
							050	-1.10	32.27	0.02	0.23	
							075	-1.06	32.68	0.09	0.17	
							100	-1.46	32.98	0.23	0.23	
39	4 Sep	71°30'	155°12'	0	26	9	000	7.97	29.62	0.73	0.30	
							003	8.07	28.63	0.76	0.27	
							006	8.47	28.98	1.02	0.15	
							009	8.54	28.97	0.73	0.23	
							012	8.37	29.03	0.58	0.32	
							015	8.42	29.15	0.75	0.26	
							018	8.35	29.21	0.52	0.23	
							021	7.83	29.37	0.69	0.21	
40	4 Sep	71°30'	155°13'	0	26	6	000	8.57	29.03	1.18	0.20	

Table 7. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/°°	Chl a (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
							003	8.58	29.13	1.17	0.29	
							006	8.59	29.02	1.11	0.16	
							009	8.57	29.02	0.86	0.28	
							012	8.50	29.04	0.64	0.28	
							015	8.48	29.13	0.85	0.21	
							018	8.50	29.18	0.62	0.31	
							021	8.51	29.21	0.73	0.24	
41	5 Sep	71°32'	156°30'	0	160	9	000	3.56	27.67	0.19	0.13	
							010	4.39	31.26	0.35	0.18	
							020	3.01	31.52	0.15	0.30	
							030	1.22	31.98	0.28	0.20	
							040	0.83	32.06	0.25	0.15	
							050	0.63	32.10	0.10	0.35	
							075	0.51	32.13	0.30	0.16	
							100	-0.16	32.38	0.40	0.19	

Table 8. Station locations, temperature, salinity, ice cover, chlorophyll *a* and phaeopigment concentrations, and primary productivity for stations taken in the Beaufort Sea, 15 Aug-15 Sep 1978, CGC *Northwind*.

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/°°	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
1	17 Aug	71°11'	150°14'	∿ 1	45	8	005	-0.01*	24.16	0.13	0.05	
							010	2.55*	30.19	0.23	0.05	0.02
							025	1.95†	31.16	0.56	0.30	0.22
							035	2.39	31.55	0.40	0.17	0.17
							045	1.57†	32.08	0.21	0.20	0.05
3	18 Aug	70°58.5'	149°17'	4-5	41	7	003	-0.27	15.93	0.18	0.06	0.01
							010	-1.03	29.11	0.27	0.07	0.01
							015	-0.45*	29.88	0.40	0.05	0.06
							020	-0.71	30.73	0.34	0.05	0.07
							025	2.80	31.52	0.26	0.18	0.11
							030	2.40	31.68	0.38	0.20	0.17
							035	2.17	31.68	0.32	0.19	0.18
4	19 Aug	70°19.8'	146°05'	1	33	5	000	-0.36	28.86	0.17	0.16	0.04
							005	-0.42	29.30	0.21	0.16	0.08
							010		31.82	0.24	0.30	0.11
							015	-1.16	32.15	0.24	0.31	0.05
							020	-1.64	32.17	0.31	0.20	0.09
							025	-1.64	32.22	0.33	0.34	0.06
5	21 Aug	70°36.2'	148°20.2'	2-4	22	5	000	-0.08	22.36	0.16	0.10	0.03
							003	-0.20	26.20	0.17	0.07	
							006	-0.84	31.31	1.30	0.05	0.27
							009	-1.52	32.06	0.70	0.24	0.27
							012	-1.45*	32.09	0.81	0.36	0.23

* Temperature based on only one thermometer
† Temperature value questionable

Table 8. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
							015	-1.52	32.10	0.49	0.91	0.21
							020	-1.53	32.08	1.05	0.68	0.24
6	22 Aug	70°55'	148°11'	∿ 5	40	5	000	0.56	9.46	0.33	0.02	
							005	-1.13*	28.38	0.38	0.10	0.04
							010	-1.42	29.80	0.27	0.07	0.04
							015	-1.39	30.12	0.36	0.04	0.07
							020	-0.17	31.05	0.34	0.08	0.12
							025	-0.64*	31.32	0.24	0.08	0.06
							030	-0.64	31.60	0.14	0.08	0.01
							035	-0.18*	31.87	0.29	0.30	0.07
7	23 Aug	70°05.9'	149°54'	0	24	8	000	0.56	24.90	0.15	0.08	
							005	0.49	25.16	0.16	0.08	0.03
							010	0.79	27.93	0.26	0.12	0.05
							015	3.46	29.97	0.57	0.20	0.08
							020	2.12	30.58	0.38	0.26	0.21
8	23 Aug	71°03.6'	150°52.9'	0	23	9	000	0.89	25.33	0.25	0.08	0.01
							005	0.92	25.65	0.23	0.07	0.03
							010	3.34	28.87	0.48	0.16	0.08
							015	3.60	29.69	0.54	0.20	0.13
							020	3.54	29.77	0.55	0.37	0.13
9	24 Aug	71°11.1'	151°51.3'	0	29	10	000	1.77	25.76	0.21	0.19	0.02
							005	1.84*	26.31	0.29	0.05	0.08
							010	1.73	28.73	0.29	0.22	0.05
							015	4.81	29.30	0.28	0.42	0.17
							020	3.51	29.93	0.27	0.40	0.05

Table 8. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
10	24 Aug	71°05'	152°51'	0	23	7	000	1.76	25.46	0.14	0.07	0.02
							005	2.22*	27.94	0.25	0.09	0.11
							010	2.68	30.24	0.96	0.27	0.23
							015	2.33	31.09	1.78	0.67	0.45
							020	2.38	31.13	1.69	0.72	0.60
11	24 Aug	71°19.8'	152°47.7'	0	55	10	000	1.96	26.02	0.25	0.08	
							005	1.75*	26.06	0.32	0.08	
							010	5.12	28.64	0.53	0.17	0.18
							015	4.91	29.23	0.32	0.08	0.09
							020	3.91	29.72	0.44	0.16	0.16
							030	2.12*	31.26	0.52	0.20	0.15
							040	2.07	31.34	0.47	0.21	0.17
							050	1.27*	31.52	0.33	0.18	0.13
12	24 Aug	71°21.6'	152°41.1'		99	10	000	2.88	26.11	0.29	0.08	0.02
							005	3.31*	26.83	0.41	0.12	0.04
							010	4.59	28.90	0.72	0.25	0.15
							015	5.74	29.19	1.03	0.29	0.09
							020	5.88	29.22	0.69	0.17	0.09
							030	5.44	29.65	0.23	0.12	0.05
							045	2.07	31.21	0.43	0.16	0.49
							060	0.72*	31.60	0.30	0.11	0.05
							075	-1.03	31.88	0.12	0.10	0.04
							090	-1.24	32.47	0.15	0.18	
13	26 Aug	71°33.5'	150°27.0'	2	1050	10	000	0.08	23.40	0.09	0.04	0.23
							005	0.21*	24.14	0.11	0.07	0.06
							010	0.30	27.54	0.22	0.05	0.05
							015	0.62	28.80	0.27	0.05	0.06

Table 8. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/oo	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
							020	0.87	30.61	0.22	0.05	0.02
							030	-0.45	31.13	0.26	0.08	0.07
							045	-1.01	31.72	0.14	0.09	0.04
							060	-1.43*	31.98	0.06	0.06	
							075	-1.20	32.16	0.04	0.08	0.03
							100	-1.16*	32.41	0.02	0.08	
							125	-1.30	32.67	0.03	0.09	
							150	-1.12	32.98	0.02	0.10	
							175	-0.96*	33.62	0.03	0.08	
							200	-0.30	34.09	0.01	0.03	
							1800	-0.36	34.52	0.02	0.03	
14	28 Aug	70°36'	147°38.7'	∿ 4	27	7	000	-0.69	21.29	0.23	0.10	0.02
							003	-0.79*	27.81	1.31	0.23	0.07
							006	-1.20	29.92	2.86	0.49	0.29
							009	-1.26	30.55			0.47
							012	-1.43	31.76	1.40	1.01	0.32
							015	-1.44	31.81	1.11	0.62	0.30
							018	-1.48	31.84	0.94	0.50	0.35
16	29 Aug	70°29'	147°23'	∿ 4	27	7	000	-0.33	21.11	0.18	0.09	
							003	-0.80*	26.37	0.65	0.16	
							006	-1.10	29.88	2.37	0.39	0.32
							009	-1.15	34.37	1.76	0.46	0.89
							012	-1.45	31.75	1.92	0.72	0.90
							015	-1.36	31.79	1.76	0.57	0.78
							018	-1.46*	31.79	2.86	1.11	0.72
							021	-1.49*	31.80	2.08	0.54	0.85

Table 8. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
17	30 Aug	70°21.9'	146°51.7'		21	7	000	-0.15	22.47	0.25	0.12	0.01
							003	-0.73	26.01	0.49	0.15	0.03
							006	-0.94	29.05	1.76	0.23	0.18
							009	-1.28*	30.60	1.51	0.32	0.39
							012	-1.38	31.45	3.12	0.59	0.88
							015	-0.99†	31.66	2.68	0.80	1.05
							018	-1.16*	31.63	3.45	0.98	1.02
18	31 Aug	70°34'	145°51.7'	1-2	20	5	000	0.44	23.65	0.24	0.13	0.01
							003	-0.20	27.13	0.29	0.18	0.03
							006	-0.63	29.37	0.36	0.19	0.10
							009	-0.99*	30.73	1.01	0.35	0.20
							012	-0.87†	31.74	4.03	1.04	1.93
							015	-1.37*	31.75	3.53	1.01	1.75
							018	-1.04†	31.75	4.42	1.30	1.63
19	1 Sep	70°12.7'	143°22.6'	0	25	11	000	2.63	26.28	0.16	0.05	
							003	-0.12	30.10	0.21	0.05	0.05
							006	-0.54	30.59	0.12	0.05	0.04
							009	-0.42*	31.06	0.28	0.20	0.16
							012	-0.90	31.62	0.08	0.44	0.50
							015	-0.41†	32.05	2.65	0.66	1.52
							018	-1.21	32.07	2.41	1.01	1.32
20	2 Sep	69°58.5'	142°15'	0	18	5	000	4.07	28.51	0.20	0.07	0.06
							003	1.97	30.09	0.16	0.44	0.04
							006	1.88†	31.00	0.53	0.12	0.44
							009	0.43	31.02	0.60	0.81	0.25
							012	0.32†	31.05	1.58	0.36	0.49
							015	0.28	31.08	2.03	0.84	0.90

Table 8. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
21	3 Sep	70°57.8'	142°20.8'	0	2560		000	-1.38	27.69	0.19	0.05	0.03
							005	-1.29	30.27	0.14	0.05	0.07
							010	-1.19	30.26	0.21	0.11	0.03
							015	-1.12	30.88	0.17	0.14	0.09
							020	-1.28	31.12	0.18	0.14	0.05
							025	-1.33	31.32	0.20	0.21	
							030	-1.33	31.59	0.26	0.14	0.11
							045	-1.53	31.83	0.25	0.23	0.11
							2400	-0.39	35.01			
22	5 Sep	69°45'	141°17.5'	0	18	10	000	3.44	29.42	0.20	0.08	
							003	2.12	30.96	0.22	0.08	0.07
							006	1.79	31.30	0.21	0.08	
							009	0.93	31.79	0.29	0.08	0.11
							012	0.12	31.85	0.55	0.06	0.15
							015	0.10*	31.85	0.47	0.08	0.28
23	6 Sep	70°28.0'	143°33.0'	0	42		000	4.36	25.60	0.12	0.06	0.01
							005	3.34	28.03	0.18	0.07	
							010	0.13	30.22	0.12	0.07	0.03
							015	-1.03	31.41	0.08	0.03	0.02
							020	-1.28*	31.87	0.14	0.05	0.12
							025	-1.24*	32.26	0.11	0.14	
							030	-1.45*	32.32	0.21	0.14	0.07
							035	-1.61	32.34	0.27	0.15	0.14
24	6 Sep	70°28.6'	143°42.3'	0	62	15	000	4.18	26.25	0.13	0.09	0.05
							005	3.02	30.33	0.18	0.05	0.10
							010	1.75*	31.08	0.16	0.05	0.01
							015	-1.11	31.34	0.13	0.05	0.02

Table 8. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/°°	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
							020	-1.26	31.52	0.15	0.06	0.01
							030	-1.48*	31.81	0.23	0.13	0.16
							045	-1.56	32.11	0.12	0.15	0.06
							055	-1.33	32.42	0.10	0.21	0.04
25	7 Sep	70°15.1'	143°40.0'		31		000	2.93	27.35	0.09	0.06	0.02
							003	2.18*	27.94	0.12	0.05	0.03
							006	-0.18	30.43	0.21	0.16	0.11
							009	-0.54	31.27	0.37	0.16	0.11
							012	-1.14	31.85	0.26	0.07	0.17
							015	-1.43	32.21	3.78	0.66	1.63
							020	-1.47*	32.23	5.46	0.23	2.18
							025	-1.51	32.23	4.16	1.11	2.16
26	8 Sep	70°07.7'	144°48.4'	0	18		000	2.33	25.13	0.28	0.07	0.02
							003	1.13	26.36	0.16	0.07	0.07
							006	0.23	28.09	0.18	0.10	0.06
							009	-0.37	30.32	0.10	0.07	
							012	-1.24	31.63	0.53	0.53	0.17
							015	-1.33*	31.82	0.92	0.92	0.28
27	8 Sep	70°17.8'	146°30.8'	∿ 6	22	8	000	-1.01	26.08	0.21	0.08	0.07
							003	-0.97	27.40	0.24	0.12	0.04
							006	-0.92	28.93	0.34	0.11	0.10
							009	-1.12	30.03	0.47	0.08	0.22
							012	-1.27	30.39	0.56	0.08	0.29
							015	-1.38	31.28	3.90	0.72	1.49
							018	-1.40*	31.32	6.11	1.64	2.56
28	9 Sep	70°28.0'	147°25.7'	2	24	8	000	-0.24	15.93	0.43	0.09	0.07

Table 8. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/∘∘	Chl a (mg m^{-3})	Phaeo	Prim Prod (mg C m^{-3} hr^{-1})
							003	-0.77*	25.60	0.22	0.08	0.09
							006	-1.01	28.30	0.42	0.06	0.10
							009	-1.06	29.44			0.21
							012	-0.74*	29.84	0.69	0.03	0.30
							015	-0.65*	30.37	1.01	0.18	0.35
							018	-1.16	30.82	2.55	0.63	1.04
							021	-1.09*	30.85	3.35	0.72	1.50
29	9 Sep	71°01'	147°56.6'	2-3	53	10	000	-0.05	24.40	0.22	0.06	0.01
							005	0.21	27.28	0.49	0.16	0.12
							010	4.88	29.16	0.54	0.16	0.04
							015	4.86	29.80	0.94	0.27	0.34
							020	4.22	30.19	0.31	0.75	0.60
							025	4.48	30.58	0.74	0.20	0.31
							030	2.63	30.83	0.70	0.17	0.30
							045	0.42*	31.54	0.25	0.10	2.93
30	10 Sep	70°44.9'	148°34'	2-3	25		000	0.12	10.35	0.31	0.07	0.08
							003	-0.89	25.92	0.25	0.08	0.11
							006	-0.98	28.33	0.38	0.11	0.13
							009	-1.17	29.65	0.65	0.09	0.19
							012	-0.91*	29.93	0.75	0.22	0.28
							015	1.89*	31.16	0.82	0.20	0.32
							018	1.28*	31.39	1.27	0.37	0.62
							021	1.11*	31.39	2.34	0.27	1.08
31	11 Sep	70°35.5'	148°00.0'	3-4	22	10	000	-0.49	16.94	0.33	0.07	0.06
							003	-0.68*	27.98	0.46	0.11	0.16
							006	0.02	30.35	0.64	0.14	0.26
							009	0.07	30.58	0.31	0.92	0.46

Table 8. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/°°	Chl a (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
							012	-0.41	31.20	2.10	0.51	0.76
							015	-0.27*	31.42			1.09
							018	-0.84	31.49	2.28	0.59	1.04
32	12 Sep	70°46.6'	149°30.4'	6-7	22	5	000	-0.55	10.48	0.53	0.14	0.08
							003	-0.82	28.54	0.44	0.16	0.15
							006	-0.82	29.61	0.37	0.08	0.10
							009	-0.56	30.31	0.70	0.14	0.24
							012	0.45†	31.00	1.30	0.30	0.66
							015	0.26†	31.10	1.76	0.43	0.79
							018	0.79†	31.10	1.68	0.62	0.98
33	13 Sep	71°12.6'	149°38.4'	0-1	67	7	000	1.44	27.26	0.47	0.13	0.03
							005	1.43*	27.26	0.47	0.11	0.08
							010	1.54	27.35	0.46	0.13	0.09
							015	1.72	27.50	0.47	0.09	0.08
							020	2.59†	30.48	0.51	0.59	0.24
							030	1.68*	31.61	0.21	0.19	0.07
							045	1.27*	31.47	0.13	0.18	0.07
							060	1.08*	31.64	0.14	0.20	0.11
34	13 Sep	70°52'	150°16'	< 1	27	8	000	-0.63	25.66	0.40	0.15	0.09
							003	-0.59	26.17	0.43	0.16	0.15
							006	-0.17	28.58	0.47	0.18	0.16
							009	0.41	29.60	0.70	0.10	0.18
							012	2.29†	30.51	0.88	0.31	0.36
							017	1.66†	30.53	1.17	0.34	0.32
							022	1.66†	30.53			0.68

Table 8. (cont.)

Sta	Date (GMT)	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Sonic Depth (m)	Secchi Depth (m)	Sample Depth (m)	Temp (°C)	S°/oo	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
35	14 Sep	71°01'	150°25'	1-2	22	7	000	-0.98	26.57	0.33	0.17	0.09
							003	-0.92*	27.35	0.39	0.14	0.10
							006	-0.95*	27.39	0.44	0.13	0.15
							009	-0.53	28.11	0.59	0.26	0.15
							012	2.37	29.98			0.44
							015	3.62*	30.17	0.89	0.34	0.40
							018	3.59	30.18	0.98	0.34	0.49
							021	3.58*	30.17	0.95	0.45	0.48

phyll *a*-primary productivity or phytoplankton cells per liter are given in Figs. 8-12.

In 1973, warm water was present throughout the water column at stations 42-44 taken near 155°W and at the surface at stations 16-20, 25, 26, and 28 located from 146°-149°10'W. Negative temperatures occurred at nearly all other stations and depths.

In 1974, only three stations west of 152°30'W had warm water layers. Stations 76 and 78, located near 71°30'N, had positive temperatures ranging from 1.74-3.66°C. At station 77, located at 71°56'N, the upper 15 m had positive temperatures. Only surface temperatures were positive at a few other stations.

In 1976, a warm water layer, probably from the Bering Sea, was present at 5-15 m at stations 13, 23, 24, 26, and 27, extending from 71°19'-71°36'N and east to 152°20'. The temperature of this layer ranged from 1.91-3.18°C.

Higher temperatures occurred at many stations in 1977, but with no consistent pattern. The warm water seen at stations 9, 10, and 11 extending from 20-60 m deep was perhaps Bering Sea water. The most striking hydrographic feature was seen at stations 39 and 40 where the temperature was near 8.5°C throughout the water column. These stations were taken because of the number of birds observed to be feeding in the area.

Stations 1, 3, 7-12, and 29, taken in 1978, had water warmer than 2°C at depths ranging from 0-45 m. The temperature ranged from 2.07-5.88°C, with the highest and lowest temperatures at station 12. Stations 34 and 35 also had warmer water from 12 m to the bottom, which was about 25 m. Station 29 was farthest east at 147°56'W. The eastern most stations, 19, 20, 22-26, had a relatively warm surface layer *ca.* 3-5 m thick. These stations were also ice-free.

B. Plankton

1. Zooplankton

Examination of acoustic records from 1976 and 1977 indicated that no layers of acoustic targets were present.

Zooplankton has been identified from 120 samples collected with six types of nets during four cruises in the Beaufort Sea. Eighty-seven (87) species and 74 other categories have been identified, including life history stages and categories where identification was made to some taxonomic rank higher than species (Table 9). Major taxa are presented systematically with genera listed in alphabetical order. Distribution charts are given in Appendix I for major taxa (Figs. I-1 - I-53).

Phylum Coelenterata - Hydrozoa

Names of organisms in this section follow Kramp (1961). Species were previously reported following Naumov (1960). A list of previously and

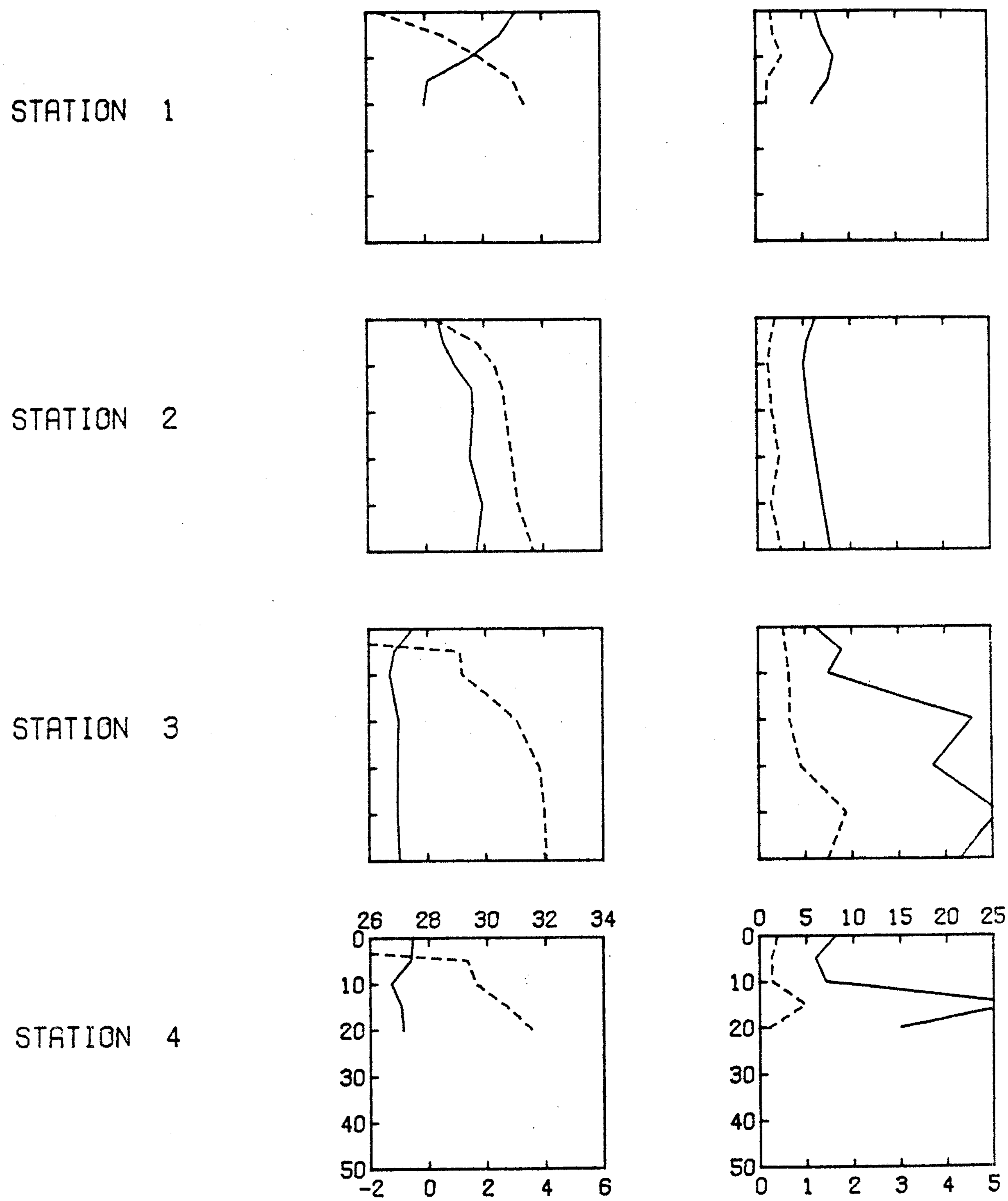


Fig. 8. Dpeth profiles of temperature-salinity and chlorophyll *a*-phytoplankton cells per liter in the Beaufort Sea, 28 Jul - 12 Aug 1973. Salinity (°/₀₀) ---; temperature (°C) ——; cells per liter ---; chlorophyll *a* (mg m^{-3}) ——;

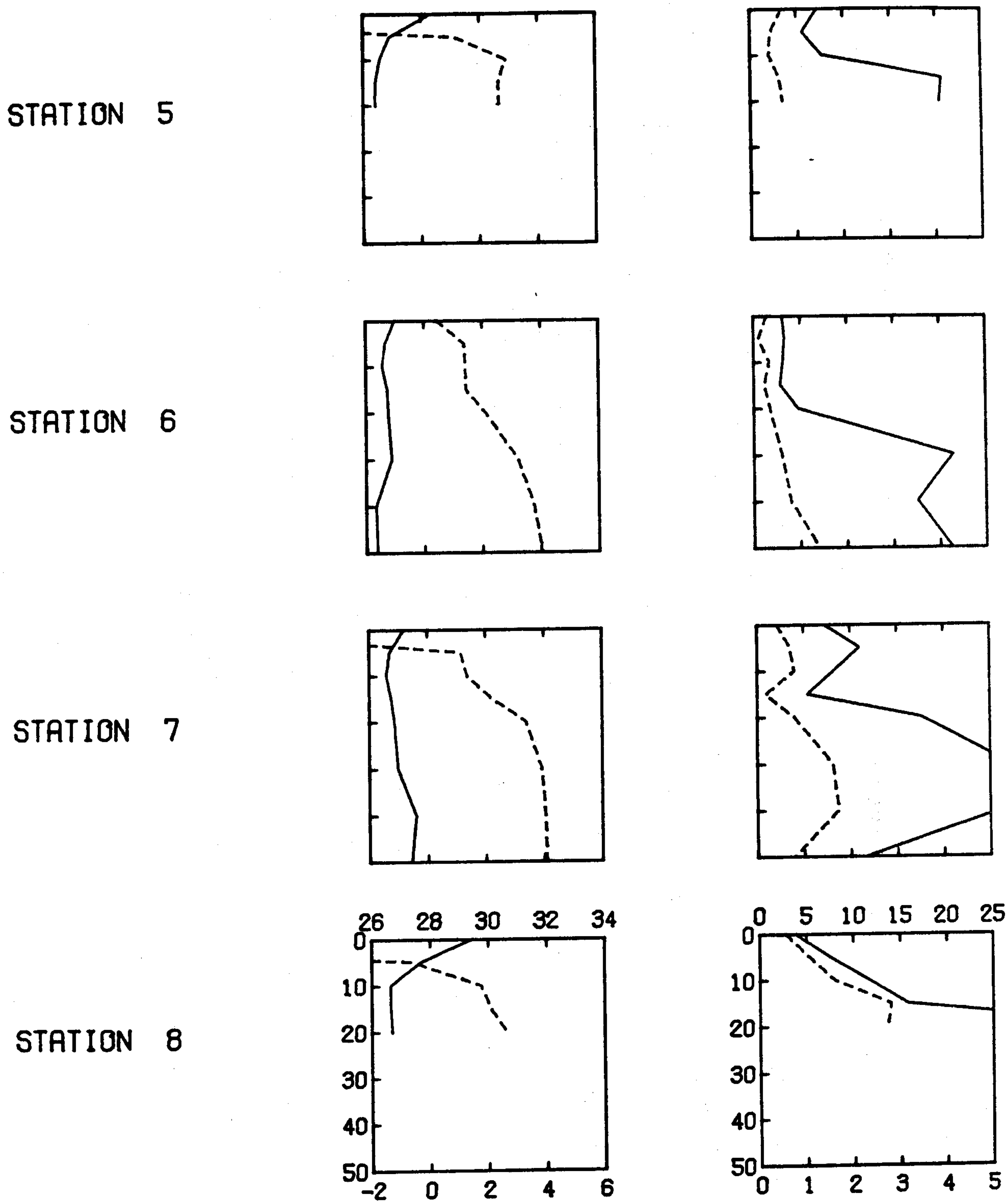


Fig. 8. (continued)

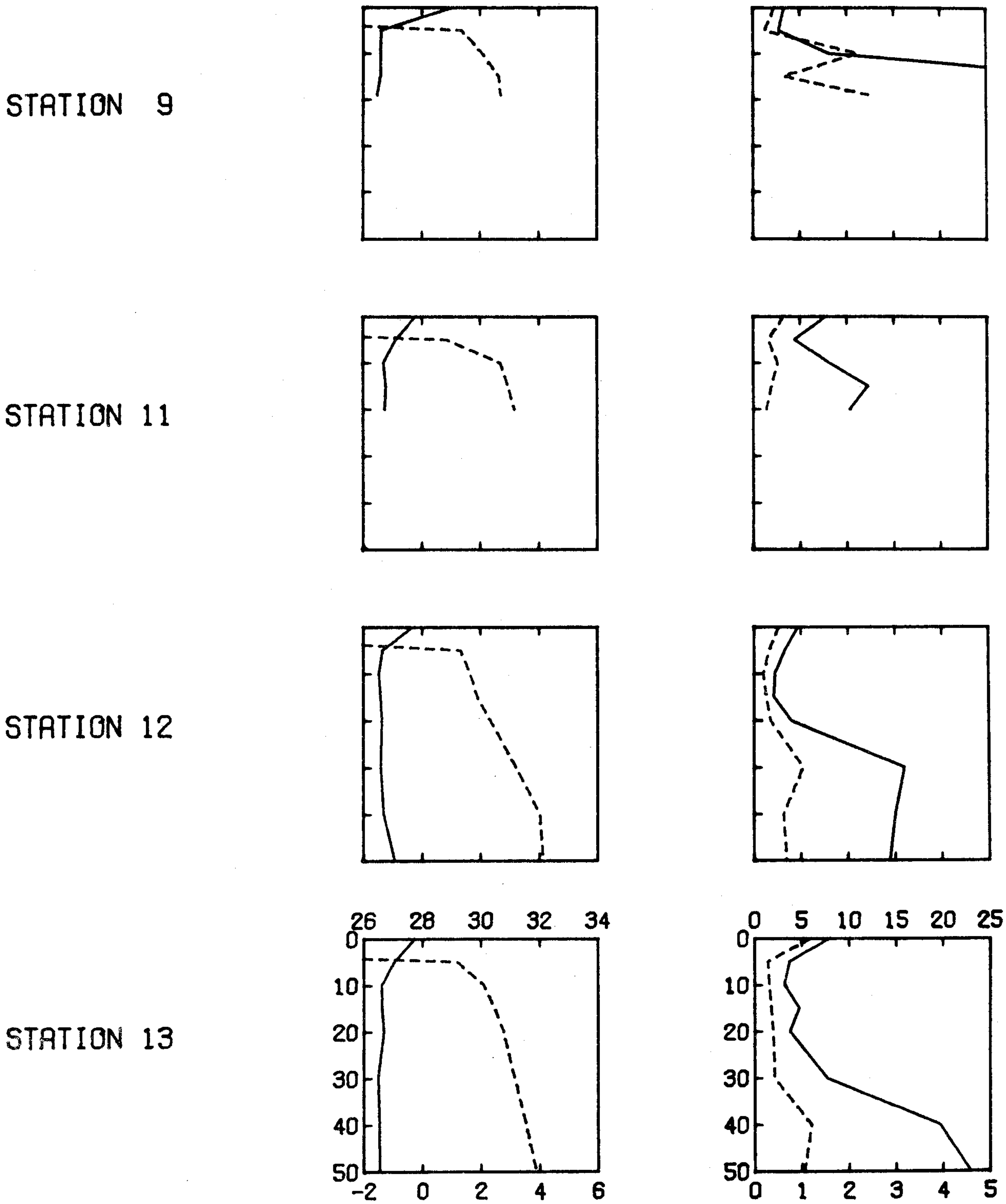


Fig. 8. (continued)

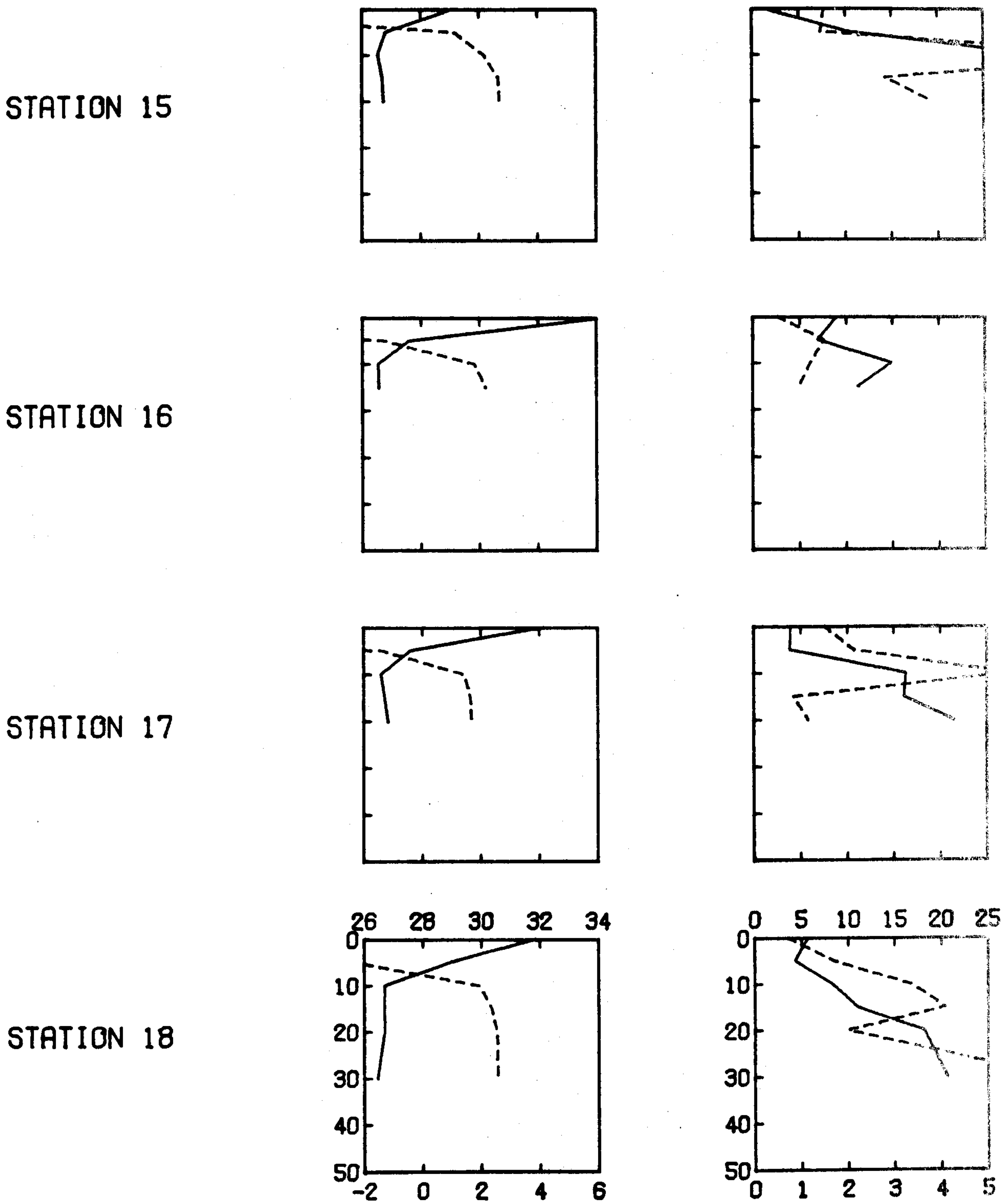


Fig. 8. (continued)

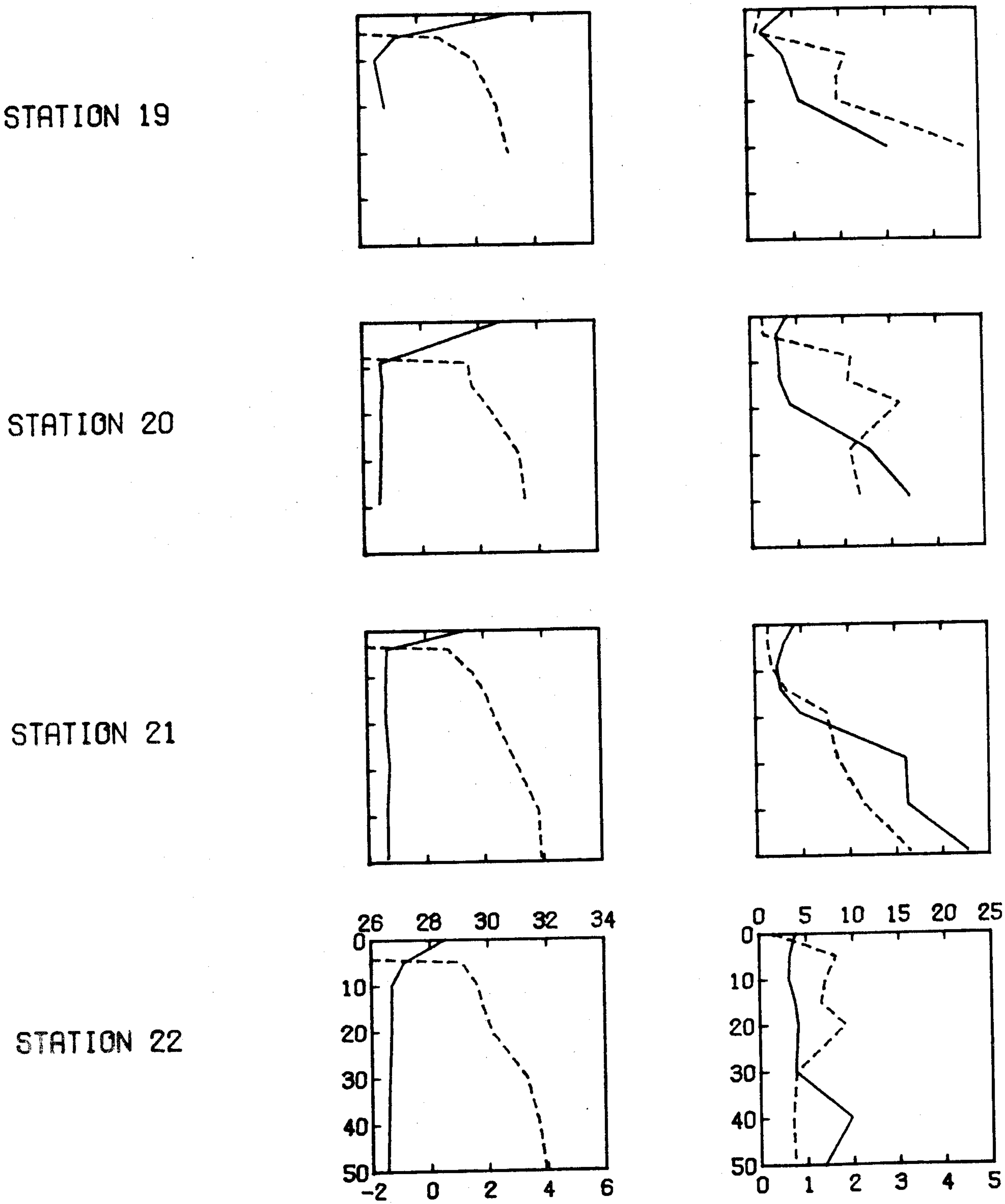


Fig. 8. (continued)

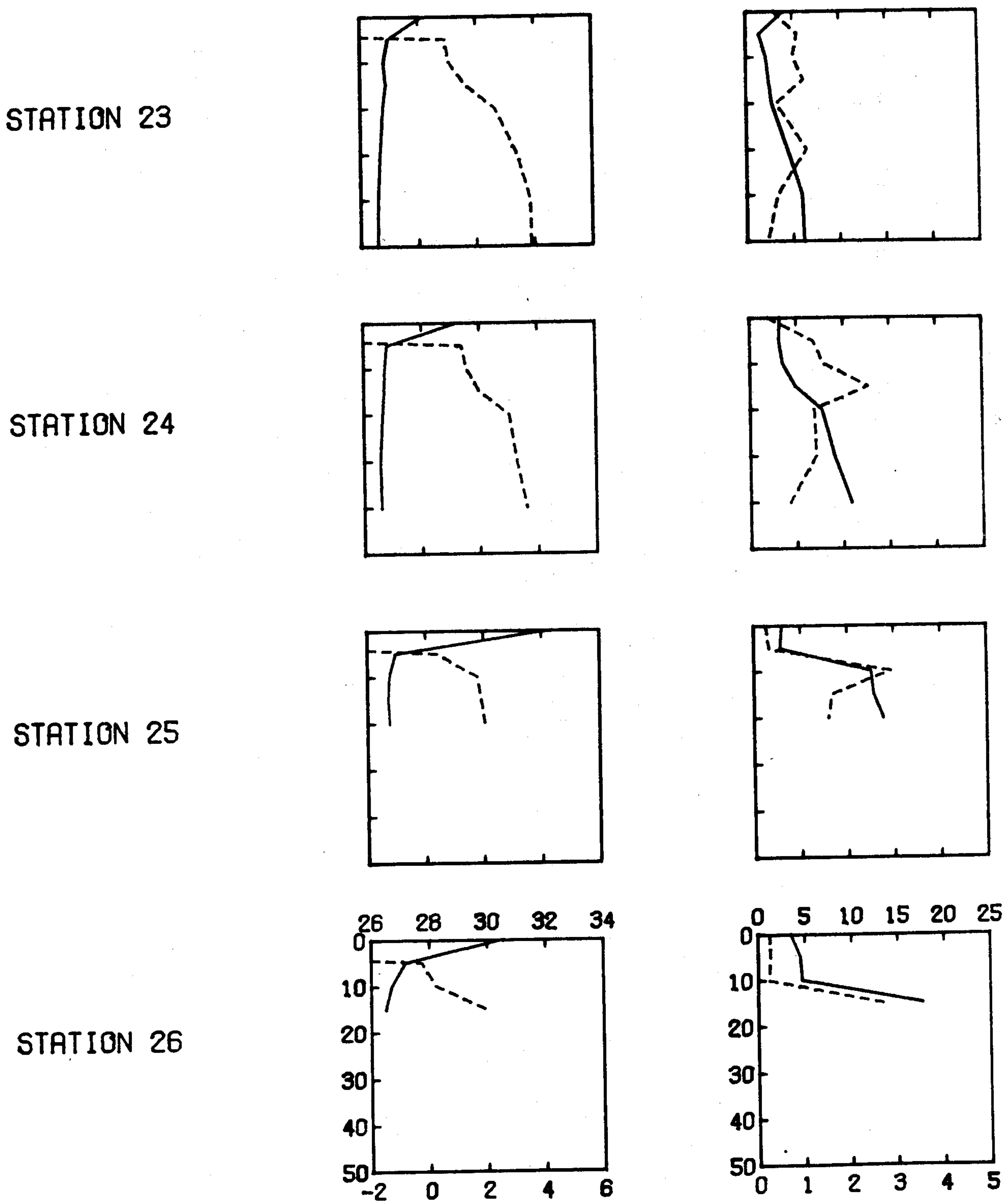


Fig. 8. (continued)

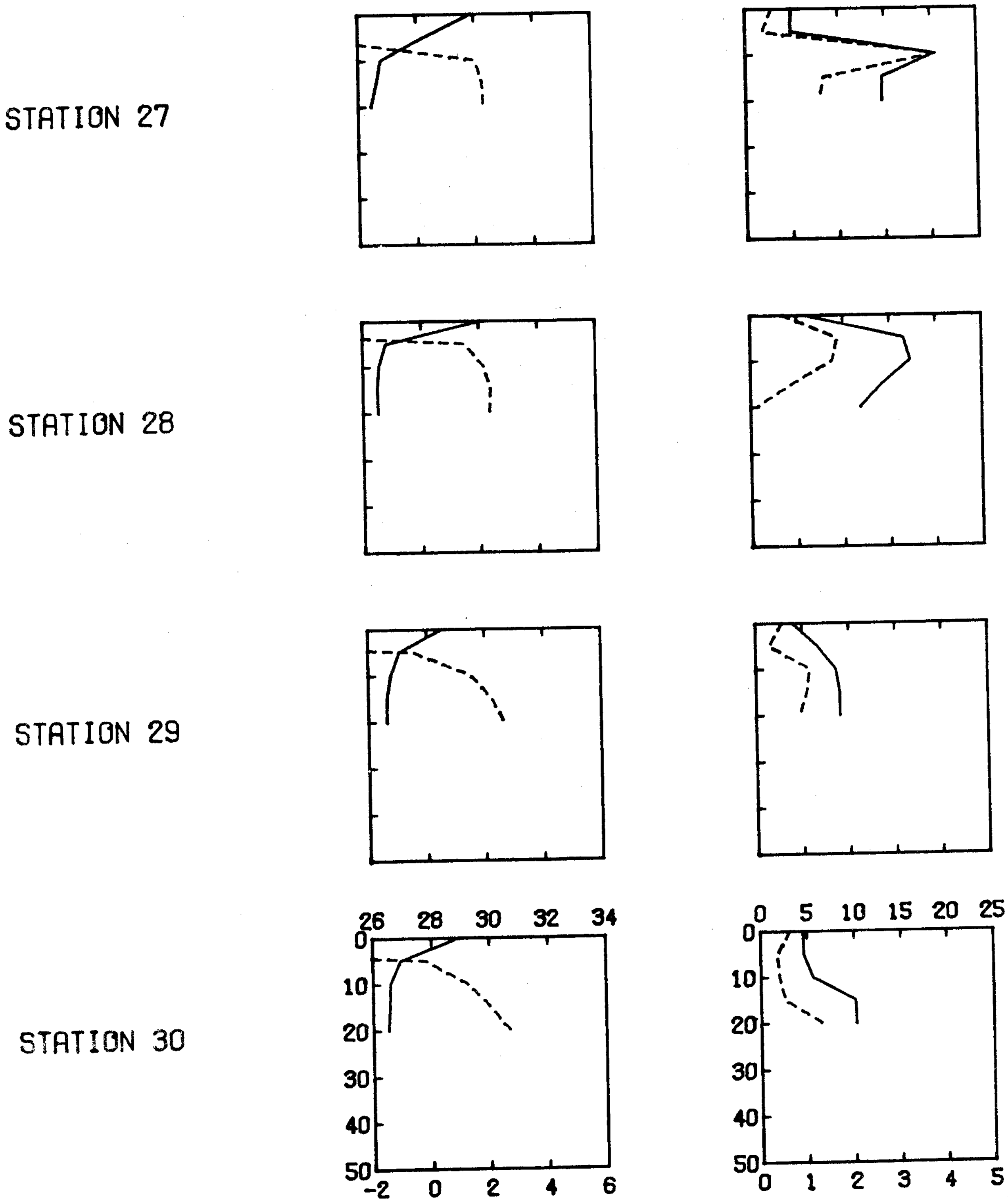


Fig. 8. (continued)

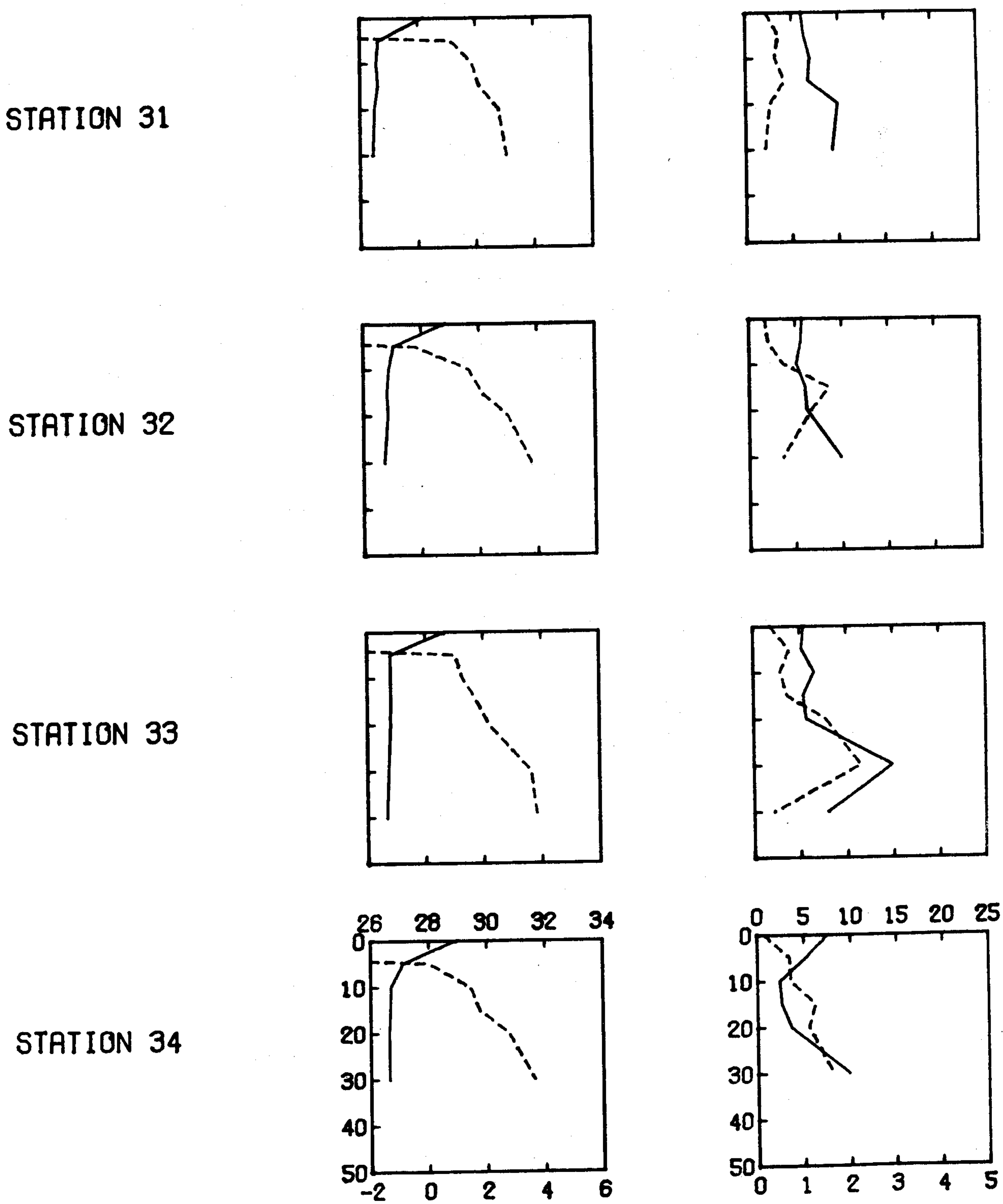


Fig. 8. (continued)

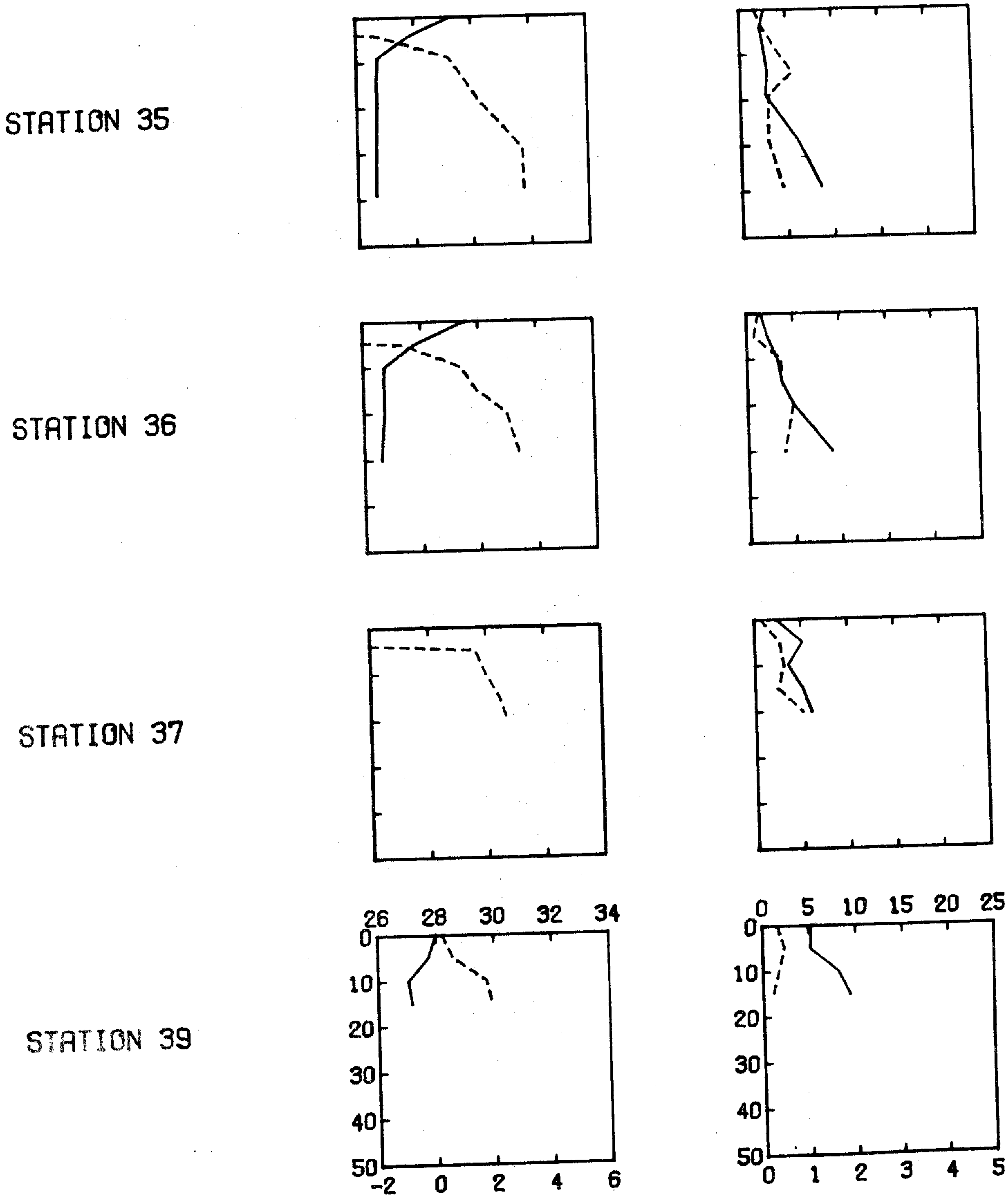
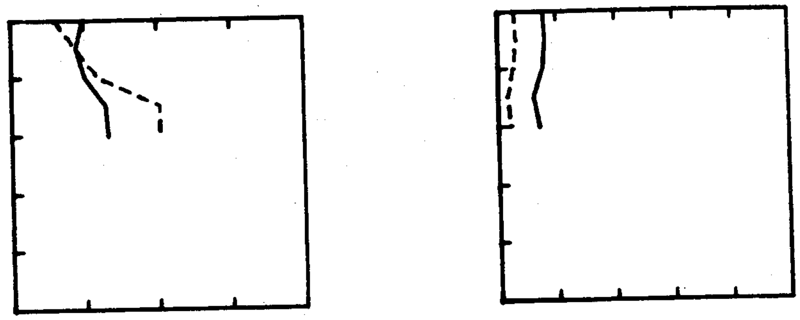
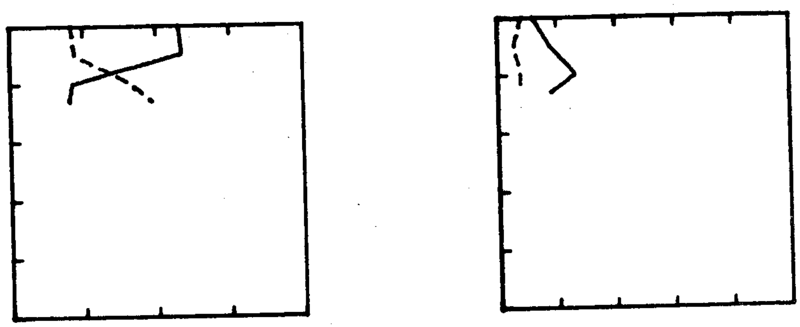


Fig. 8. (continued)

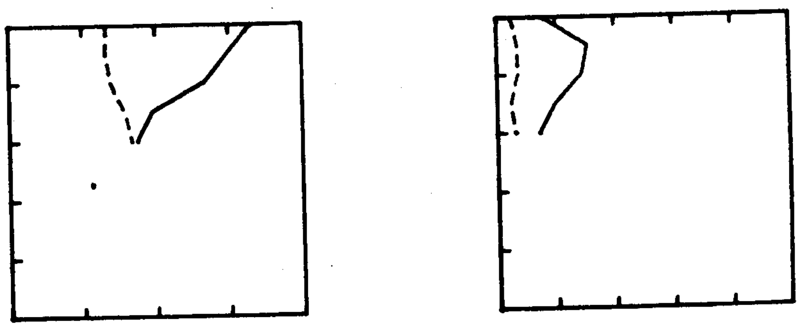
STATION 40



STATION 41



STATION 42



STATION 43

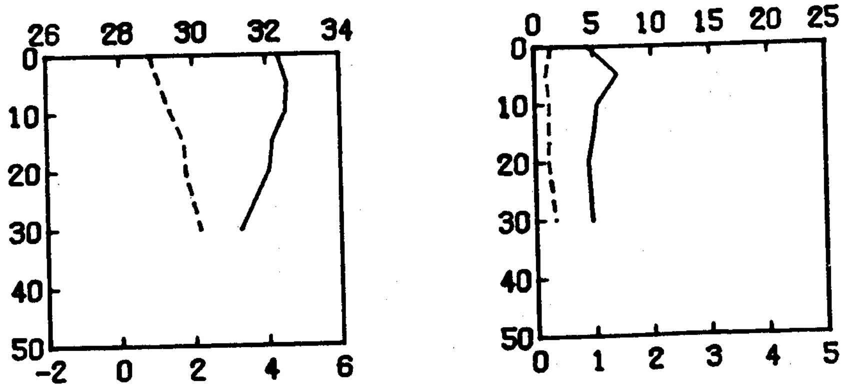


Fig. 8. (continued)

STATION 44

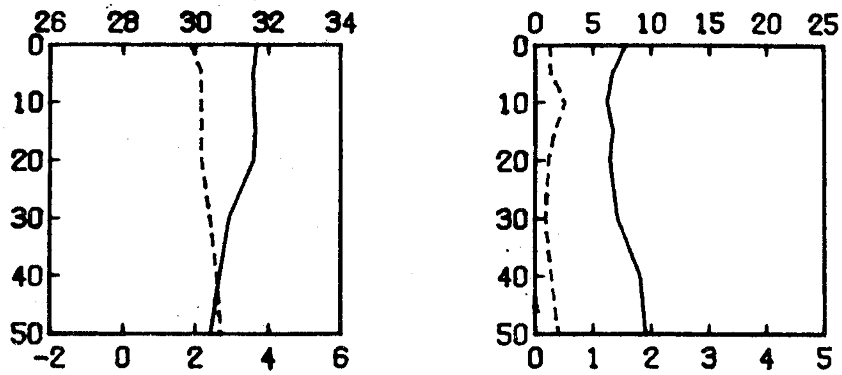


Fig. 8. (continued)

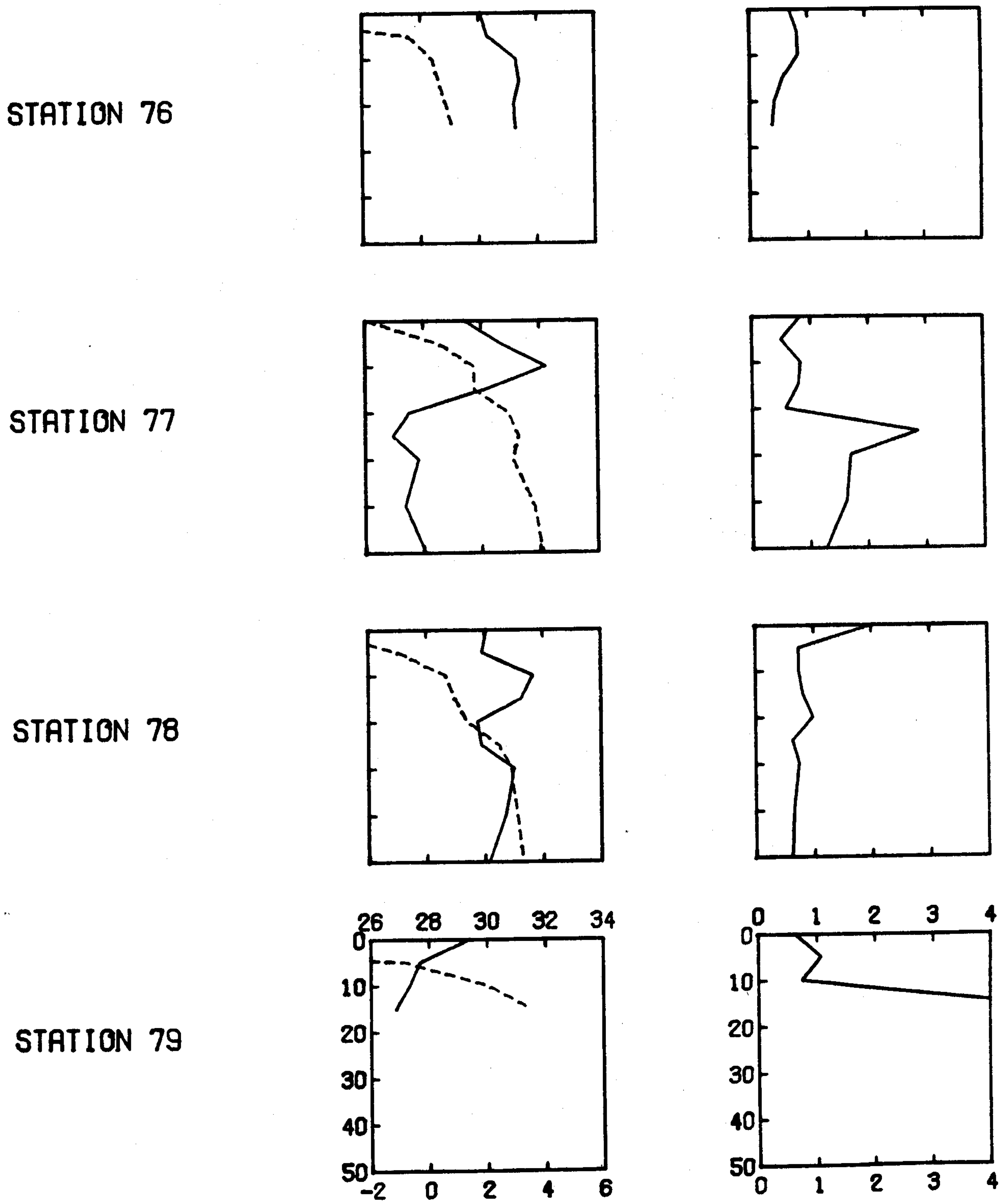


Fig. 9. Depth profiles of temperature-salinity and chlorophyll *a* concentrations in the Beaufort Sea, 19 Aug - 5 Sep 1974. Salinity (°/₀₀) ---; temperature (°C) ——; chlorophyll *a* (mg m^{-3}) ---.

STATION 80

STATION 81

STATION 82

STATION 83

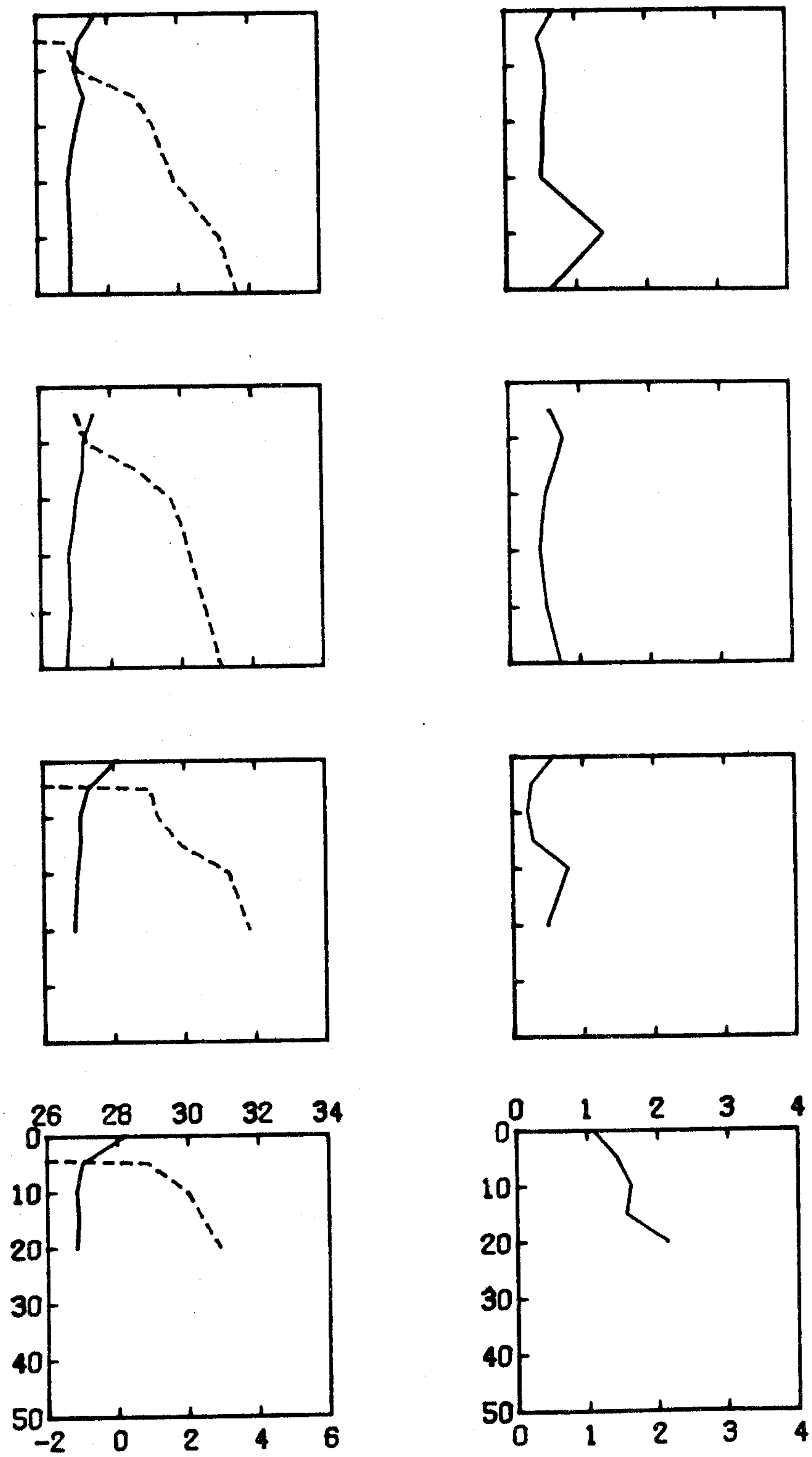


Fig. 9. (continued)

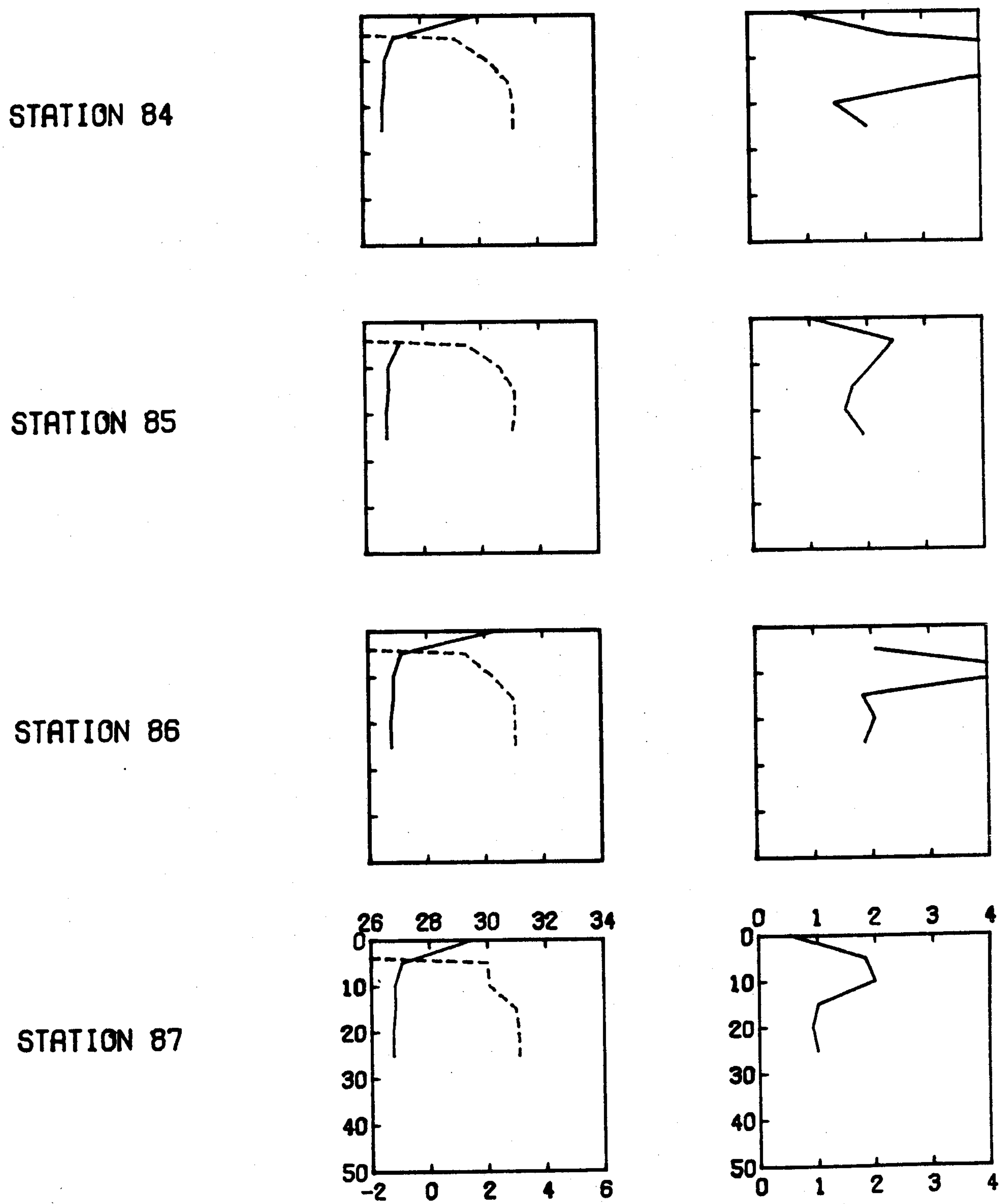


Fig. 9. (continued)

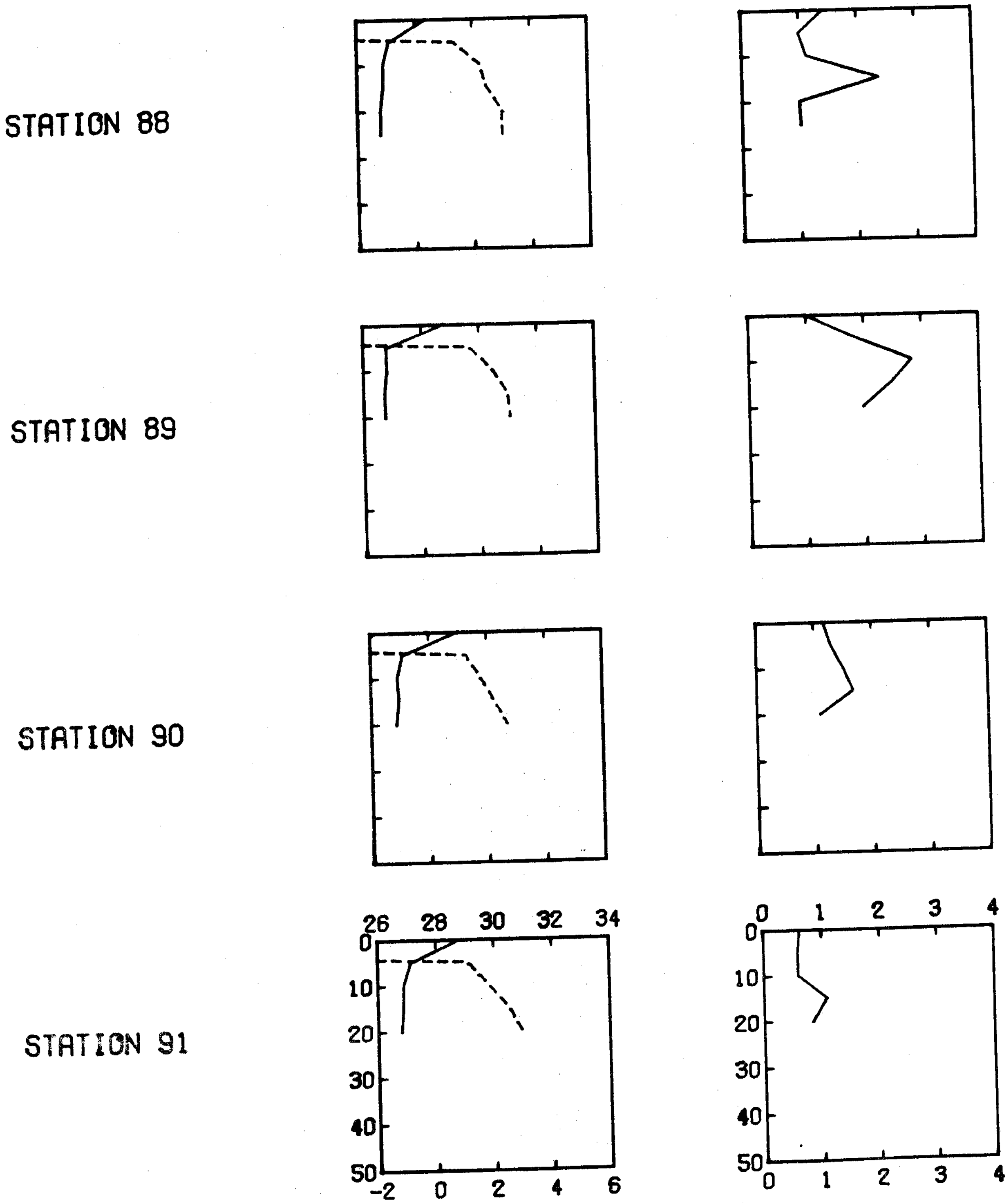


Fig. 9. (continued)

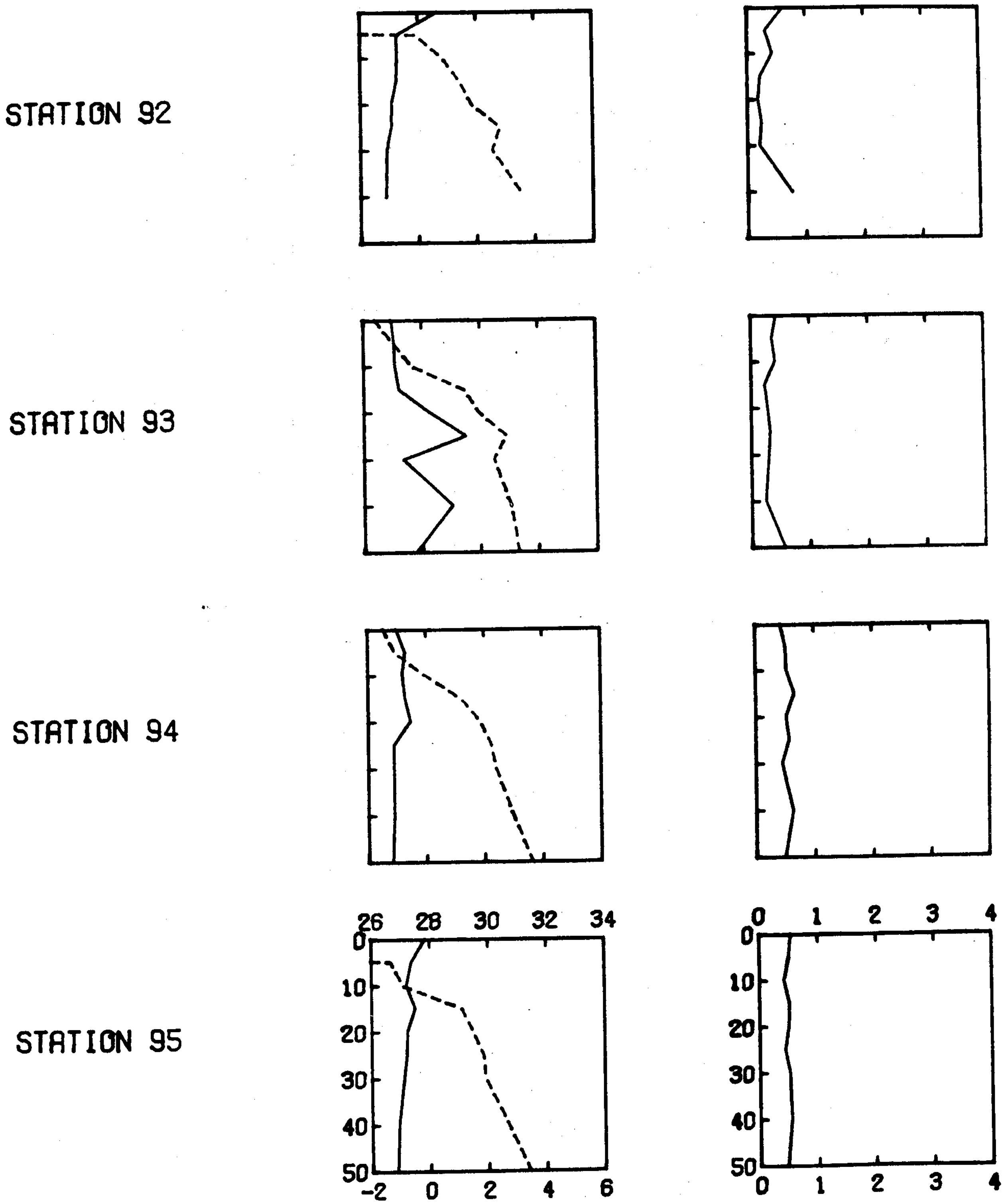


Fig. 9. (continued)

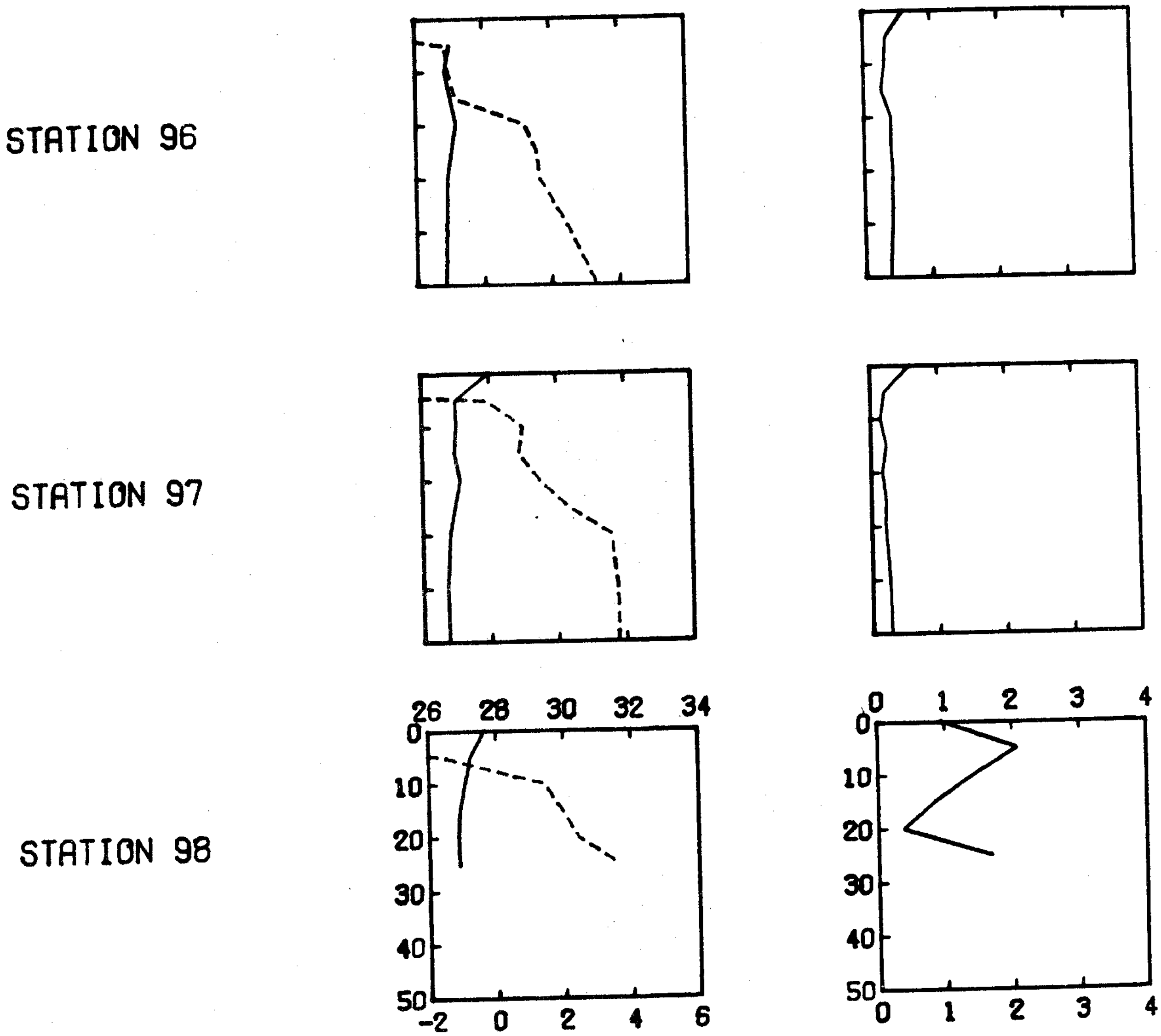
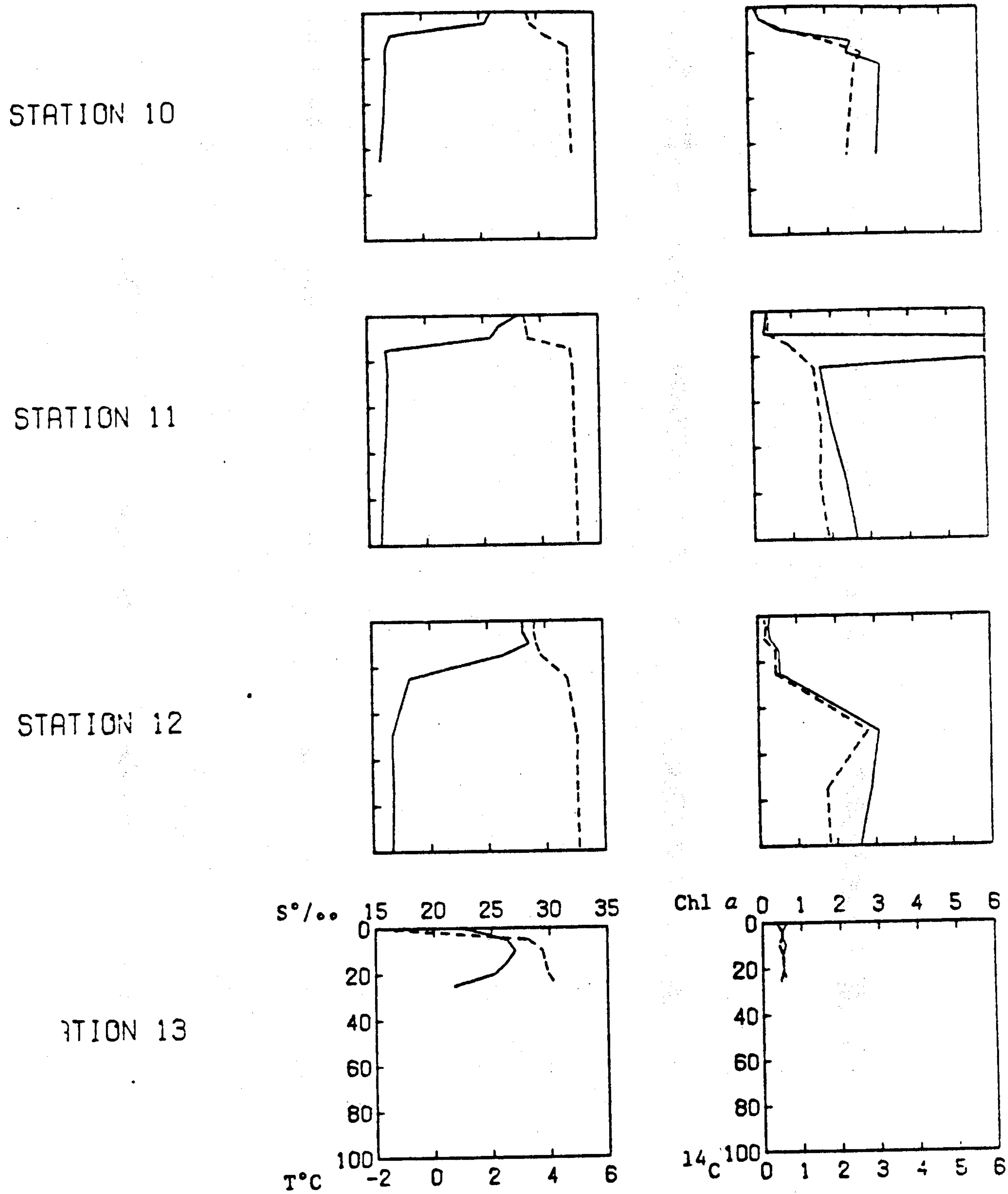


Fig. 9. (continued)



ig. 10. Depth profiles of temperature-salinity and chlorophyll a-^{14}C :ation in the Beaufort Sea, 17 Aug - 2 Sep 1976. Salinity (°/°°) ----; ture (°C) ——; ^{14}C assimilation (mg C m^{-3} hr^{-1}) ----; chlorophyll a ' ——.

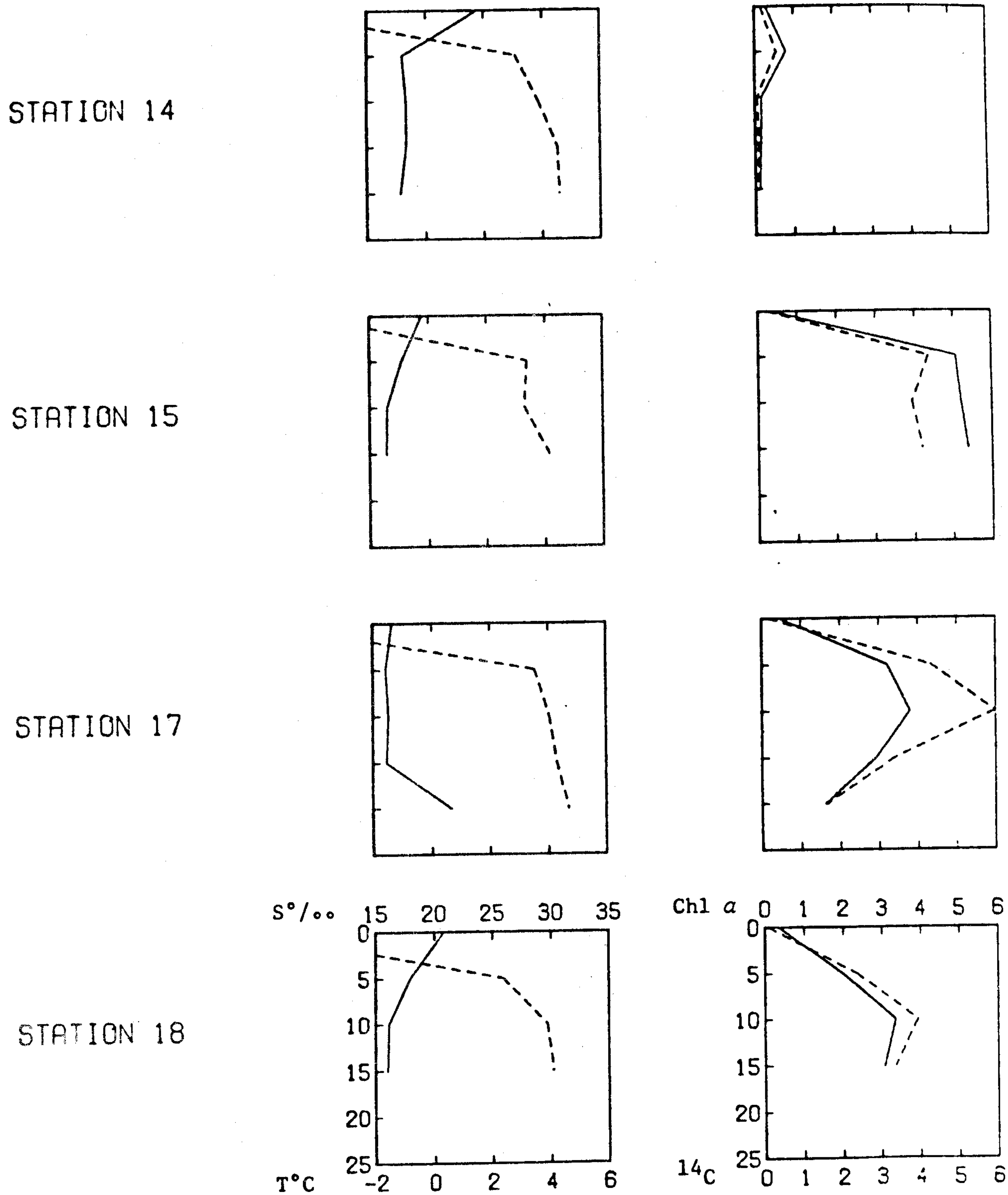


Fig. 10. (continued)

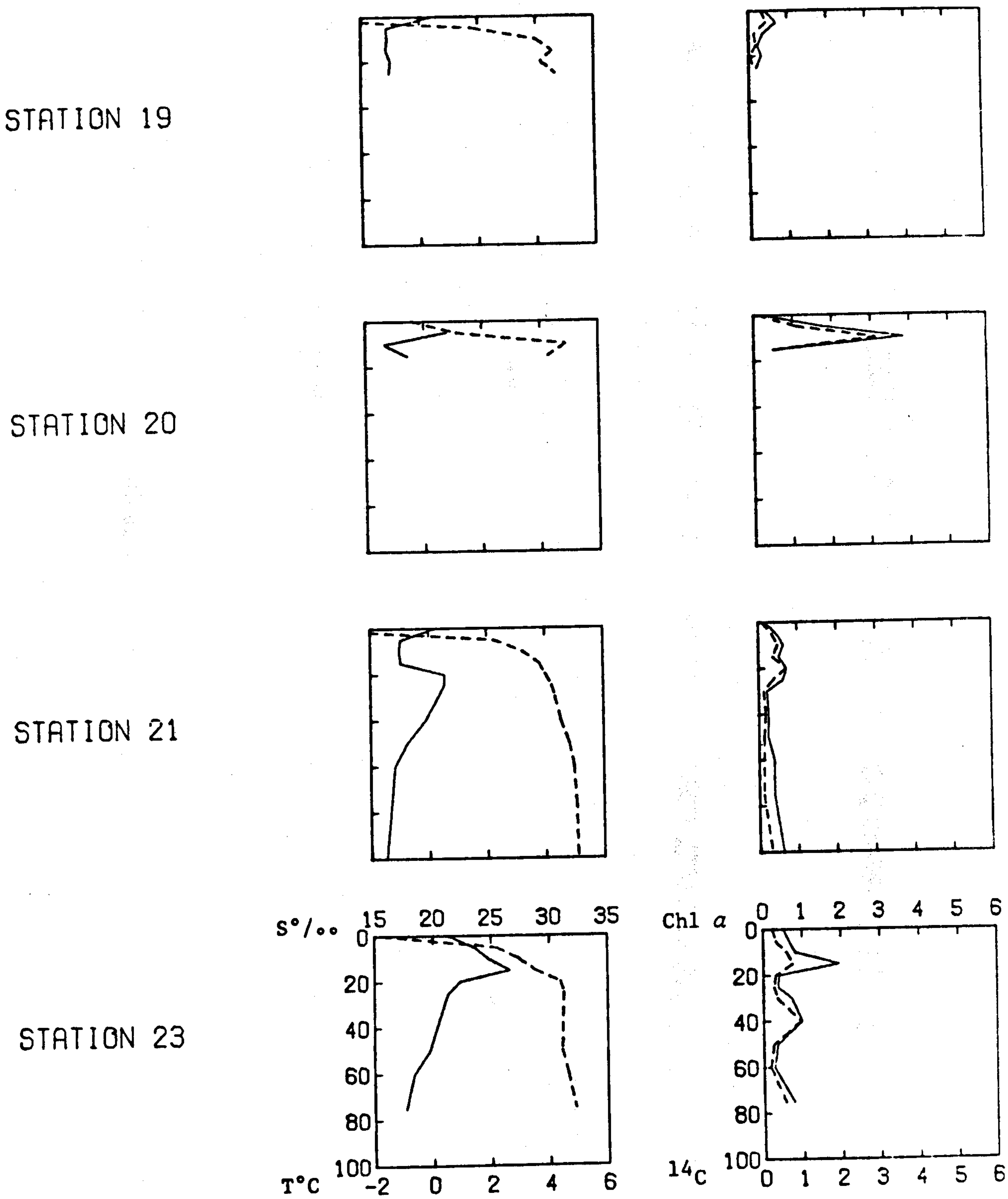


Fig. 10. (continued)

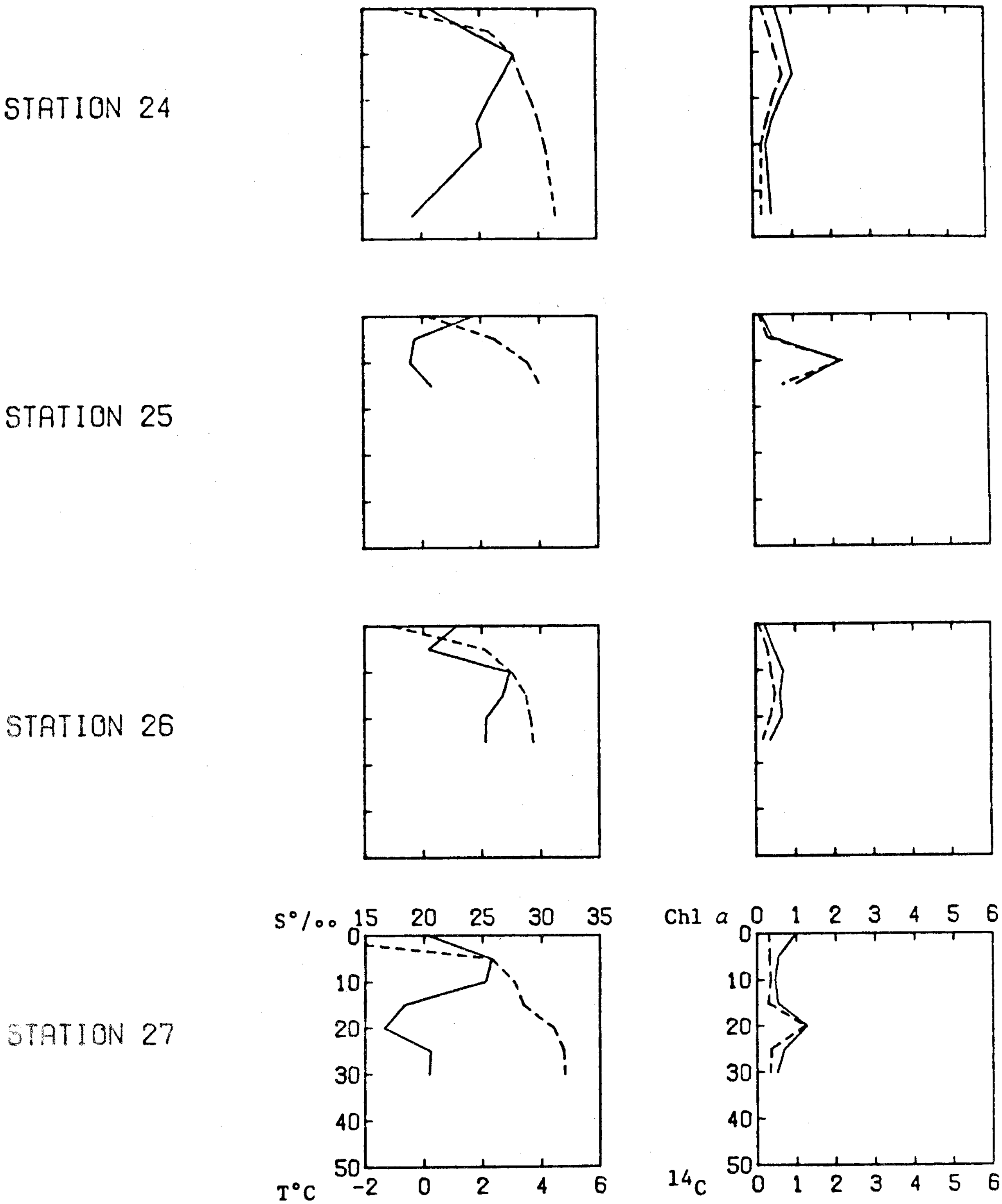


Fig. 10. (continued)

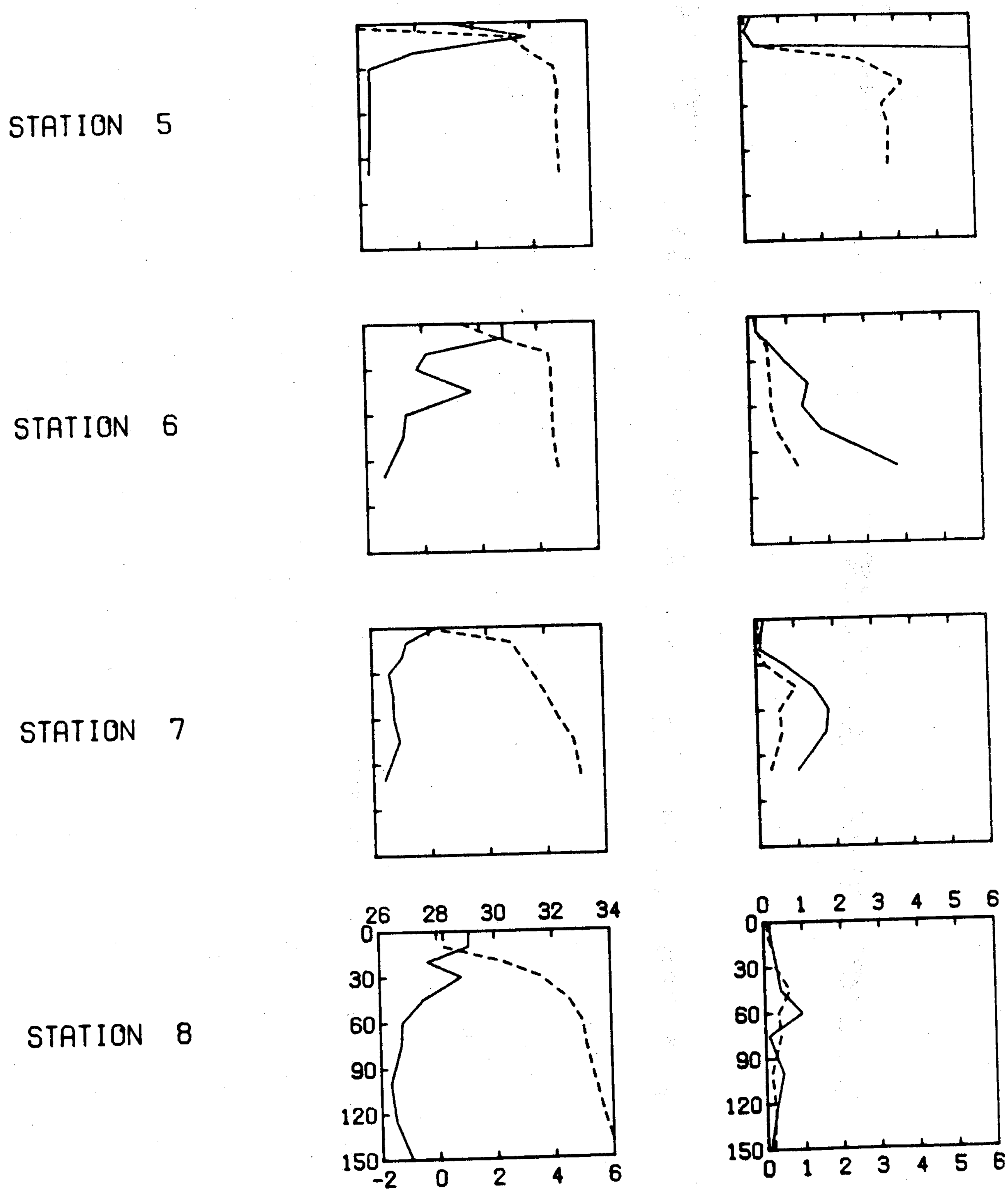


Fig. 11. Depth profiles of temperature-salinity and chlorophyll a-^{14}C assimilation in the Beaufort Sea, 7 Aug - 5 Sep 1977. Salinity (°/₀₀) ---; temperature (°C) ——; ^{14}C assimilation (mg C m^{-3} hr^{-1}) ---; chlorophyll a (mg m^{-3}) ——.

STATION 9

STATION 10

STATION 11

STATION 12

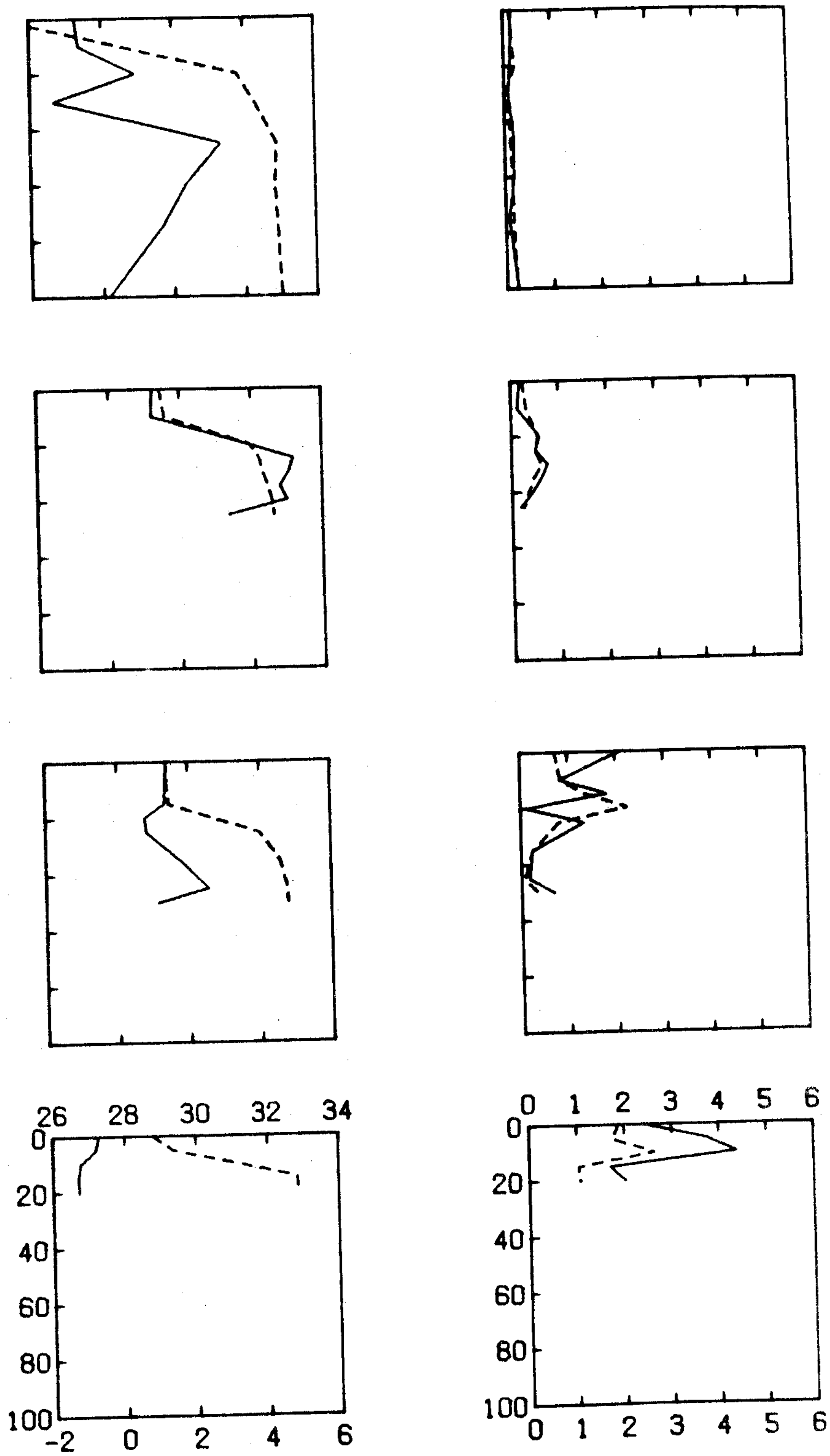


Fig. 11. (continued)

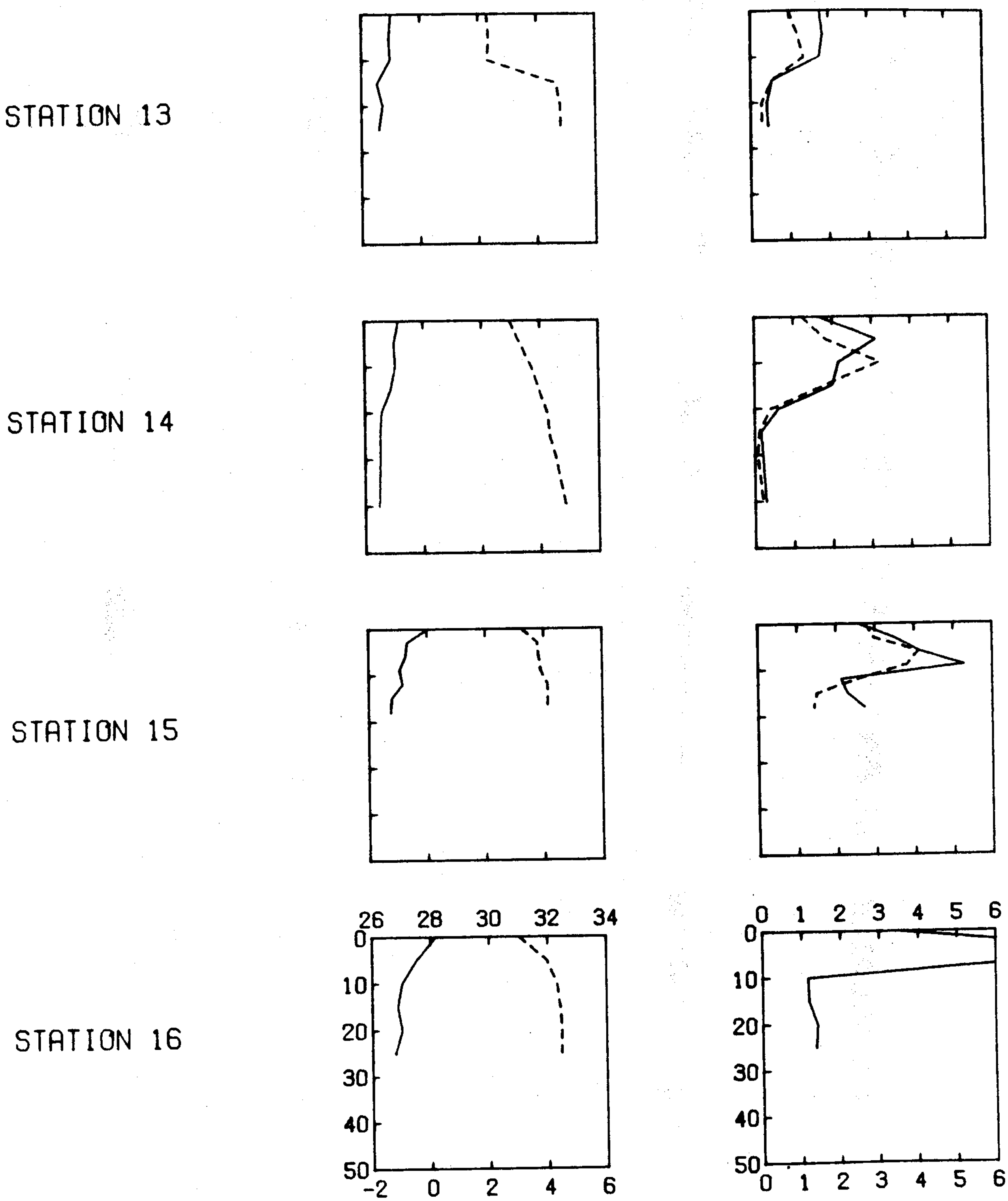


Fig. 11. (continued)

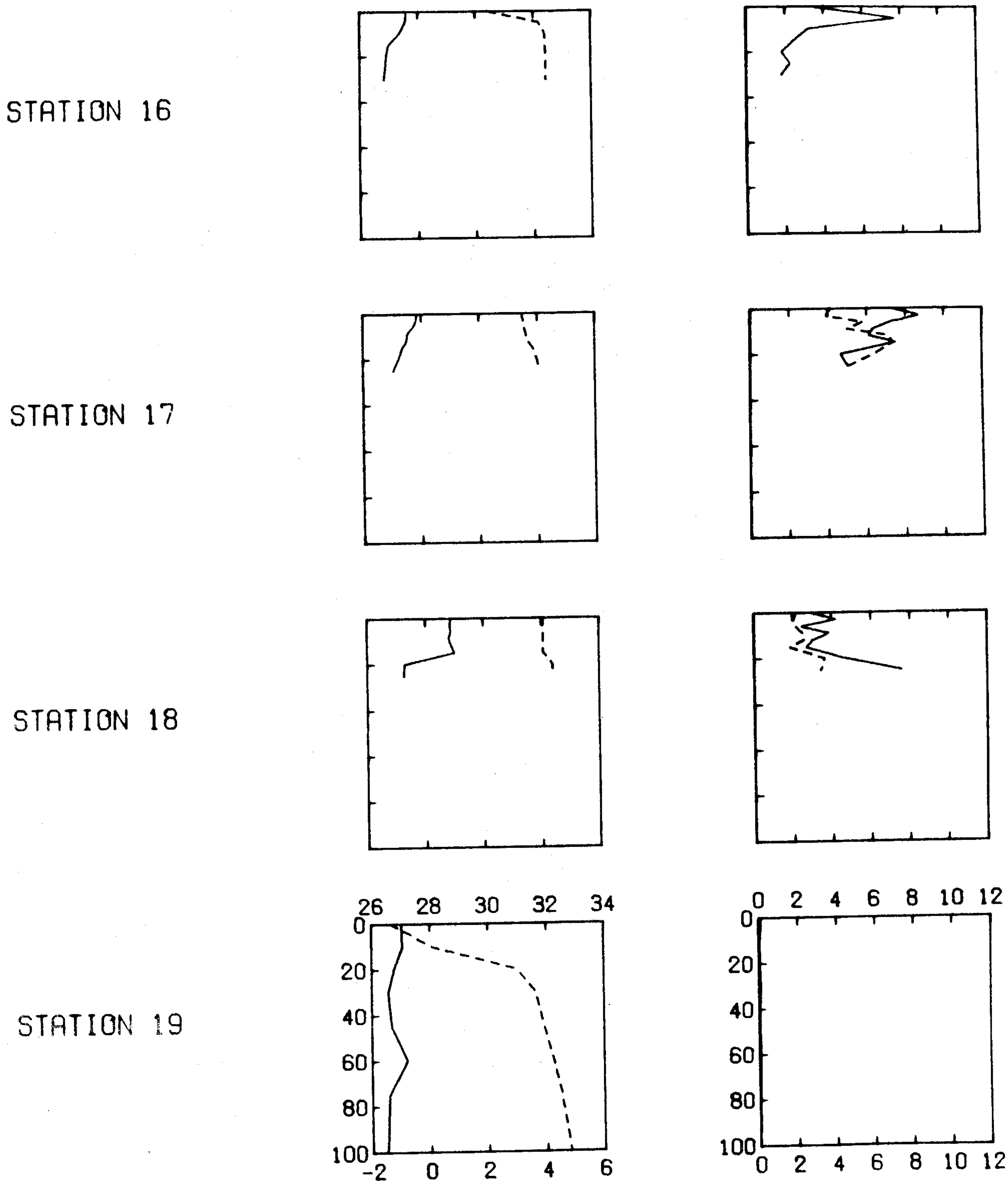


Fig. 11. (continued)

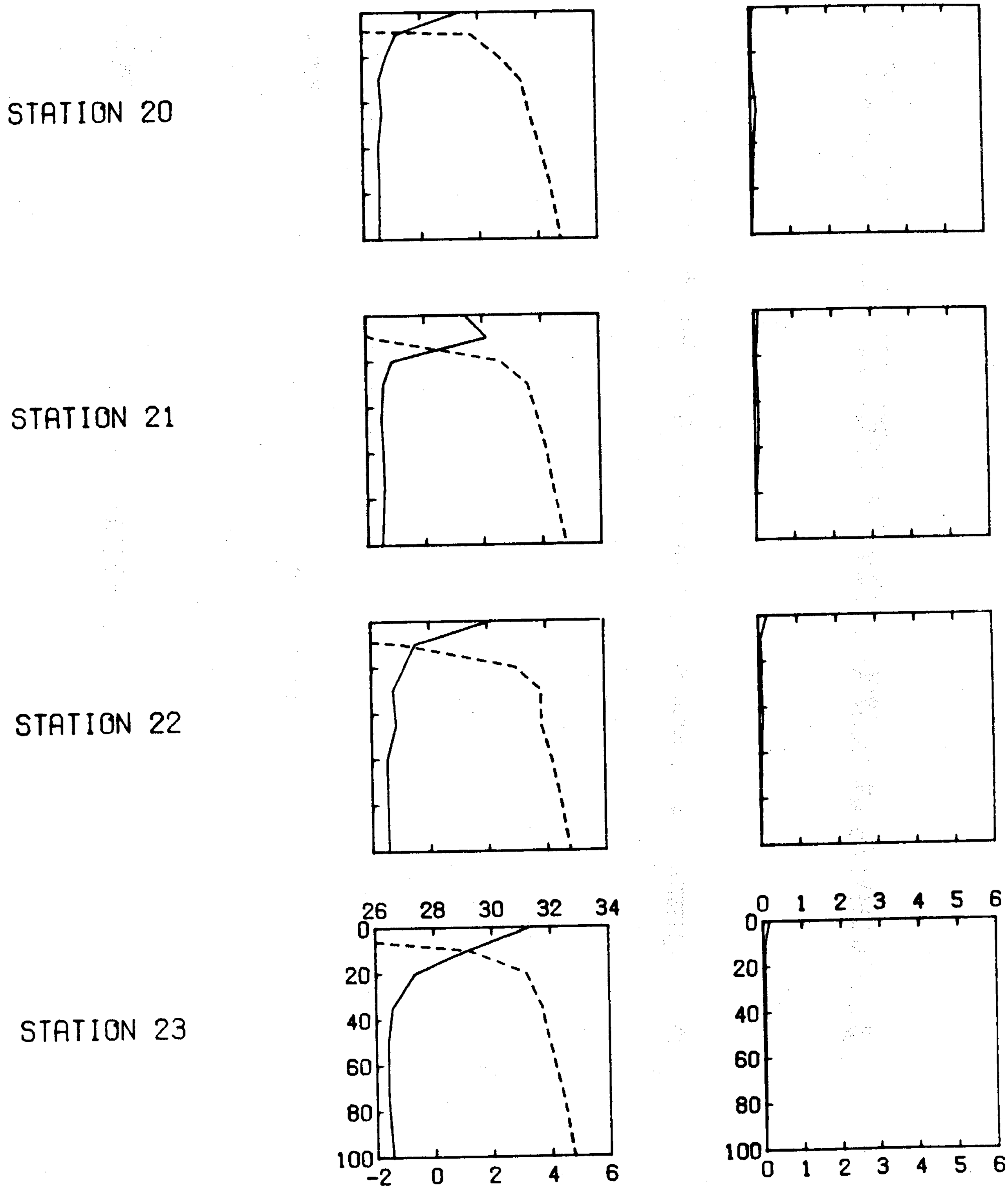


Fig. 11. (continued)

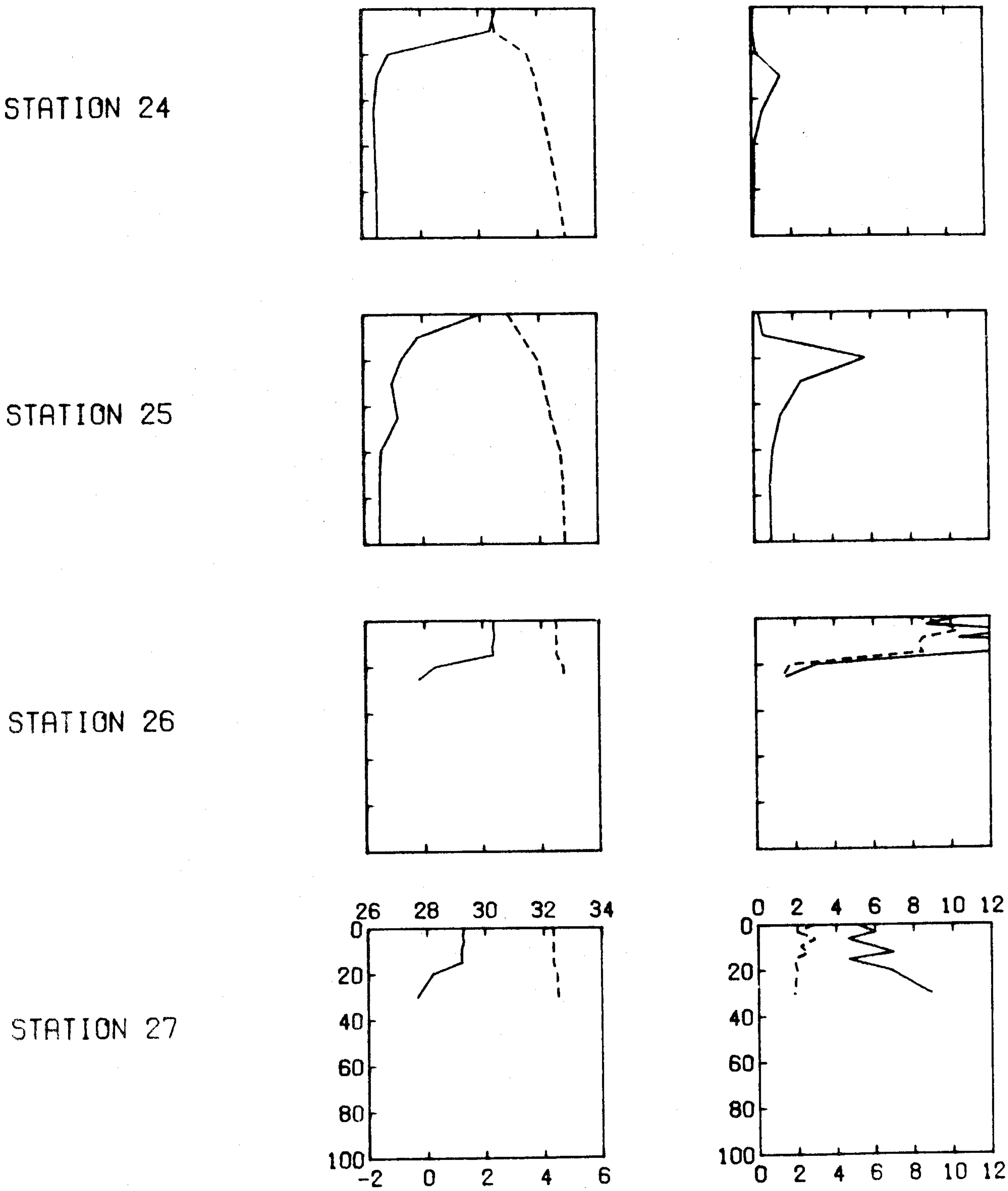


Fig. 11. (continued)

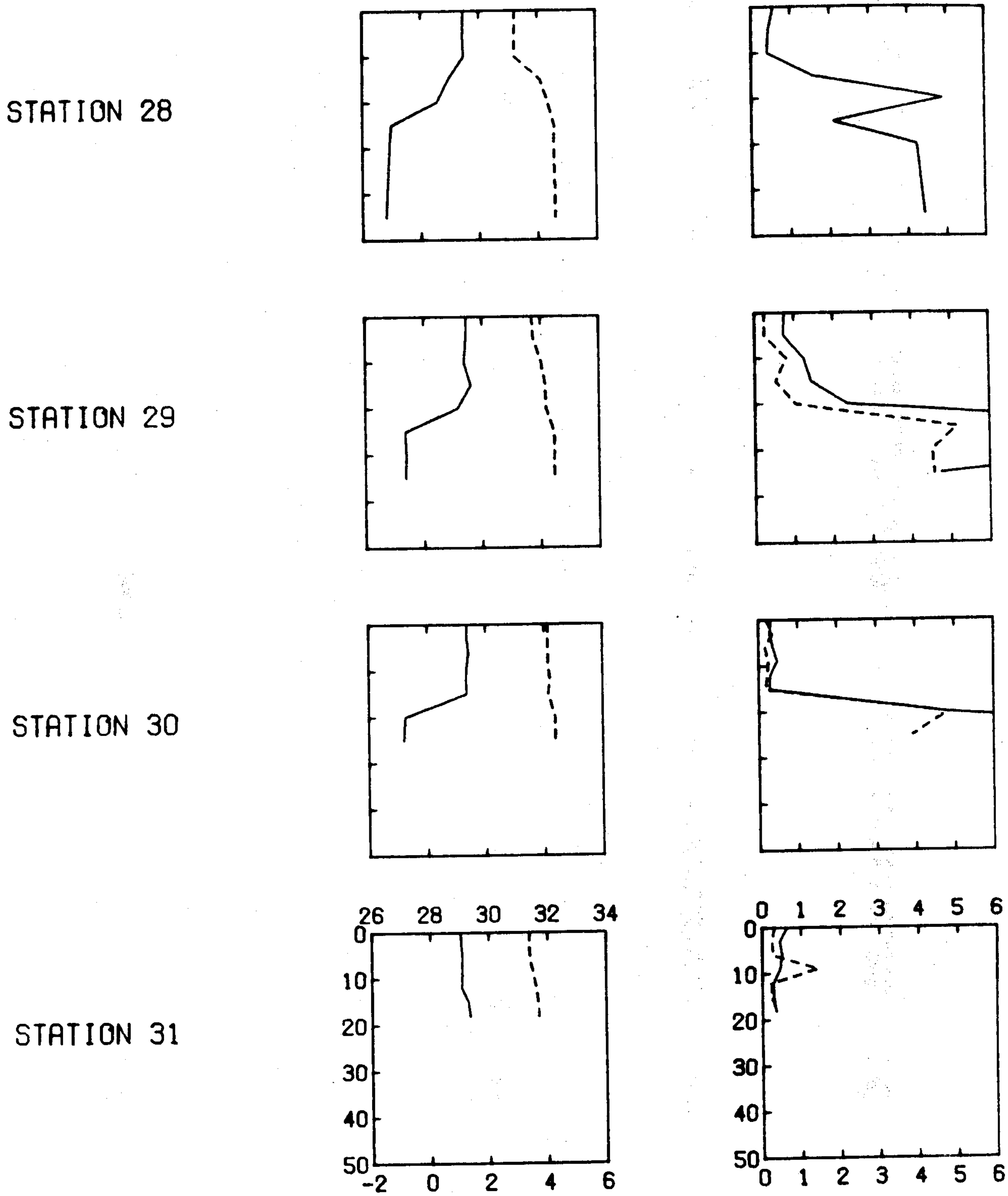


Fig. 11. (continued)

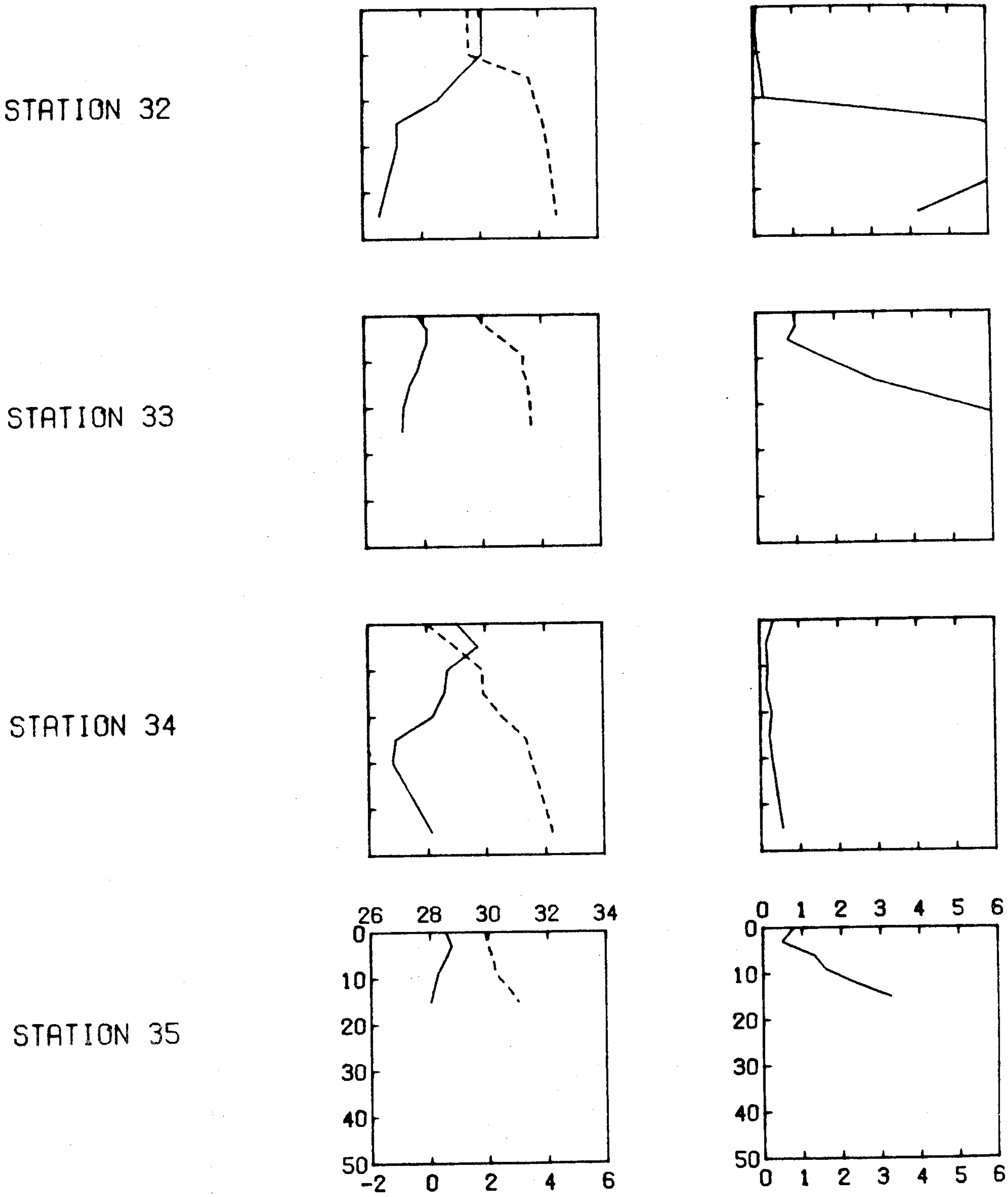


Fig. 11. (continued)

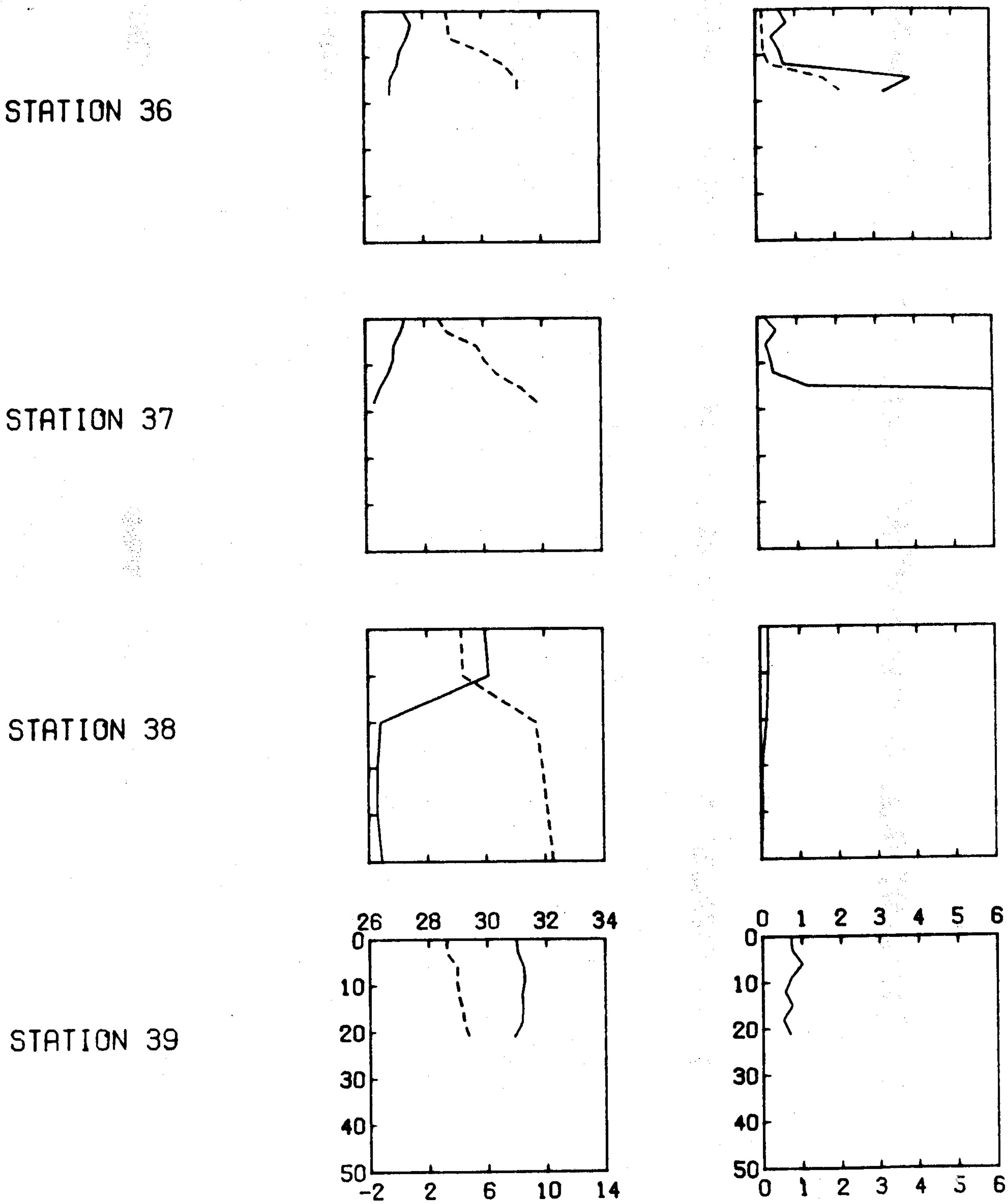


Fig. 11. (continued)

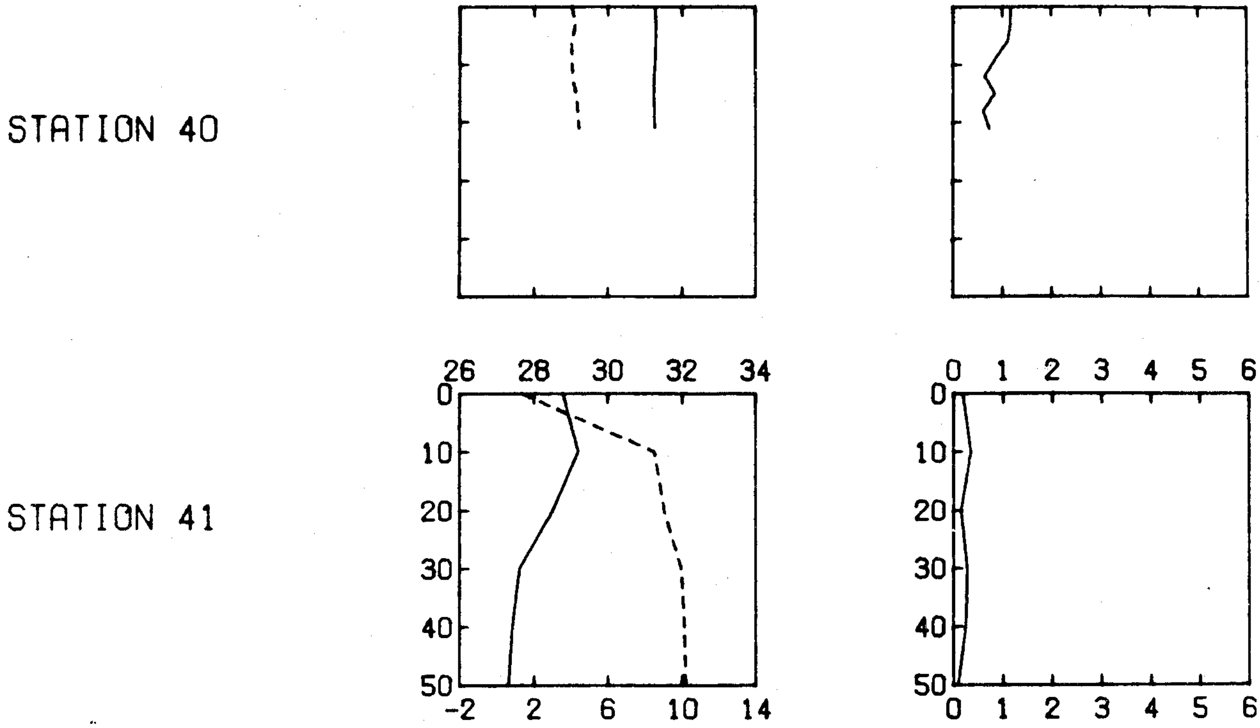


Fig. 11. (continued)

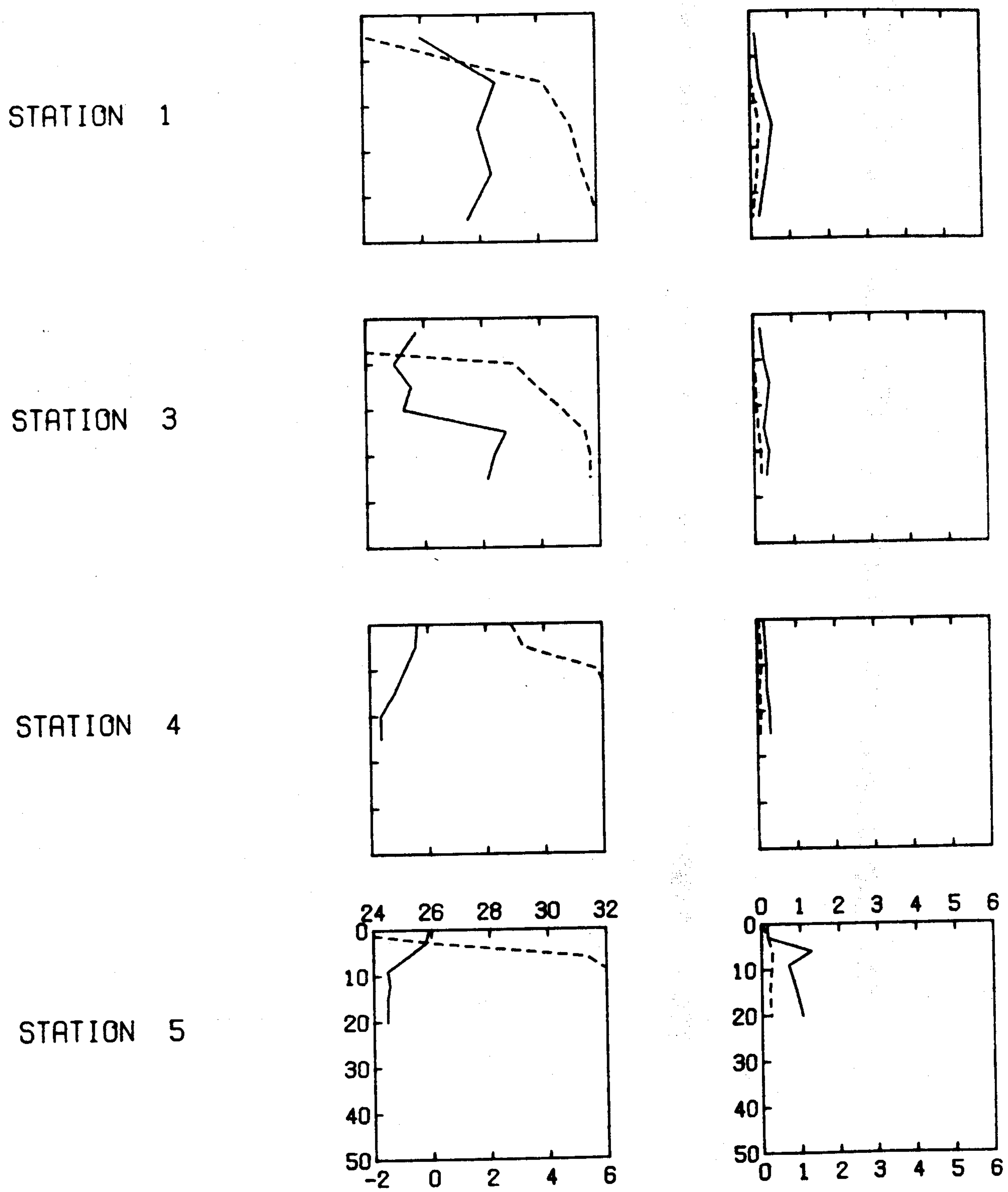


Fig. 12 Depth profiles of temperature-salinity and chlorophyll a-^{14}C assimilation in the Beaufort Sea, August-September 1978. Salinity (°/oo) ----; temperature (°C) ——; ^{14}C assimilation (mg C m^{-3} hr^{-1}) ----; chlorophyll a (mg m^{-3}) ——.

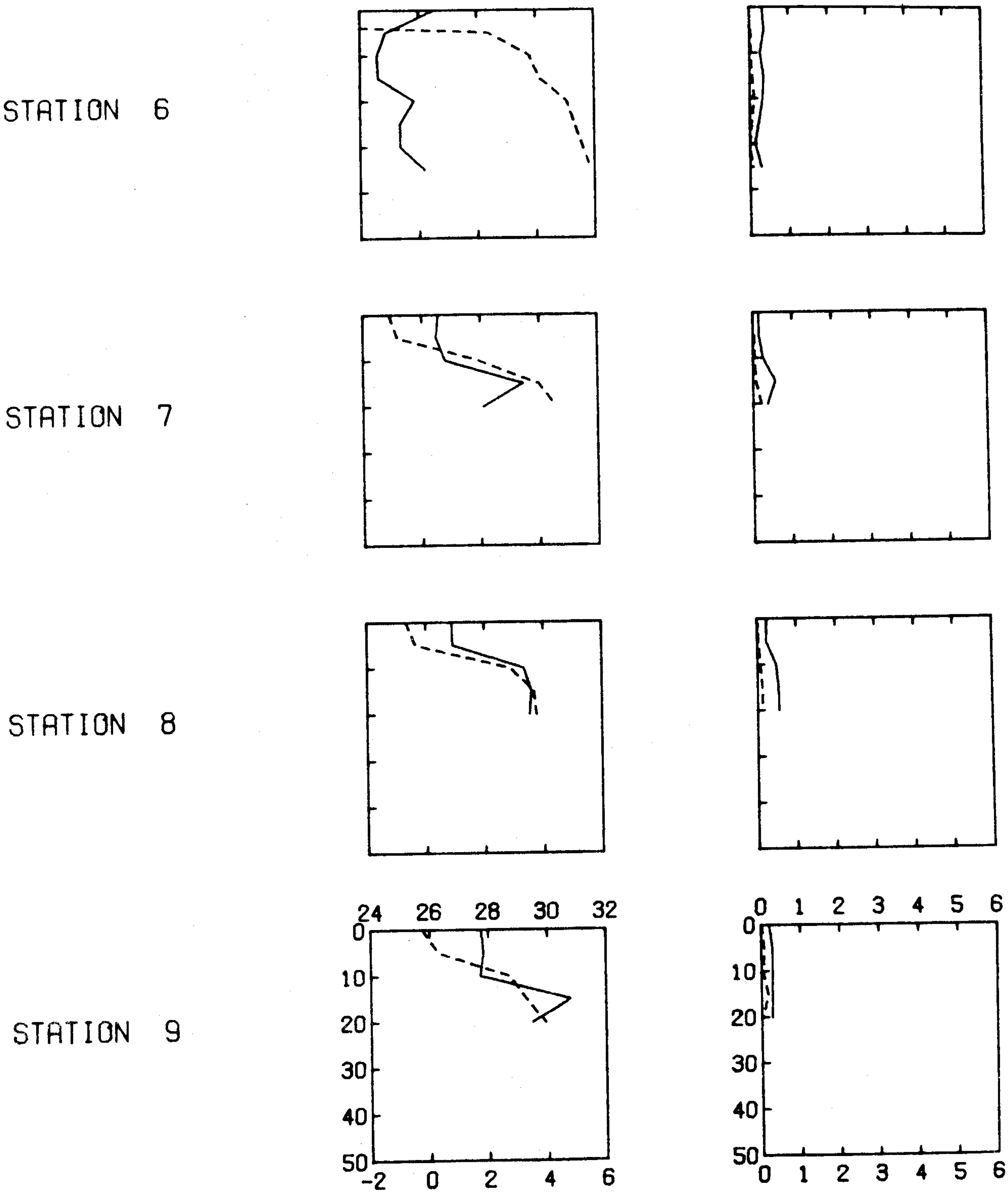


Fig. 12. (continued)

STATION 10

STATION 11

STATION 12

STATION 13

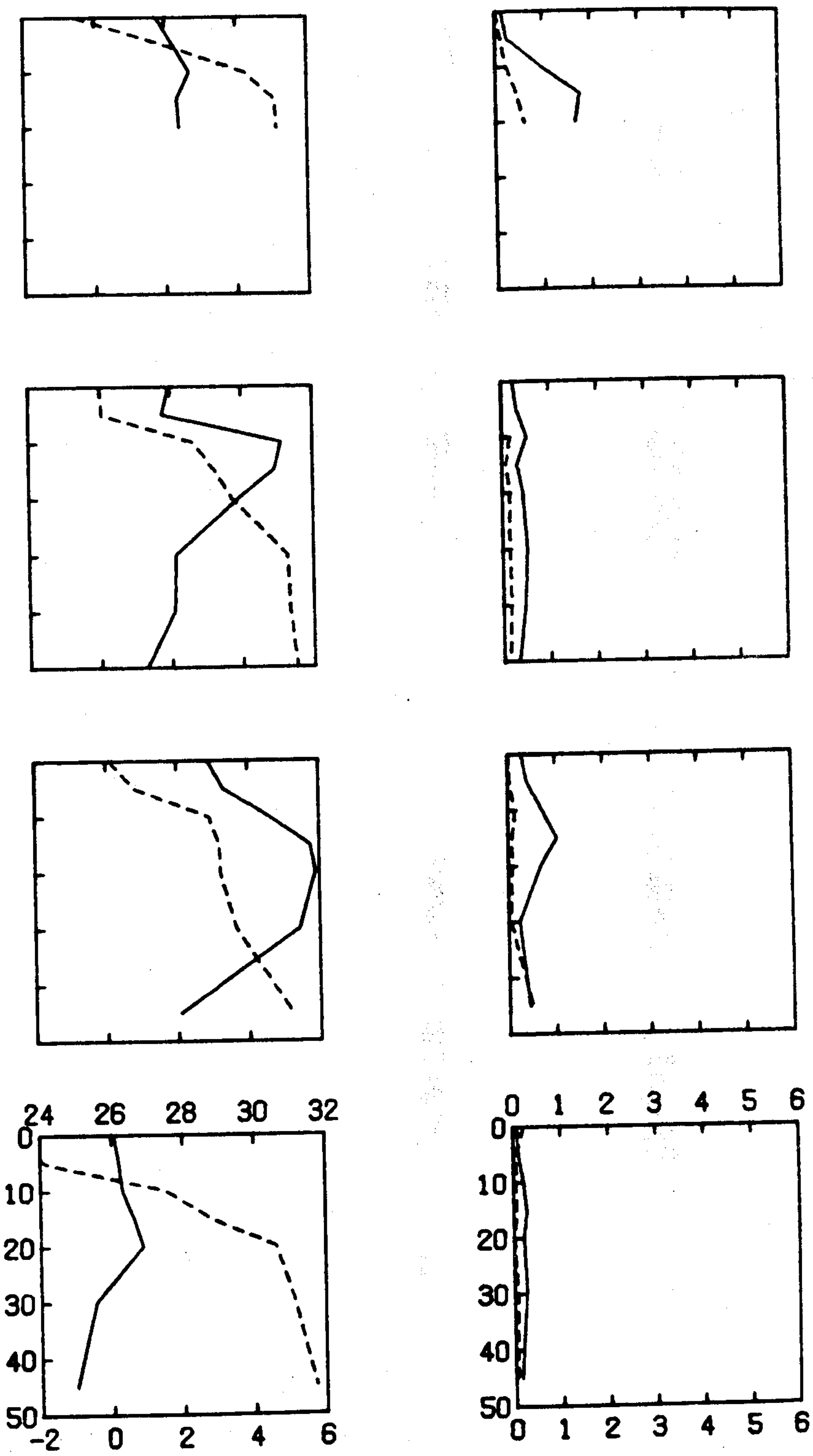


Fig. 12.(continued)

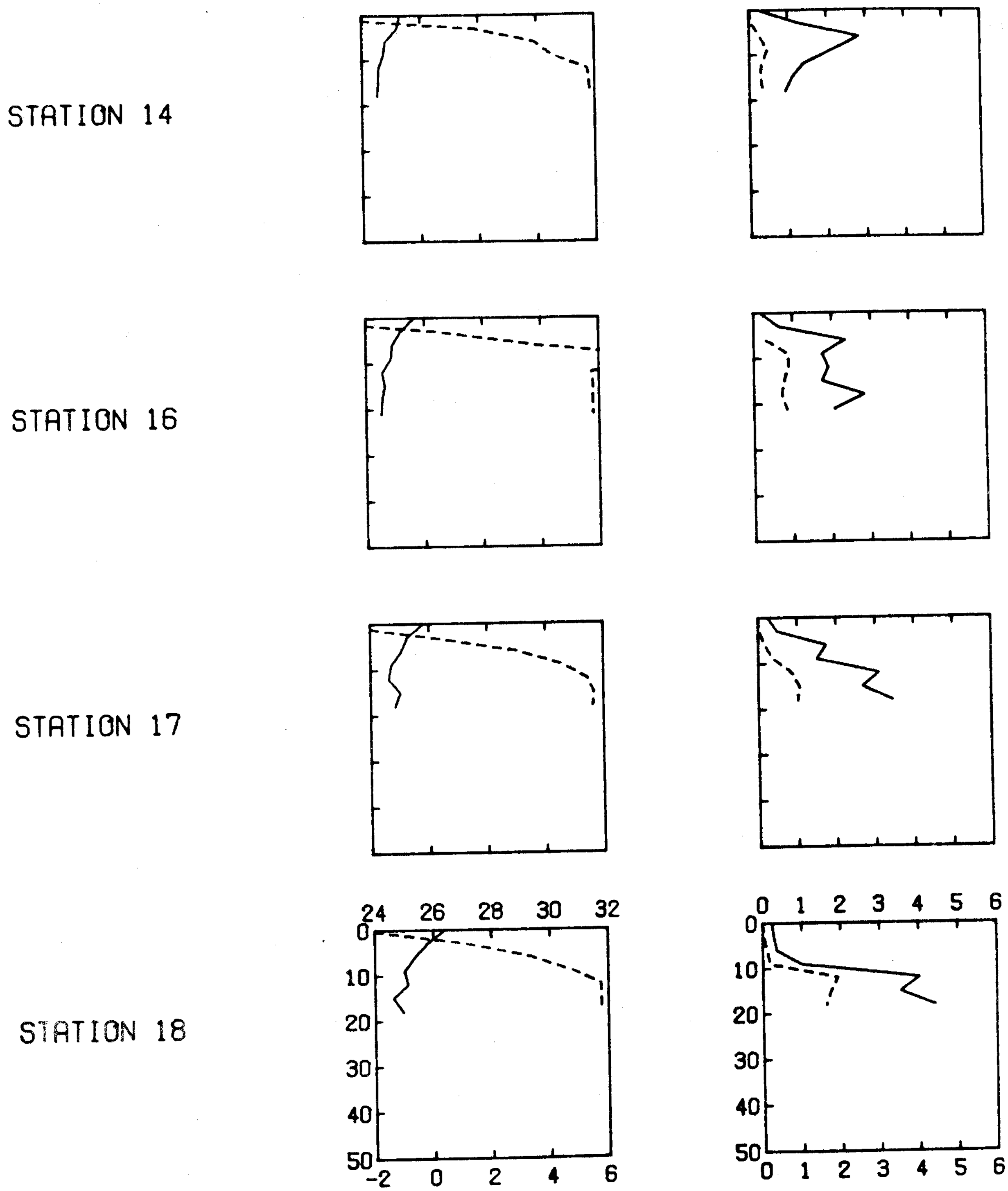


Fig. 12. (continued)

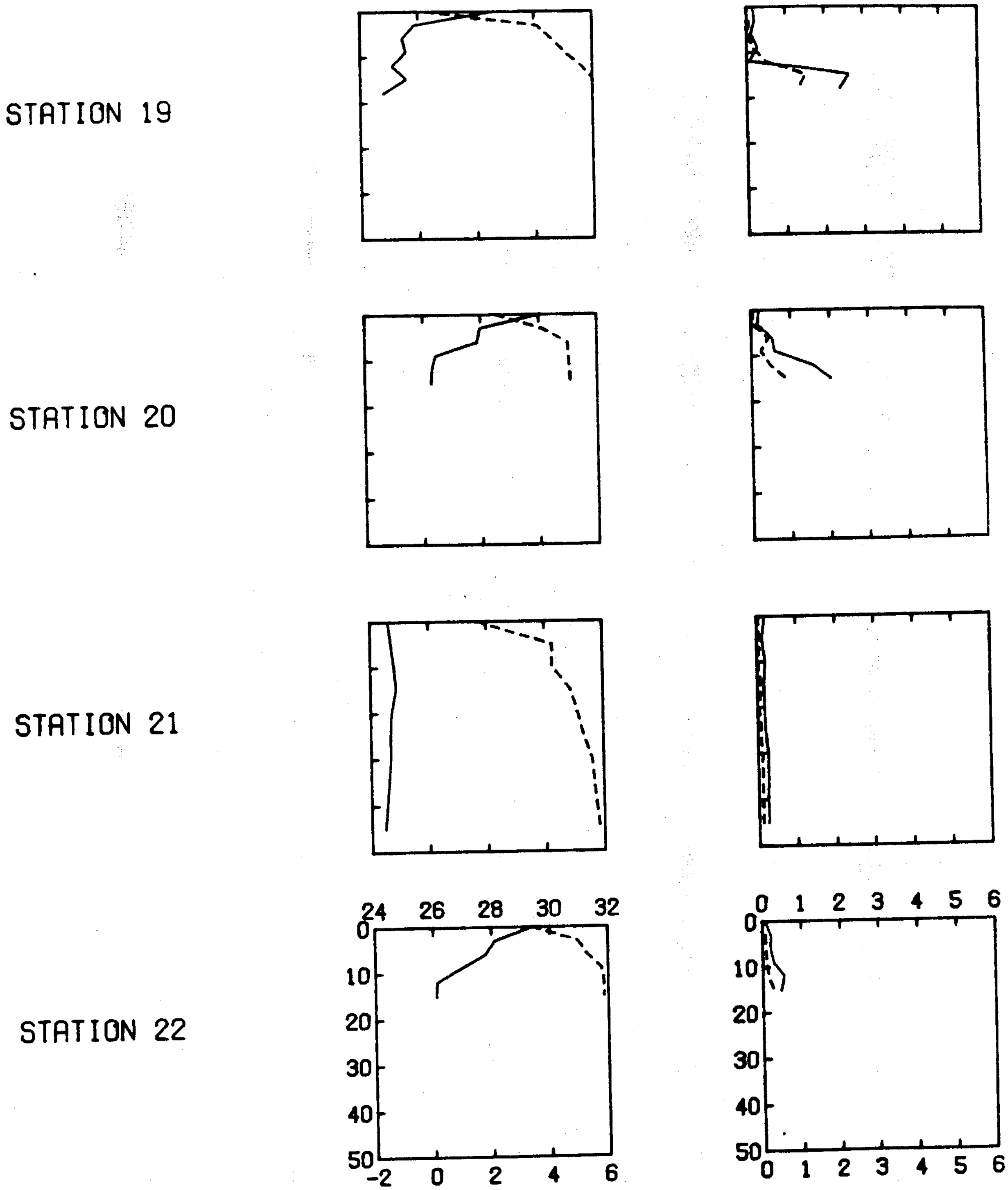


Fig. 12. (continued)

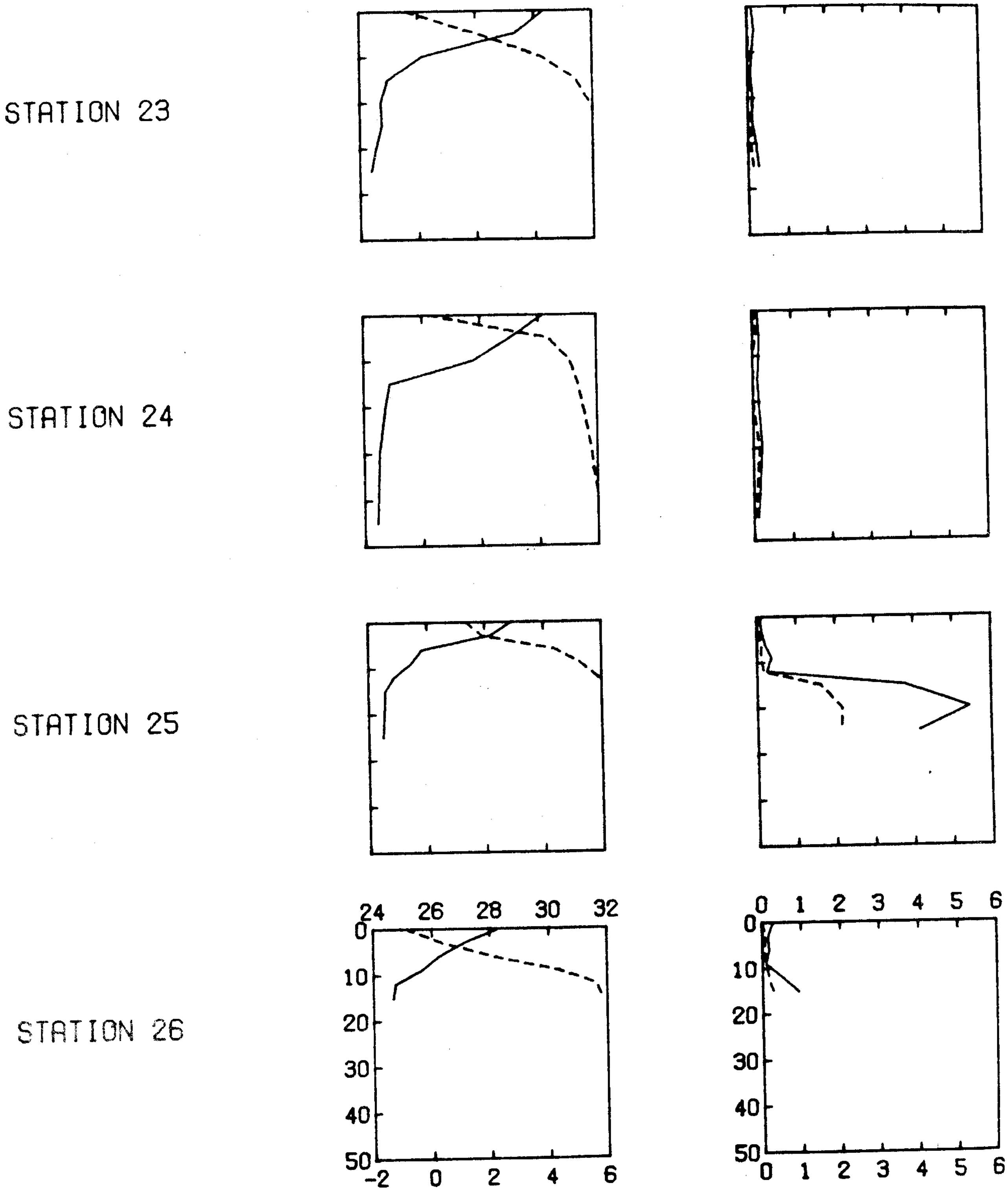


Fig. 12. (continued)

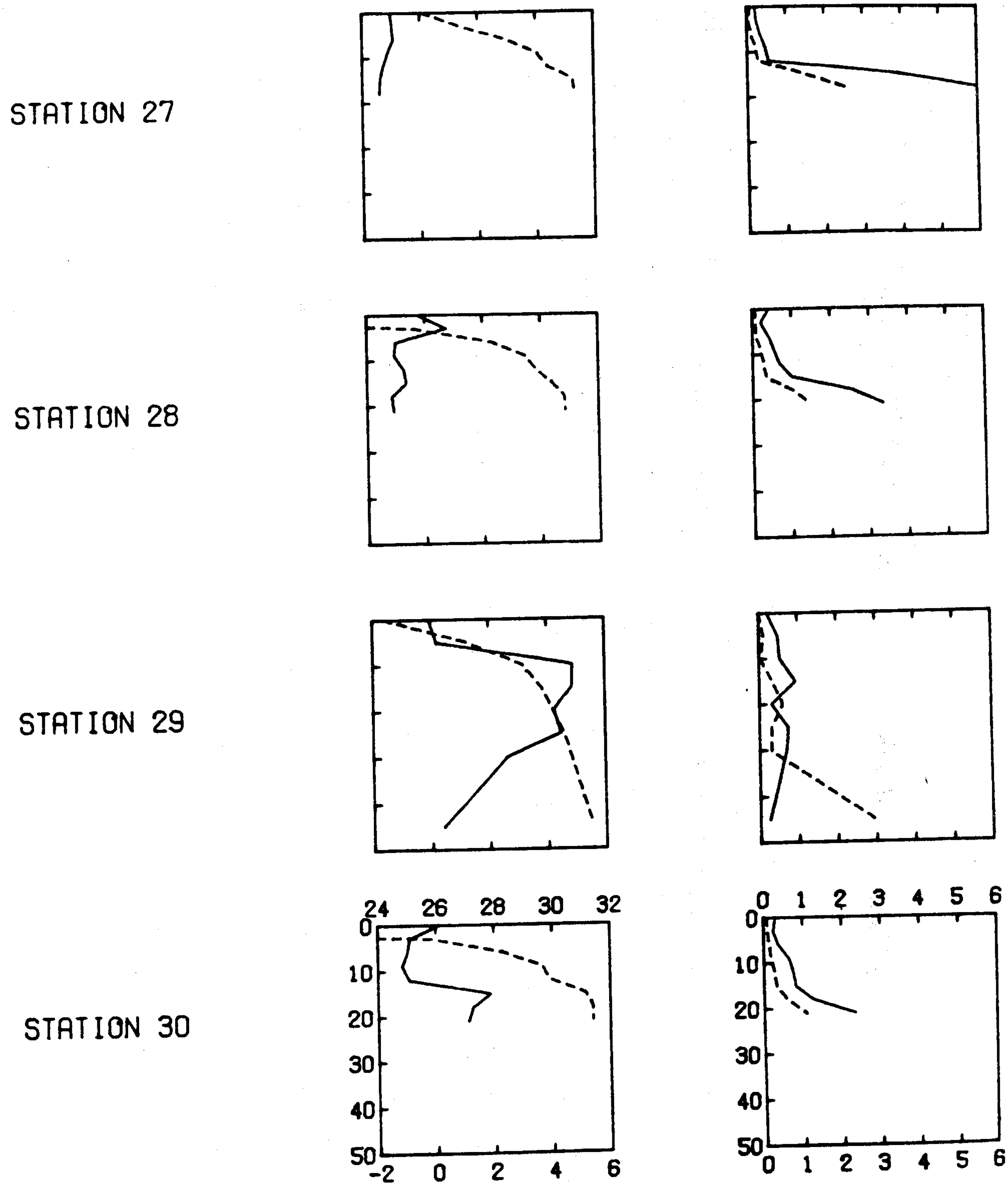


Fig. 12. (continued)

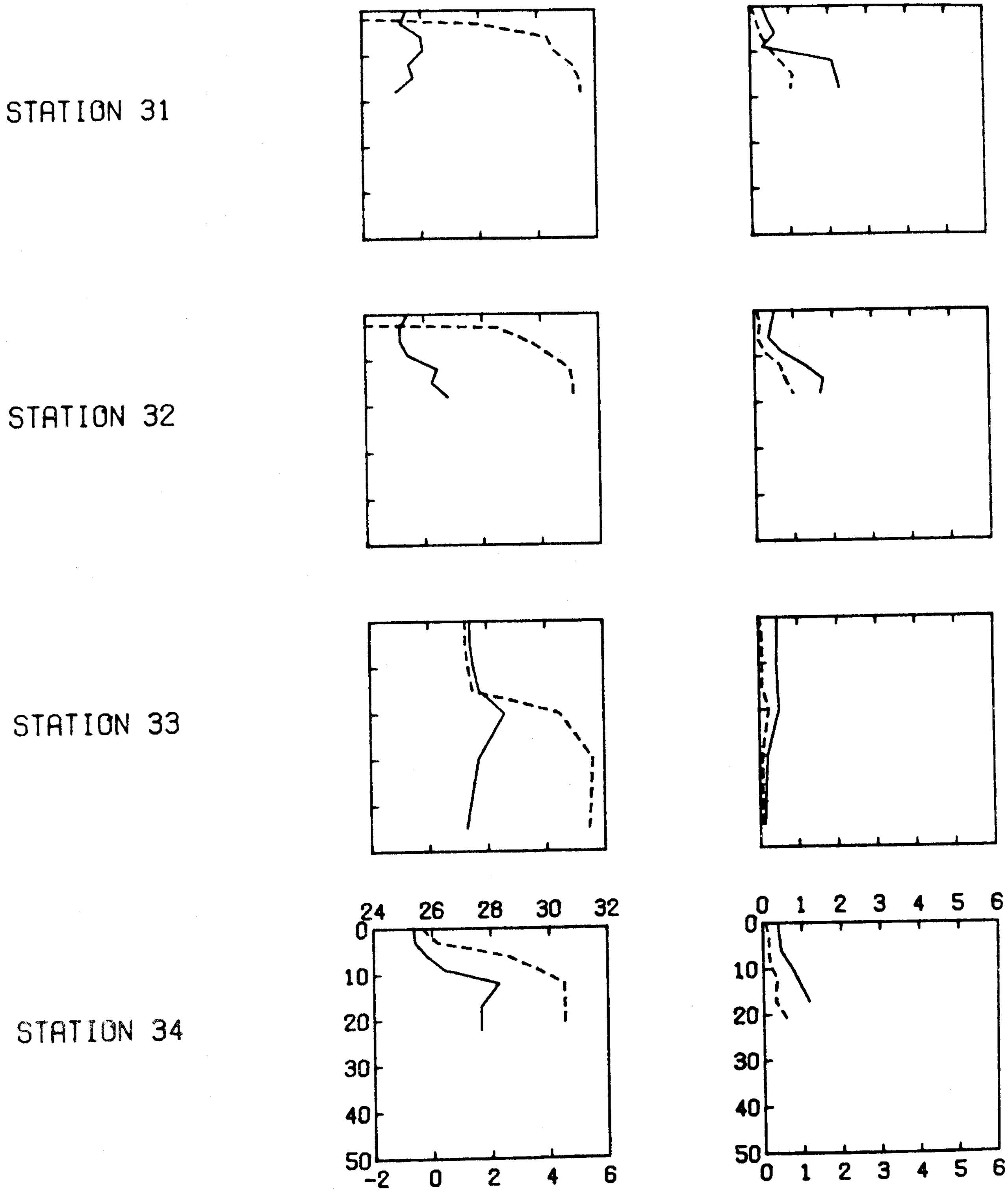
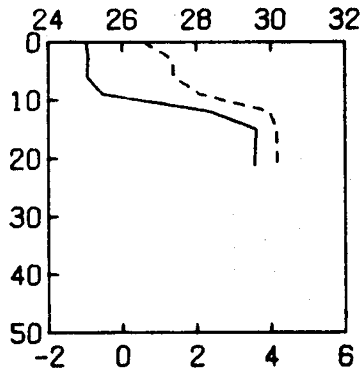


Fig. 12. (continued)

STATION 35



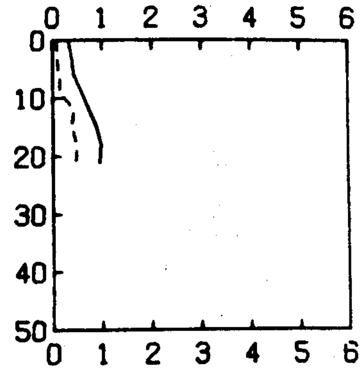


Fig. 12. (continued)

Table 9. Zooplankton species present in the Beaufort Sea, 1972 and 1976-1978.

- Coelenterata
  - Hydrozoa
    - *Aeginopsis laurentii* Brandt
    - *Aglantha digitale* (Müller)
    - *Bougainvillia superciliaris* (L. Agassiz)
    - *Catablema vesicarium* (A. Agassiz)
    - *Eumedusa birulae* (Linko)
    - *Euphysa flammea* (Linko)
    - *Halitholus cirratus* Hartlaub
    - *Melicertum octocostatum* (M. Sars)
    - *Melicertum* sp.
    - *Obelia* sp.
    - *Plotocnide borealis* Wagner
    - *Rathkea octopunctata* (M. Sars)
    - *Rathkea* spp.
    - *Sarsia tubulosa* (M. Sars)
    - *Staurophora mertensi* Brandt
    - Unidentified Hydrozoa
  - Scyphozoa
    - *Cyanea capillata* (Linneaus)
    - Unidentified Scyphozoa
  - Siphonophora
    - *Dimophyes arctica* Chun
    - Unidentified Siphonophora
- Ctenophora
  - *Beroë cucumis* Fabricius
  - *Pleurobrachia pileus* (Vanhöffen)
  - Unidentified Ctenophora
- Annelida - Polychaeta
  - Unidentified pelagic larvae
- Mollusca
  - Unidentified Mollusca larvae
    - Lamellibranch larvae
    - Gastropod veligers
  - Gastropoda - Pteropoda
    - *Clione limacina* Phipps
    - *Limacina helicina* (Phipps)
    - Unidentified Pteropoda
- Arthropoda - Crustacea
  - Ostracoda
    - *Conchoecia borealis maxima* Brady & Norman
    - *Conchoecia elegans* G. O. Sars

Table 9. (cont.)

Philomedes globosus (Lilljeborg)
Unidentified Ostracoda

Copepoda
- Calanoida
  - *Acartia clausi* Giesbrecht
  - *Acartia longiremis* (Lilljeborg)
  - *Acartia* spp.
  - *Calanus cristatus* Krøyer
  - *Calanus glacialis* Jaschnov
  - *Calanus hyperboreus* Krøyer
  - *Calanus marshallae* Frost
  - *Calanus plumchrus* Marukawa
  - *Centropages abdominalis* Sato
  - *Chiridius obtusifrons* Sars
  - *Derjuginia tolli* (Linko)
  - *Eucalanus bungii* Johnson
  - *Euchaeta glacialis* Hansen
  - *Eurytemora richingsi* Heron and Damkaer
  - *Gaidius tenuispinus* Sars
  - *Heterorhabdus norvegicus* (Boeck)
  - *Limnocalanus macrurus* Sars
  - *Metridia longa* (Lubbock)
  - *Microcalanus pygmaeus* (G. O. Sars)
  - *Neoscolecithrix farrani* Smirnov
  - *Pseudocalanus elongatus* (Boeck)
  - *Pseudocalanus major* G. O. Sars
  - *Pseudocalanus minutus* (Krøyer)
  - *Pseudocalanus* spp.
  - *Scaphocalanus magnus* (Scott)
  - *Scolecithricella minor* (Brady)
  - *Spinocalanus antarcticus* Wolfenden
  - *Spinocalanus longicornis* Sars
  - Unidentified Calanoida, adult females
  - Unidentified Calanoida, adult males
  - Unidentified Calanoida, adults
  - Unidentified Calanoida, juveniles
  - Unidentified Calanoida, nauplii
- Cyclopoida
  - *Oithona similis* Claus
  - *Oncaea borealis* G. O. Sars
  - Unidentified Cyclopoida
- Harpacticoida
  - Unidentified Harpacticoida
- Unidentified Copepoda nauplii

Cirripedia
- Unidentified nauplii
- Unidentified cyprids

Table 9. (cont.)

Mysidacea
  Boreomysis arctica Krøyer
  Mysis litoralis (Banner)
  Mysis oculata (Fabricius)
  Mysis relicta Loven
  Mysis spp.
  Neomysis rayii Murdoch
  Unidentified Mysidacea larvae

Cumacea
  Unidentified Cumacea

Cladocera
  Unidentified Polyphemidae
  Unidentified Cladocera

Amphipoda
  Gammaridea
    Apherusa glacialis (Hansen)
    Lagunogammarus wilkitzkii Birula
    Metopa invalida Sars
    Onisimus glacialis Sars
    Onisimus nanseni Sars
    Onisimus sp.
    Unidentified Gammaridea
  Hyperiidea
    Hyperia galba (Montagu)
    Hyperia medusarum (Müller)
    Hyperoche medusarum (Krøyer)
    Parathemisto abyssorum Boeck
    Parathemisto libellula (Lichtenstein)
    Parthemisto sp.
    Scina sp.
    Unidentified Hyperiidea
  Unidentified Amphipoda

Euphausiacea
  Thysanoëssa inermis (Krøyer)
  Thysanoëssa longipes Brandt
  Thysanoëssa raschii (M. Sars)
  Unidentified Euphausiacea larvae
  Unidentified, unstaged furcilia

Decapoda
  Anomura
    Unidentified Paguridae
    Unidentified Anomura zoea
  Brachyura
    Atelecyclidae
      Telmessus sp. megalopae

Table 9. (cont.)

Inachidae
- *Chionoecetes opilio* (O. Fabricius)
- *Chionoecetes* spp.

Oregoniinae
- *Hyas* sp. megalopae
- Unidentified Oregoniinae

Unidentified Brachyura zoea

Caridea

Crangonidae
- *Sclerocrangon boreas* (Phipps)
- Unidentified Crangonidae larvae

Hippolytidae
- *Eualus gaimardii* (Bell)
- *Eualus stoneyi* Rathbun
- *Hippolyte* spp.
- *Spirontocaris* spp.
- Unidentified Hippolytidae

Oplophoridae
- *Hymenodora glacialis* (Buchholz)

Pandalidae
- *Pandalus borealis* Krøyer
- *Pandalus danae* Stimpson
- *Pandalus goniurus* Stimpson
- *Pandalus* sp.

Unidentified Caridea zoea

Echinodermata

Ophiuroidea
- Unidentified Ophiuroidea

Unidentified pluteus larvae

Unidentified larvae

Chaetognatha
- *Eukrohnia hamata* Möbius
- *Sagitta elegans* Verrill
- *Sagitta maxima* (Conant)
- *Sagitta* spp.
- Unidentified Chaetognatha

Chordata

Larvacea
- *Fritillaria borealis* Lohmann
- *Fritillaria haplostoma* Fol
- *Fritillaria* spp.
- *Oikopleura labradoriensis* Lohmann
- *Oikopleura vanhöffeni* Lohmann
- *Oikopleura* spp.

Table 9. (cont.)

- Pisces
  - Eggs
    - Pleuronectidae
      - *Hippoglossoides robustus* Gill & Townsend
  - Larvae
    - Agonidae
      - *Aspidophoroides olriki* Lütken
    - Cottidae
      - *Myoxocephalus quadricornis* (Linneaus)
      - Unidentified Cottidae
    - Cyclopteridae
      - *Liparis koefoedi* Parr
      - *Liparis* spp.
      - Unidentified Cyclopteridae
    - Gadidae
      - *Boreogadus saida* (Lepechin)
      - Unidentified Gadidae
    - Pleuronectidae
      - *Pleuronectes quadrituberculatus* Pallas
    - Stichaeidae
      - *Lumpenus fabricii* (Valenciennes)
      - *Lumpenus* sp.

- Other organisms
  - Foraminifera - unidentified
  - Nematoda - unidentified
  - Crustacean eggs - unidentified
  - Invertebrate eggs - unidentified
  - Unidentified organisms

---

currently used names is included in the discussion (Table 14).

Hydrozoans were present in 112 samples with one species, *Aglantha digitale*, being the most common of 12 species identified. It was present in 109 samples and was the numerically dominant coelenterate in 96 samples. The highest concentration occurred north of Harrison Bay in 1978 when 309,230 per 1000 m^3 were found. *Aglantha digitale* is neritic in origin (Shirley and Leung 1970) and is a common holoplanktonic organism with essentially a worldwide distribution (Hand and Kan 1961).

Aeginopsis laurentii was the only other hydrozoan regularly present in large numbers. It was not common in samples collected in 1972 and 1976, but was present in 47 of 69 samples in 1977 and 1978. Numerically dominant in five samples, the highest concentration was 1,120 per 1000 m^3 off Flaxman Island (Sta. 18) in 1978. It is holoplanktonic and commonly occurs at depths of 1,000 m to the surface in all Arctic seas (Naumov 1960). A reproducing population is reported to occur in the central Arctic (Shirley and Leung 1970).

Catablema vesicarium, a common, surface dwelling, coastal species, was present in 28 of 69 samples collected in 1977 and 1978 with a peak concentration of 410 per 1,000 m^3 near the Canadian border (Sta. 20) in 1978. *Rathkea octopunctata* was present in 18 samples with at least one specimen collected each year. The greatest abundance of this species, 14,500 per 1,000 m^3, was found twice in 10-0 m ring net tows taken in 1976. *Bougainvillia superciliaris* was present once in 1976 and five times in 1978, but never in large numbers. *Eumedusa birulai* was found twice in 1977 and five times in 1978. *Euphysa flammea* is a neritic species found in 19 samples with a high concentration of 180 per 1,000 m^3 off Narwhal Island (Sta. 16) in 1978. Naumov (1960) reported *Plotocnide borealis* to be a very rare species found at depths from 200 m to the surface. This species was found in 19 samples with at least one occurrence each year. *Halitholus cirratus* was present at least once each field season. It is a coastal species (Naumov 1960).

The remaining medusae were recorded only from samples collected in 1978. One specimen was tentatively identified as *Staurophora mertensi* and three specimens from two samples were identified as *Melicertum octocostatum*. *Sarsia tubulosa* was found in low numbers in five samples. The genus *Obelia* was present in deep water at station A north of Pitt Point with a density of 110 per 1,000 m^3.

Phylum Coelenterata - Scyphozoa

All 24 samples containing scyphozoans were collected west of 149°W. Only medusae found in the 22 samples collected in 1976 were identified to species. All were *Cyanea capillata*, a coastal species present in Arctic and north temperate regions (Mayer 1910). It is a known commensal with the amphipods *Hyperia medusarum* and *Hyperoche medusarum* (MacGinitie 1955). No such association was evident in our samples. The highest concentration of this species was 900 per 1,000 m^3 in the 20-0 m ring net tow at station 26 north of Cape Simpson in 1976.

Phylum Coelenterata - Siphonophora

Members of this order were identified to species only for the 1972 samples; *Dimophyes arctica* was found in low numbers at two stations. This is a cosmopolitan species occupying deep water in low latitudes and the upper layers in high latitudes (Totton 1965; Alvariño 1971). A whole siphonophore is a composite of several developmental stages and is rarely collected intact in plankton tows. This may explain why siphonophores were found in only 8% of our zooplankton samples.

Phylum Ctenophora

Two ctenophore species, *Beroë cucumis* and *Pleurobrachia pileus* were collected and both are considered to have reproducing populations in the central Arctic (Leung 1970b). *Beroë cucumis* was present in 1976, 1977, and 1978 in 16 samples. *Pleurobrachia pileus* was found in 28 samples from 1977 and 1978. The fragile ctenophores are easily damaged by the handling and preserving technique associated with our sampling methods, therefore, the numbers reported here probably are underestimates of the natural concentrations.

Phylum Annelida

Polychaete larvae were widespread, occurring in 78 of 120 samples, primarily at inshore locations. Abundance was greatest in 1976, but the use of different nets in succeeding years prevents interyear comparison of abundances. Adult polychaetes are common benthic organisms and their meroplanktonic larvae would be expected to be common in the water column.

Phylum Mollusca

Mollusca were represented in these collections primarily by the pteropods, *Limacina helicina* (previously reported as *Spiratella helicina*) and *Clione limacina*. *Limacina helicina* was found in 61% of the samples, with the greatest concentrations occurring in 1976 and 1977. A maximum 30,750 per 1,000 m^3 occurred in the 20-0 m ring net tow at station 18 north of Prudhoe Bay in 1976, while 8,650 per 1,000 m^3 were present in the umbrella net tow at station 37 north of Point McIntyre in 1977. The greatest abundance found in a bongo net tow was 7,440 per 1,000 m^3 at station 31 near Flaxman Island in 1977. While such a range in abundance is possible, the use of more than one net type makes direct comparison difficult.

Clione limacina was widely distributed in samples collected in 1977 and 1978. The highest concentration, 3,030 per 1,000 m^3, occurred north of Tangent Point (Sta. 39) in 1977; all other samples contained much lower numbers.

Clione limacina is reported to feed exclusively on *L. helicina* (Lalli 1970) and only five samples contained the predator without its prey. The abundance of *L. helicina* exceeded that of *C. limacina* in 33 of 35 samples where both species were present, usually by a factor of 10 or more.

Unidentified mollusc larvae were found in 32 samples with lamellibranch larvae and gastropod veligers being identified in 1976. These were not separated in other years.

Phylum Arthropoda - Crustacea - Ostracoda

Conchoecia borealis maxima was the most common ostracod, occurring in 34 samples, usually in small numbers. This species was most abundant in 1977 shoreward of the 100 m depth contour. It is a pelagic animal, found in depths from the surface to 1,500 m and is the most common ostracod in the central Arctic (Leung 1972c, 1975). *Conchoecia elegans* and *Philomedes globosus* were also collected.

Phylum Arthropoda - Crustacea - Copepoda

The Copepoda were, by far, the most abundant taxonomic group with 28 species being identified with certainty. *Calanus glacialis*, *C. hyperboreus*, and *Metridia longa* were generally the most abundant species. They are reported to be a major element in Arctic offshore collections and occur widely in the upper 300 m throughout the Arctic (Grainger 1965). In our samples, more adults were present in 1977. *Calanus glacialis* was more abundant at western stations, with *C. hyperboreus* and *M. longa* more abundant at eastern stations, although *C. glacialis* stage VI females were dominant forms at some 1977 inshore eastern stations (Sta. 14, 18, 28, 29, and 33). Many of the *C. glacialis* females were carrying eggs. This species has been described as breeding when phytoplankton are abundant (Heinrich 1962), while *C. hyperboreus* and *Metridia longa* appear to breed independently of their immediate food source. It has also been suggested that these *Calanus* species may take more than one year to reach maturity, reproducing whenever environmental conditions are favorable (Cairns 1967; Harding 1966). *Metridia longa* was more abundant in 1976 and 1977 in samples collected in deeper water.

Pseudocalanus spp. were abundant in 1976, 1977, and 1978 with three species comprising this category. They were grouped together in 1976, although *P. minutus* was thought to be the most abundant species. *Pseudocalanus major* is a strictly Arctic species that has been found rarely since it was described by Sars (1900). *Pseudocalanus elongatus* was the third species present and was most abundant east of 151°W. Females were common at nearshore stations taken between 142°-151°W in 1977 and 1978.

Limnocalanus macrurus (identified as *L. grimaldii* in English and Horner 1977) is reported from nearshore, less saline, shallow water (Grainger 1965). It was most abundant in 1976 at stations off Prudhoe Bay and was also collected primarily at stations east of 149°W in 1977 and 1978. Stage VI males and females were most numerous, although stage III, IV, and V copepodites were also present.

Another brackish water species is *Derjuginia tolli* which occurred in low numbers at nearshore stations all three years. It was present as stage III, IV, and V copepodites and stage VI adult males and females.

Oithona similis, a cyclopoid copepod, was commonly collected at all stations in 1976. All developmental stages were present, with stage IV and V copepodites being most abundant. Some adult females were ovigerous; only a few adult males were found. This species was not collected in 1977 and was found at only two stations in 1978 with all stages being abundant at both stations.

Several species characteristic of the Bering Sea were collected, including *Calanus plumchrus*, *C. cristatus*, *C. marshallae*, and *Eucalanus bungii*. With the exception of *C. marshallae*, these species have been reported previously from the Beaufort Sea. *Calanus marshallae* has been described as a neritic species found in the north Pacific and Bering Sea (Frost 1974). It is replaced by *C. glacialis* north of Bering Strait. The three females identified in the 1978 samples represent a considerable range extension for this species. *Acartia clausi* and *Centropages abdominalis* may also be more characteristic of the Bering Sea.

Copepod species in our samples that are generally thought to occur in deep water include *Chiridius obtusifrons*, *Euchaeta glacialis*, *Eurytemora richingsi*, *Gaidius tenuispinus*, *Heterorhabdus norvegicus*, and *Microcalanus pygmaeus*. Widespread Arctic species include *Oncaea borealis* and *Scaphocalanus magnus*.

Arthropoda - Crustacea - Cirripedia

Barnacle larvae were present in two-thirds of all zooplankton samples collected, with the nauplius stage dominating in both concentrations and number of occurrences. The maximum concentration of nauplii was at station 13 in 1976 when 1,303,200 per 1,000 m^3 were collected in the 10-0 m tow. The highest density for cyprid larvae was also in 1976 in the 10-0 m tow from station 26 where 941,200 per 1,000 m^3 were collected.

Nauplii were widely distributed, while cyprids were found at inshore stations primarily west of 147°W. Johnson (1956) found a greater abundance of meroplankton in the Chukchi and western Beaufort seas then in the eastern Beaufort Sea. He attributed this to the greater area of shallow water which would favor the production of planktonic larvae by benthic adults. The absence of adult barnacles is expected because they are not planktonic animals.

Arthropoda - Crustacea - Mysidacea

Mysidacea were collected in 38% of all zooplankton samples. The two most common species, *Mysis oculata* and *M. litoralis*, were present in almost 20% of all zooplankton hauls with half of the samples containing these species taken in 1977. Sixteen samples contained both species, with *M. oculata* being slightly more abundant.

Mysis relicta was found in two samples collected in 1977 and in four samples taken in 1978. The highest density of this primarily fresh to brackish water form, was found inshore at station 20 near the Canadian border in 1978.

Other mysid species were collected at only two stations in 1972. Two specimens of *Boreomysis arctica* were collected in a ring net tow at station 4 and one specimen of *Neomysis rayii* was collected in an Isaacs-Kidd mid-water trawl at station 51. Members of the genus *Boreomysis* are deep water species (Banner 1948a) and *B. arctica* is considered to be primarily an Atlantic species (Stephensen 1933b). *Neomysis rayii* is a neritic species, occurring along the west coast of North America, through the Bering Sea, and into the adjacent Arctic Ocean (Banner 1948b).

Arthropoda - Crustacea - Cumacea

Cumaceans were found in only four of 120 samples, two in 1977 and two in 1978. Members of this widespread order are benthic, deep water forms and are rarely found in the water column (Sars 1900a).

Arthropoda - Crustacea - Cladocera

The only cladoceran collected was found in the 20-0 m ring net haul at station 25 off Pitt Point in 1976. This unidentified member of the family Polyphemidae was probably either *Podon leuckarti* G. O. Sars or *Evadne nordmanni* Loven. Both species have been reported from less saline inshore waters in the Arctic (English and Horner 1977).

Arthropoda - Crustacea - Amphipoda

The amphipods were a widespread group with the two suborders Gammaridea and Hyperiidea each representd in *ca.* 80% of the zooplankton samples.

Gammaridea

Gammaridea were identified to species only for 1972 and 1978 samples. Although not usually numerous, they were present in 80% of the zooplankton samples collected. Five species were identified, with the pelagic species *Apherusa glacialis, Onisimus glacialis,* and *O. nanseni* predominating.

Apherusa glacialis is a circumpolar Arctic species that inhabits the upper water layers (Tencati and Geiger 1968) and is a known prey species of the Arctic cod, *Boreogadus saida* (Barnard 1959). Samples containing this species were usually collected in areas with little or no ice, although this species is reported to live among ice floes (Stephensen 1931). This species was more abundant in 1978 then in 1972.

Onisimus glacialis was found in three samples from 1972 and 12 samples from 1978. It is an Arctic and probably circumpolar species (Stephensen 1923; Bousfield 1951). Holmquist (1965) reported this species to be found in abundance near coasts, particularly in areas with a large fresh-water influence. This did not appear to be the situation in our samples.

Onisimus nanseni is a circumpolar species indicative of Arctic water when found at the surface (Dunbar 1954) with a distribution similar to *O. glacialis* (Stephensen 1933a). Four samples containing *O. nanseni* were collected, two over depths of 500 m in 1972 and two inshore over depths of

20 m. This agrees with Stephensen (1923), who said that the species may be found inshore as well as over rather deep water. Our collections were made with a net, but other investigators report baited traps to be more efficient collecting gear (Stephensen 1923; Barnard 1959; Tencati and Geiger 1968). Both *O nanseni* and *O. glacialis* are food items of birds, fish, and seals (Dunbar 1942, 1954; Barnard 1959; Holmquist 1965).

One specimen of *Metopa invalida* was collected in each of three samples in 1972. All were collected over depths of less than 50 m. Sars described this species in 1895 and it was not reported again until Dunbar (1954) found it at Ungava Bay, Canada. Dunbar (1954) called it a subarctic species that was not known outside regions of Atlantic water influence.

One specimen of the herbivorous species *Lagunogammarus wilkitzkii*, was collected offshore in 1972. It is an Arctic species that feeds on algae and organic matter on the underside of the ice (Tencati and Geiger 1968). It was considered by Gurjanova (1930) to be characteristic of low salinity water. It is known to breed successfully in the Arctic and is probably not heavily preyed upon (Barnard 1959).

Hyperiidae

Hyperiidae collected in 1976 were not identified to species. The two most common amphipods, *Parathemisto abyssorum* and *P. libellula*, both pelagic, Arctic-subarctic, circumpolar species (Dunbar 1954), were present in *ca.* 75% of the samples collected in other years. *Parathemisto libellula* had the highest density for a single species of Hyperiidae at station 37 near Harrison Bay in 1977 when a calculated 7,970 per 1,000 m^3 were collected. Hyperiidae were much less abundant in all other samples.

Hyperia galba was present in 30 samples and had its highest concentration, 200 per 1,000 m^3, offshore from the Maguire Islands (Sta. 22) in 1972. *Hyperia medusarum* was present in an umbrella net tow at station 37 off Point McIntyre in 1977 and in an Isaacs Kidd mid-water trawl at station 51 north of Oliktok in 1972. *Hyperoche medusarum* was found in one sample from 1972 (Sta. 55) and three times in 1977.

Amphipoda - Crustacea - Euphausiacea

Euphausids were present in 54% of the zooplankton samples, with three species, *Thysanoëssa inermis*, *T. longipes*, and *T. raschii*, being identified. *Thysanoëssa inermis* and *T. raschii* have roughly the same horizontal distributions (Dunbar 1940; Brinton 1962), both being Arctic boreal species with a depth distribution of 0-300 m (Boden *et al.* 1955).

According to Dunbar (1940), *T. inermis* is the most common euphausid in the Arctic and is the principle food of several whale species. However, in our samples, *T. raschii* was usually more abundant. The highest number of *T. inermis*, 100 per 1,000 m^3, was found over the 200 m depth contour off Barter Island in 1972 and at three locations, off the mouth of the Sagavanirktok River, north of Harrison Bay, and off Pitt Point, in 1976. The maximum number of *T. raschii*, 510 per 1,000 m^3, occurred near Demarcation Point in 1977.

Thysanoëssa longipes is found primarily in the north Pacific and in the American Arctic at depths from 0-500 m (Boden *et al.* 1955; Brinton 1962). This species was found in eight samples with a maximum density of 80 per 1,000 m^3 in a shallow bongo tow off Pitt Point (Sta. 25) in 1976.

Arthropoda - Crustacea - Decapoda

Decapods are representd in these samples by larvae of the tribes Anomura, Brachyura, and Caridea. Shrimp larvae (Caridea) were found all years at most inshore stations. Identification is generally restricted to family because of difficulties in separating young stages present in our samples. Three adults were collected in 1977. Hippolytidae, in addition to being the most abundant larval group, was represented by two adults, *Eualus gaimardii* and *E. stoneyii*, collected off Barter Island in 1977. Pandalidae were rarely collected with *Pandalus borealis*, *P. danae*, and *P. goniurus* being the only three species identified. One member of the Oplophoridae, an adult *Hymenodora glacialis*, was collected well offshore at a deep water station in 1977. One specimen of the Crangonidae was collected near the Canadian border in 1978.

Only zoea larvae of the Anomura were collected. This group was more abundant west of 150°W in 1977, while it was more common east of 150°W in 1972 and 1978. Limited sampling occurred east of 150°W in 1976 because of heavy ice conditions.

Except for two Brachyuran megalopae collected off Pitt Point in 1976, only zoea larvae of this group were collected. A westward restriction of this group similar to that of the Anomura occurred in 1977 and 1978 with boundaries about 153°W and 148°W. Johnson (1956) found abundant crab larvae in the Chukchi Sea and relatively few in the eastern Beaufort Sea. He suggested that the greater area of shallow water in the Chukchi and western Beaufort seas is more conducive to the greater production of benthic organisms than in the deeper water in the eastern area.

Phylum Echinodermata

Unidentified bipinnaria larvae, along with pluteus larvae of ophiuroids and echinoids, were found, with the largest concentrations occurring in 1976. Large numbers of these meroplanktonic larvae would be expected because ophiuroids are one of the most common groups of benthic invertebrates in the shallow Beaufort Sea.

Phylum Chaetognatha

Chaetognaths were present in 92% of the samples with *Eukrohnia hamata* and *Sagitta elegans* being the two species found in greatest numbers. The maximum concentration of *S. elegans*, 100,970 per 1,000 m^3, was found at station 29 in 1978, while *E. hamata* was found in greatest abundance, 2,220 per 1,000 m^3, in the upper 100 m at station 20 located near 73°N in 1977. (This station was located outside the boundaries of our chart and is not shown in Fig. 6.) *Eukrohnia hamata* was not identified in samples collected in 1976, but both species were present in samples collected the other years. Twenty-six samples containing both species were collected inside the 100 m contour with *S. elegans* being the dominant species 22 times. Outside the 100 m contour, *E. hamata* was dominant in 9 of 17 samples containing both species.

The tendency for *S. elegans* to be more abundant at inshore stations and *E. hamata* to be more abundant offshore agrees with the known distributions of these organisms. *Sagitta elegans* is typical of the upper 150 m in the Arctic and subarctic regions (Alvariño 1965). *Eukrohnia hamata* is an oceanic species with a worldwide distribution occurring in deep water near the equator, rising to the upper layers in higher latitudes, and to the surface in polar regions (Alvariño 1965).

Phylum Chordata - Larvacea

Larvacea were represented in 94% of the samples by three species from two genera. *Fritillaria borealis* was abundant in 1976 and 1978 when it was present in all but one sample collected. Concentrations ranged as high as 362,000 per 1,000 m^3 found off Tangent Point in 1976 and 524,570 per 1,000 m^3 at station A in 1978. Abundances these two years contrast with those from 1972 and 1977 when this genus was reported in small numbers from *ca.* 38% of the samples.

The genus *Oikopleura* was represented in 107 samples by *O. vanhöffeni*, *O. labradoriensis*, or both. These species are found at depths from 0-900 m (Leung 1972a) and occur widely in the Arctic (Grainger 1965). *Oikopleura vanhöffeni* was most abundant, 11,500 per 1,000 m^3, off Narwhal Island in 1972, while 8,000 *O. labradoriensis* per 1,000 m^3 were found in an umbrella net tow taken off the Jones Islands in 1977.

Phylum Chordata - Pisces

Small numbers of fish larvae were collected in 47 samples with Gadidae present in 31. The Arctic cod, *Boreogadus saida*, identified in 19 samples was the most comm species. *Myoxocephalus quadricornis* was collected four times; *Liparis koefoedi*, *Lumpenus fabricii*, and *Aspidophoroides olriki* were each collected twice; and *Pleuronectes quadrituberculatus* was collected once.

One fish egg, identified as *Hippoglossoides robustus*, was collected at station 29 in 1972 and at station 7 in 1977.

Other organisms

This category includes protozoans, nematodes, unidentified crustacean and other invertebrate eggs, and organisms that could not be identified. Unidentified foraminiferans were found in seven samples collected in 1977 and 1978, but never in large numbers. Unidentified nematodes occurred at six stations in 1977 and 1978, also in small numbers. Small numbers of invertebrate eggs were collected at three stations in 1977 and 1978.

2. Phytoplankton

A list of phytoplankton species known to occur in the Beaufort Sea is given in Table 10. Not all of the species have been found in all sampling years. Only *Leptocylindrus minimus* had not been identified previously from the Beaufort Sea.

To facilitate data analysis, the phytoplankton have been grouped into four categories based on taxonomic affinities. These categories are *Chaetoceros*, all other diatoms, flagellates, and dinoflagellates. The genus *Chaetoceros* was the most important group of diatom species, consisting of *ca*. 18 species. The all other diatoms category consists of a variable number of genera and species depending on the year. Most of the flagellates have not been identified on the cell count sheets, but have been grouped into size classes. The unidentified flagellates and all identified flagellate species have been grouped together to form the flagellate category. Dinoflagellates were never very numerous in the total cell counts, but are given category status here because they are a major taxonomic group in the phytoplankton.

In the cell counts, the group *Chaetoceros* spp. consists of small cells, usually about 6 μm along the apical axis, that are difficult to identify in the counting chambers or without resting spores. Species known to be included in this group are *Ch. fragilis*, *Ch. furcellatus*, *Ch. gracilis*, *Ch. socialis*, and *Ch. wighami*. When *Ch. furcellatus* spores were present, they were counted separately as spores, but were grouped into *Chaetoceros* spp. when listed on the OCSEAP data cards. Among the small *Chaetoceros* species only *Ch. septentrionalis* has been separately identified on the count sheets and OCSEAP data cards. This is because its distinctive, wavy setae make it easy to recognize in the counting chambers.

One hundred five categories of phytoplankton from six phyla, including 73 species and 32 other categories such as unidentified species and groups of species, were found in the 1973 samples. Standing stock ranged from *ca*. 5×10^4 at station 6-05 to > 4×10^6 at station 15-10. Small flagellates comprised 63% of the population, and dinoflagellates comprised 22% of the population at station 6-05. *Chaetoceros* spp. were most abundant at station 15-10, comprising 90% of the population.

Chaetoceros spp. plus all other diatoms were the most abundant organisms at most stations and depths (Fig. 13); flagellates were most abundant at some stations and were usually the most abundant organisms in the upper layers and nearly always at the surface.

Dinoflagellates were more numerous in 1973 than in other years, sometimes comprising more than 25% of the population. They were especially abundant at stations 6, 12, and 39-44. Abundant species included *Gonyaulax catenata*, *G. spinifera*, *Gymnodinium lohmanni*, *Protoperidinium bipes*, *P. pallidum*, *P. brevipes*, and *Oxytoxum* sp. (Balech 1977 transferred the marine species of *Peridinium* Ehrenberg having 3 cingular and 1 transitional plate to the genus *Protoperidinium* Bergh. These species are listed in the OCSEAP taxonomic code and have been

Table 10. List of phytoplankton species found in the Beaufort Sea. This list does not include species known primarily from the ice or benthos. Names and authors are those given in Hustedt (1930, 1959-1962), Hendy (1974), and Parke and Dixon (1976).

Bacillariophyta

Amphiprora hyperborea Grunow
Asterionella kariana Grunow
Bacterosira fragilis Gran
Biddulphia aurita (Lyngbye) Brébisson & Godey
Chaetoceros atlanticus Cleve
Chaetoceros borealis Bailey
Chaetoceros ceratosporum Ostenfeld
Chaetoceros compressus Lauder
Chaetoceros concavicornis Mangin
Chaetoceros danicus Cleve
Chaetoceros debilis Cleve
Chaetoceros decipiens Cleve
Chaetoceros fragilis Meunier
Chaetoceros furcellatus Bailey
Chaetoceros gracilis Schütt
Chaetoceros karianus Grunow
Chaetoceros mitra (Bailey) Cleve
Chaetoceros radicans Schütt
Chaetoceros septentrionalis Østrup
Chaetoceros socialis Lauder
Chaetoceros subsecundus (Grunow) Hustedt
Chaetoceros subtilis Cleve
Chaetoceros teres Cleve
Chaetoceros wighami Brightwell
Chaetoceros spp.
Coscinodiscus centralis Ehrenberg
Coscinodiscus curvatulus Grunow
Coscinodiscus oculus-iridis Ehrenberg
Coscinodiscus spp.
Cylindrotheca closterium (Ehrenberg) Reimann & Lewin
Detonula confervacea (Cleve) Gran
Eucampia zoodiacus Ehrenberg
Gomphonema sp.
Leptocylindrus danicus Cleve
Leptocylindrus minimus Gran
Licmophora sp.
Melosira arctica (Ehrenberg) Dickie
Melosira jurgensii Agardh
Melosira moniliformis (O. F. Müller) Agardh
Navicula pelagica Cleve
Navicula transitans Cleve
Navicula spp.
Nitzschia delicatissima Cleve
Nitzschia frigida Grunow
Nitzschia grunowii Hasle
Nitzschia seriata Cleve
Nitzschia spp.

Table 10. (cont.)

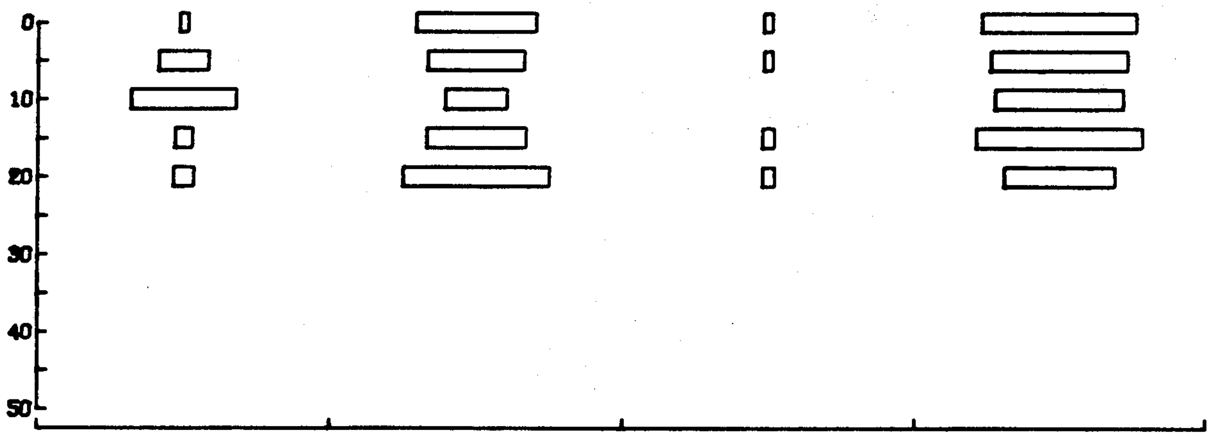
Porosira glacialis (Gran) Jørgensen
Rhizosolenia alata Brightwell
Rhizosolenia hebatata Bailey
Skeletonema costatum (Greville) Cleve
Stauroneis granii Jørgensen
Thalassionema nitzschioides Hustedt
Thalassiosira anguste lineata (A. Schmidt) Fryxell & Hasle (formerly *T. polychorda* (Gran) Jørgensen or *Coscinosira polychorda* (Grunow) Gran)
Thalassiosira antarctica Comber
Thalassiosira decipiens (Grunow) Jørgensen
Thalassiosira gravida Cleve
Thalassiosira hyalina (Grunow) Gran
Thalassiosira lacustris (Grunow) Hasle (formerly *Coscinodiscus lacustris* Grunow)
Thalassiosira nordenskioeldii Cleve
Thalassiosira spp.
Thalassiothrix frauenfeldii Grunow
Unidentified diatoms, mostly pennate diatoms

Dinophyta
Amphidinium longum Lohmann
Ceratium arcticum (Ehrenberg) Cleve
Ceratium longipes (Bailey) Gran
Cladopyxix sp.
Dinophysis acuta Ehrenberg
Dinophysis norvegica Claparède & Lachmann
Dinophysis rotundata Claparède & Lachmann
Dinophysis sphaerica Stein
Gonyaulax catenata (Levander) Kofoid
Gonyaulax spinifera (Claparède & Lachmann) Diesing
Gonyaulax spp.
Gymnodinium lohmanni Paulsen
Gymnodinium spp.
Oxytoxum spp.
Protoperidinium belgicum (Wulff) Balech
Protoperidinium bipes (Paulsen) Balech (previously reported as *Peridinium minusculum* Pavillard)
Protoperidinium brevipes (Paulsen) Balech
Protoperidinium conicum (Gran) Balech
Protoperidinium depressum (Bailey) Balech
Protoperidinium grenlandicum (Woloszynska) Balech
Protoperidinium pallidum (Ostenfeld) Balech
Protoperidinium pellucidum Bergh
Protoperidinium spp.
Scrippsiella faeroense (Paulsen) Balech & Soares (previously reported as *Peridinium triquetrum* (Ehreberg) Lebour)
Scrippsiella trochoidea (Stein) Loeblich III (previously reported as *Peridinium trochoideum* (Stein) Lemmermann)
Protoceratium reticulatum (Claparède & Lachmann) Bütschlii
Unidentified dinoflagellates

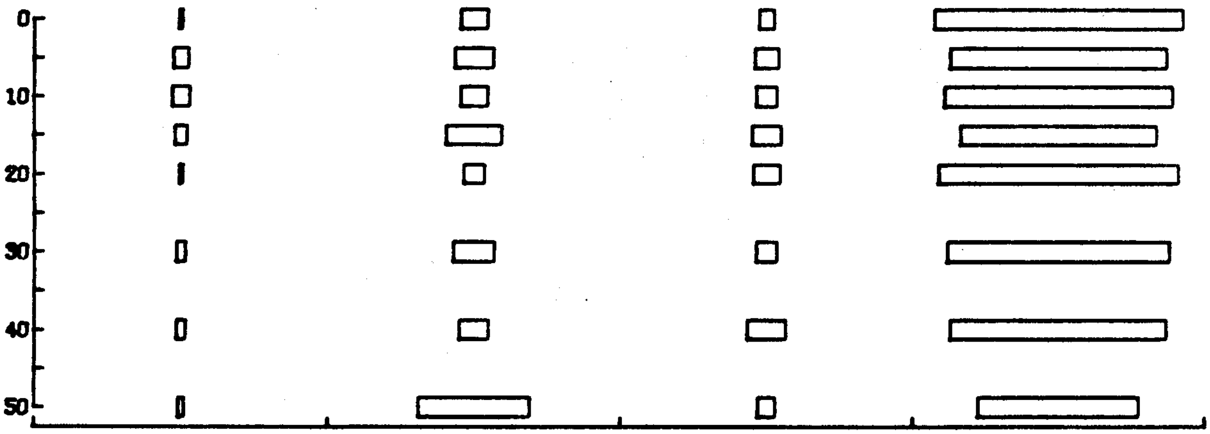
Table 10. (cont.)

Haptophyta
Phaeocystis pouchetii (Hariot) Lagerheim
Cryptophyta
Chroomonas spp.
Cryptomonas spp.
Chrysophyta
Calycomonas gracilis Lohmann
Calycomonas ovalis Wulff
Dinobryon balticum (Schütt) Lemmermann
Dinobryon petiolatum Willén
Distephanus speculum (Ehrenberg) Haeckel
Ebria tripartita (Schumann) Lemmermann
Pelagococcus subviridis Norris
Chlorophyta
Platymonas spp.
Pterosperma spp.
Euglenophyta
Dinema litorale Skuja
Eutreptiella braarudii Throndsen
Choanoflagellates[2]
Diaphanoeca aperta Manton
Diaphanoeca grandis Ellis
Monosiga marina Grøntved
Parvicorbicula socialis (Meunier) Deflandre
Unidentified species
Organisms of Unknown Affinities
Hexasterias problematica Cleve
Piropsis polita Meunier
Radiosperma corbiferum Meunier

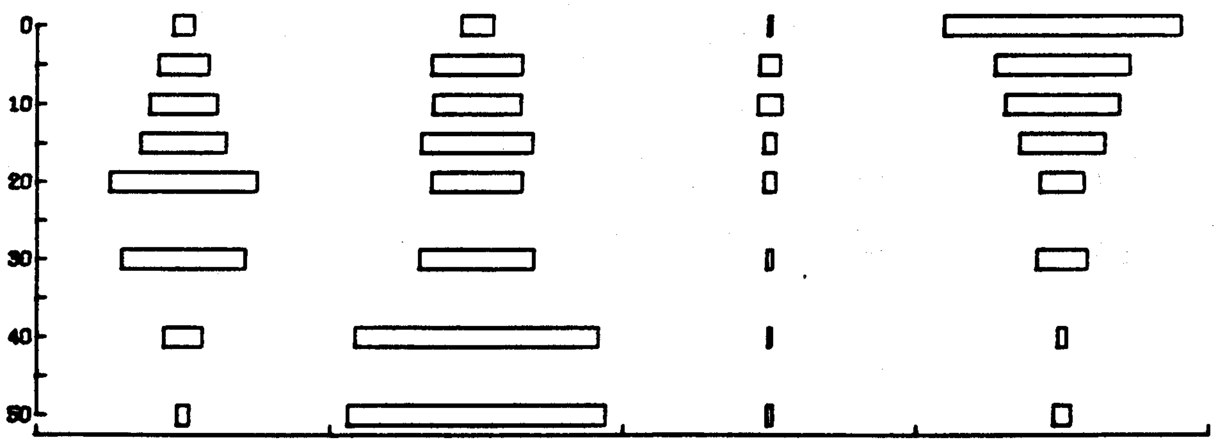
[2] Choanoflagellates are included here because some species appear to be relatively important numerically in the Beaufort Sea, although Parke and Dixon (1976) do not include them in the algae because they are not photosynthetic (see Leadbeater 1972).



Station 1

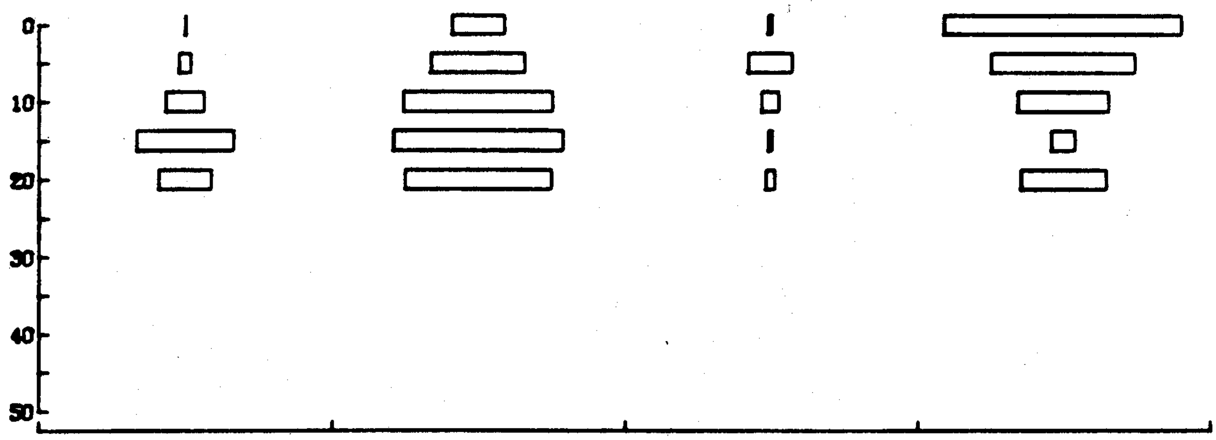


Station 2

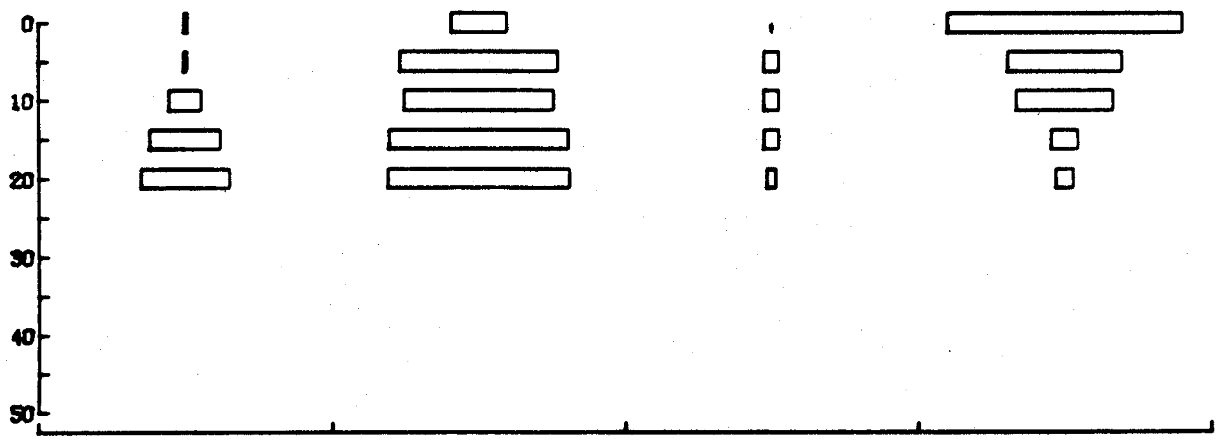


Station 3

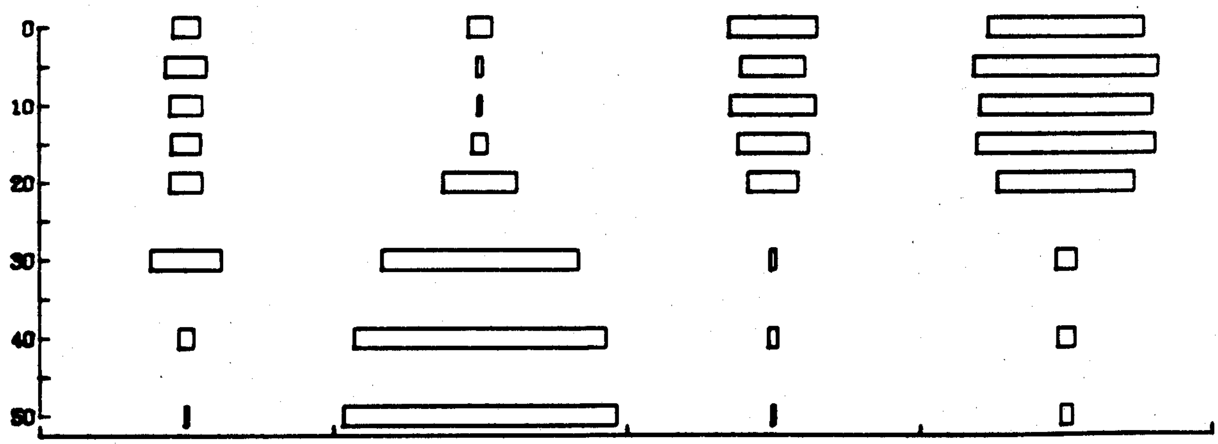
Fig. 13. Percentage of phytoplankton by major category by depth for each station, CGC *Glacier*, 28 Jul - 12 Aug 1973. Percentages add up to 100% running from left to right across the diagram.



Station 4

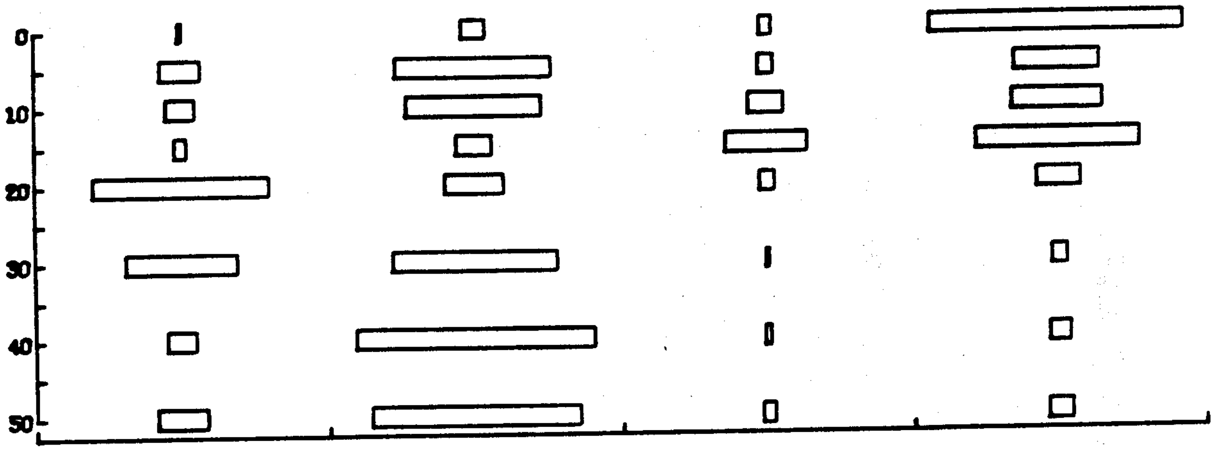


Station 5

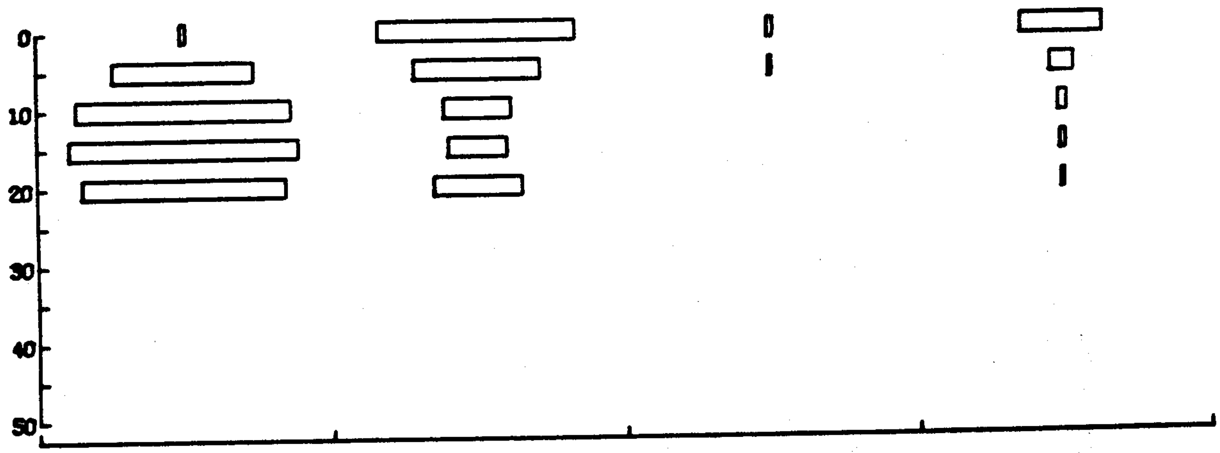


Station 6

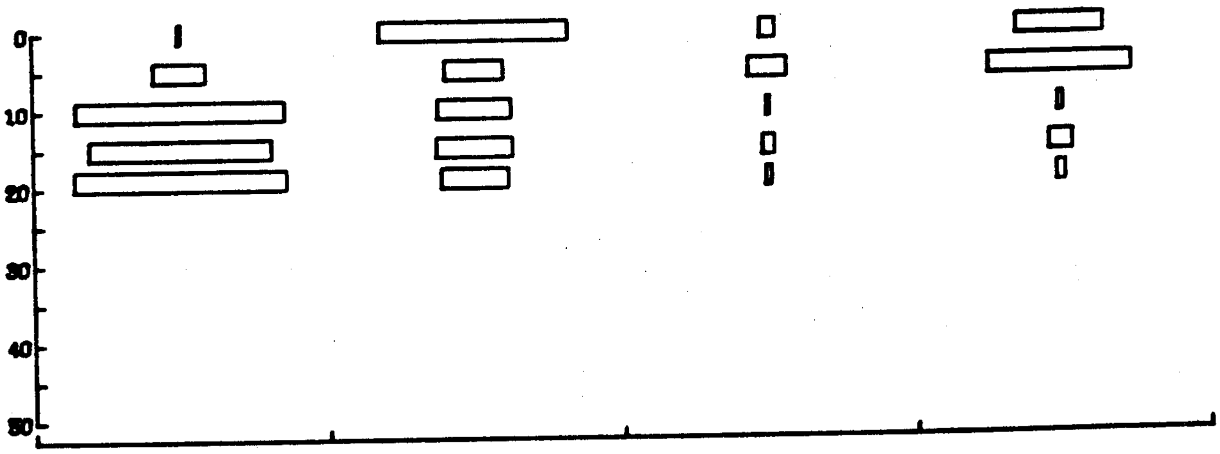
Fig. 13. (continued)



Station 7

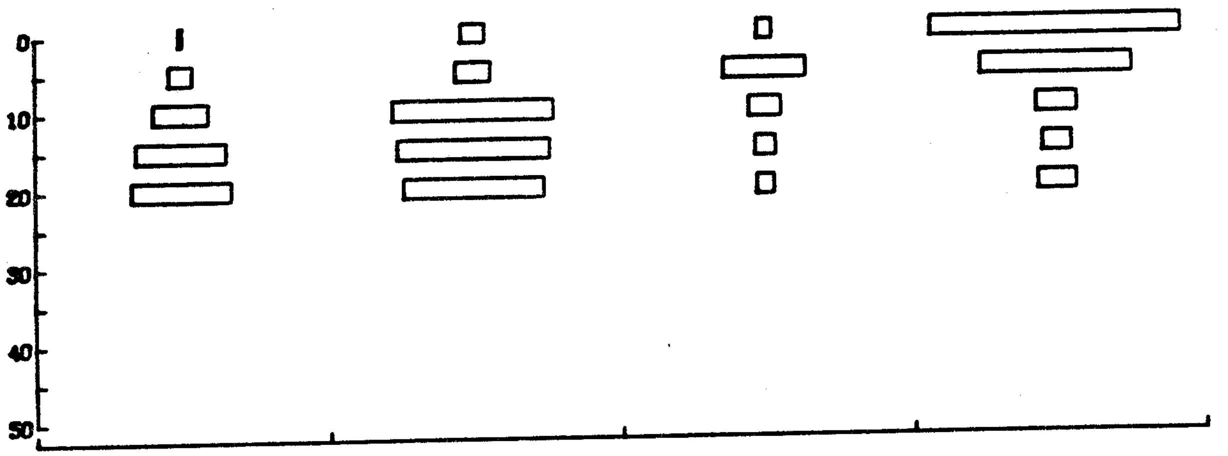


Station 8

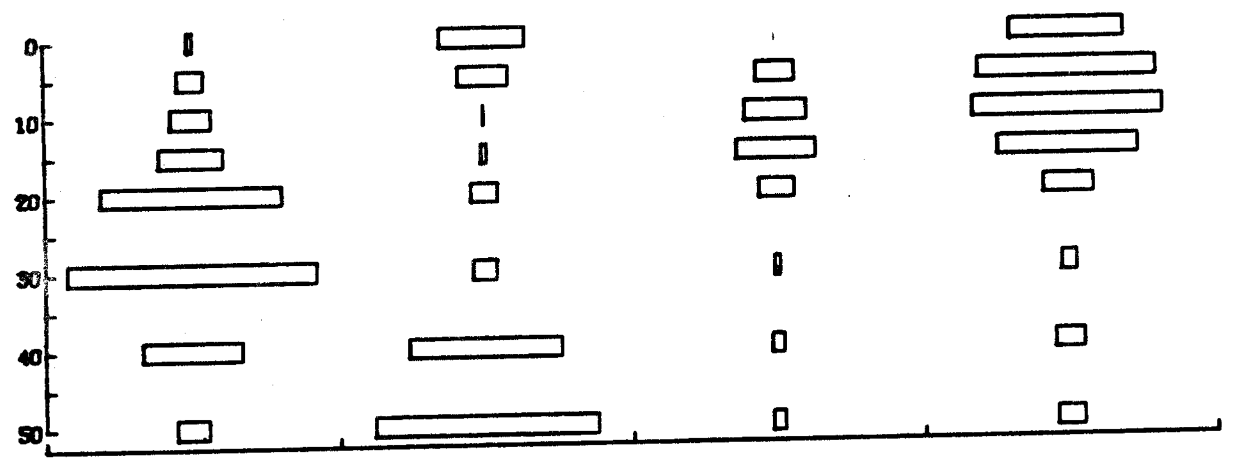


Station 9

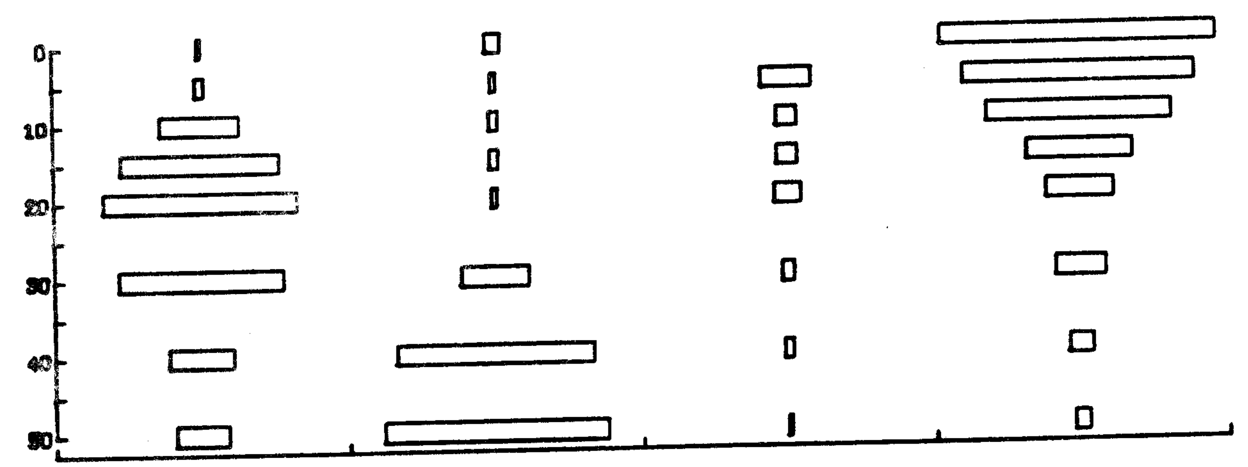
Fig. 13. (continued)



Station 11

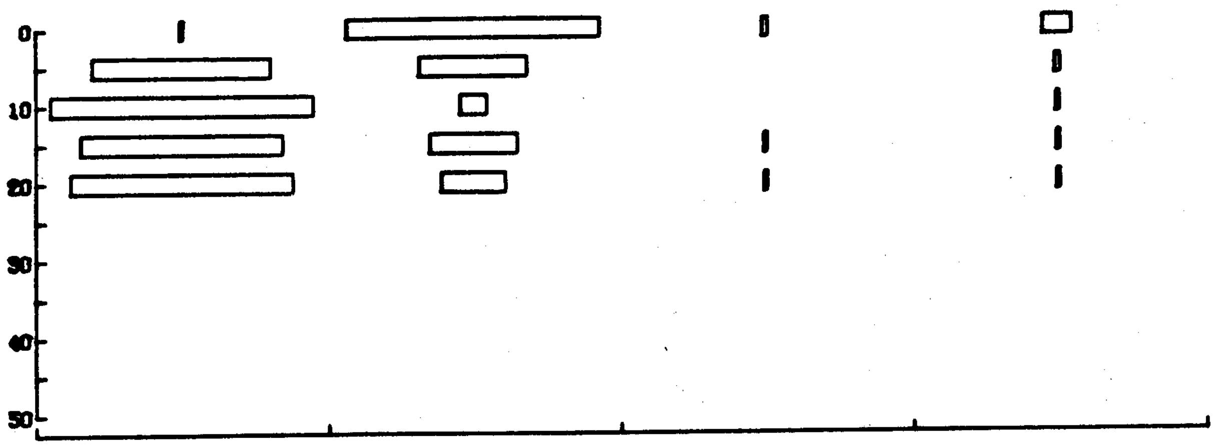


Station 12

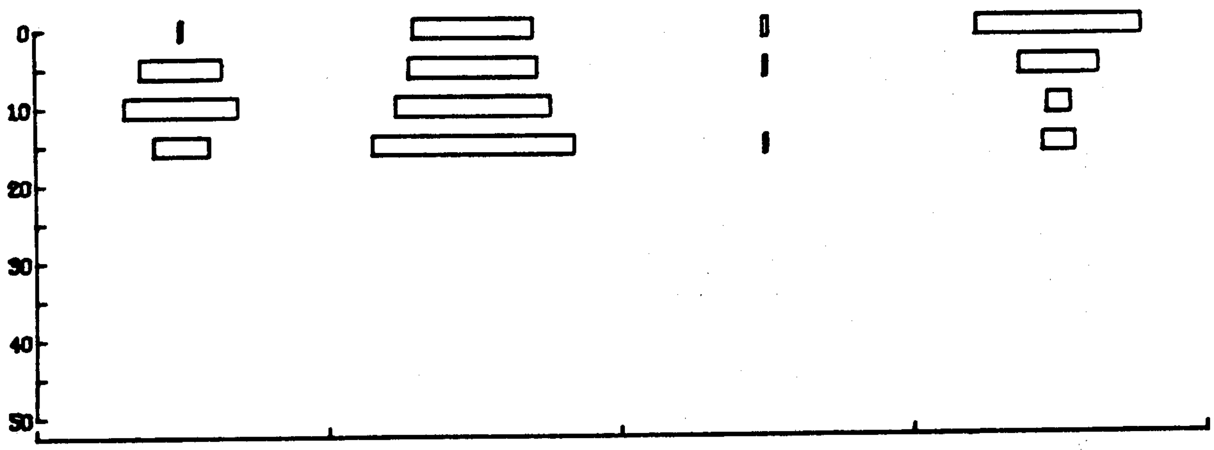


Station 13

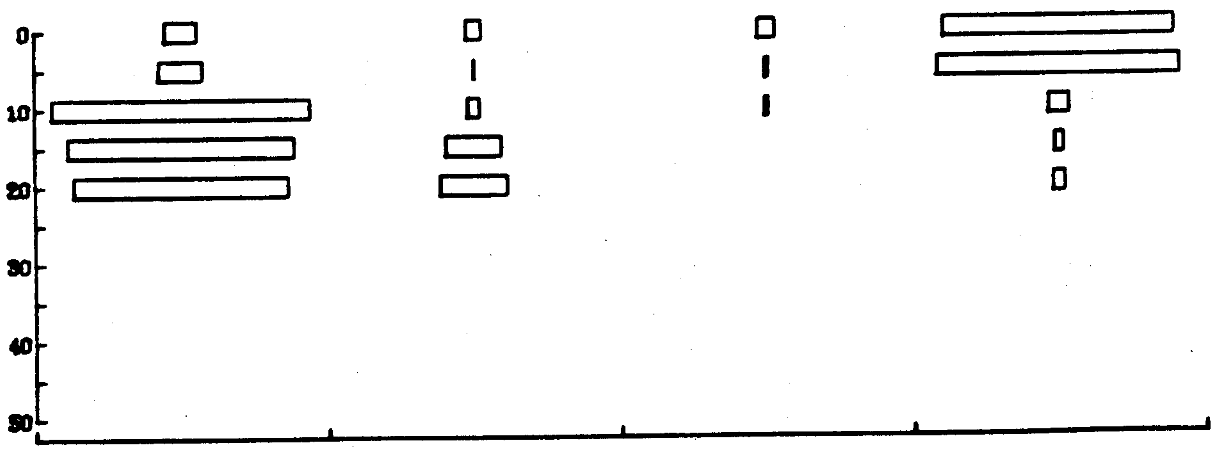
Fig. 13. (continued)



Station 15

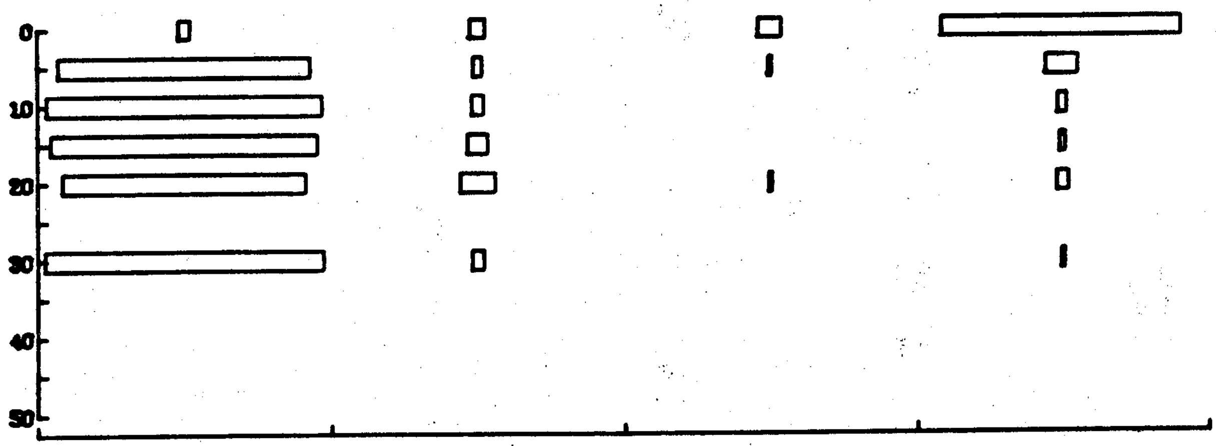


Station 16

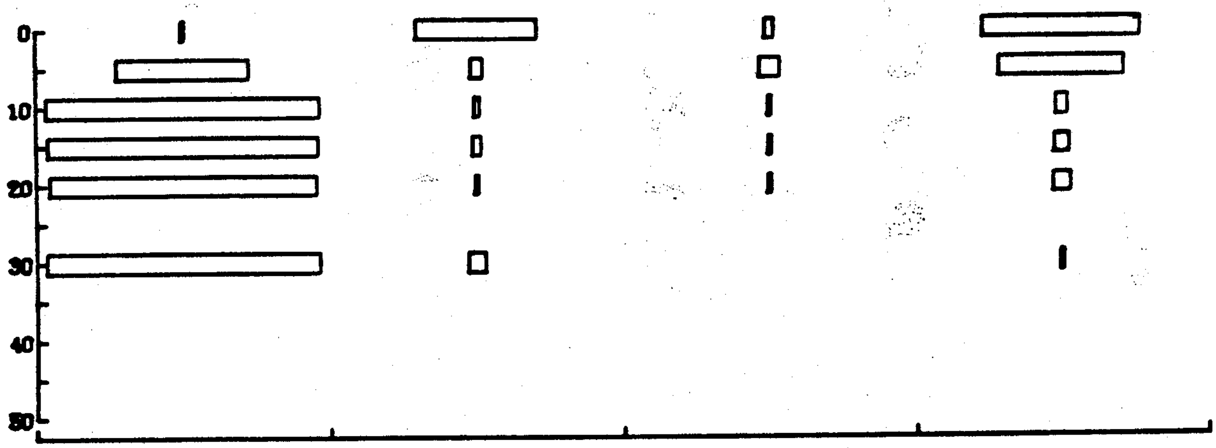


Station 17

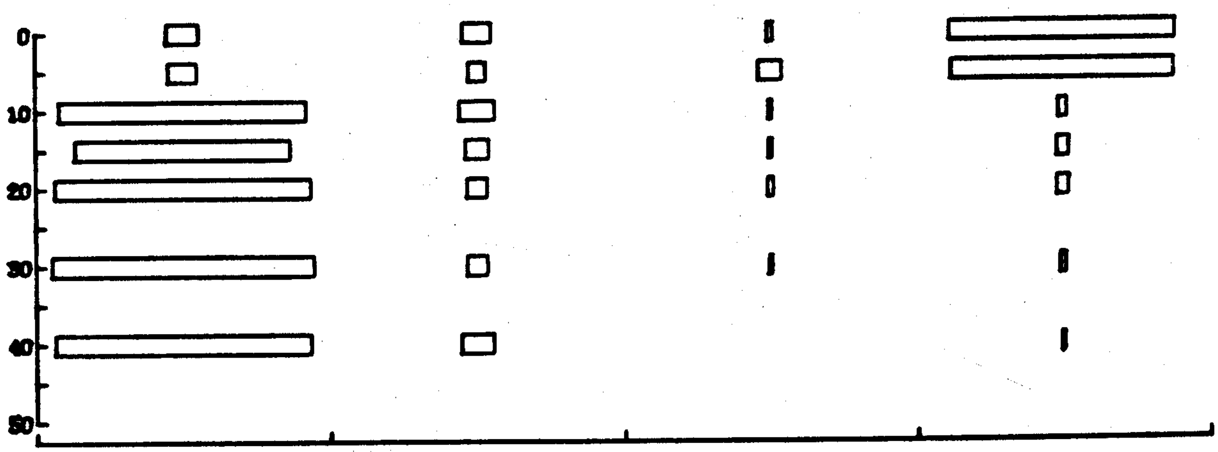
Fig. 13. (continued)



Station 18

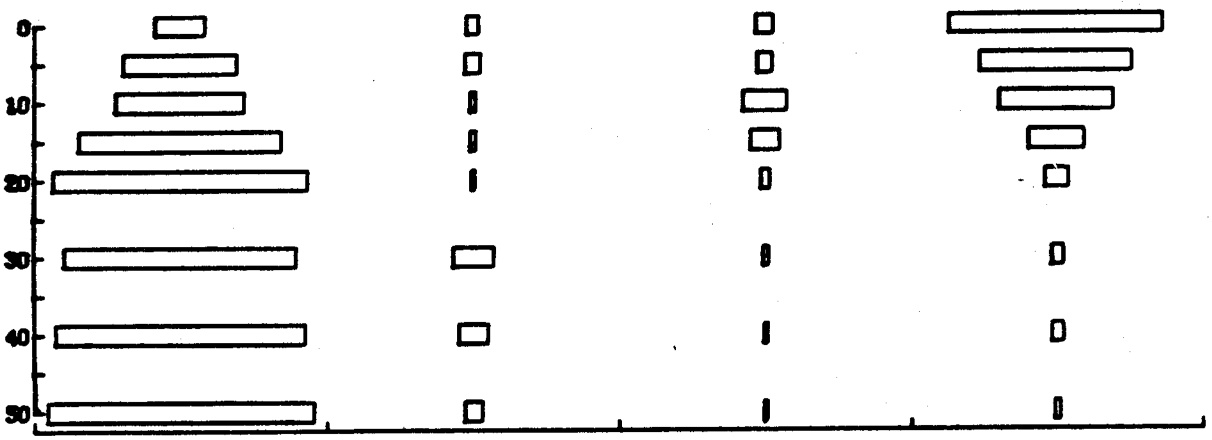


Station 19

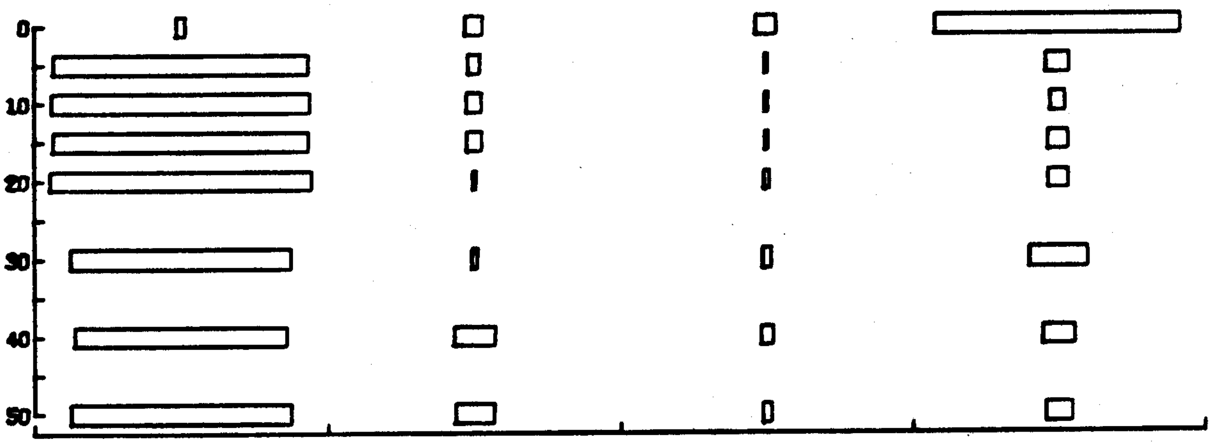


Station 20

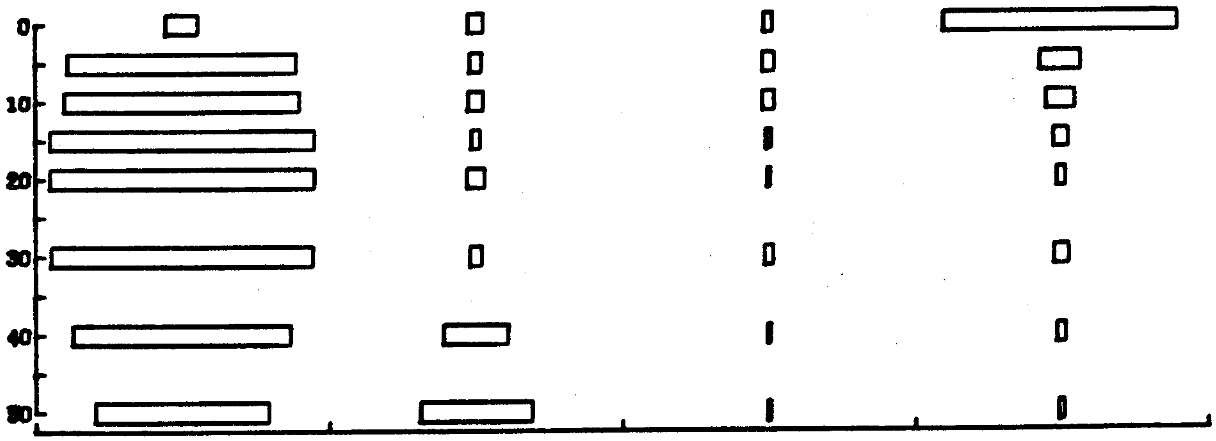
Fig. 13. (continued)



Station 21

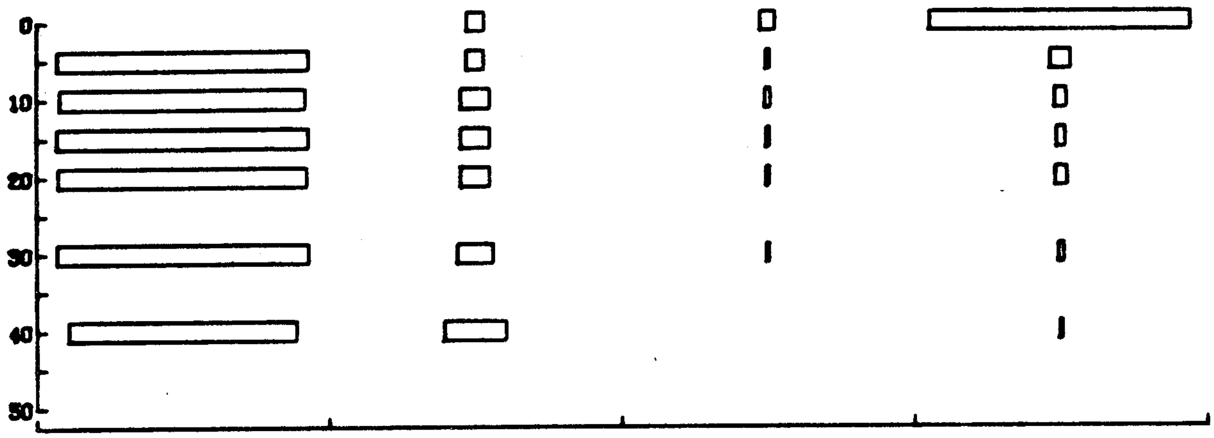


Station 22

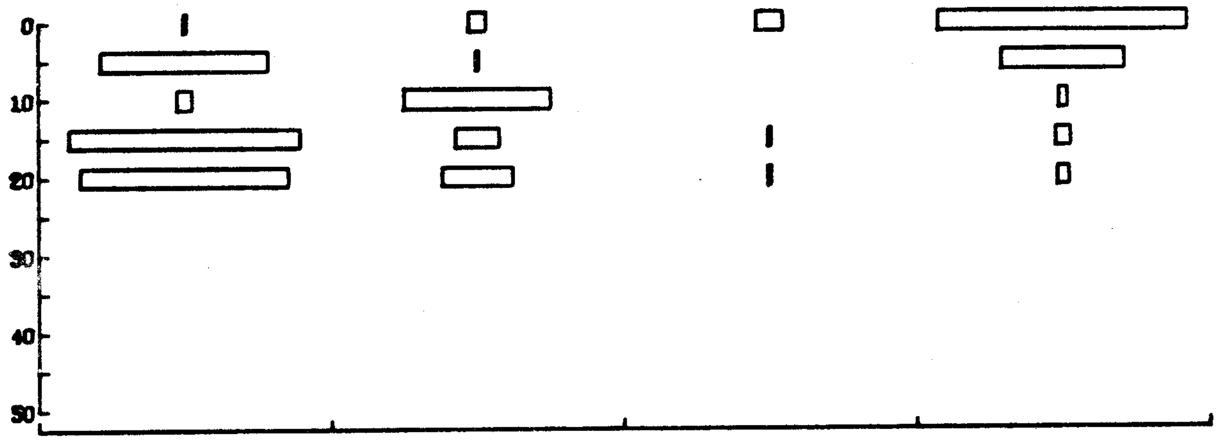


Station 23

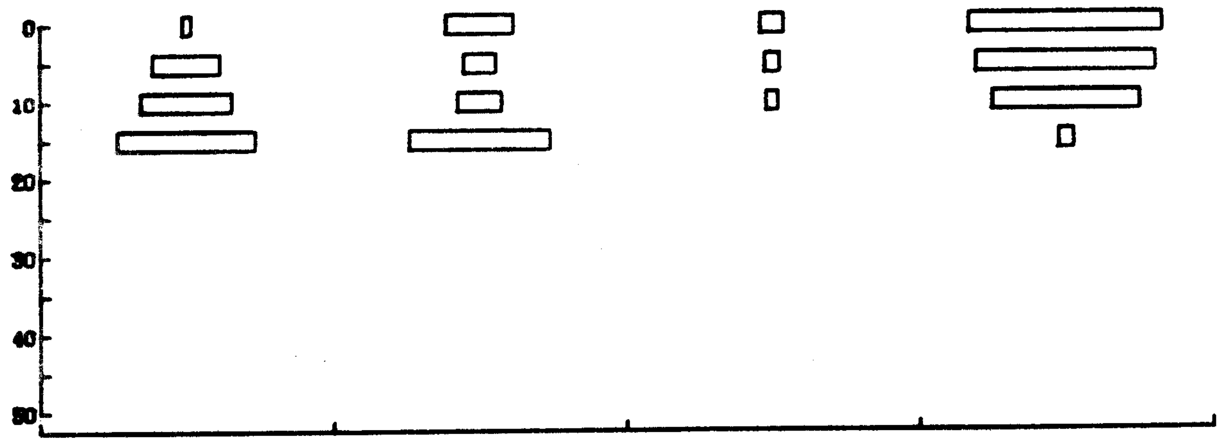
Fig. 13. (continued)



Station 24

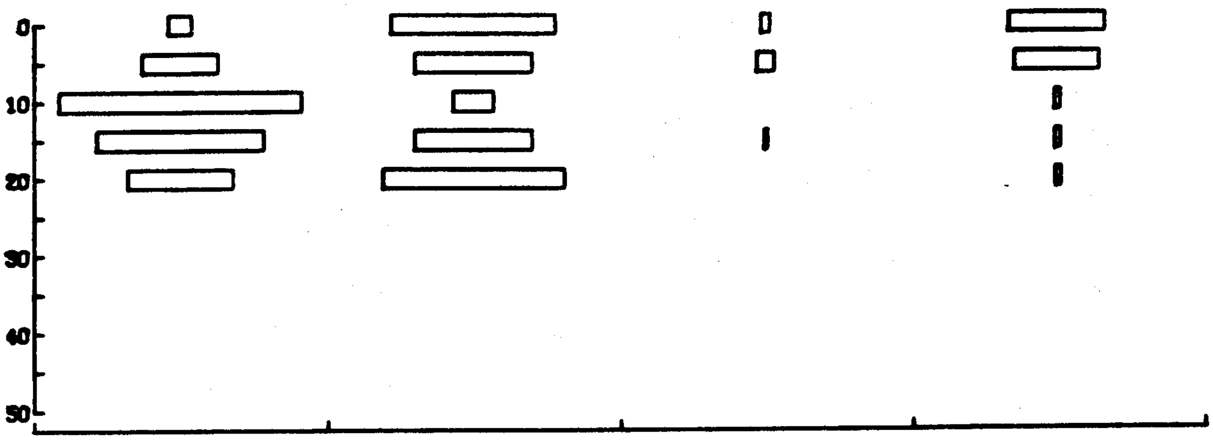


Station 25

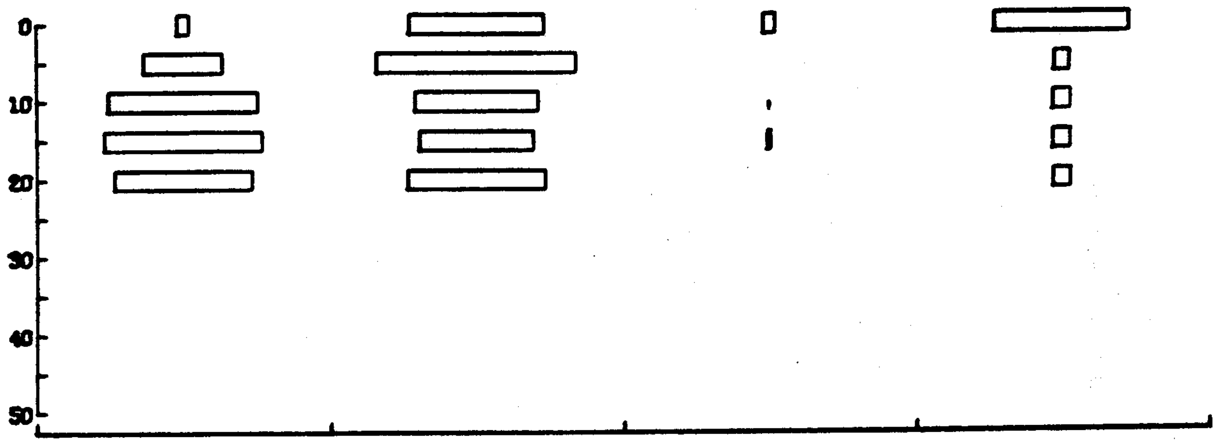


Station 26

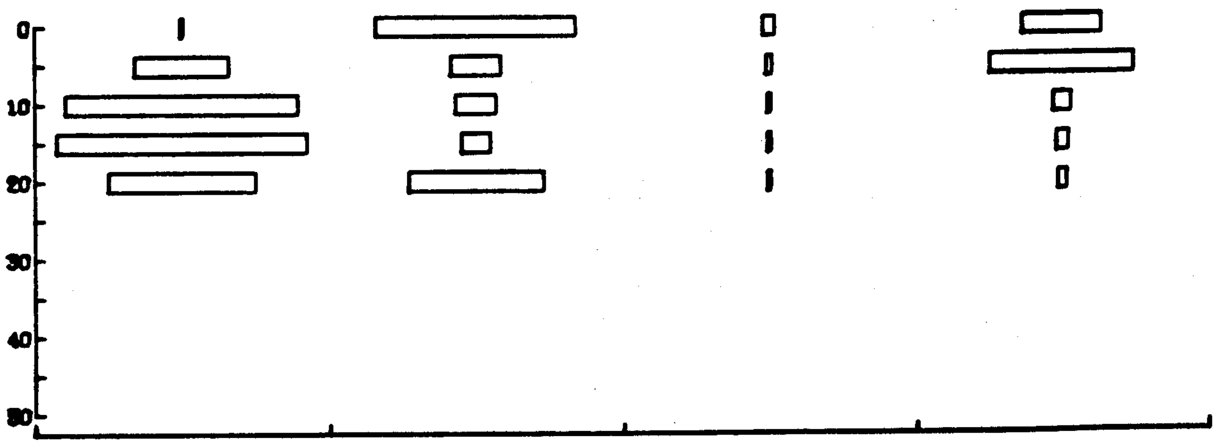
Fig. 13. (continued)



Station 27

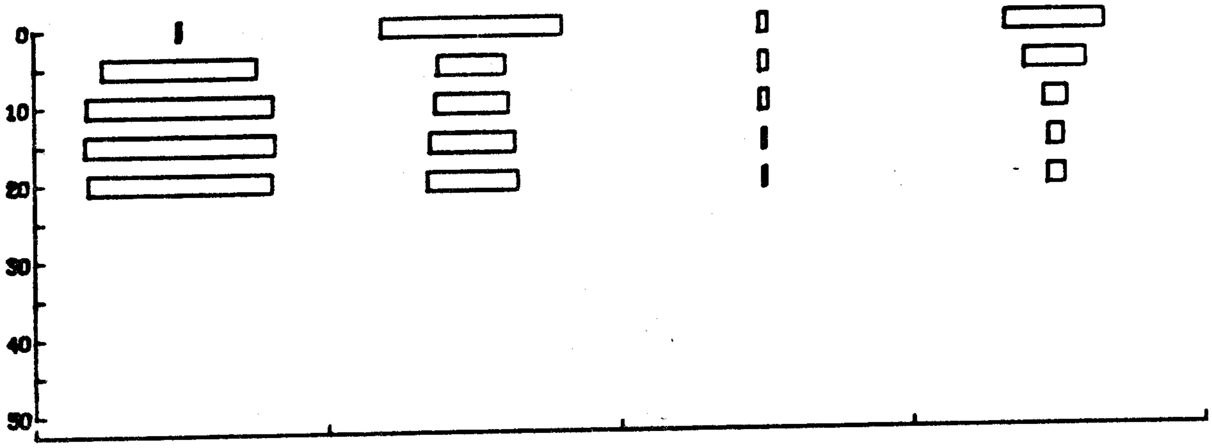


Station 28

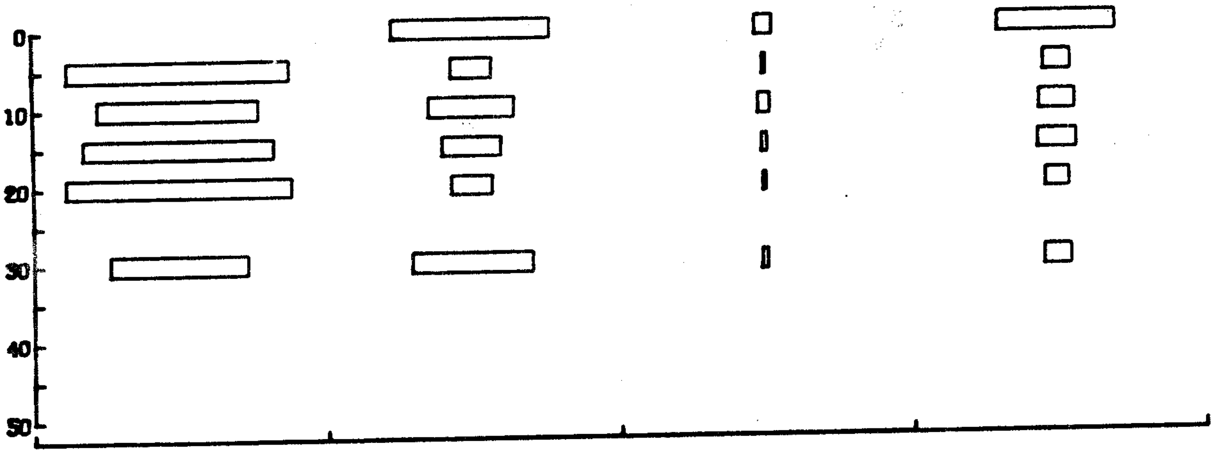


Station 29

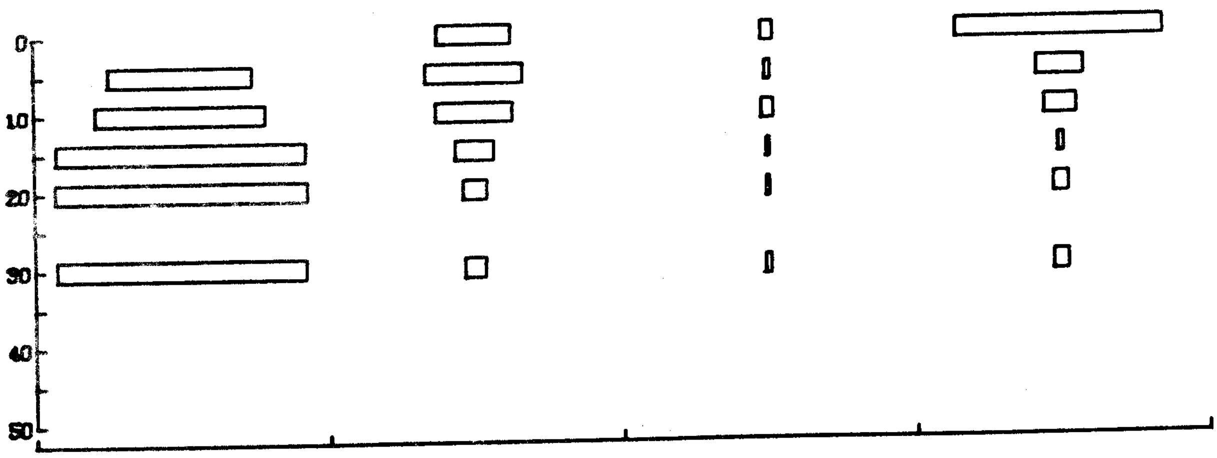
Fig. 13. (continued)



Station 30

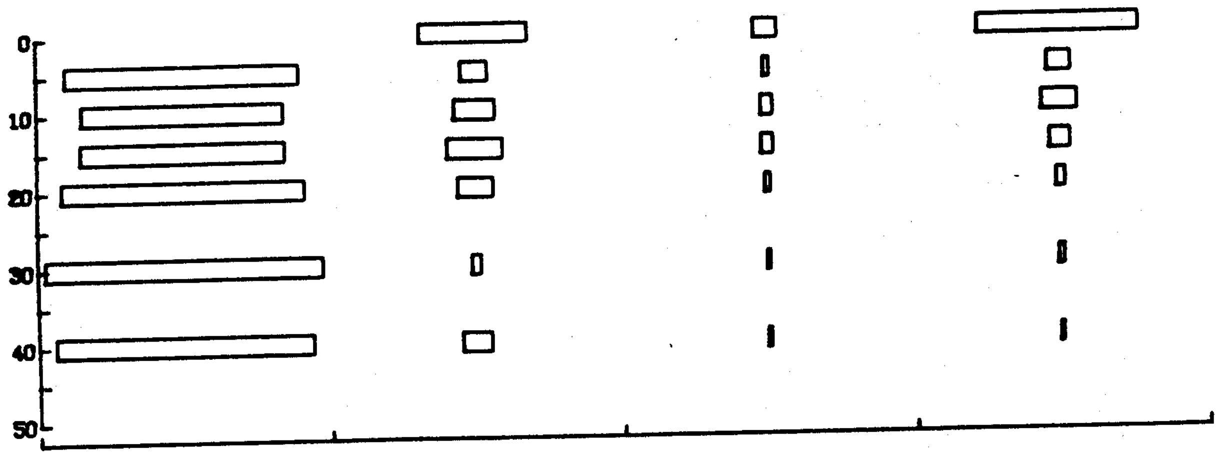


Station 31

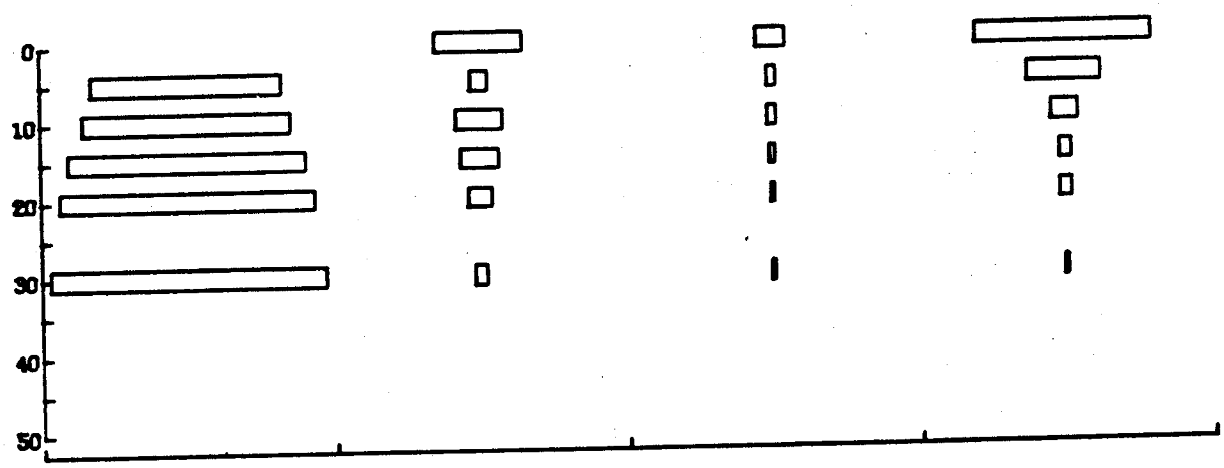


Station 32

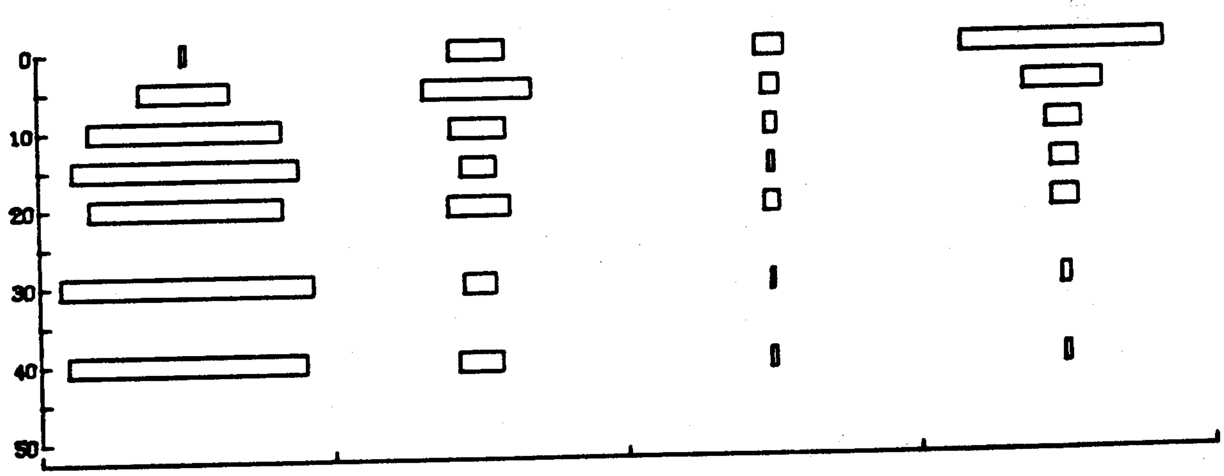
Fig. 13. (continued)



Station 33

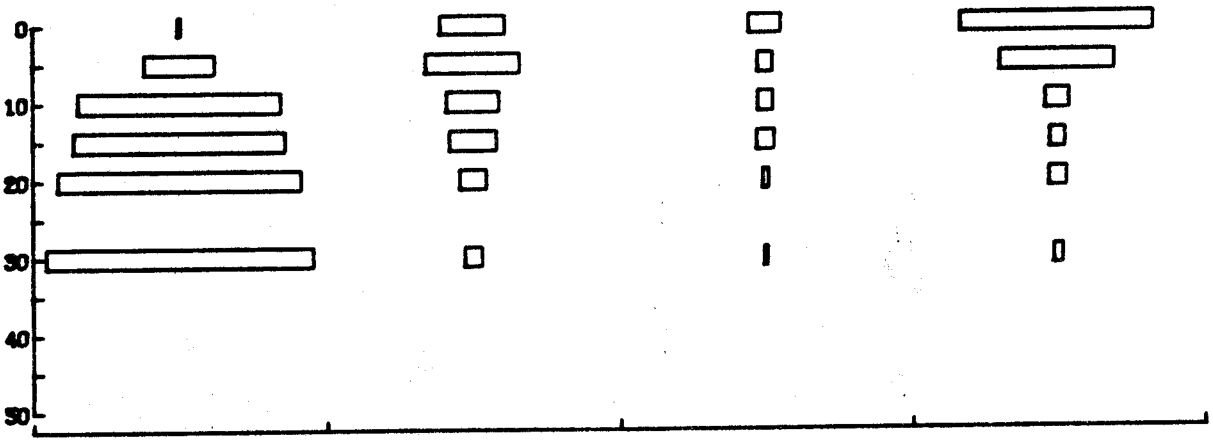


Station 34

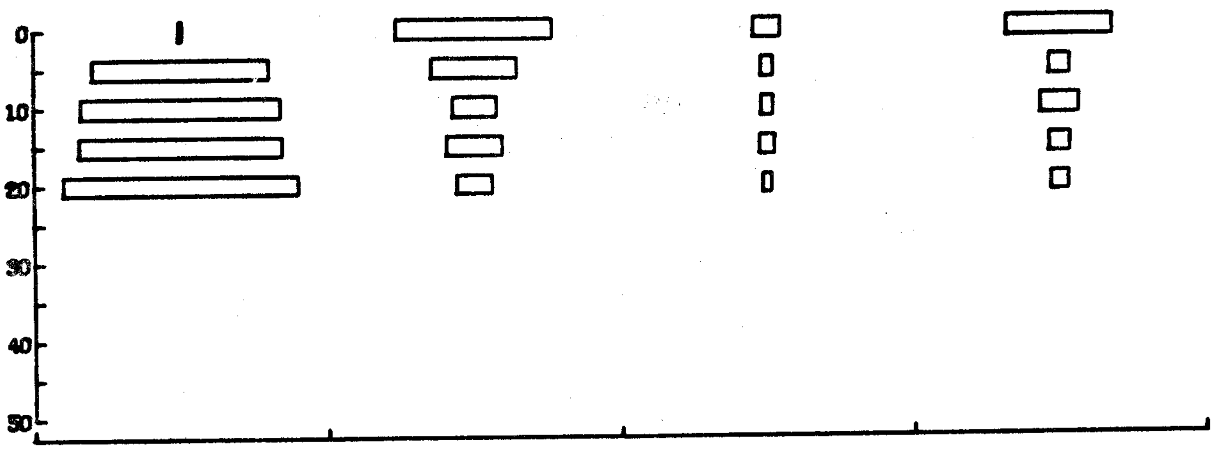


Station 35

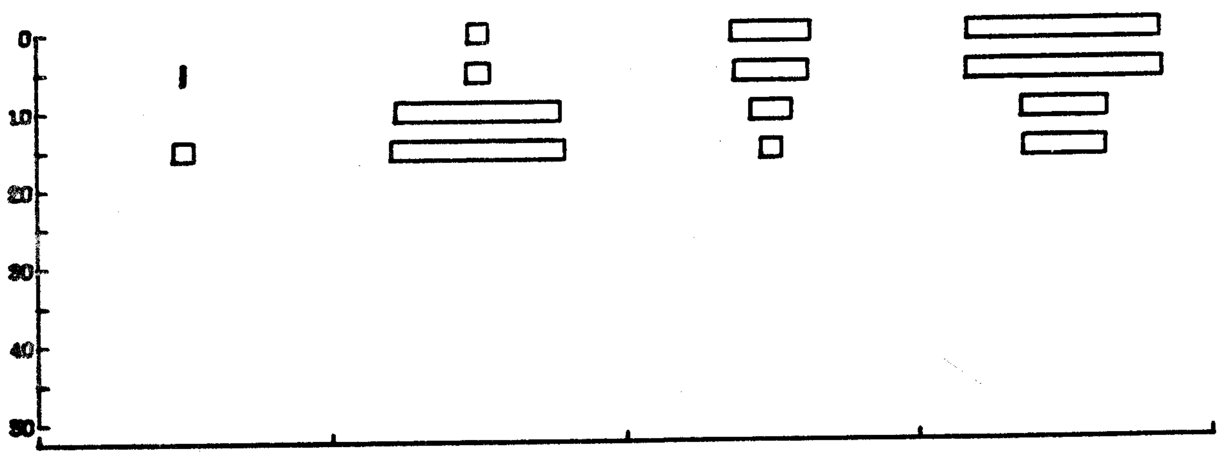
Fig. 13. (continued)



Station 36

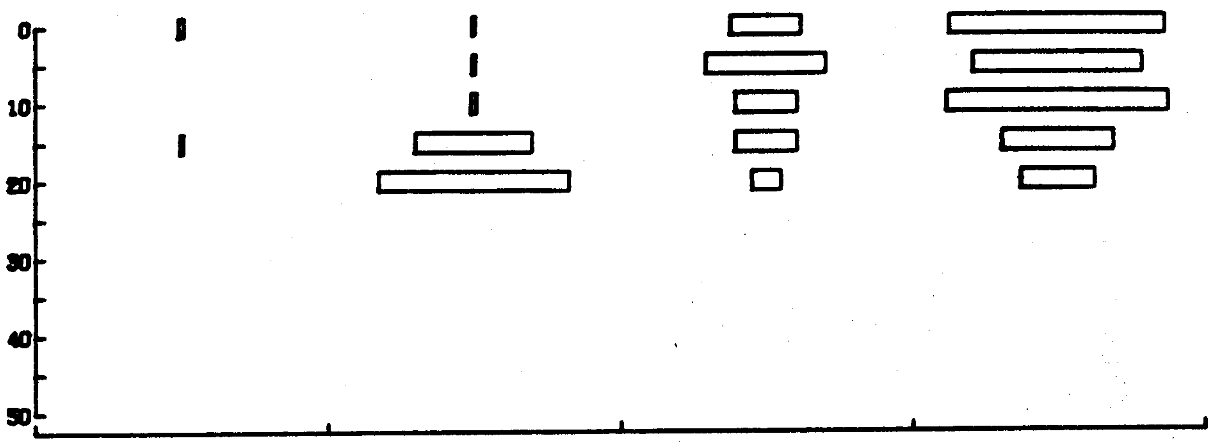


Station 37

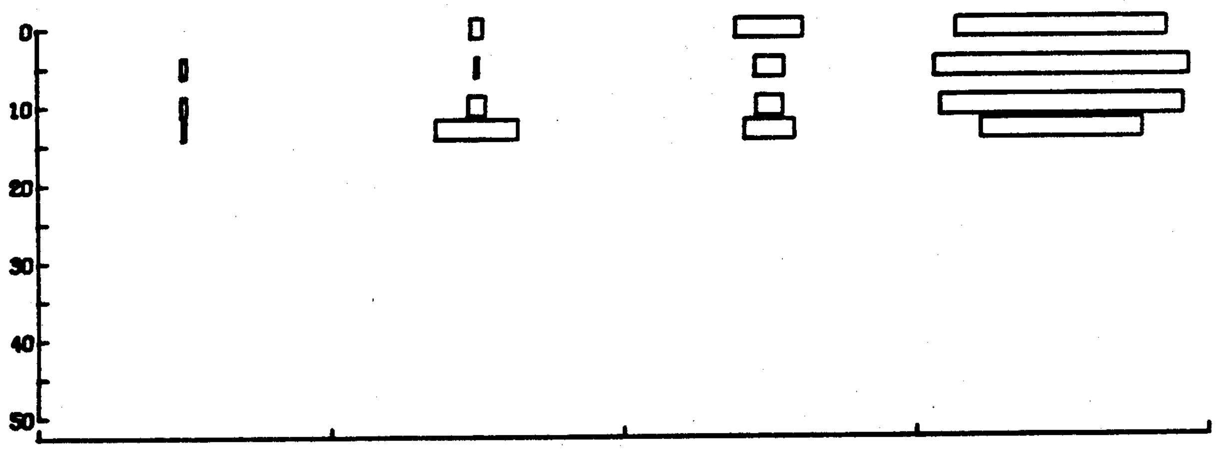


Station 39

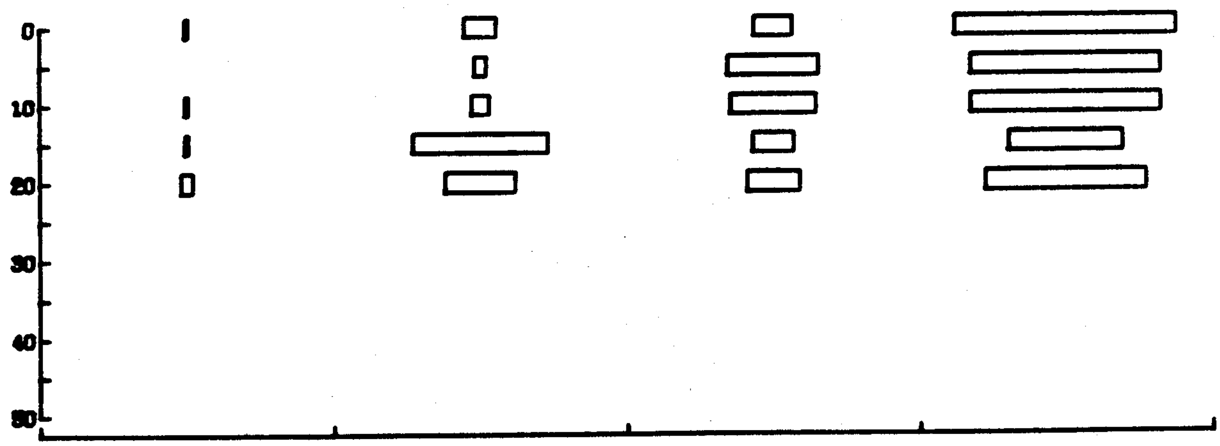
Fig. 13. (continued)



Station 40

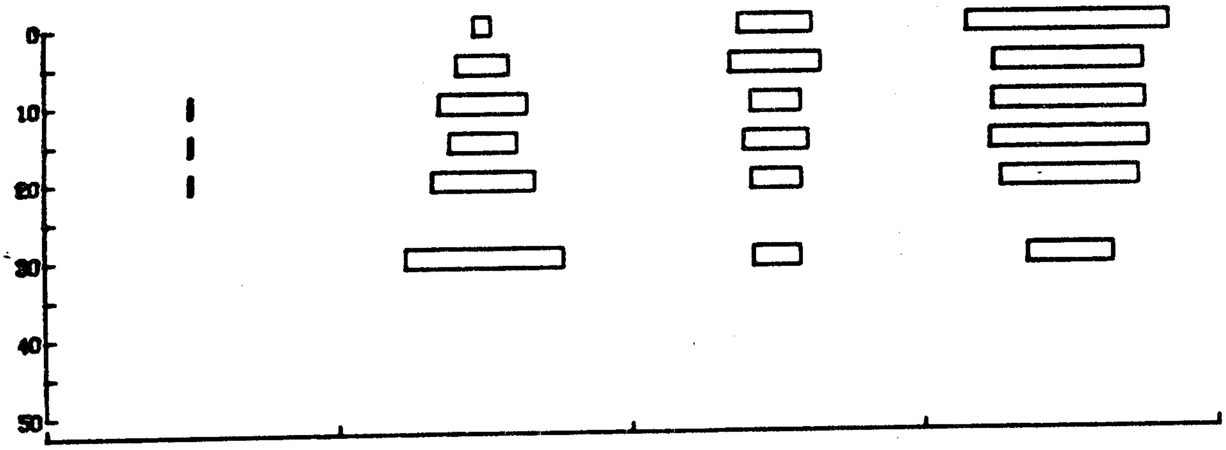


Station 41

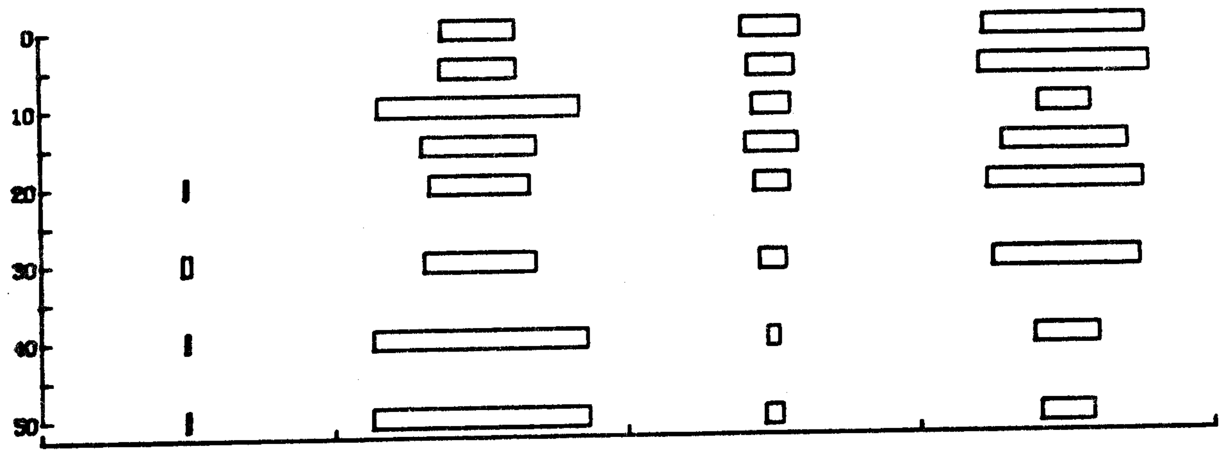


Station 42

Fig. 13. (continued)



Station 43



Station 44

Fig. 13. (continued)

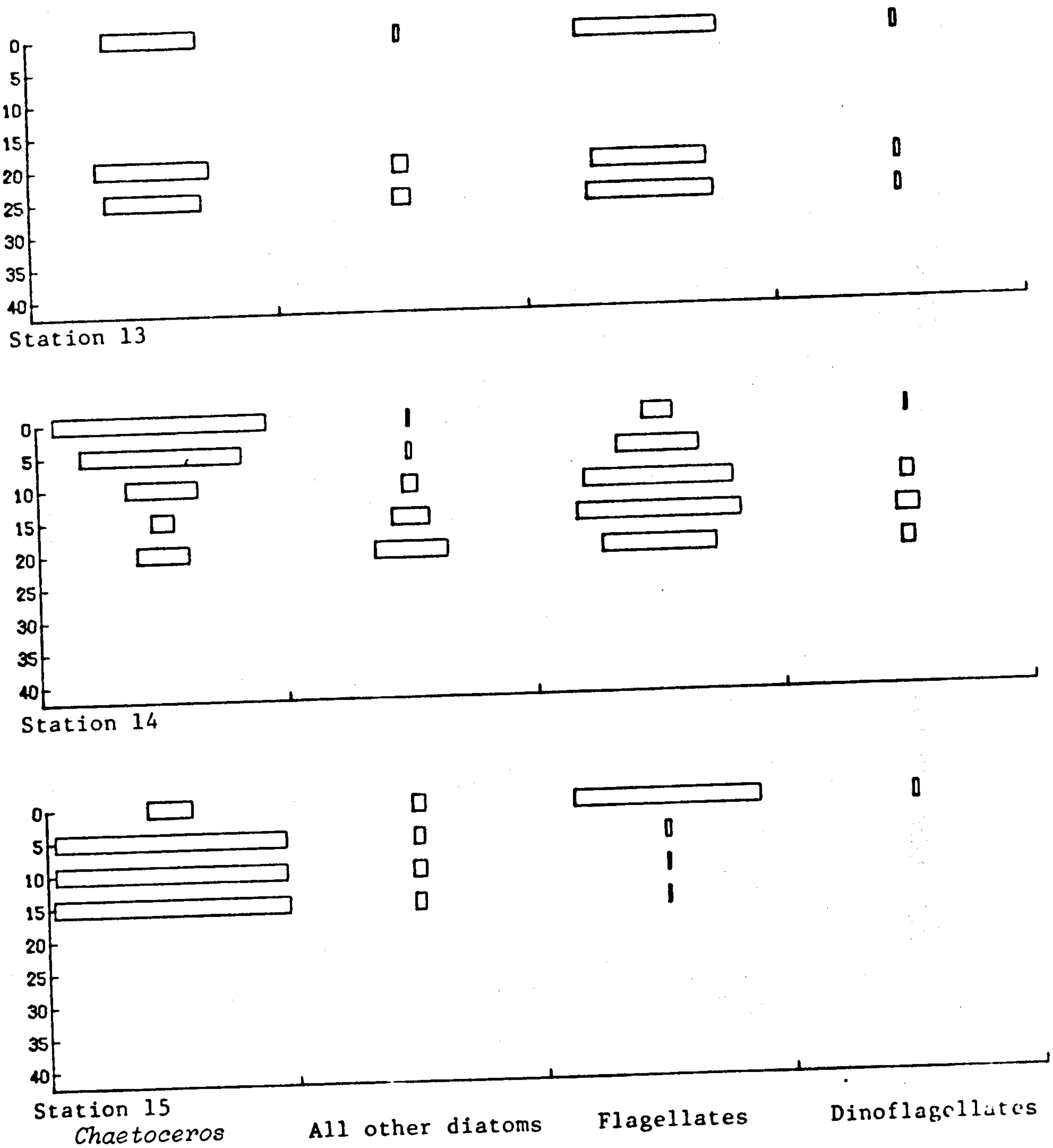


Fig. 14. Percentage of phytoplankton by major category by depth for each station, CGC *Glacier* 1976. Blanks indicate depths where samples were not analyzed. Percentages add up to 100% running from left to right across the diagram.

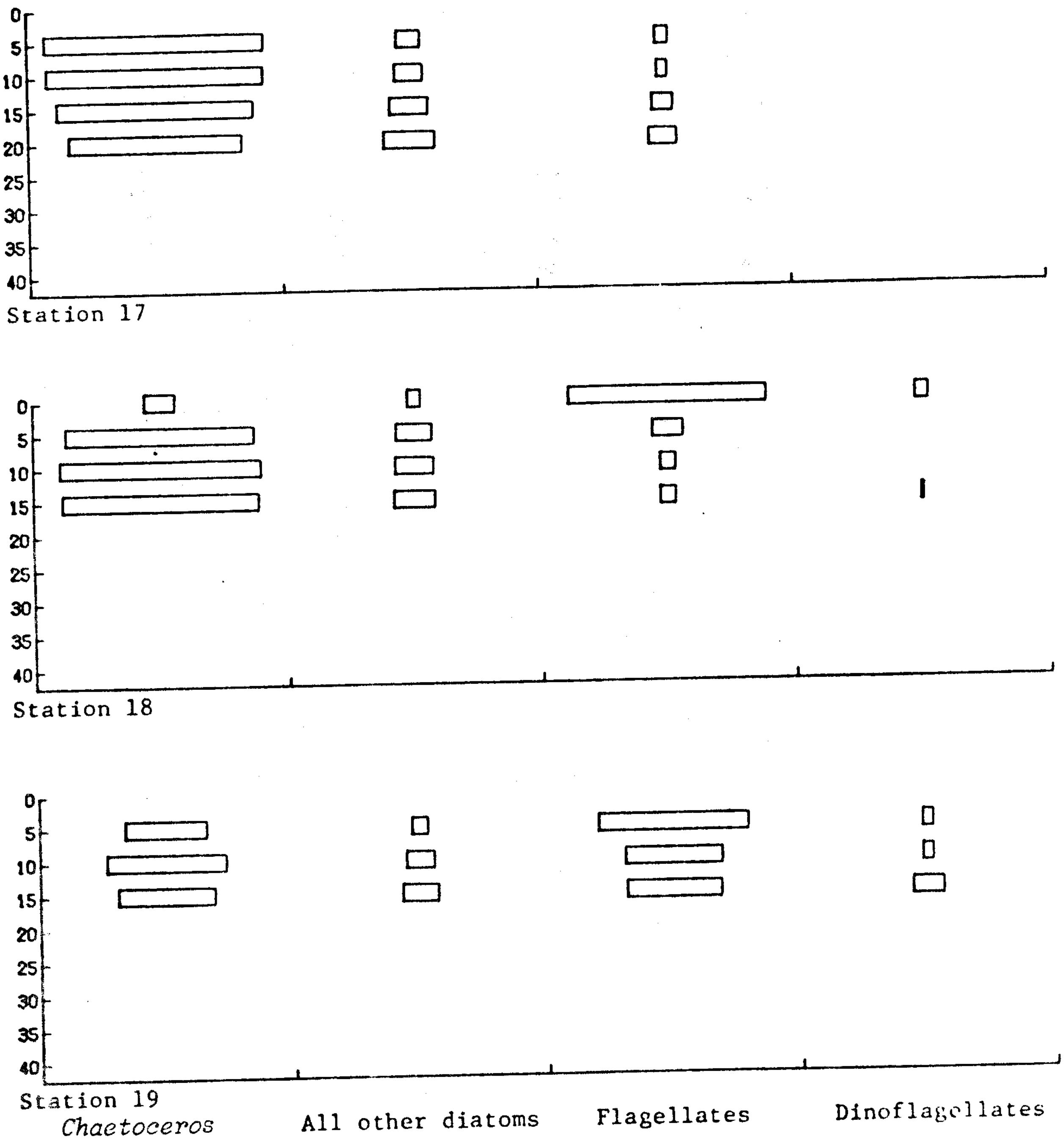


Fig. 14. (continued)

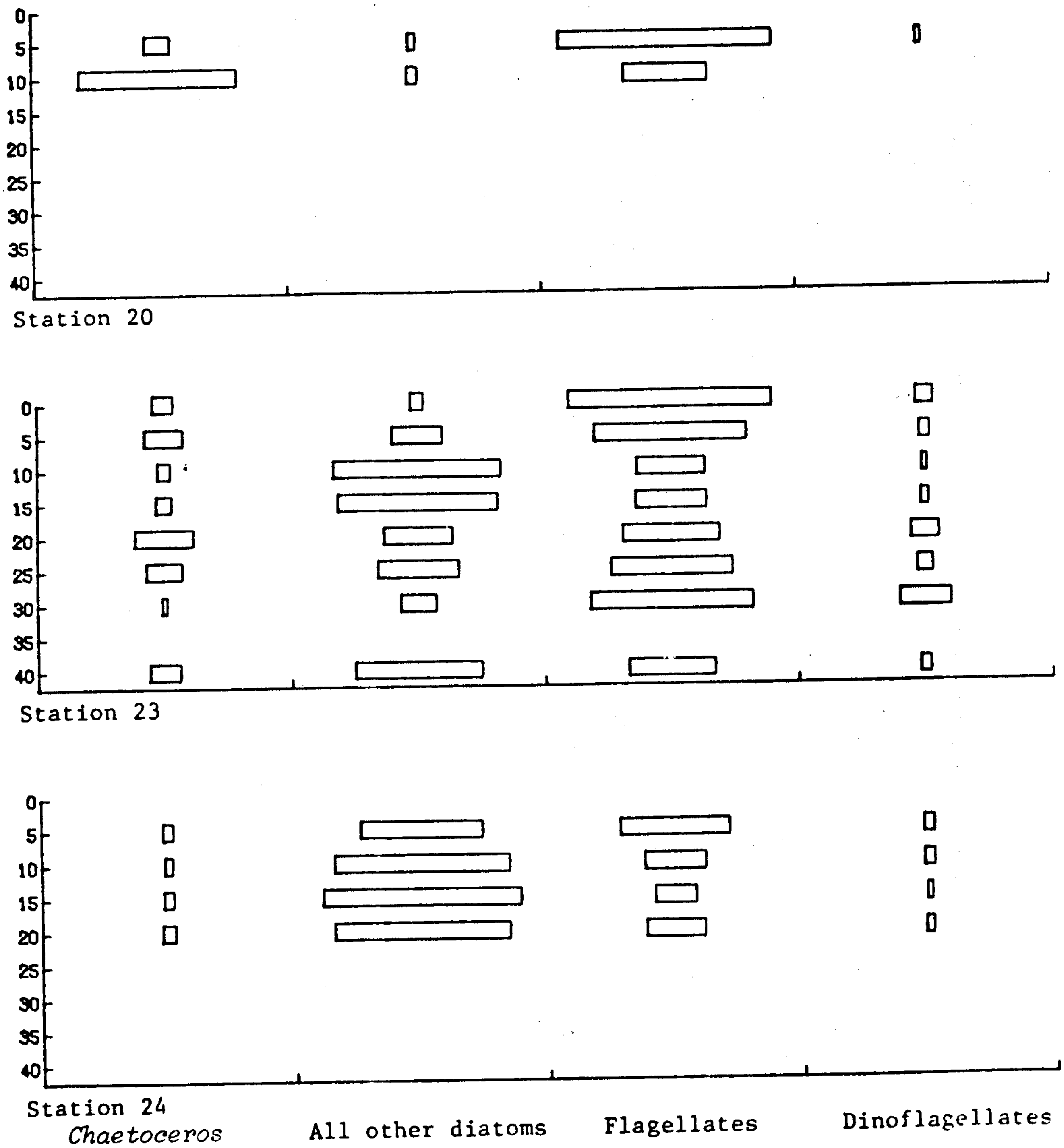


Fig. 14. (continued)

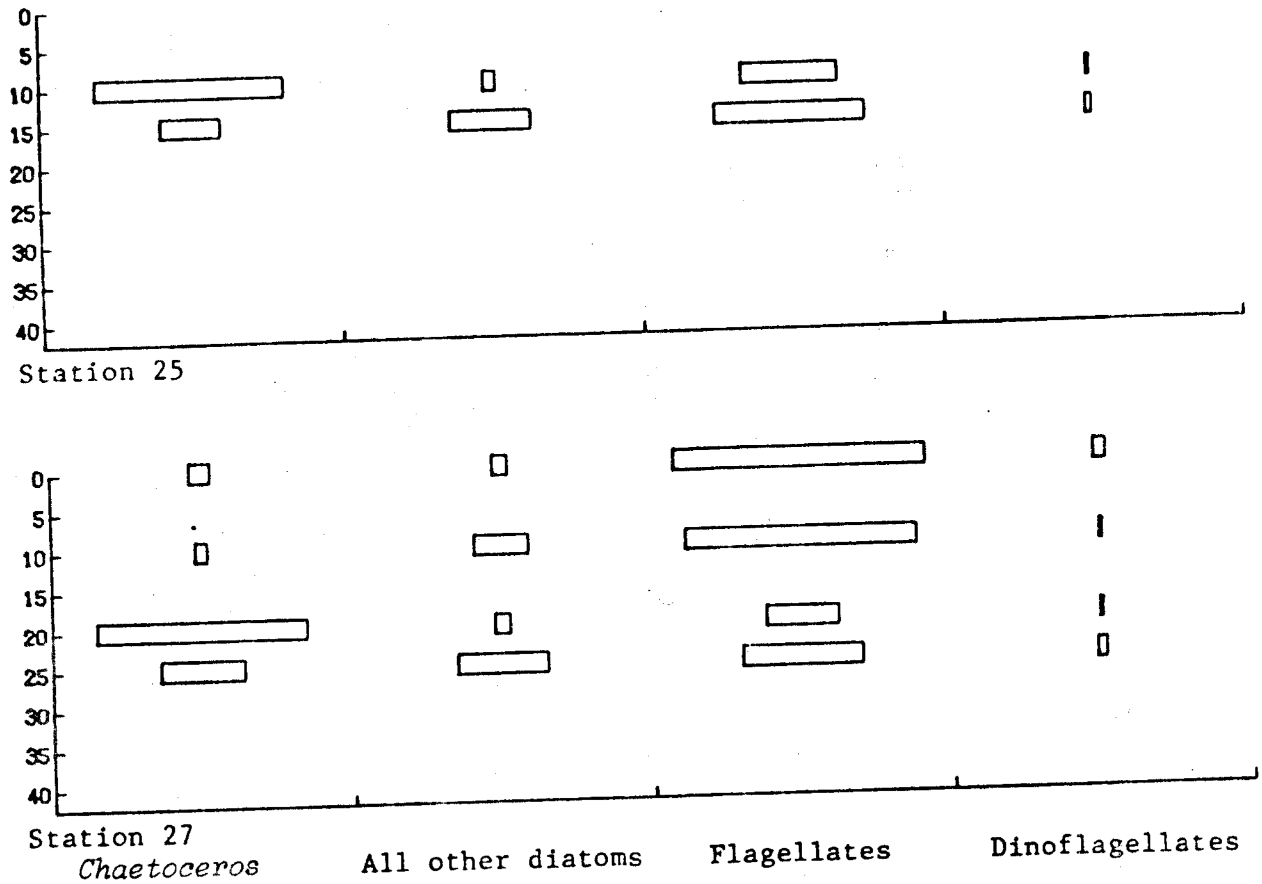


Fig. 14. (continued)

previously reported as *Peridinium*.)

Primary productivity was not measured during the 1973 cruise. Chlorophyll *a* is listed in Table 4 and vertical profiles of chlorophyll *a* and total cell numbers are shown in Fig. 8. Chlorophyll *a* in the upper 50 m ranged from 0.27 mg m^{-3} at station 15-00 to 8.77 mg m^{-3} at station 9-19. Integrated chlorophyll *a* ranged from 13 mg m^{-2} at station 41 to 566 mg m^{-2} at station 13.

Generally, where chlorophyll *a* was high, cell numbers were high; where the chlorophyll concentration did not vary much with depth, the cell numbers did not vary much with depth. Highest chlorophyll *a* concentrations usually occurred at depth and where *Chaetoceros* spp. or all other diatoms were most abundant. Relatively high chlorophyll occurred at the surface at station 34 where flagellates were most numerous. At stations 40-43, the highest chlorophyll concentration was at 5-10 m and where a combination of unidentified flagellates and dinoflagellates were most abundant; however, the highest chlorophyll concentration at these stations was only 1.55 mg m^{-3}.

Phytoplankton standing stock samples collected in the Beaufort Sea in 1974 have not been analyzed. Only chlorophyll *a* concentrations are available for the Beaufort Sea (Table 5, Fig. 9). Chlorophyll *a* ranged from 0.15 mg m^{-3} at station 97-10 to 7.24 mg m^{-3} at station 84-10. Concentrations were low, usually < 1.00 mg m^{-3} throughout the cruise, with high concentrations usually below the surface. Highest chlorophyll *a* concentrations generally occurred at stations 84-90 located near the 20 m isobath from Barter Island west to about 147°15'W. Integrated chlorophyll values ranged from 12 mg m^{-2} at station 97 to 234 mg m^{-2} at station 77.

In 1976, 75 categories of phytoplankton from six phyla, including 61 species and 14 other categories such as unidentified species and groups of species were found. Standing stock ranged from *ca.* 1.0 x 10^5 cells ℓ^{-1} at station 14-20 to 5.0 x 10^6 cells ℓ^{-1} at station 15-10. Small flagellates were the most abundant organisms at station 14-10 with *ca.* 5.0 x 10^4 cells ℓ^{-1}, while *Chaetoceros* spp., with 4.7 x 10^6 cells ℓ^{-1}, was most abundant at station 15-10.

Species of *Chaetoceros* were the most abundant organisms at most stations (Fig. 14) and were especially numerous below the surface at stations 15, 17, and 18 near Prudhoe Bay. In addition to *Chaetoceros* spp., identified *Chaetoceros* species included *Ch. atlanticus*, *Ch. compressus*, *Ch. concavicornis*, *Ch. debilis*, and *Ch. septentrionalis*.

Cylindrotheca closterium and *Leptocylindrus minimus* were most abundant in warm water at stations 23-24.

Small flagellates, mostly < 10 μm in diameter, were generally more abundant at western stations and at the surface at the eastern stations. Where flagellates were abundant, productivity and chlorophyll *a* were low, suggesting that many of the flagellates were not photosynthetic (Table 11).

Primary productivity and chlorophyll *a* values are listed in Table 6

Table 11. Per cent *Chaetoceros* species, all other diatoms, flagellates, and dinoflagellates at depth of greatest carbon uptake, 17 Aug - 2 Sep 1976.

Station Depth \ Category	*Chaetoceros* spp.	All other diatoms	Flagellates	Dinoflagellates
13-20	46	6	46	2
14-05	65	2	33	< 1
15-05	93	4	2	< 1
17-10	85	11	4	< 1
18-10	79	15	6	< 1
19-05	32	6	59	4
20-10	62	4	33	< 1
23-15	6	63	28	3
24-15	4	78	16	2
25-10	63	4	32	1
27-10	71	5	24	1

and vertical profiles are shown in Fig. 10. Primary productivity ranged from 0.07 mg C m^{-3} hr^{-1} at station 14-10 to 5.98 mg C m^{-3} hr^{-1} at station 17-10, with integrated productivity ranging from 4 mg C m^{-2} hr^{-1} at station 14 to 150 mg C m^{-2} hr^{-1} at station 12.

Chlorophyll *a* concentrations ranged from 0.12 mg m^{-3} at station 14-20 to 5.38 mg m^{-3} at station 15-15. Integrated chlorophyll values ranged from 7 mg m^{-2} at station 14 to 290 mg m^{-2} at station 21 and 200 mg m^{-2} at station 12.

In general, high carbon uptake occurred at the same depths as high chlorophyll *a* concentrations, but high carbon uptake and high standing stock did not always occur at the same depth. The same species were usually abundant at the depth of greatest productivity except at stations 23 and 24 where *Leptocylindrus minimus* and *Cylindrotheca closterium* were the most abundant species. Relatively high carbon uptake and chlorophyll concentrations were found near Prudhoe Bay except at the surface where small flagellates comprised *ca.* 75% of the population. Primary productivity was generally < 1 mg C m^{-3} hr^{-1} at stations and depths where flagellates were the most abundant.

Seventy-six categories of phytoplankton from five phyla, including 58 species and 18 other categories including unidentified species and groups of species were present in 1977 samples. Standing stock ranged from < 1 x 10^5 to > 12 x 10^6 cells ℓ^{-1}, with the highest numbers occurring at stations 29 and 30 located northwest of Barter Island.

Species of *Chaetoceros*, measuring *ca.* 6 μm along the apical axis, were the most abundant organisms at nearly all stations and depths (Fig. 15). This genus accounted for *ca.* 97% of the total number of cells at depths with the highest cell numbers. Sixteen species of *Chaetoceros* were identified with certainty; other cells were grouped as *Chaetoceros* spp. Other abundant diatoms species were *Bacterosira fragilis*, *Nitzschia grunowii*, and *Thalassiosira* spp., including *T. antarctica*, *T. gravida*, and *T. nordenskioeldii*. *Leptocylindrus minimus*, common in warm water in 1976, was tentatively identified at only one station in 1977.

Small flagellates, < 10 μm in diameter, were generally not as abundant as in 1976, except at station 19 where they comprised almost 100% of the organisms in the upper 30 m. At most depths and stations east of Prudhoe Bay, flagellates comprised less than 20% of the total number of organisms.

Primary productivity and chlorophyll *a* concentrations are listed in Table 7 and vertical profiles are given in Fig. 11. Primary productivity ranged from 0.02 mg C m^{-3} hr^{-1} at station 7-20 to 10.35 mg C m^{-3} hr^{-1} at station 26-06. Integrated productivity ranged from 8.46 mg C m^{-2} hr^{-1} at station 31 to 169.50 mg C m^{-2} hr^{-1} at station 26. *Chaetoceros* spp. and small flagellates were the most abundant organisms at station 7-20, while *Chaetoceros* spp. were the most abundant organisms at stations 26 and 31.

In the upper 50 m, chlorophyll ranged from 0.02 mg m^{-3} at station 38-50 to 18.84 mg m^{-3} at station 26-12. Integrated chlorophyll ranged from 4.50 mg m^{-2} at station 23 to 240.61 mg m^{-2} at station 26. The four

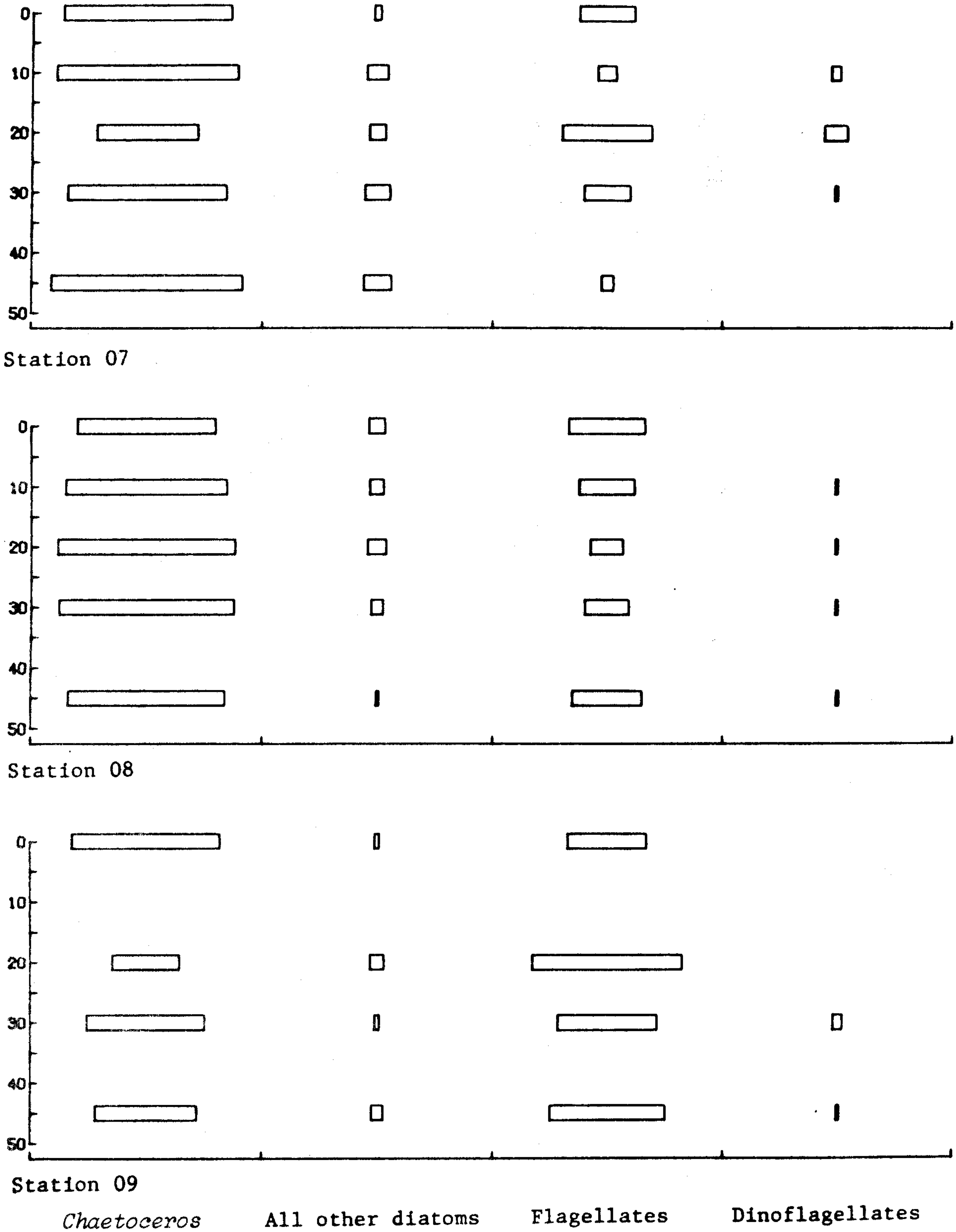


Fig. 15. Percentage of phytoplankton by major category by depth for each station, CGC *Glacier* 1977. Blanks indicate depths were samples were not analyzed. Percentages add up to 100% running from left to right across the diagram.

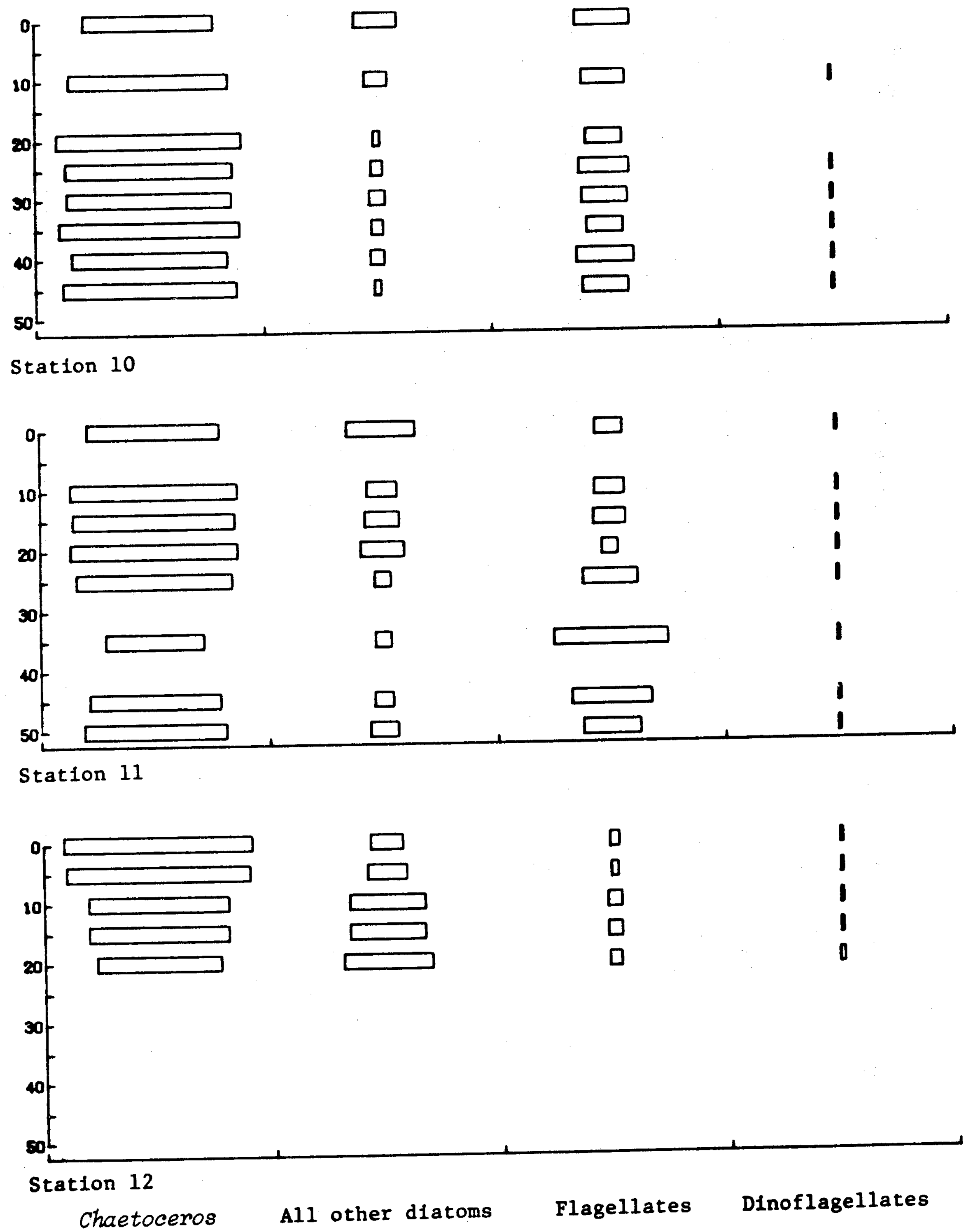


Fig. 15. (continued)

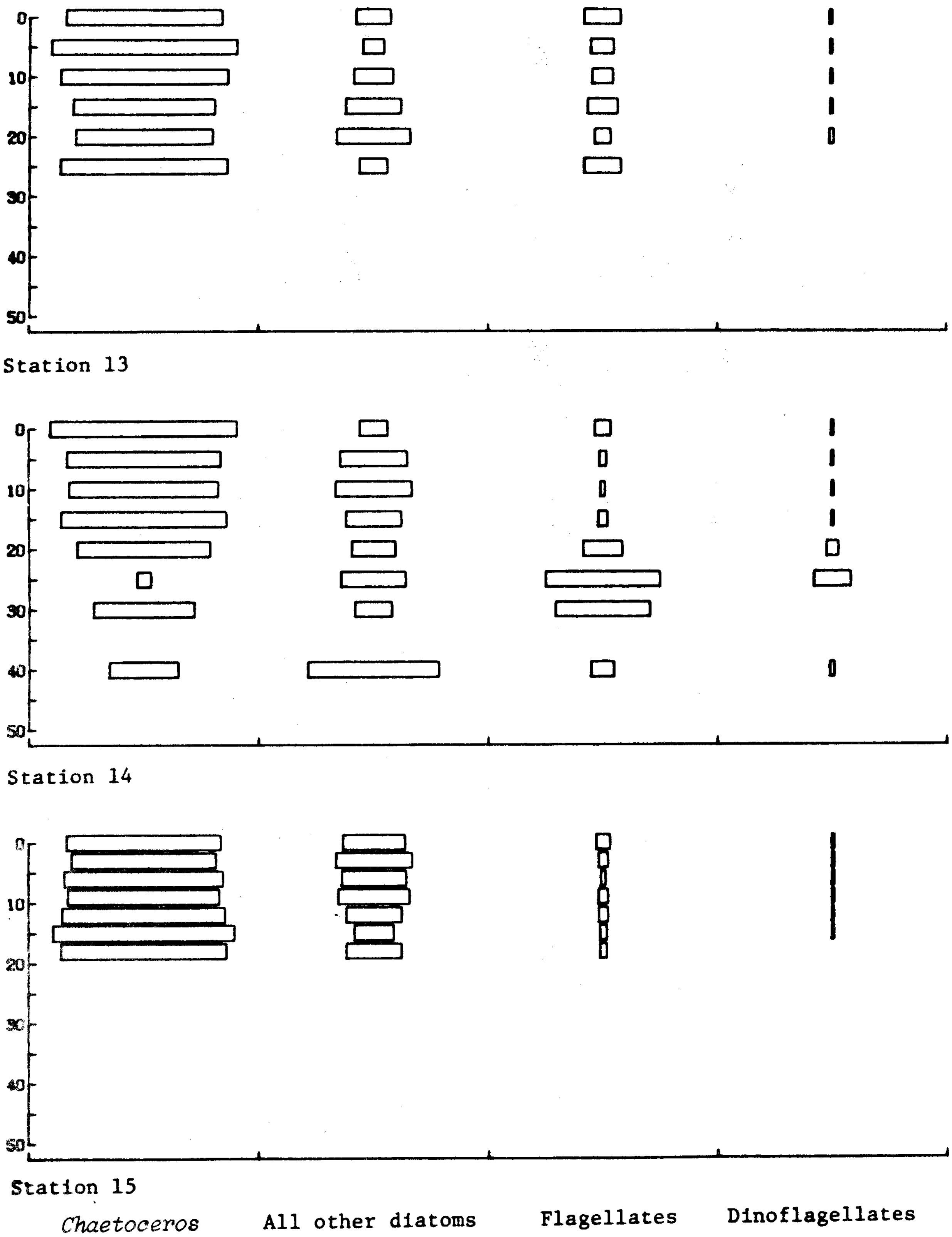


Fig. 15. (continued)

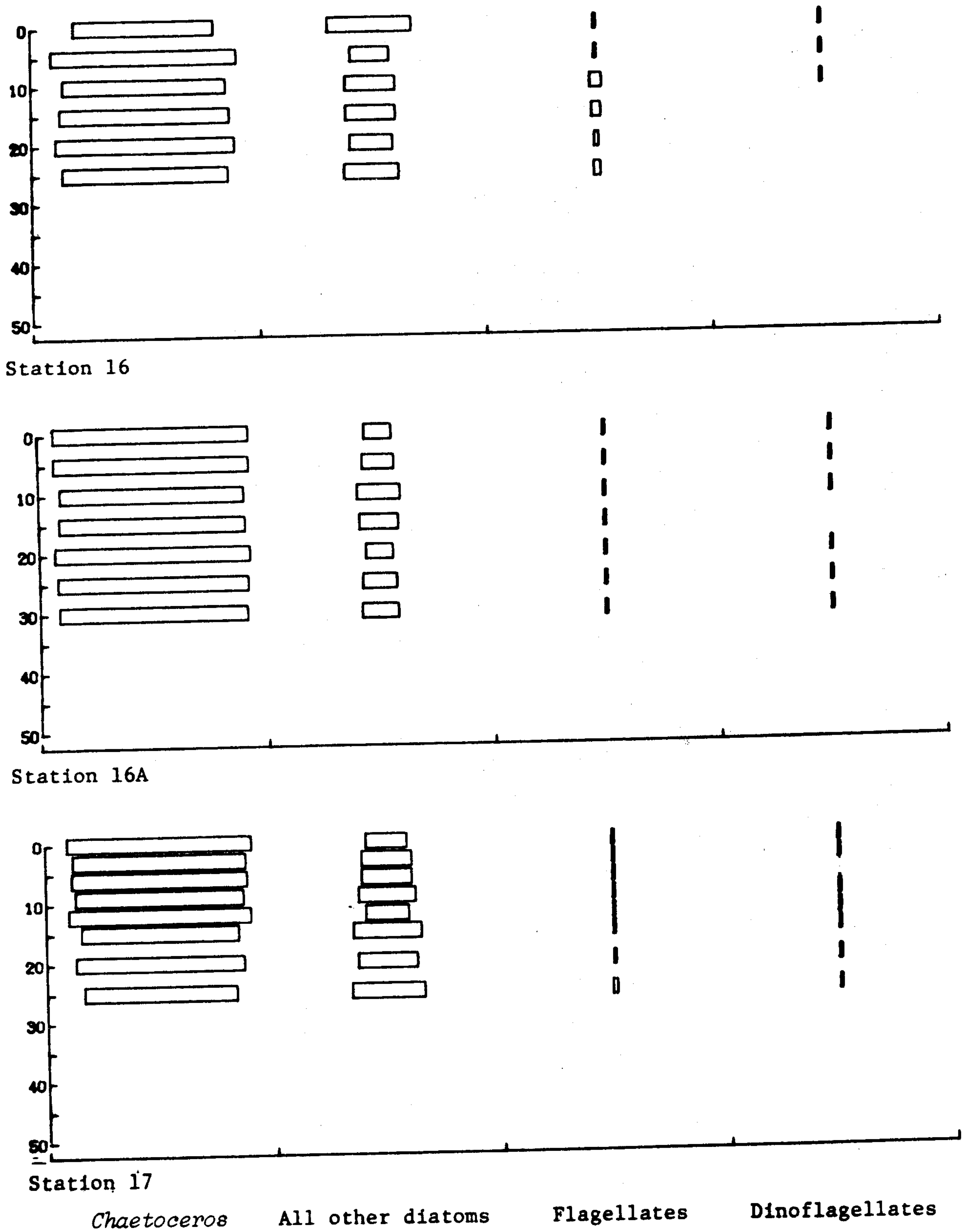


Fig. 15. (continued)

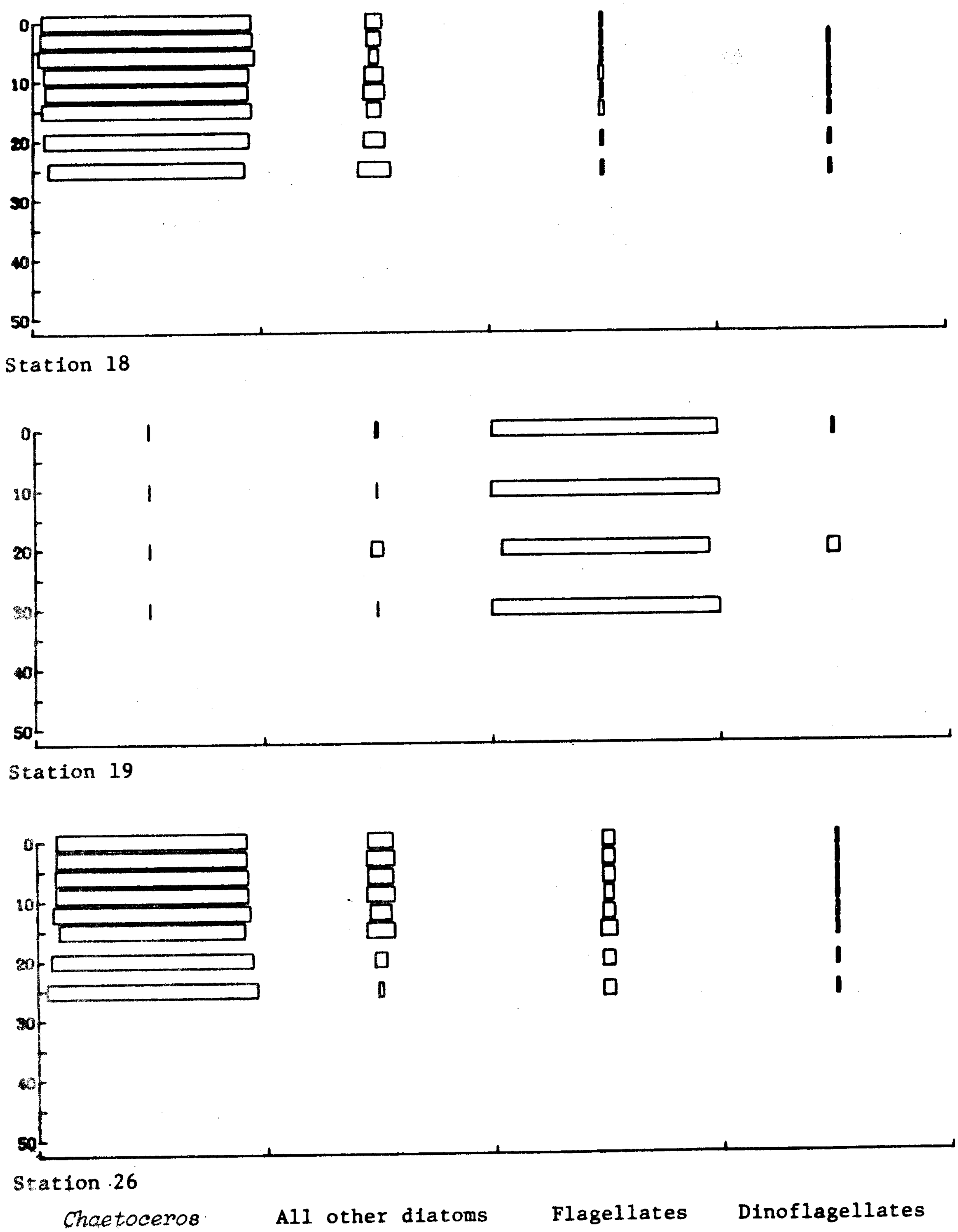


Fig. 15. (continued)

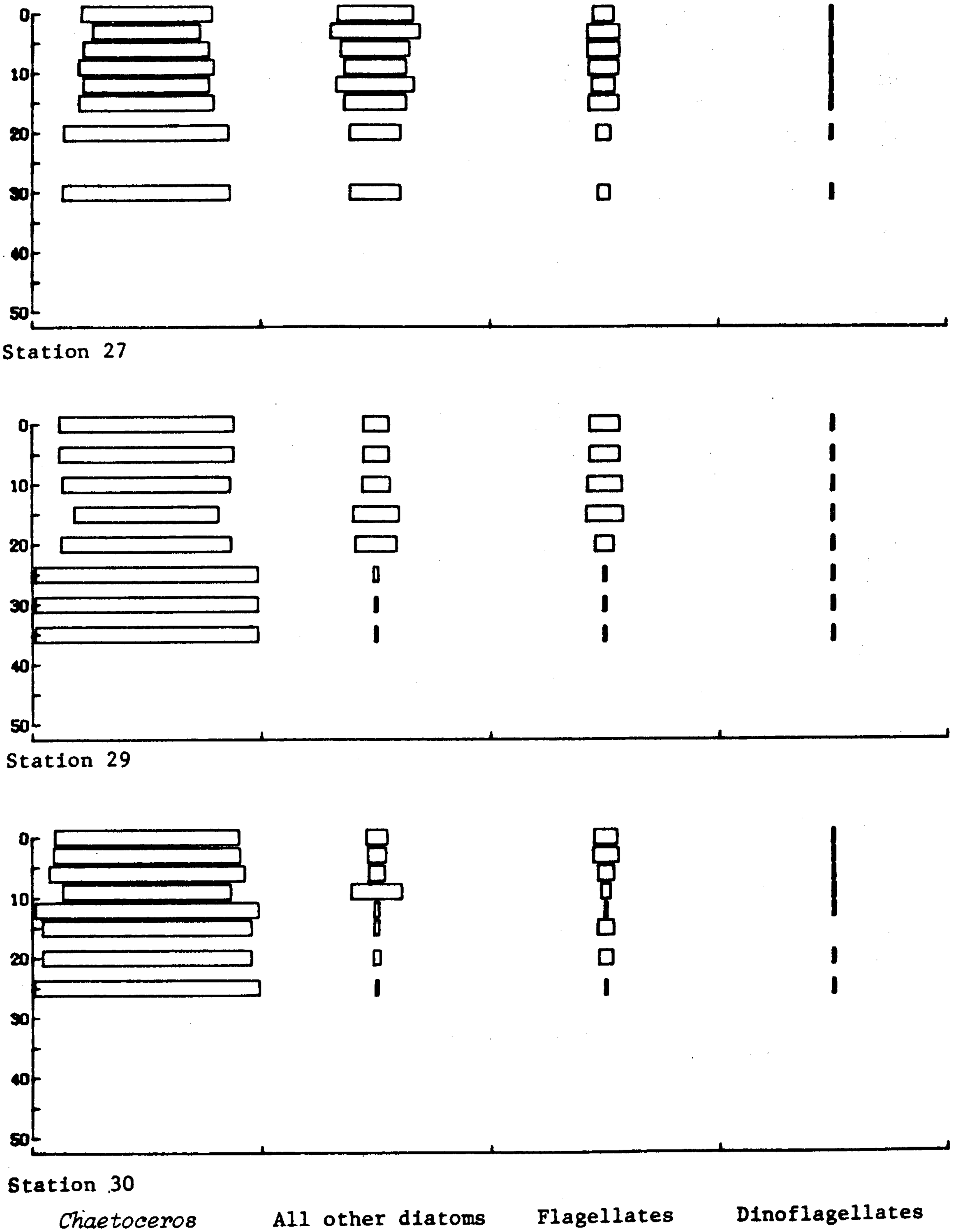


Fig. 15. (continued)

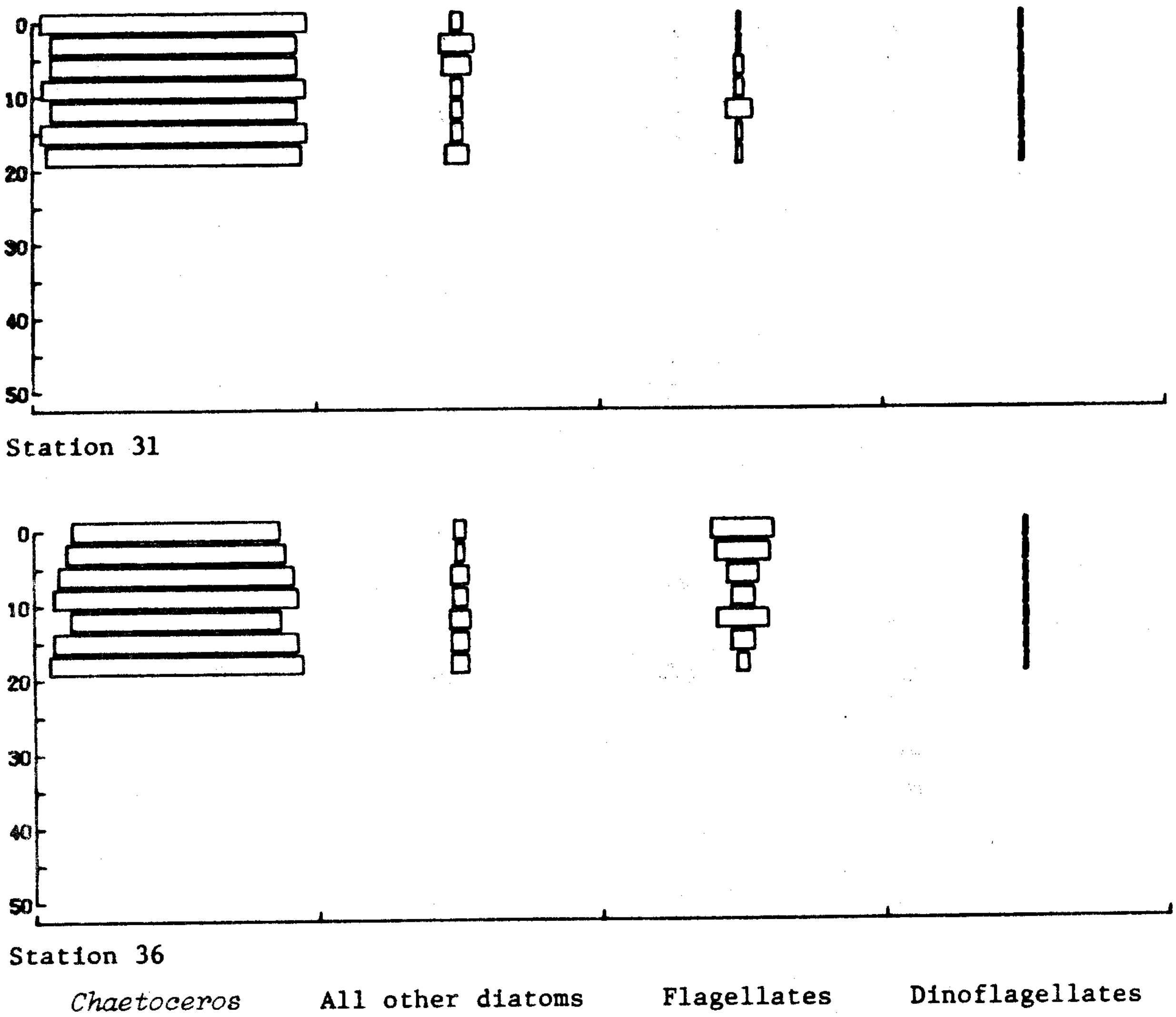


Fig. 15. (continued)

stations, including station 23, with the lowest integrated chlorophyll concentrations, were in deep water where ice concentrations ranged from 1-8 oktas.

High chlorophyll concentrations generally were found at the same depths as high productivity and where diatoms were the most abundant organisms. At stations and depths where productivity and chlorophyll *a* were low, flagellates comprised more than 50% of the population. At nearly all stations, small, unidentified *Chaetoceros* spp. were the most abundant taxonomic group at the depth of greatest carbon uptake (Table 12).

In 1978, 83 categories of phytoplankton from five phyla, including 48 species and 35 other categories, such as unidentified species and groups of species, were present. Standing stock ranged from $< 1 \times 10^5$ cells ℓ^{-1} at several stations and depths to $> 4 \times 10^6$ cells ℓ^{-1} at station 27-18. In general, standing stock was considerably lower in 1978 than in 1976 and 1977.

Chaetoceros spp. were the most abundant organisms at most stations and most depths, except at the surface (Fig. 16). Other diatoms that were common included *Nitzschia delicatissima, N. grunowii, Thalassiosira antarctica, T. gravida,* and *T. nordenskioeldii.* Diatoms other than *Chaetoceros* spp. were the most abundant organisms only at station 33 north of Harrison Bay.

Small flagellates, < 10 µm in diameter, were common and usually dominant in surface samples. They were most abundant at stations 10-12, the Pitt Point transect; at stations 7-9 along the 20 m isobath off Harrison Bay; and at station 4 near the Canning River. Flagellates were dominant at some depths where primary productivity was highest for a station, but only at station 29-45 was productivity < 1.00 mg C m^{-3} hr^{-1} and flagellates comprised 97% of the total population (Table 13).

Dinoflagellates were relatively abundant in 1978. They were especially common at stations 11 and 12 off Pitt Point; at stations 7-9, 13, 33, and 34 off Harrison Bay; and at station 29 in deep water off Prudhoe Bay. At most stations east of Prudhoe Bay, dinoflagellates comprised < 1% of the population at any depth. Species present included *Dinophysis acuta, D. sphaerica, Gonyaulax catenata, G. spinifera, Gymnodinium lohmanni, Protoperidinium brevipes, P. bipes, P. pallidum, Scrippsiella trochoidea, Ceratium arcticum,* and *C. longipes.*

Primary productivity and chlorophyll *a* values are listed in Table 8 and vertical profiles are shown in Fig. 12. Primary productivity was generally low, ranging from 0.01 mg C m^{-3} hr^{-1} at several stations and depths to 2.93 mg C m^{-3} hr^{-1} at station 29-45 where unidentified flagellates comprised 97% of the population. Integrated productivity ranged from 1.25 mg C m^{-2} hr^{-1} at station 7 to 32.05 mg C m^{-2} hr^{-1} at station 29.

Chlorophyll *a* ranged from 0.09 mg m^{-3} at stations 13-00 and 25-00 to 6.11 mg m^{-3} at station 27-18. Integrated chlorophyll ranged from 4.63 mg m^{-2} at station 22 to 37.35 mg m^{-2} at station 16.

Table 12. Percent *Chaetoceros* species, all other diatoms, flagellates, and dinoflagellates at depth of greatest carbon uptake, 7 Aug - 5 Sep 1977.

Category Station Depth	*Chaetoceros* spp.	All other diatoms	Flagellates	Dinoflagellates
2-27	78	18	4	< 1
3-27	21	69	9	1
4-25	20	67	12	1
5-45	88	8	4	< 1
6-100	82	13	5	1
7-45	83	12	5	-
8-45	68	1	30	< 1
9-20	29	6	65	-
10-20	81	3	16	-
11-20	73	19	7	< 1
12-10	61	33	6	< 1
13-10	73	17	9	1
14-10	65	33	2	< 1
15-06	69	28	2	< 1
17-15	69	30	1	< 1
18-20	90	9	1	< 1
26-06	84	11	5	< 1
27-00	57	33	9	1
29-25	97	2	1	< 1

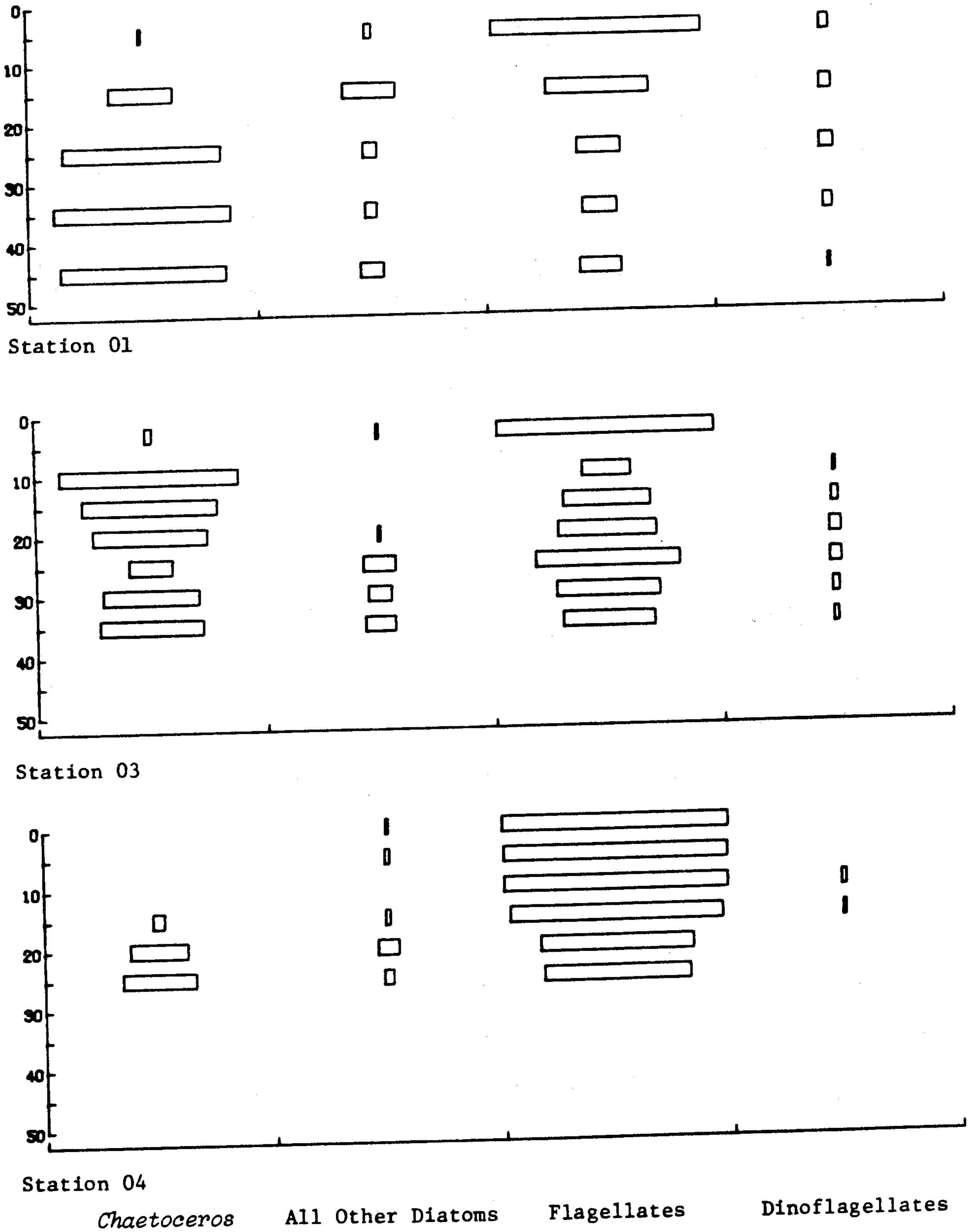


Fig. 16. Percentage of phytoplankton by major category by depth for each station, CGC *Northwind* 1978. Blanks indicate depths where samples were not analyzed. Percentages add up to 100% running from left to right across the diagram.

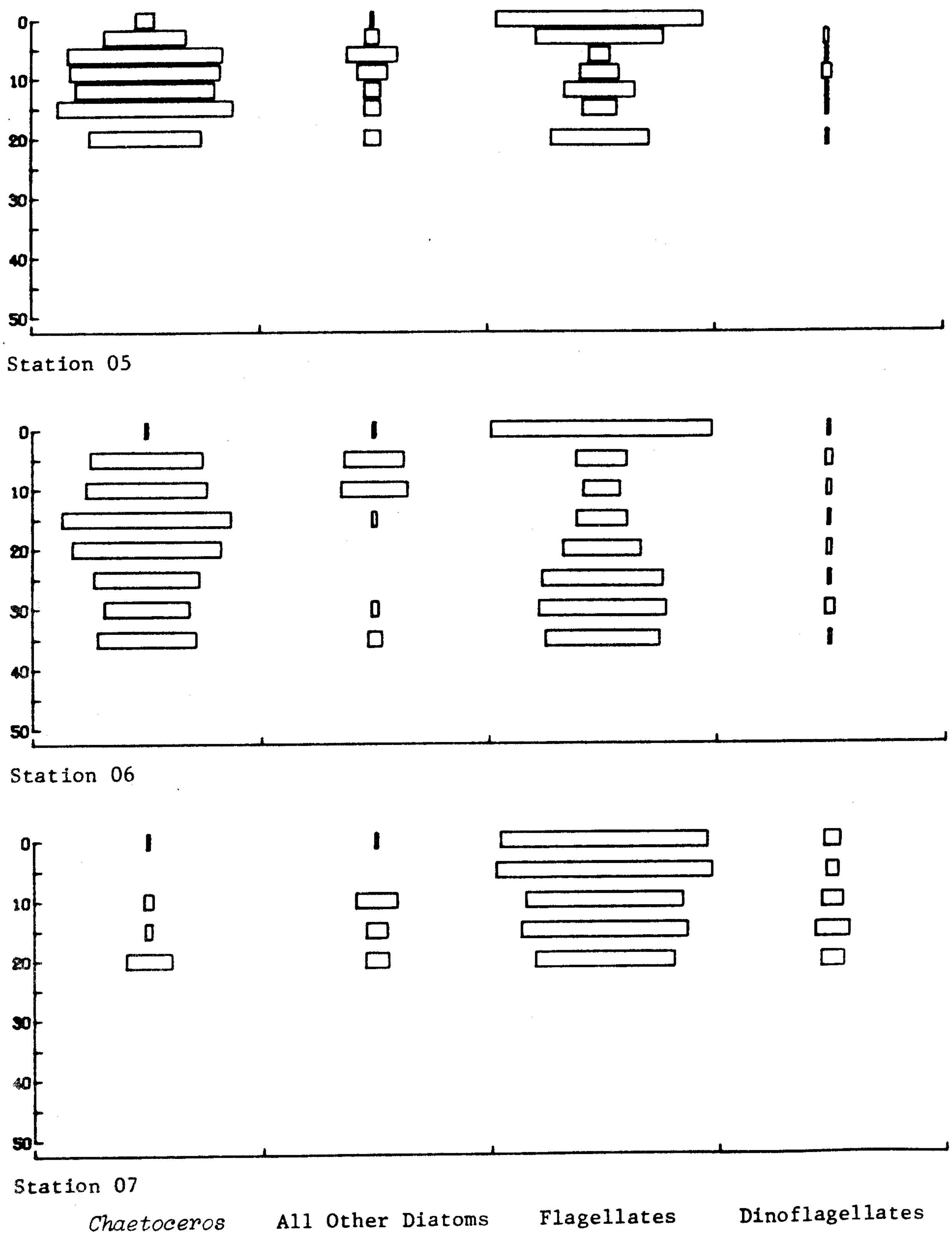


Fig. 16. (continued)

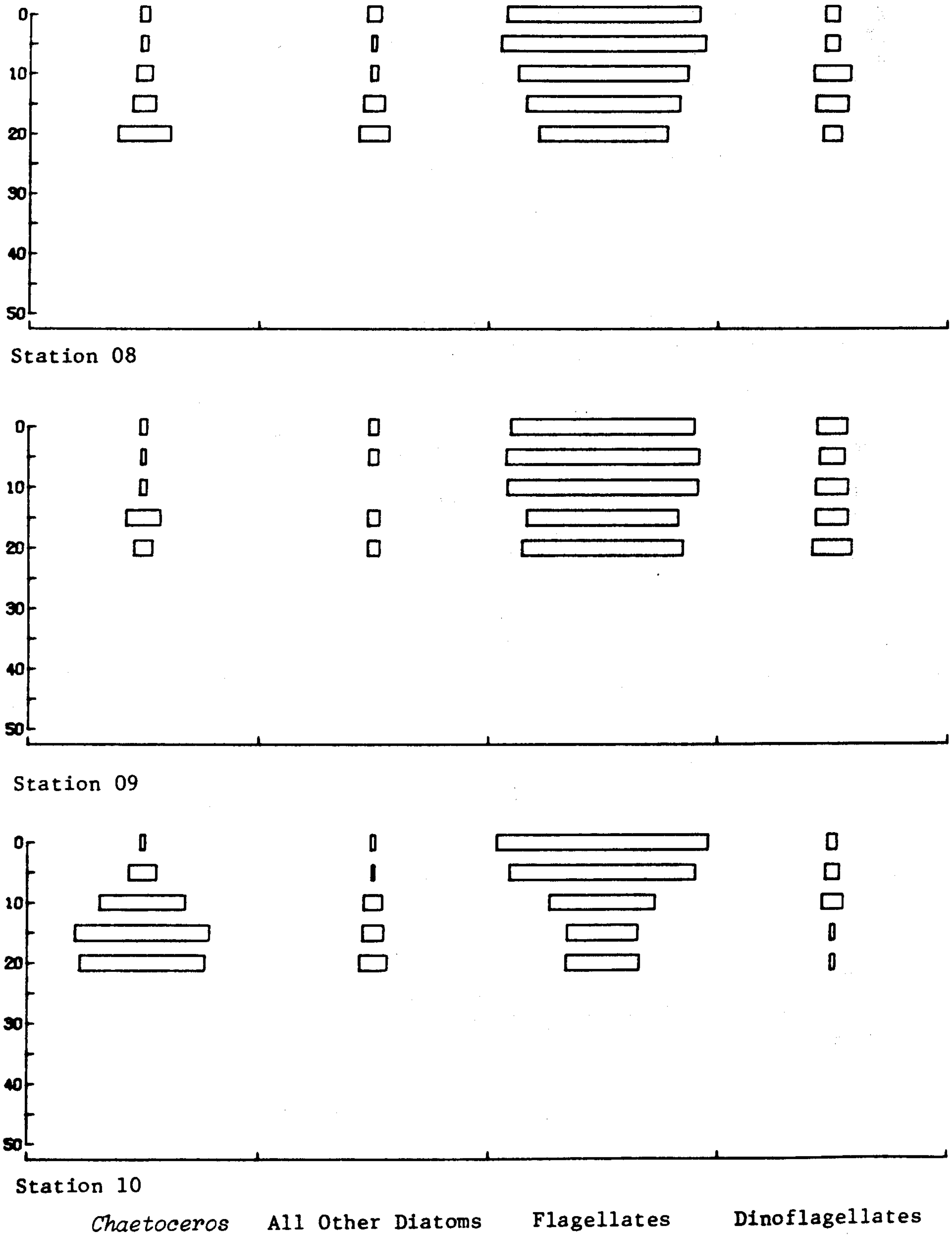


Fig. 16. (continued)

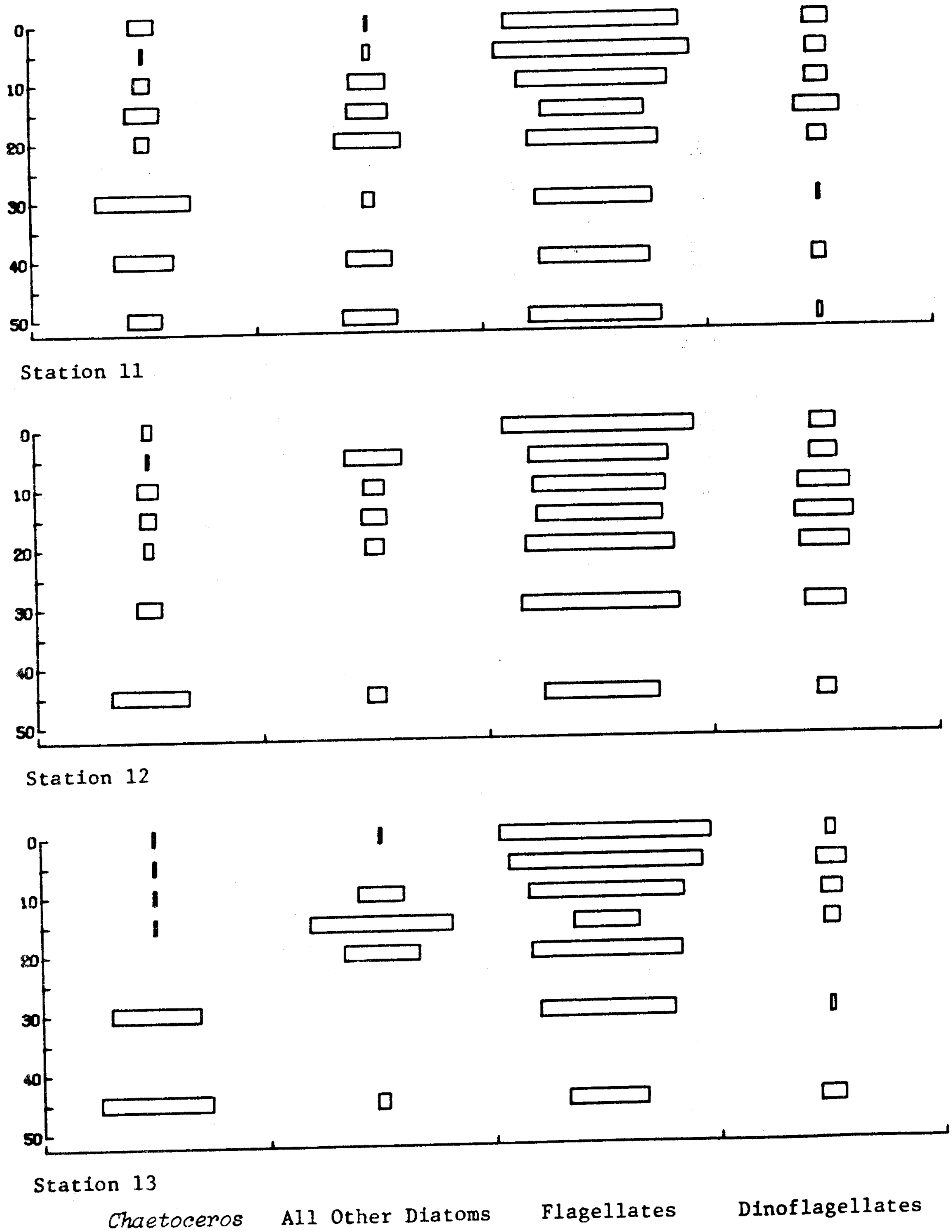
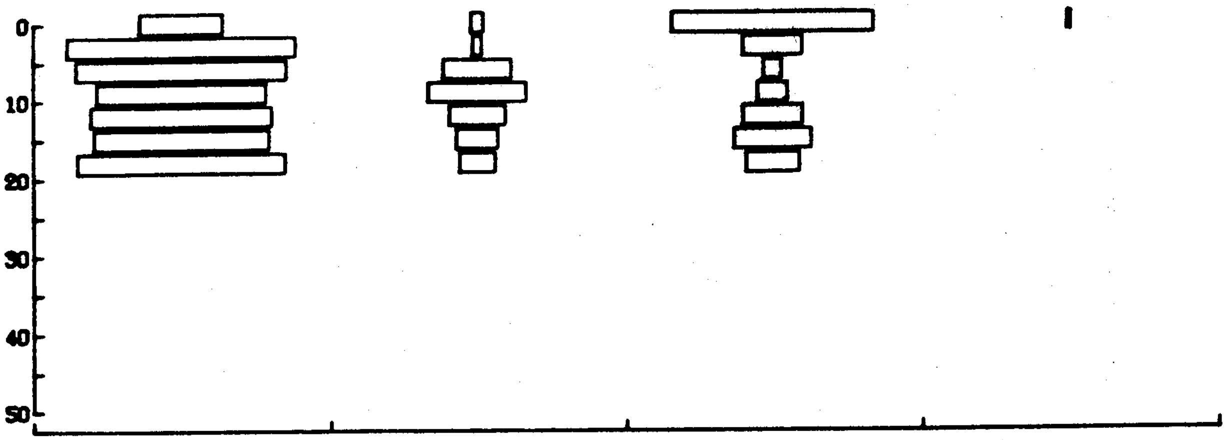
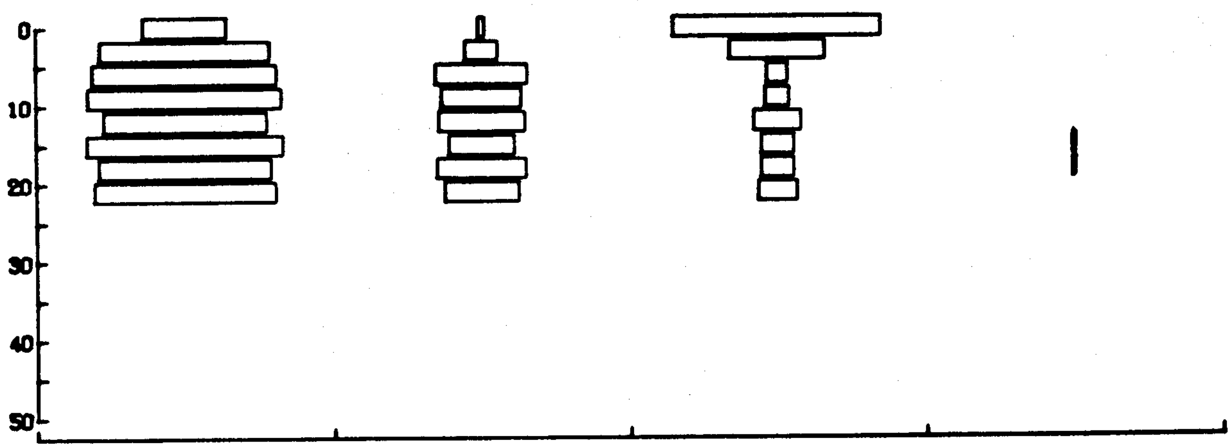


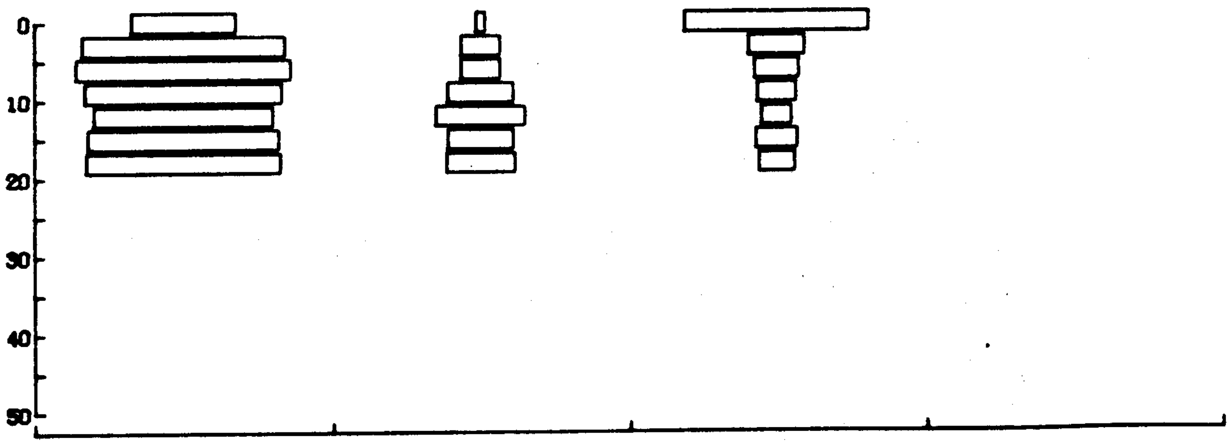
Fig. 16. (continued)



Station 14



Station 16



Station 17

Chaetoceros All Other Diatoms Flagellates Dinoflagellates

Fig. 16. (continued)

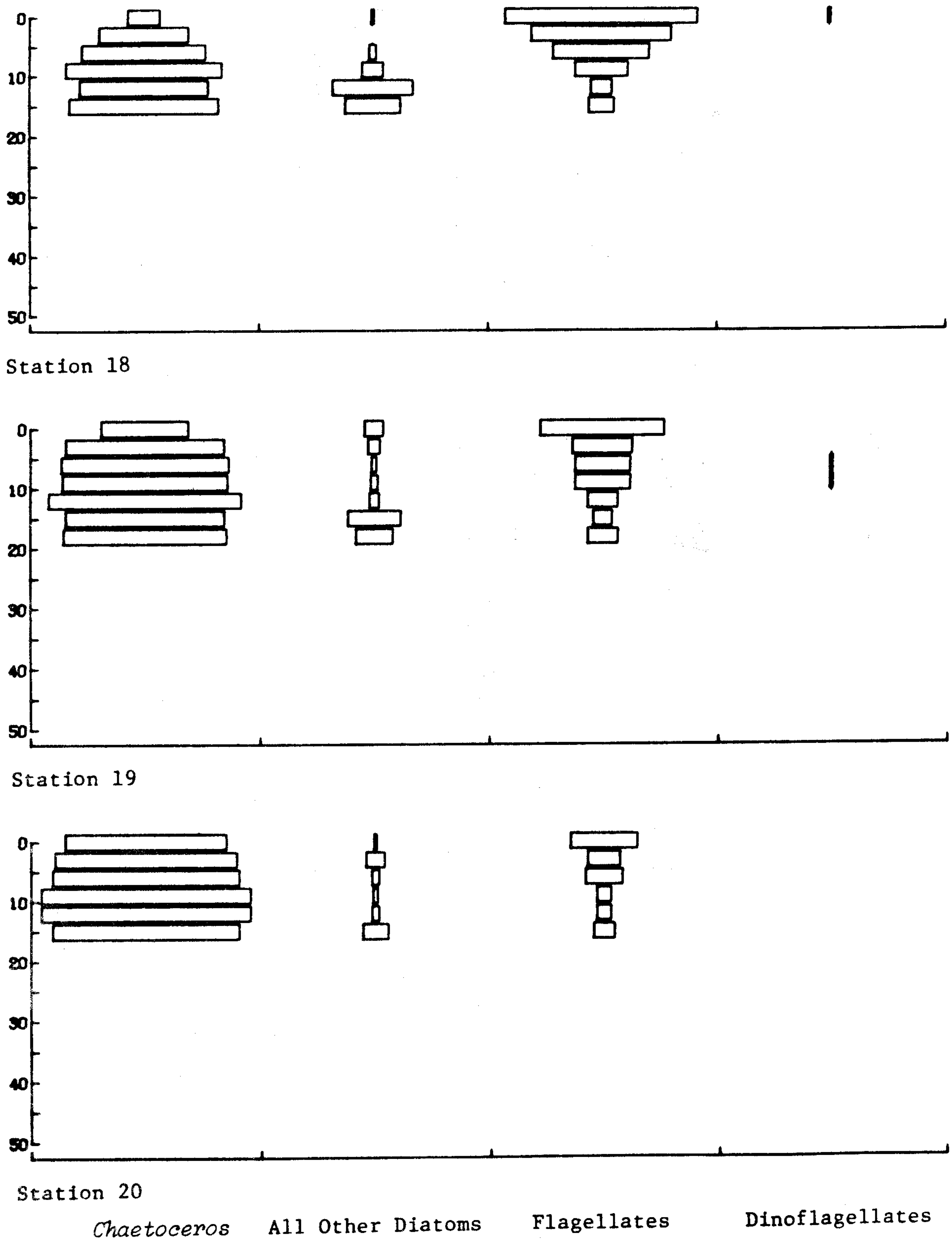
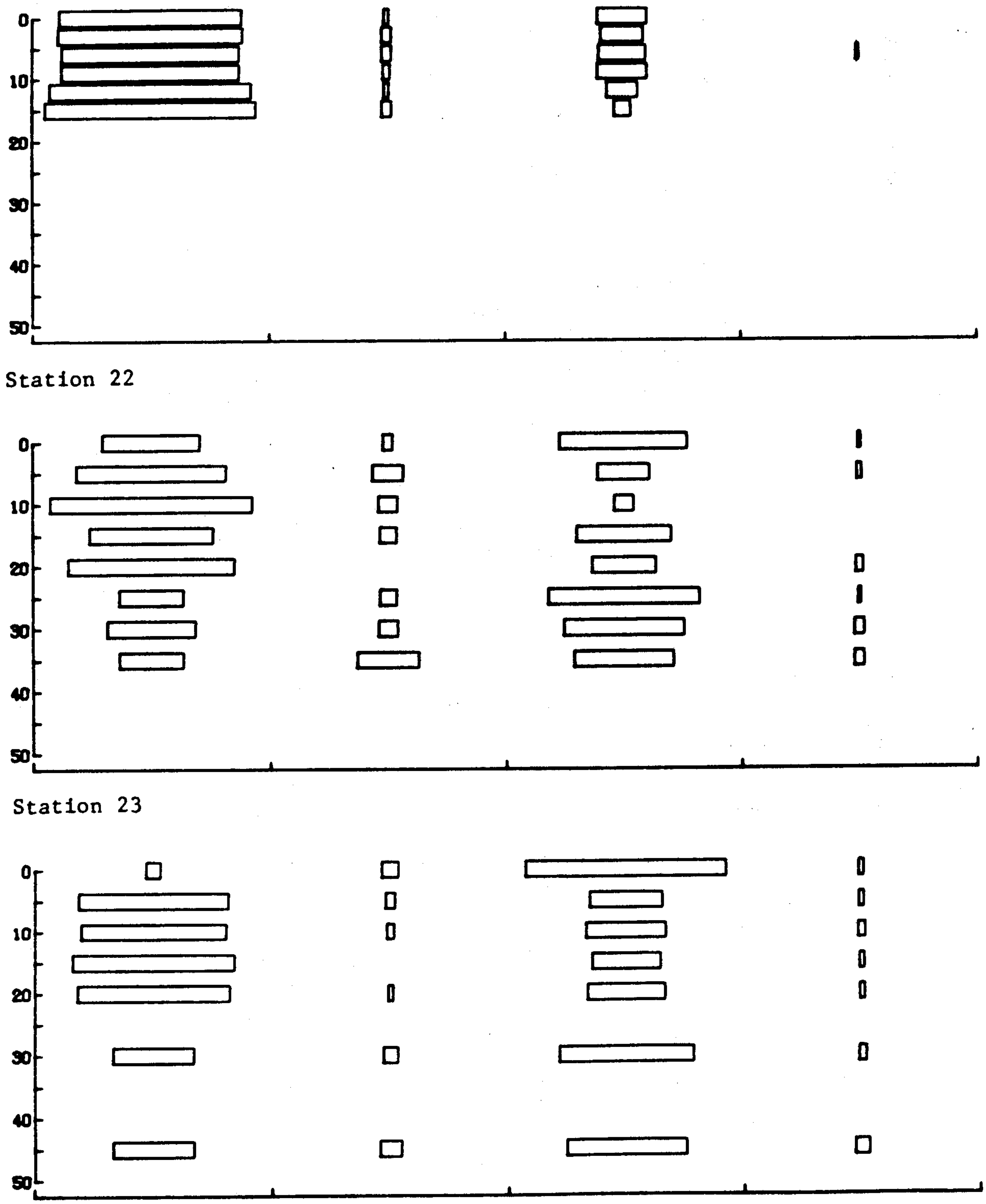


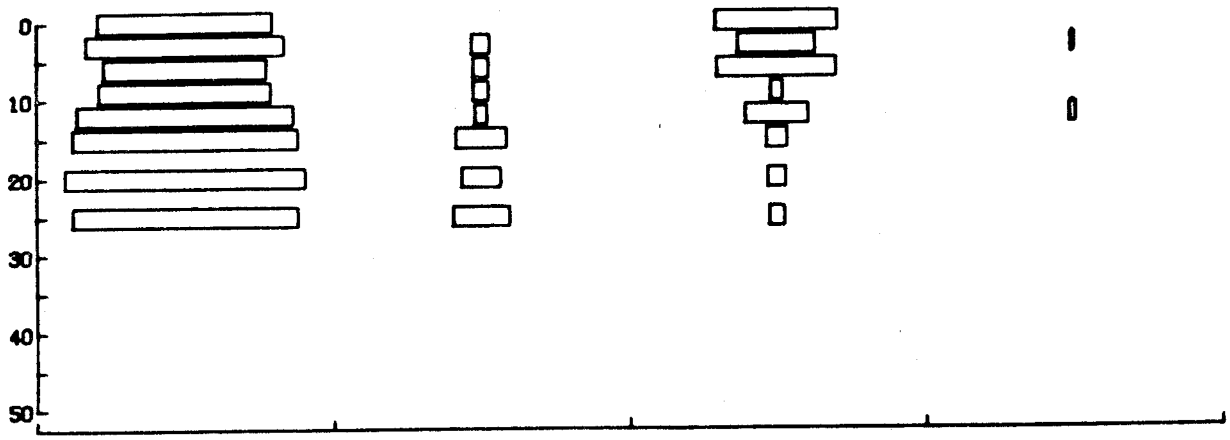
Fig. 16. (continued)



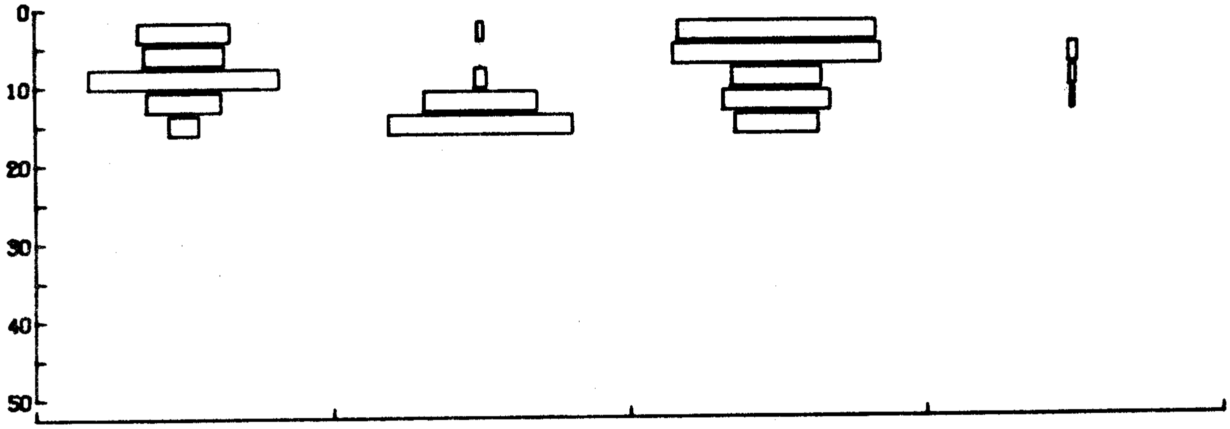
Station 24

Chaetoceros All Other Diatoms Flagellates Dinoflagellates

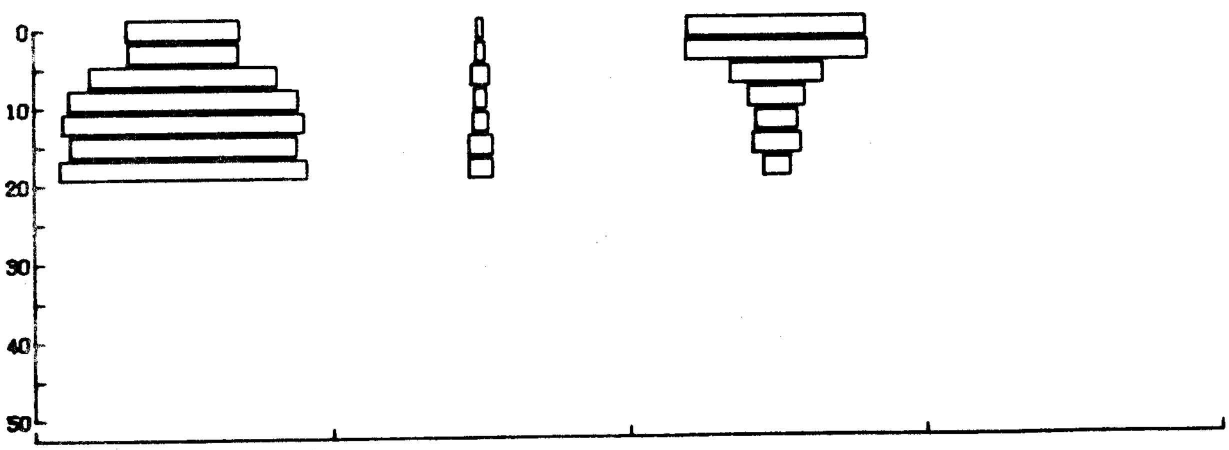
Fig. 16. (continued)



Station 25



Station 26



Station 27

Chaetoceros All Other Diatoms Flagellates Dinoflagellates

Fig. 16. (continued)

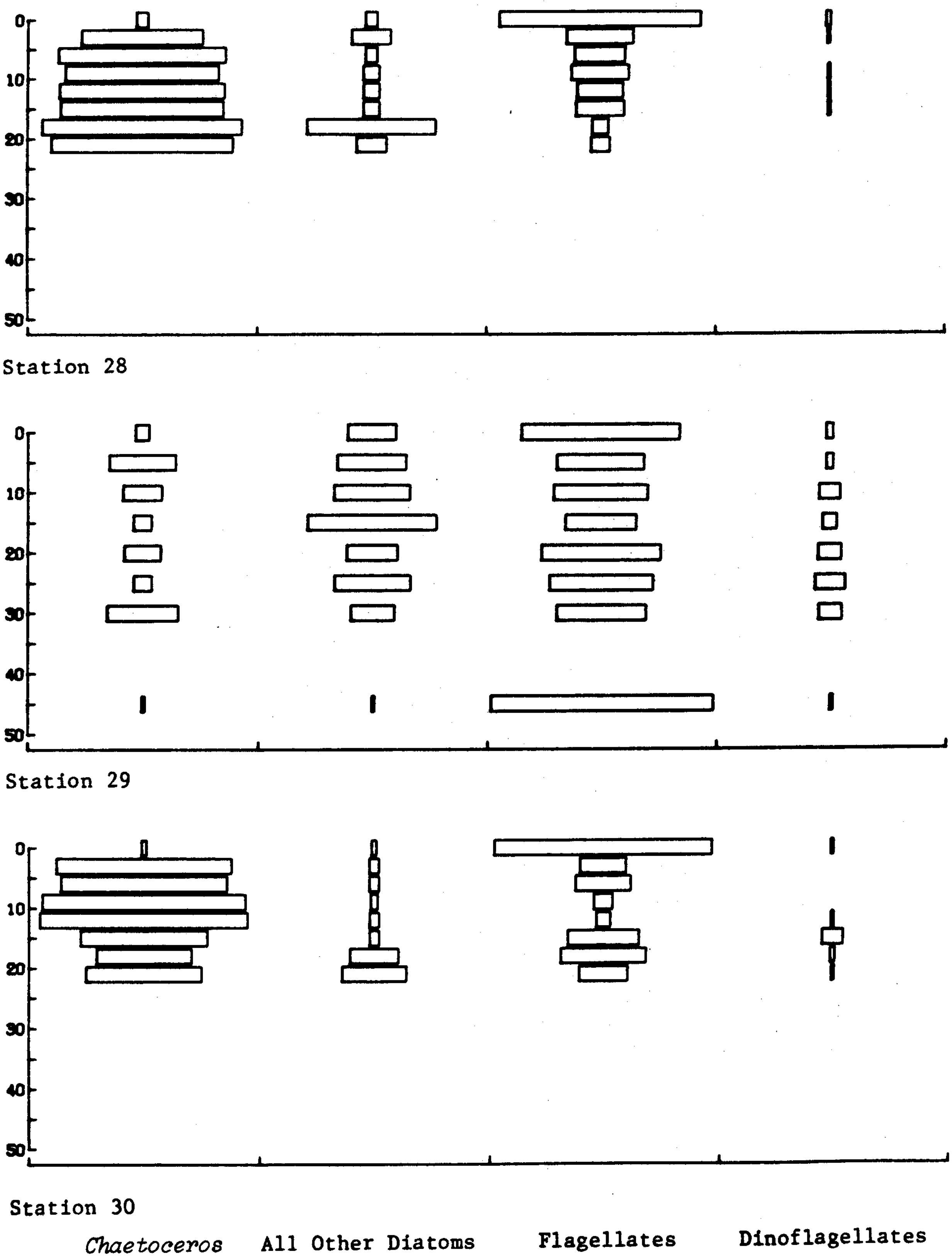


Fig. 16. (continued)

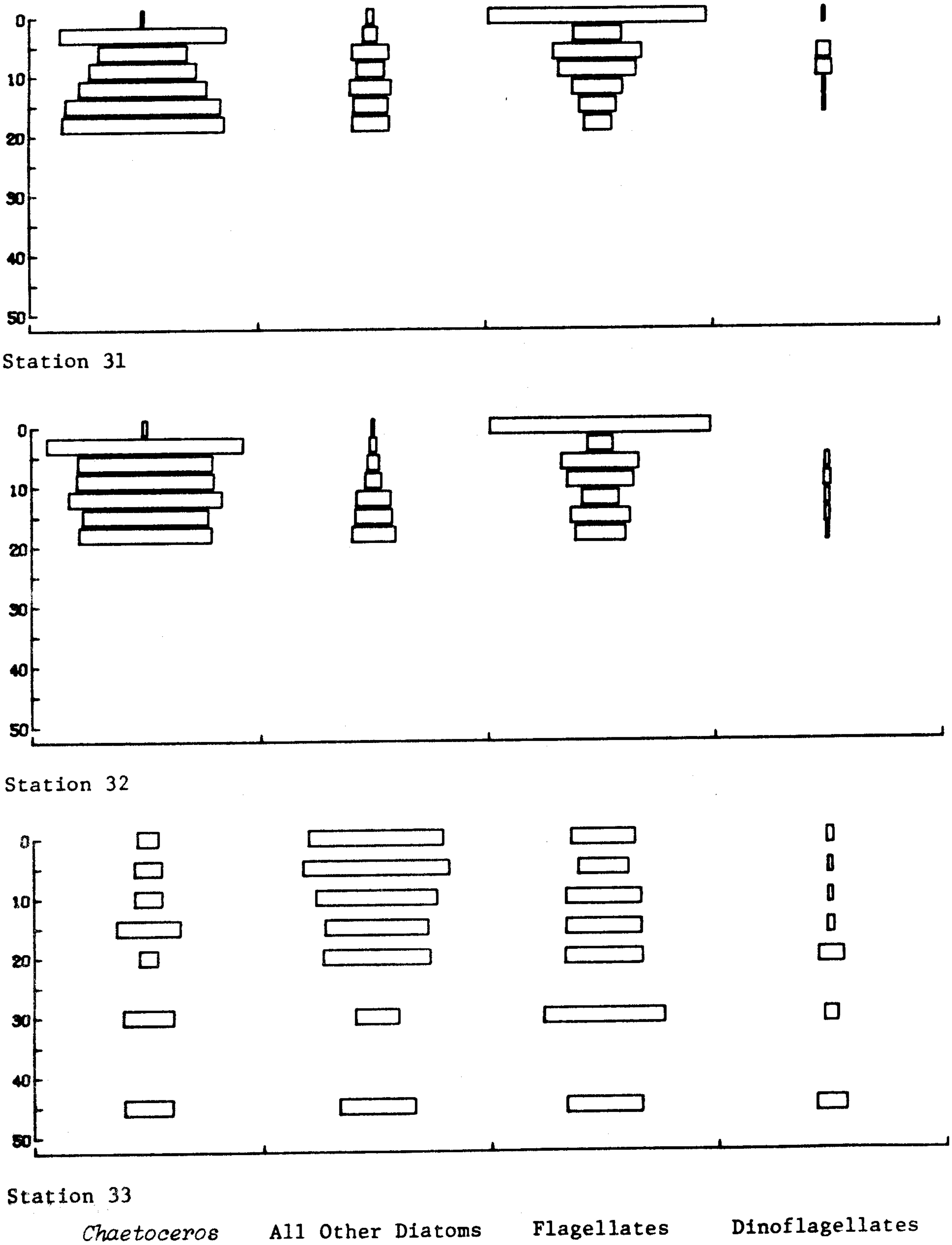


Fig. 16. (continued)

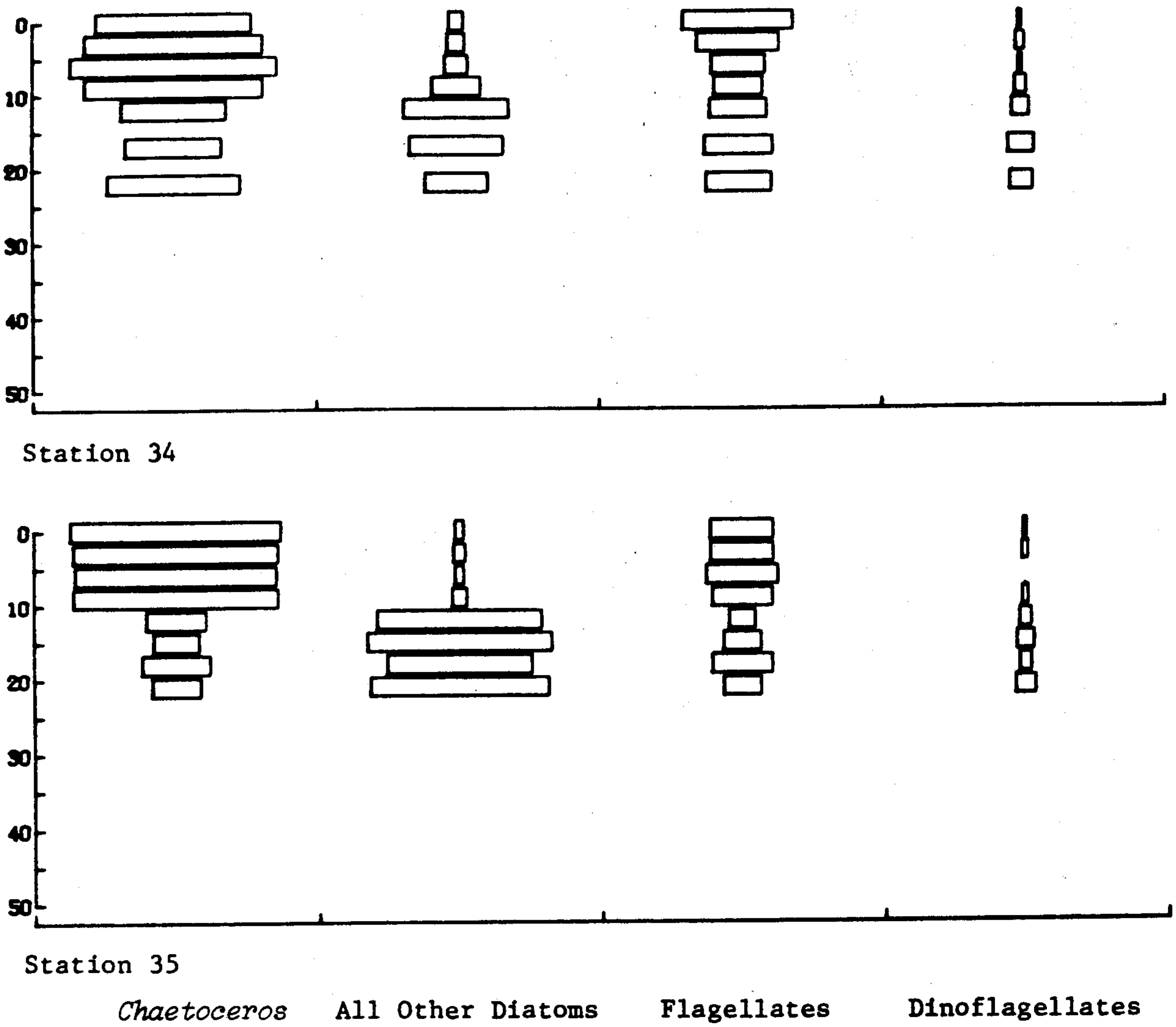


Fig. 16. (continued)

Table 13. Percent *Chaetoceros* species, all other diatoms, flagellates, and dinoflagellates at depth of greatest carbon uptake, 15 Aug - 15 Sep 1978.

Category Station Depth	*Chaetoceros* spp.	All other Diatoms	Flagellates	Dinoflagellates
1-25	69	6	19	6
3-35	45	13	40	2
4-10	-	-	98	2
5-6, 9	68, 69	22, 13	9, 17	1, 4
6-20	65	-	34	2
7-20	20	10	61	10
8-15, 20	10, 23	9, 13	67, 56	14, 8
9-15	15	5	66	14
10-20	54	12	32	2
11-40	26	20	49	6
12-45	34	8	51	8
13-00	1	1	94	4
14-9	57	33	10	< 1
16-12	55	29	16	< 1
17-15*	64	22	14	< 1
18-12*	56	35	9	< 1
19-15*	69	23	8	-
20-15	81	11	9	-
22-15	89	4	7	-
23-35	27	26	42	4
24-30	30	6	57	3
25-20*	81	13	6	< 1
26-15	10	62	28	-
27-18*	83	8	9	< 1
28-21*	79	13	8	< 1
29-45*	1	1	97	1
30-21*	50	28	21	1
31-15*	68	15	16	1
32-18	58	19	22	1
33-20	8	47	34	11
34-22	47	22	23	8
35-18	24	51	21	4

* Highest primary productivity was < 1.0 mg C m^{-3} hr^{-1}.

Carbon uptake and chlorophyll *a* concentrations were generally lower in 1978 than in 1976 and 1977. Only at nine stations was the carbon uptake > 1.0 mg m^{-3} hr^{-1}. At stations 4, 7, 8, 9, 13, and 29, highest productivity occurred at depths where flagellates comprised more than 60% of the total cell number. However, high carbon uptake at these stations and depths was < 0.23 mg C m^{-3} hr^{-1}, except at station 29 where it was the highest of all stations and depths.

VII. Discussion

All plankton sampling reported here has been done during the Beaufort Sea summer, primarily during August and the first half of September. Except for a few plankton samples collected in Stefansson Sound and just north of Narwhal Island in winter and spring, there are no plankton samples from other times of the year. For the phytoplankton, this means we have missed the early and perhaps most productive part of the year, the time of the spring bloom that apparently occurs during the early stages of breakup. We have also missed the fall season just before freezeup when phytoplankton production is decreasing prior to the winter low.

For the zooplankton, we have missed breeding periods that occur in the fall, winter, and spring. We don't know how many herbivorous species are able to overwinter when their food supply is essentially not present. Do they have overwintering stages or do they turn to alternative food sources? Some copepods apparently take more than one year to mature and reproduce whenever environmental conditions are favorable (Cairns 1967; Harding 1966).

Zooplankton densities calculated from samples collected during four cruises to the western Beaufort Sea are reported with little reference to gear type. Two assumptions have been implicit in the comparisons made: 1) nets fished with 100% filtration efficiency for the duration of the tow; 2) all taxa are collected equally well by the all the nets used.

Gear such as we used is unlikely to filter at more than 95% efficiency initially (Tranter and Smith 1968), with decreasing filtration performance as the net mesh becomes clogged. The results of this assumption is an underestimation of the resident zooplankton population.

The second assumption implies calculated densities to be dependent strictly on the local zooplankton population and independent of gear used. However, this assumption is weakened by the varying ability of the zooplankton to avoid capture in the different gear used and the patchy distribution of the population.

Volume of water filtered affects the calculated abundances in a complex way (Tranter and Smith 1968). The greater volume of a longer tow depresses the reported density of the collected organisms as well as increases the chance of sampling a zooplankton patch. Perhaps more distortion occurs in shorter tows, particularly those taken with the ring net. The rather small volumes inflate abundances and rare organisms can have widely fluctuating densities even between samples taken at the same station.

The bongo net can be towed rapidly enough to catch the faster moving plankton and, fitted with a 500 μm mesh net, minimizes the clogging caused by phytoplankton and smaller zooplankton. The double oblique method of towing the bongo net requires *ca.* 1 km of open water to complete a tow which prohibited the use of the bongo net when ice conditions were heavy as frequently occurred in 1976.

The 0.75 m ring net was used in 1976 as a reserve sampler for stations with heavy ice conditions because vertical net tows require little open water. The disadvantage of this net is its apparent inability to collect faster swimming zooplankton species.

In 1977, the umbrella net was used as the reserve sampler. This net has the advantage of filtering nine times more water than the ring net for a given tow length, decreasing the effects of small volume tows. However, as this net approached the surface, the sides of the non-rigid square mouth tended to bow outward. This unknown additional mouth area was not accounted for when calculating abundances and would result in a slight underestimate of the population density.

Several hydrozoan species are reported here under names different from those used in previous reports. Keys and illustrations in Naumov (1960) were used for the identification of medusae. Kramp (1961) is a more recent and authoritative nomenclatural source and names used to report these animals have been changed to reflect this (Table 14).

The pteropod *Limacina helicina* has previously been reported as *Spiratella helicina*. The generic name *Limacina* conforms to that given by van der Spoel (1967). *Lagunogammarus wilkitzkii* is the new name for *Gammarus wilkitzkii* (Bousfield 1979). This amphipod was collected only once during this study.

Euphausids, mysids, and amphipods are known food items of seals (Dunbar 1941; Lowry *et al.* 1979). The abundances of these food species found in seal stomachs do not match well with abundances obtained from net samples. This discrepancy reflects the inadequacy of zooplankton sampling techniques. Results are contradictory, but avoidance of nets is a known phenomenon (Clutter and Anraku 1968). This, along with the swimming ability of prey species, suggests that straining of the water column by a net will not necessarily compare well with the selective feeding on these species by seals.

Amphipods, mysids, and euphausids in large numbers are good acoustical targets (Macaulay pers. comm.) The pteropod *Limacina helicina* has been associated with a scattering layer at 50 m in the central Arctic (Hansen and Dunbar 1970). No such layers were seen in our acoustical data from 1976 and 1977. Concentrations of animals obtained in the net samples support the hypothesis that few large zooplankton species were present.

Grainger (1965) found that zooplankton collected from the Arctic

Table 14. List of hydrozoan names based on Kramp (1961) and Naumov (1960).

Kramp	Naumov
Aeginopsis laurentii Brandt 1838	*Aeginopsis laurentii*
Aglantha digitale (O.F. Müller (1776)	*Aglantha digitale*
Bougainvillia superciliaris (L. Agassiz 1849)	*Bougainvillia superciliaris*
Catablema vesicarium (A. Agassiz 1862)	*Perigonimus vesicarius*
Eumedusa birulai (Linko 1913)	*Calycopsis birulai*
Euphysa flammea (Linko 1905)	*Corymorpha flammea*
Halitholus cirratus Hartlaub 1913	*Perigonimus yoldia-arcticae*
Melicertum octocostatum (M. Sars 1835)	*Melicertum campanula*
Obelia sp.	*Obelia* sp.
Plotocnide borealis Wagner 1885	*Plotocnide borealis*
Rathkea octopunctata (M. Sars 1835)	*Rathkea octopunctata*
Sarsia tubulosa (M. Sars 1835)	*Coryne tubulosa*
Staurophora mertensi Brandt 1838	*Cuspidella mertensii*

Ocean, southern Beaufort Sea, and Amundsen Gulf could be divided into three groups based on horizontal distribution. Similar distributions could be distinguished in our samples. Grainger's first group includes species of wide occurrence, inshore and offshore, in surface waters and at depth. Species from our samples include the medusae *Aglantha digitale* and *Aeginopsis laurentii*, the pteropods *Limacina helicina* and *Clione limacina*, the copepods *Calanus glacialis*, *C. hyperboreus*, *Metridia longa*, and *Oithona similis*, the chaetognath *Sagitta elegans*, and the larvaceans *Oikopleura vanhöffeni* and *Fritillaria borealis*.

The second group, comprised of species found almost exclusively offshore, includes the ostracod *Conchoecia borealis*, the copepods *Chiridius obtusifrons*, *Gaidius tenuispinus*, *Schaphocalanus magnus*, and *Heterorhabdus norvegicus*, and the chaetognath *Eukrohnia hamata*.

The third group comprises species found in coastal waters and includes the meroplanktonic medusae *Euphysa flammea*, *Halitholus cirratus*, and *Eumedusa birulai*, the copepods *Limnocalanus macrurus*, *Derjuginia tolli*, *Acartia longiremis*, and *Pseudocalanus* spp., and the amphipod *Hyperoche medusarum*.

Similar species groups could be defined on the basis of temperature and salinity ranges with widely occurring species generally having fairly wide temperature and salinity tolerances; offshore species occurring in relatively cold, highly saline water, and coastal species tolerating higher temperatures and lower salinities.

Johnson (1956) reported the presence of Bering Sea water in the Beaufort Sea based on the presence of the expatriate copepod species *Calanus cristatus*, *C. plumchrus*, *Centropages abdominalis*, and *Eucalanus bungii*. These species have also been found in our samples. The intrusion of Bering Sea water has since been documented by hydrographic means as well (Hufford 1973; Paquette and Bourke 1974).

The species that contribute meroplanktonic life history stages to the plankton must also be considered (English and Horner 1977). This group includes polychaetes, barnacles, echinoderms, hydrozoans, and gastropods, and is especially important in the shallow western region of the Beaufort Sea (Johnson 1956).

The existence of an unbalanced ecosystem was suggested by MacGinitie (1955) and again by Redburn (1974). It was found that the peak concentrations of phytoplankton and zooplankton were separated by about two weeks. MacGinitie (1955) reported a cyclical pattern of abundances in both diatoms and zooplankton, particularly copepods. The pattern of cycling diatom and zooplankton abundance began in July after ice breakup and continued during the open season with high abundances occurring on a 30-40 day cycle, lengthening to 40-50 days in the fall.

Redburn (1974) attributes the phase difference between phytoplankton and zooplankton peaks in part to the time lag between the initial high primary productivity period and the onset of zooplankton grazing. He further suggested that seasonal changes of this sort are common in the neritic environment and that the presence of relatively few zooplankton species helps to continue the cycle by reducing competition and allowing a small number of organisms to dominate.

Nearly 100 species of phytoplankton have been identified in the OCSEAP Beaufort Sea samples. This does not include groups of species where identification was made only to genus. However, some categories identified as species are probably groups of species that are difficult or impossible to separate into individual species using the inverted microscope technique. For example, organisms identified as *Nitzschia grunowii*, an important component of the early spring community, includes *N. cylindrus* as well.

All species, except *Leptocylindrus minimus*, have been identified previously from the Beaufort Sea. This species has been reported from the Bering Sea and in the OCSEAP samples was found only in warmer water identified as being from the Bering Sea.

With the exception of *L. minimus*, the most abundant species are widely distributed across the western Beaufort Sea. Small species of the genus *Chaetoceros* were the most abundant diatoms present throughout the sampling periods and were widely distributed across the Beaufort Sea. Other common diatoms in 1976 included *Nitzschia delicatissima* (another species group), *N. grunowii, Thalassiosira antarctica, Th. nordenskoeldii, Cylindrotheca closterium,* and *Eucampia zoodiacus. Bacterosira fragilis, Nitzschia grunowii,* and *Thalassiosira* spp. were abundant in 1977, while *Leptocylindrus minimus* was only identified at one station. *Nitzschia delicatissima, N. grunowii,* and *Thalassiosira* spp. were common in 1978.

Microflagellates were abundant all years. They were most common in surface samples, perhaps because they are better able to adapt to higher light intensities. It is not possible to determine in preserved samples whether these organisms are photosynthetic or not, but it is likely that most are not. Because of their small size and the difficulty identifying them, they have been grouped into size classes based on the length and diameter of the cells.

Dinoflagellates were nearly always present, but were never very abundant, usually being < 5% of the total population. On occasion, however, they comprised 10-25% of the population. This was especially true at five stations off Smith Bay in mid-August 1973 when dinoflagellates were very abundant (Fig. 13). In temperate waters dinoflagellates usually become numerous in fall when nutrient concentrations are low; this is apparently the situation in the nearshore Beaufort Sea as well.

Primary productivity was not measured in 1973 and 1974, but rates during 1976-1978 were variable with two- and three-fold differences between years. Chlorophyll *a* concentrations were also variable, although high values were generally *ca.* 6-8 mg m^{-3}. Highest productivity and standing stock occurred in 1977, the year with the least amount of ice cover. Highest productivity and chlorophyll occurred below the surface and at depths where diatoms, usually *Chaetoceros* spp., were the most abundant organisms. In 1978, highest productivity often occurred at depths where flagellates were dominant, but in those cases, the high productivity was < 0.5 mg C m^{-3} hr^{-1}. Low productivity and chlorophyll concentrations at depths where flagellates were abundant probably indicates that most of the flagellates were not photosynthetic.

Studies of the effects of oil on plankton have produced a variety of results. In Chedabucto Bay, Conover (1971) found up to 10% of the oil (Bunker C) in the water column was associated with zooplankton, but the oil had no apparent effect on the organisms. Moreover, he suggested that *ca*. 20% of the oil was carried to the bottom in zooplankton feces.

Corner *et al*. (1976) suggested that hydrocarbons such as naphalene were more readily accumulated by *Calanus* from food organisms than from solution in seawater, although a greater amount of hydrocarbon may be present in solution. These authors showed that the rate of depuration is also slower when animals have eaten the hydrocarbons. While the rate of depuration of aromatic hydrocarbons accumulated in copepods directly from seawater is relatively fast, a small amount remains in the animals to be transferred to a higher trophic level. Corner *et al*. (1976) and Lee (1975) found evidence that copepods are able to metabolize aromatic hydrocarbons, so that some potentially harmful hydrocarbons are transferred up the food chain as harmless compounds rather than as carcinogens.

Following the Tsesis oil spill in the northern Baltic Sea, Johansson (1980) found zooplankton to be heavily contaminated with oil, but there were no changes in the species composition or developmental stages between spill and control stations. Species changes were not detected in the phytoplankton community either, but phytoplankton biomass increased, possibly because of decreased zooplankton grazing. Sedimentation of oil through adsorption onto detritus particles was probably more important than sedimentation as fecal pellets.

Phytoplankton production may be increased, decreased, or not affected depending on species present, season, temperature, light conditions, and the amount and type of oil used (Shiels *et al*. 1973). Phytoplankton growth can be stimulated by petroleum at levels < 100 μg ℓ^{-1} and inhibited at levels > 100 μg ℓ^{-1} (Prouse *et al*. 1976). However, the ratio of the aromatic to paraffin content of the oil has a great influence on the threshold level at which oil inhibits growth of some phytoplankton (Anderson *et al*. 1974).

Many of the studies have utilized cultures of algae which may or may not be common in the marine environment; only Adams (1975); Hsiao (1976, 1978); and Hsiao *et al*. (1978) have studied true Arctic marine phytoplankton species. Adams (1975) found slightly enhanced ^{14}C uptake and a greater abundance and variety of genera in oil contaminated samples, but this may have been the result of reduced zooplankton grazing. Productivity and diversity were not greatly changed by the oil perturbation leading Adams (1975) to suggest that the phytoplankton community is relatively stable and therefore less vulnerable to oil than higher level components of the food chain. Adams failed to point out however, that subtle changes may occur in the phytoplankton community that might not become apparent for some time after the perturbation; also, changes at the lowest level of the food web might seriously affect higher levels.

Hsiao (1976, 1978) and Hsiao *et al.*(1978) showed that there is a differential survival rate following exposure to crude oil depending on species. A green flagellate, *Chlamydomonas pulsatilla* Wohlenweber was able to survive longer and resume growth, while diatoms were more sensitive and were not able to recover their normal growth rates following exposure to crude oil.

In temperate, controlled ecosystem enclosures, Lee and Takahashi (1977), found a drastic decline in the diatom population followed by a bloom of the microflagellate, *Chrysochromulina kappa* Parke and Manton, after treatment with oil; tintinnids and rotifers that feed on microflagellates also increased. The diatom, *Cerataulina bergoni* Peragallo, was dominant in the control system, although a short microflagellate bloom also occurred.

Hutchinson *et al.* (1979) have shown that the least soluble hydrocarbons are the most toxic. This suggests that partitioning between hydrocarbon molecules in water and into cellular lipids is high. These less soluble fractions in living organisms are persistent and are therefore available for food chain accumulation. In addition, in tundra soils, there is apparently increased hydrocarbon absorption with increasing organic content and these high molecular weight compounds are less likely to be biodegradable, leading to accumulation in terrestrial food chains as well.

These experiments show that there are major changes in the phytoplankton community following exposure to oil and these can lead to changes in the herbivore population. Changes in the zooplankton community could lead to changes at higher trophic levels, too.

It is not clear how susceptible organisms in the Arctic marine ecosystem are to damage by oil pollution (Percy and Mullin 1975). The most likely oil-organism interactions are with sub-ice oil lenses, oil dispersed in the water column, and oil trapped in bottom sediments. The most likely levels of effect are short-term lethal effects, sublethal physiological effects, and behavioral effects, all of which could affect planktonic organisms.

The general consensus appears to be that the initial impact of oil on plankton will be light to moderate with a decrease in population densities affecting local productivity; the greatest danger will be to small, local breeding populations of larval fish. Effective recovery will be fast to moderate because most plankton populations are dense and widely dispersed with rapid regeneration capability, although larval fish and shellfish may take longer to recover. The impact on fish and marine mammals is also expected to be light because they are able to avoid spills. Local fish populations would probably recover rapidly because of rapid dispersal mechanisms. Recovery of marine mammal populations would be slow if the population is seriously affected because of slow reproductive rates.

In the open ocean and outer continental shelf areas, the impact on plankton populations is expected to be light depending on the chance of actual contact with a floating slick; recovery should be relatively fast. The initial impact on, and expected recovery of, a polar ecosystem is not known. Recovery could be slow because polar organisms have slower growth rates and extended life cycles. Also, spilled oil may persist longer at cold temperatures (Hyland and Schneider 1976).

VIII. References cited

Aagaard, K. 1977. STD measurements in possible dispersal regions of the Beaufort Sea. Environmental Assessment of the Alaskan Continental Shelf Annual Reports 14:473-507.

Adams, W. A. 1975. Light intensity and primary productivity under sea ice containing oil. Beaufort Sea Project Tech. Rep. #29. Beaufort Sea Project, Department of the Environment, Victoria, B.C. 156 pp.

Alexander, V. 1974. Primary productivity regimes of the nearshore Beaufort Sea, with reference to potential roles of ice biota, pp. 609-632. In J. C. Reed and J. E. Sater, eds., The Coast and Shelf of the Beaufort Sea. Arctic Institute of North America, Arlington, VA.

Alexander, V. 1980. Interrelationships between the seasonal sea ice and biological regimes. Cold Regions Science and Technology 2:157-178.

Alvariño, A. 1965. Chaetognaths. Oceanogr. Mar. Biol. Ann. Rev. 3:115-194.

Alvariño, A. 1971. Siphonophores of the Pacific with a review of the world distribution. Bull. Scripps Instn. Oceanogr. 16:1-432.

Anderson, J. W., J. M. Neff, B. A. Cox, H. E. Tatum, and G. M. Hightower. 1974. Characteristics of dispersions and water-soluble extracts of crude and refined oils and their toxicity to estuarine crustaceans and fish. Mar. Biol. 27:75-88.

Atlas, R. M., A. Horowitz, and M. Busdosh. 1978. Prudhoe crude oil in arctic marine ice, water, and sediment ecosystems: degradation and interactions with microbial and benthic communities. J. Fish. Res. Board Can. 35:585-590.

Balech, E. 1974. El genero *Protoperidinium* Bergh, 1881 (*Peridinium*, Ehrenberg, 1831, partum). Revista del Museo Argentino de Ciencias Naturales "Bernardino Rivadavia" e Instituto Nacional de Investigacion de las Ciencias Naturales Hidrobiologia 4:1-79.

Banner, A. H. 1948a. A taxonomic study of the Mysidacea and Euphausiacea (Crustacea) of the Northeastern Pacific. Part I. Mysidacea from Family Lophogastridae through Tribe Erythropini. Trans. R. Can. Inst. 26:345-399.

Banner, A. H. 1948b. A taxonomic study of the Mysidacea and Euphausiacea (Crustacea) of the Northeastern Pacific. Part II. Mysidacea from Tribe Mysini through Subfamily Mysidellinae. Trans. R. Can. Inst. 27:65-125.

Banner, A. H. 1950. A taxonomic study of the Mysidacea and Euphausiacea (Crustacea) of the Northeastern Pacific. Part III. Euphausiacea. Trans. R. Can. Inst. 28:1-63.

Barnard, J. L. 1959. Epipelagic and under ice Amphipoda of the Central Arctic Basin, pp. 115-152. In V. Bushnell, ed., Scientific Studies at Fletcher's Ice Island, T-3, 1952-1955. Geophysical Research Papers No. 63.

Barnard, J. L. 1969. The families and genera of marine gammaridean Amphipoda. Bull. U.S. Natn. Mus. 271:1-535.

Barnes, R. D. 1974. Invertebrate Zoology, 3rd ed. W. B. Saunders Co., Philadelphia. 870 pp.

Bigelow, H. 1920. Medusae and ctenophores from the Canadian Arctic Expedition. Rep. Can. arct. Exped. 8(H);1-22.

Blackburn, J. E. 1973. A survey of the abundance, distribution and factors affecting distribution of ichthyoplankton in Skagit Bay. M.S. Thesis, Univ. Washington, Seattle. 136 pp.

Boden, B. P., M. W. Johnson, and E. Brinton. 1955. The Euphausiacea (Crustacea) of the North Pacific. Bull Scripps Instn. Oceanogr. 6:287-400.

Bousfield, E. 1951. Pelagic Amphipoda of the Belle Isle Strait region. J. Fish. Res. Board Can. 8:134-163.

Bousfield, E. 1979. The amphipod Superfamily Gammaroidea in the North-eastern Pacific region: systematics and distributional ecology. Bull. Biol. Soc. Wash. 3:297-357.

Brinton, E. 1962. The distribution of Pacific euphausiids. Bull. Scripps Instn. Oceanogr. 8:51-270.

Bursa, A. S. 1963. Phytoplankton in coastal waters of the Arctic Ocean at Point Barrow, Alaska. Arctic 16:239-262.

Busdosh, M., and R. M. Atlas. 1977. Toxicity of oil slicks to Arctic amphipods. Arctic 30:85-92.

Cairns, A. A. 1967. The zooplankton of Tanquary Fjord, Ellesmere Island, with special reference to calanoid Copepoda. J. Fish. Res. Board Can. 24:555-568.

Clutter, R. I., and M. Anraku. 1968. Avoidance of samplers, pp. 57-76. In Zooplankton Sampling. Monographs on Oceanographic Methodology 2. Unesco, Paris.

Codispoti, L. A., and F. A. Richards. 1968. Micronutrient distributions in the East Siberian and Laptev seas during summer 1963. Arctic 21: 67-83.

Conover, R. J. 1971. Some relations between zooplankton and Bunker C oil in Chedabucto Bay following the wreck of the tanker *Arrow*. J. Fish. Res. Board Can. 28:1327-1330.

Cooney, R. T., and J. J. Crane. 1972. Nearshore marine biology - Colville area, pp. 217-230. In P. J. Kinney, D. M. Schell, V. Alexander, D. C. Burrell, R. Cooney, and A. S. Naidu, eds., Baseline Data Study of the Alaskan Arctic Aquatic Environment. Univ. Alaska, Inst. Mar. Sci. Rep. R72-3.

Corner, E. D. S., R. P. Harris, C. C. Kilvington, and S. C. M. O'Hara. 1976. Petroleum compounds in the marine food web: short-term experiments on the fate of napthalene in *Calanus*. J. mar. biol. Ass. U.K. 56:121-133.

Coyle, K. O. 1974. The ecology of the phytoplankton of Prudhoe Bay, Alaska, and the surrounding waters. M.S. Thesis, Univ. Alaska, Fairbanks. 265 pp.

Crane, J. J. 1974. Ecological studies of the benthic fauna in an Arctic estuary. M.S. Thesis, Univ. Alaska, Fairbanks.

Dawson, J. K. 1971. Species of Arctic Ocean chaetognaths, pp. 3-21. In H. A. Kobayashi, ed., Taxonomic Guides to Arctic Zooplankton III. Univ. So. Calif., Dep. Biol. Sci. Tech. Rep. 4.

Dunbar, M. J. 1940. On the size distribution and breeding cycles of four marine planktonic animals from the Arctic. J. Anim. Ecol. 9:215-226.

Dunbar, M. J. 1941. On the food of seals in the Canadian Eastern Arctic. Can. J. Research D 19:150-155.

Dunbar, M. J. 1942. Marine macroplankton from the Canadian Eastern Arctic. I. Amphipoda and Schizopoda. Can. J. Research D 20:33-46.

Dunbar, M. J. 1954. The amphipod Crustacea of Ungave Bay, Canadian Eastern Arctic. J. Fish. Res. Board Can. 11:709-798.

Ehrenbaum, E. H. 1909. Eier und Larven von Fischen des nordischen Planktons. Nord. Plankt. 1:1-413.

English, T. S. 1976. Alaska marine ichthyoplankton key. Environmental Assessment of the Alaskan Continental Shelf Annual Reports 7:543-578.

English, T. S., and R. Horner. 1977. Beaufort Sea plankton studies. Environmental Assessment of the Alaskan Continental Shelf Annual Reports 9:275-627.

Foy, M. G., and S. I. C. Hsiao. 1976. Phytoplankton data from the Beaufort Sea, 1973 to 1975. Fisheries and Marine Service, Environment Canada Tech. Rep. No. 617. 44 pp.

Frost, B. W. 1974. *Calanus marshallae*, a new species of calanoid copepod closely allied to the sibling species *C. finmarchicus* and *C. glacialis*. Mar. Biol. 26:77-99.

Gorbunova, N. N. 1954. Reproduction and development of the walleye pollock. Trudy Inst. Okeanol. 11:132-195. (In Russian)

Grainger, E. H. 1965. Zooplankton from the Arctic Ocean and adjacent Canadian water. J. Fish. Res. Board Can. 22:543-564.

Grainger, E. H. 1974. Nutrients in the southern Beaufort Sea, pp. 589-605. In J. C. Reed and J. E. Sater, eds., The Coast and Shelf of the Beaufort Sea. Arctic Institute of North America, Arlington, VA.

Grainger, E. H. 1975. Biological productivity of the southern Beaufort Sea: the physical and chemical environment of the plankton. Beaufort Sea Project Tech. Rep. #12a. Beaufort Sea Project, Department of the Environment, Victoria, B.C. 82 pp.

Grainger, E. H., and K. Grohe. 1975. Zooplankton data from the Beaufort Sea, 1951-1975. Fisheries and Marine Service, Environment Canada Tech Rep. No. 591. 54 pp.

Griffiths, R. P., S. S. Hayaska, T. M. McNamara and R. Y. Morita. 1978. Relative microbial activity and bacterial concentrations in water and sediment samples taken in the Beaufort Sea. Can. J. Microbiol. 24:1217-1226.

Gurjanova, E. 1930. Beiträge zur Fauna der Crustacea-Malacostraca des arktischen Gebietes. Zool. Anz. 86:231-248. (Reference not seen, cited from Tencati, J., and S. Geiger 1968.)

Gurjanova, E. 1951. Bokoplavy morej SSSR i sopredel'nykh vod (Amphipoda-Gammaridea). Opred. po Faune SSSR, Akad. Nauk SSSR 41:1-1029. (In Russian)

Hamilton, R. A., C. L. Ho, and H. J. Walker. 1974. Breakup flooding and nutrient source of Colville River delta during 1973, pp. 637-648. In J. C. Reed and J. E. Sater, eds., The Coast and Shelf of the Beaufort Sea. Arctic Institute of North America, Arlington, VA.

Hand, C., and L. Kan. 1961. The medusae of the Chukchi and Beaufort seas of the Arctic Ocean including the description of a new species of *Eucodonium* (Hydrozoa: Anthomedusae). Arctic Institute of North America Publ. 1. 55 pp.

Hansen, W. J., and M. J. Dunbar. 1970. Biological causes of scattering layers in the Arctic Ocean, pp. 508-526. In G. B. Farquhar, ed., Proceedings of the International Symposium on Biological Sound Scattering in the Oceans. Department of the Navy, Washington D.C.

Harding, G. C. H. 1966. Zooplankton distribution in the Arctic Ocean with notes on life cycles. M. S. Thesis, McGill Univ., Montreal. 134 pp.

Hart, J. F. L. 1960. The larval development of British Columbia Brachyura. II. Majiidae, Subfamily Oregoniinae. Can. J. Zool. 38:539-546.

Hartlaub, C. 1933. Craspedote Medusen. Nord. Plankt. 6(7):1-601.

Haynes, E. B. 1973. Descriptions of prezoea and stage I zoeae of *Chionoecetes bairdi* and *C. opilio* (Oxyrhyncha, Oregoniinae). Fish. Bull. U.S. 71:769-771.

Haynes, E. B. 1978. Description of the larvae of the humpy shrimp, *Pandalus goniurus*, reared in situ in Kachemak Bay, Alaska. Fish. Bull. U.S. 76:235-248.

Heinrich, A. K. 1962. The life histories of plankton animals and seasonal cycles of plankton communities in the oceans. J. Cons. perm. int. Explor. Mer 27:15-24.

Hendey, N. I. 1974. A revised check-list of British marine diatoms. J. mar. biol. Ass. U.K. 54:277-300.

Herlinveaux, R. H., and B. R. de Lange Boom. 1975. The physical oceanography of the southeastern Beaufort Sea. Beaufort Sea Project Tech. Rep. #18. Beaufort Sea Project, Department of the Environment, Victoria, B.C. 97 pp.

Holmquist, C. 1965. The amphipod genus *Pseudalibrotus*. Ztschr. Zool. Syst. Evolutionforsch. 3:19-46.

Horner, R. 1972. Ecological studies on Arctic sea ice organisms. Univ. Alaska, Inst. Mar. Sci. Rep. R72-17. 176 pp.

Horner, R. 1976. Sea ice organisms. Oceanogr. Mar. Biol. Ann. Rev. 14: 167-182.

Horner, R. 1977. History and recent advances in the study of ice biota, pp. 269-283. In M. J. Dunbar, ed., Polar Oceans. Arctic Institute of North America, Calgary, Alberta.

Horner, R., K. O. Coyle, and D. R. Redburn. 1974. Ecology of the plankton of Prudhoe Bay, Alaska. Univ. Alaska, Inst. Mar. Sci. Rep. R74-2, Sea Grant Rep. 73-15. 78 pp.

Hsiao, S. I. C. 1976. Biological productivity of the southern Beaufort Sea: phytoplankton and seaweed studies. Beaufort Sea Project Tech. Rep. #12c. Beaufort Sea Project, Department of the Environment, Victoria, B.C. 99 pp.

Hsiao, S. I. C. 1978. Effects of crude oils on the growth of Arctic marine phytoplankton. Environ. Pollut. 17:93-107.

Hsiao, S. I. C., M. G. Foy, and D. W. Kittle. 1977. Standing stock, community structure, species composition, distribution, and primary production of natural populations of phytoplankton in the southern Beaufort Sea. Can. J. Bot. 55:685-694.

Hsiao, S. I. C., D. W. Kittle, and M. G. Foy. 1978. Effects of crude oil and the oil dispersant Corexit on primary production of Arctic marine phytoplankton and seaweed. Environ. Pollut. 15:209-221.

Hufford, G. L. 1973. Warm water advection in the southern Beaufort Sea August through September 1971. J. Geophys. Res. 78:2702-2707.

Hufford, G. L. 1974a. On apparent upwelling in the southern Beaufort Sea. J. Geophys. Res. 79:1305-1306.

Hufford, G. L. 1974b. Dissolved oxygen and nutrients along the north Alaskan shelf, pp. 567-588. In J. C. Reed and J. E. Sater, eds., The Coast and Shelf of the Beaufort Sea. Arctic Institute of North America, Arlington, VA.

Hufford, G. L., S. H. Fortier, D. E. Wolfe, J. F. Doster, and D. L. Noble. 1974. Physical oceanography of the western Beaufort Sea. In Marine Ecological Survey of the western Beaufort Sea, U.S.C.G. Oceanogr. Rep. CG-373-64:1-182.

Hustedt, F. 1930. Die Keiselalgen. In L. Rabenhorst, Kryptogamen-Flora von Deutschland, Österreich und der Schweiz VII(1):1-920.

Hustedt, F. 1959-62. Die Kieselalgen. In L. Rabenhorst, Kryptogamen-Flora von Deutschland, Österreich und der Schweiz VII(2):1-845.

Hutchinson, T. C., J. A. Hellebust, D. Mackay, D. Tom, and P. Kauss. 1979. Relationship of hydrocarbon solubility to toxicity in algae and cellular membrane effects, pp. 541-547. In Proc. 1979 Oil Spill Conference (Prevention, Behavior, Control, Cleanup), Los Angeles. American Petroleum Institute Publ. No. 4308.

Hyland, J. L., and E. D. Schneider. 1976. Petroleum hydrocarbons and their effect on marine organisms, populations, communities, and ecosystems, pp. 464-506. In Sources, Effects and Sinks of Hydrocarbons in the Aquatic Environment. American Institute of Biological Sciences, Washington, D.C.

Jaschnov, W. A. 1948. Order Copepoda, pp. 183-215. In N. S. Gaevskoi, ed., Guide to the Fauna and Flora of the Northern Seas of the USSR. Gos. Isd. Sovetskaya Nauka, Moscow. (In Russian)

Johansson, S. 1980. Impact of oil on the pelagic ecosystem, pp. 61-79. In J. J. Kineman, R. Elmgren, and S. Hansson, eds., The *Tsesis* Oil Spill. U.S. Department of Commerce, Office of Marine Pollution

Assessment, NOAA, Boulder, CO.

Johnson, M. W. 1956. The plankton of the Beaufort and Chukchi Sea areas of the Arctic and its relation to the hydrography. Arctic Institute of North America Tech. Paper No. 1. 32 pp.

Johnson, M. W. 1958. Observations on inshore plankton collected during summer 1957 at Point Barrow, Alaska. J. mar. Res. 17:272-281.

Johnson, M. W. 1963. Zooplankton collections from the high polar basin with special reference to the Copepoda. Limnol. Oceanogr. 8:89-102.

Kramp, P. L. 1961. Synopsis of the Medusae of the World. J. mar. biol. Ass. U.K. 40:1-469.

Lalli, C. M. 1970. Structure and function of the buccal apparatus of *Clione limacina* (Phipps) with a review of feeding in gymnosomatous pteropods. J. exp. mar. Biol. Ecol. 4:101-118.

Leadbeater, B. S. C. 1972. Fine-structural observations on some marine choanoflagellates from the coast of Norway. J. mar. biol. Ass. U.K. 52:67-79.

Lebour, M. V. 1926. A general survey of larval euphausiids, with a scheme for their identification. J. mar. biol. Ass. U.K. 14:519-527.

Lee, R. F. 1975. Fate of petroleum hydrocarbons in marine zooplankton, pp. 549-553. In Proceedings of the Conference on Prevention and Control of Oil Pollution, San Francisco. American Petroleum Institute.

Lee, R. F., and M. Takahashi. 1977. The fate and effect of petroleum in controlled ecosystem enclosures. Rapp. P.-v. Réun. Cons. int. Explor. Mer 171:150-156.

Leung, Y. M. 1970a. Euphausiids of the Arctic Basin and peripheral seas, pp. 38-45. In Y. M. Leung and H. A. Kobayashi, eds., Taxonomic Guides to Arctic Zooplankton. Univ. So. Calif., Dep. Biol. Sci. Tech. Rep. 2.

Leung, Y. M. 1970b. Ctenophores of the Central Arctic, pp. 30-50. In H. Kobayashi, ed., Taxonomic Guides to Arctic Zooplankton (II). Univ. So. Calif., Dep. Biol. Sci. Tech. Rep. 3.

Leung, Y. M. 1971. Pteropods of the Central Arctic, pp. 22-28. In H. A. Kobayashi, ed., Taxonomic Guides to Arctic Zooplankton III. Univ. So. Calif., Dep. Biol. Sci. Tech. Rep. 4.

Leung, Y. M. 1972a. Appendicularians of the Central Arctic, pp. 3-12. In H. Kobayashi, ed., Taxonomic Guides to Arctic Zooplankton (III). Univ. So. Calif., Dep. Biol. Sci. Tech Rep. 2.

Leung, Y. M. 1972b. Mysids of the Arctic Ocean and confluent seas, pp.

13-21. In H. Kobayashi, ed., Taxonomic Guides to Arctic Zooplankton (VI). Univ. So. Calif, Dep. Biol. Sci. Tech. Rep. 2.

Leung, Y. M. 1972c. Ostracods of the Central Arctic, pp. 29-40. In H. Kobayashi, ed., Taxonomic Guides to Arctic Zooplankton (VI). Univ. So. Calif., Dep. Biol. Sci. Tech. Rep. 2.

Leung, Y. M. 1975. On the ostracod fauna of the Arctic Basin. Astarte 8:41-47.

Lohmann, H. 1933. Die Appendicularian. Nord. Plankt. 2(3):1-47.

Lowry, L. F., K. J. Frost, and J. J. Burns. 1979. Trophic relationships among ice inhabiting phocid seals and functionally related marine mammals. Environmental Assessment of the Alaskan Continental Shelf Final Reports, Biological Studies 6:573-629.

MacGinitie, G. E. 1955. Distribution and ecology of the marine invertebrates of Point Barrow, Alaska. Smithson. Misc. Collns 128(9):1-201.

McEwan, G. F., M. W. Johnson, and T. R. Folsom. 1954. A statistical analysis of the performance of the Folsom plankton sample splitter based upon test observations. Arch. Meteor. Geophys. Bioklimat. Ser. A 7:507-527.

Mann, A. 1925. The marine diatoms of the Canadian Arctic Expedition, 1913-1918. Rep. Can. arct. Exped. IV(F):1-33.

Matheke, G. E. M. 1973. The ecology of the benthic microalgae in the sublittoral zone of the Chukchi Sea near Barrow, Alaska. M.S. Thesis, Univ. Alaska, Fairbanks. 114 pp.

Mayer, A. G. 1910. Medusae of the World. Vol. III. The Scyphomedusae. Carnegie Inst. Wash. Publ. 109:499-735.

Mountain, D. G. 1974. Preliminary analysis of Beaufort shelf circulation in summer, pp. 27-48. In J. C. Reed and J. E. Sater, eds., The Coast and Shelf of the Beaufort Sea. Arctic Institute of North America, Arlington, VA.

Naumov, D. V. 1960. Hydroids and Hydromedusae of the USSR. Keys to the Fauna of the USSR. Zoological Inst., Acad. Sci. USSR No. 70. Isdatel'stvo Akad. Nauk SSSR, Moskva-Leningrad. (Transl. from Russian by Israel Program for Scientific Translations, Jerusalem 1969.) 660 pp.

O'Rourke, J. C. 1974. Inventory of physical oceanography of the eastern Beaufort Sea, pp. 567-588. In J. C. Reed and J. E. Sater, eds., The Coast and Shelf of the Beaufort Sea. Arctic Institute of North America, Arlington, VA.

Paquette, R. G., and R. H. Bourke. 1974. Observations on the coastal current of arctic Alaska. J. mar. Res. 32:195-207.

Parke, M., and P. S. Dixon. 1976. Check-list of British marine algae - third revision. J. mar. biol. Ass. U.K. 56:527-594.

Percy, J. A. 1977. Responses of Arctic marine benthic crustaceans to sediments contaminated with crude oil. Environ. Pollut. 13:1-10.

Percy, J. A., and T. C. Mullin. 1975. Effects of crude oils on Arctic marine invertebrates. Beaufort Sea Project Tech. Rep. #11. Beaufort Sea Project, Department of the Environment, Victoria, B.C. 167 pp.

Prouse, N. J., D. C. Gordon, and P. D. Keizer. 1976. Effects of low concentrations of oil accommodated in seawater on the growth of unialgal marine phytoplankton cultures. J. Fish. Res. Board Can. 33: 810-818.

Rass, T. S. 1949. Composition of the Barents Sea and systematic identification of fish eggs and larvae of these waters. Trudy vses. Nauchno-issled. Inst. Morsk. ryb. khoz. Okeanogr. 17:7-65. (In Russian)

Redburn, D. R. 1974. The ecology of the inshore marine zooplankton of the Chukchi Sea near Point Barrow, Alaska. M.S. Thesis, Univ. Alaska, Fairbanks. 172 pp.

Redfield, A. C., B. H. Ketchum, and F. A. Richards. 1963. The influence of organisms on the composition of seawater, pp. 26-77. In M. N. Hill, ed., The Sea, vol. 2. John Wiley and Sons, New York.

Sars, G. O. 1870. Carcinologiske Bidrag til Norges Fauna. I. Monographie over de ved Norges Kyster forekommende Mysider 1-3. K. norske Videnskabsselskab i Trondhjem. 229 pp.

Sars, G. O. 1895. An Account of the Crustacea of Norway. I. Amphipoda. Alb. Cammermeyers Forlag, Christiania and Copenhagen. 711 pp.

Sars, G. O. 1900a. An Account of the Crustacea of Norway. III. Cumacea. Bergen Museum, Bergen. 115 pp.

Sars, G. O. 1900b. Crustacea. Scient. Results Norw. N. polar Exped. 1(5):1-141.

Sars, G. O. 1928. An Account of the Crustacea of Norway. IX. Ostracoda. Bergen Museum, Bergen. 277 pp.

Schell, D. M. 1974. Regeneration of nitrogenous nutrients in arctic Alaskan estuarine waters, pp. 649-664. In J. C. Reed and J. E. Sater, eds., The Coast and Shelf of the Beaufort Sea. Arctic Institute of North America, Arlington, VA.

Schmitt, W. 1919. The schizopod crustaceans of the Canadian Arctic Expedition, 1913-1918. Rep. Can. arct. Exped. VII(B):1-9.

Shiels, W. E., J. J. Goering, and D. W. Hood. 1973. Crude oil phytotoxicity studies, pp. 413-446. In D. W. Hood, W. E. Shiels, and E. J. Kelley, eds., Environmental Studies of Port Valdez. Univ. Alaska, Inst. Mar. Sci. Occas. Publ. 3.

Shirley, D. W., and Y. M. Leung. 1970. Medusae of the Central Arctic, pp. 3-18. In H. Kobayashi, ed., Taxonomic Guides to Arctic Zooplankton (II). Univ. So. Calif., Dep. Biol. Sci. Tech. Rep. 3.

Shoemaker, C. 1920. The amphipod crustaceans of the Canadian Arctic Expedition. Rep. Can. arct. Exped. VII(E):1-30.

Smith, D. L. 1977. A Guide to Marine Coastal Plankton and Marine Invertebrate Larvae. Kendall/Hunt Publishing Co., Dubuque, IA. 161 pp.

Smith, R. I., and J. T. Carlton. 1975. Light's Manual: Intertidal Invertebrates of the California Coast. Univ. California Press, Berkeley. 716 pp.

Stephensen, K. 1923. Crustacea Malacostraca. V. (Amphipoda. I.) Danish Ingolf-Expedition 3(8):1-100.

Stephensen, K. 1931. Crustacea Malacostraca. VII. (Amphipoda. III.) Danish Ingolf-Expedition 3(11):177-290.

Stephensen, K. 1933a. Amphipoda. The Godthaab Exepdition 1928. Meddr Grønland 79(7)1-88.

Stephensen, K. 1933b. Schizopoda. The Godthaab Expedition 1928. Meddr Grønland 79(9):1-20.

Strickland, J. D. H., and T. R. Parsons. A Practical Handbook of Seawater Analysis. Bull. Fish. Res. Board Can. 167. 311 pp.

Tencati, J. R. 1970. Amphipods of the Central Arctic, pp. 3-37. In Y. M. Leung and H. Kobayashi, eds., Taxonomic Guides to Arctic Zooplankton. Univ. So. Calif., Dep. Biol. Sci. Tech. Rep. 2.

Tencati, J. R., and S. Geiger. 1968. Pelagic amphipods of the slope waters of northeast Greenland. J. Fish. Res. Board Can. 25:1637-1650.

Tidmarsh, G. W. 1973. The Copepoda (Calanoida, Cyclopoida) of northern Baffin Bay and southern Nares Strait: their distribution and aspects of their biology. M.S. Thesis, McGill Univ., Montreal. Baffin Bay-North Water Project, Arctic Institute of North America Sci. Rep. 3. 181 pp.

Totton, A. K. 1965. A Synopsis of the Siphonophora. Trustees of the British Natural History Museum. Thanet Press, Margate. 230 pp.

Tranter, D. J., and P. E. Smith. 1968. Filtration performance, pp. 27-56. In Zooplankton Sampling. Monographs on Oceanographic

Methodology 2. Unesco, Paris.

Unesco. 1966. Monographs on Oceanographic Methodology. 1. Determinations of photosynthetic pigments in sea-water. Unesco, Paris. 69 pp.

U.S. Naval Oceanographic Office. 1968. Instructional Manual for obtaining Oceanographic Data, 3rd ed. Publ. 607. Washington, D.C.

Utermöhl, H. 1931. Neue Wege in der quantitativen Erfassung des Planktons. Verh. int. Verein. theor. angew. Limnol. 5:567-596.

van der Spoel, S. 1967. Euthecosomata: A Group with Remarkable Developmental Stages (Gastropoda, Pteropoda). J. Noorduijn en Zoon N.V., Gorinchem, The Netherlands. 375 pp.

Vidal, J. 1971. Key to the calanoid copepods of the Central Arctic Ocean, pp. 1-128. In H. Kobayashi, ed., Taxonomic Guides to Arctic Zooplankton (IV). Univ. So. Calif., Dep. Biol. Sci. Tech. Rep. 5.

Willey, A. 1920. Report on the marine Copepoda collected during the Canadian Arctic Expedition. Rep. Can. arct. Exped. VII(K):1-46.

Wing, B. L. 1974. Kinds and abundance of zooplankton collected by the USCG Icebreaker *Glacier* in the eastern Chukchi Sea, September-October 1970. NOAA Tech. Rep. NMFS SSRF 679. 18 pp.

Wing, B. L., and N. Barr. 1977. Midwater invertebrates from the southern Chukchi Sea: species and abundance in catches incidental to midwater trawling survey of fishes, September-October 1970. NOAA Tech. Rep. NMFS-SSRF-710. 43 pp.

Yingst, D. R. 1972. Pelagic polychaetes of the Central Arctic Basin, pp. 1-42. In H. Kobayashi, ed., Taxonomic Guides to Arctic Zooplankton (V). Univ. So. Calif., Dep. Biol. Sci. Tech. Rep. 1.

Zimmer, C. 1933. Schizopoden. Nord. Plankt. 3(6):1-179.

Appendix I

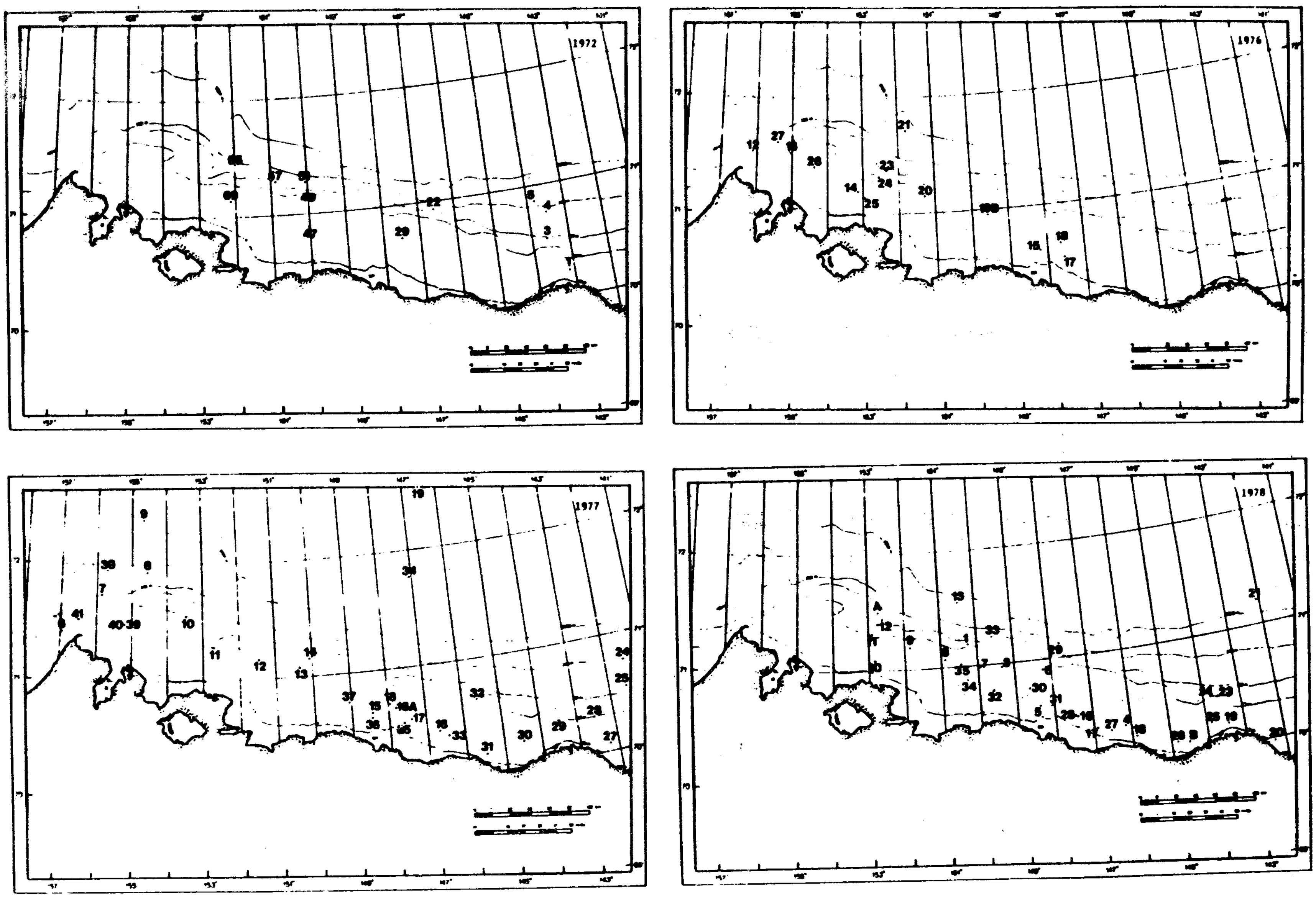


Fig. I-1. Station locations where zooplankton samples were collected, 1972, 1976, 1977, and 1978.

Figs. I-2 - I-53. Abundance (number per 1000 m^3) of zooplankton taxa collected in net hauls in the Beaufort Sea, August - September 1972, 1976, 1977, and 1978. Symbols of similar size denote like intervals of the stated range. Shape and shading of symbols indicate type of gear used.

- bongo net - 335 μm mesh, 1976
- bongo net - 500 μm mesh, 1976, 1977, 1978
- 1/2 m ring net - 570 μm mesh, 1972
- 1 m ring net - 570 μm mesh, 1972
- 3/4 m ring net - 308 μm mesh, 10-0 m, 1976
- 3/4 m ring net - 308 μm mesh, 20-0 m, 1976
- 2 m umbrella net - 216 μm mesh, 1977
- Isaacs-Kidd midwater trawl - 38 mm mesh, 1972

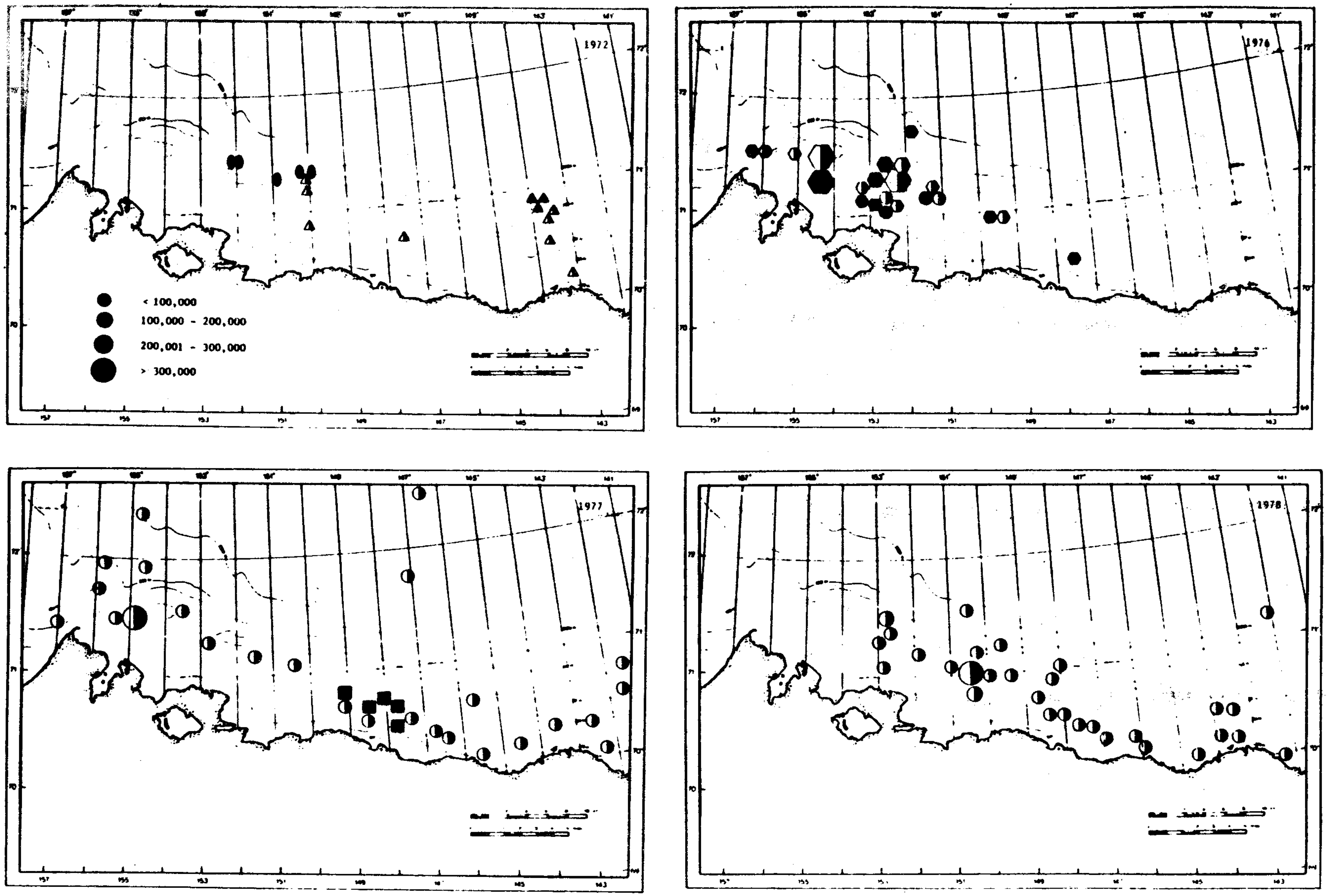


Fig. I-2. Distribution of *Aglantha digitale*.

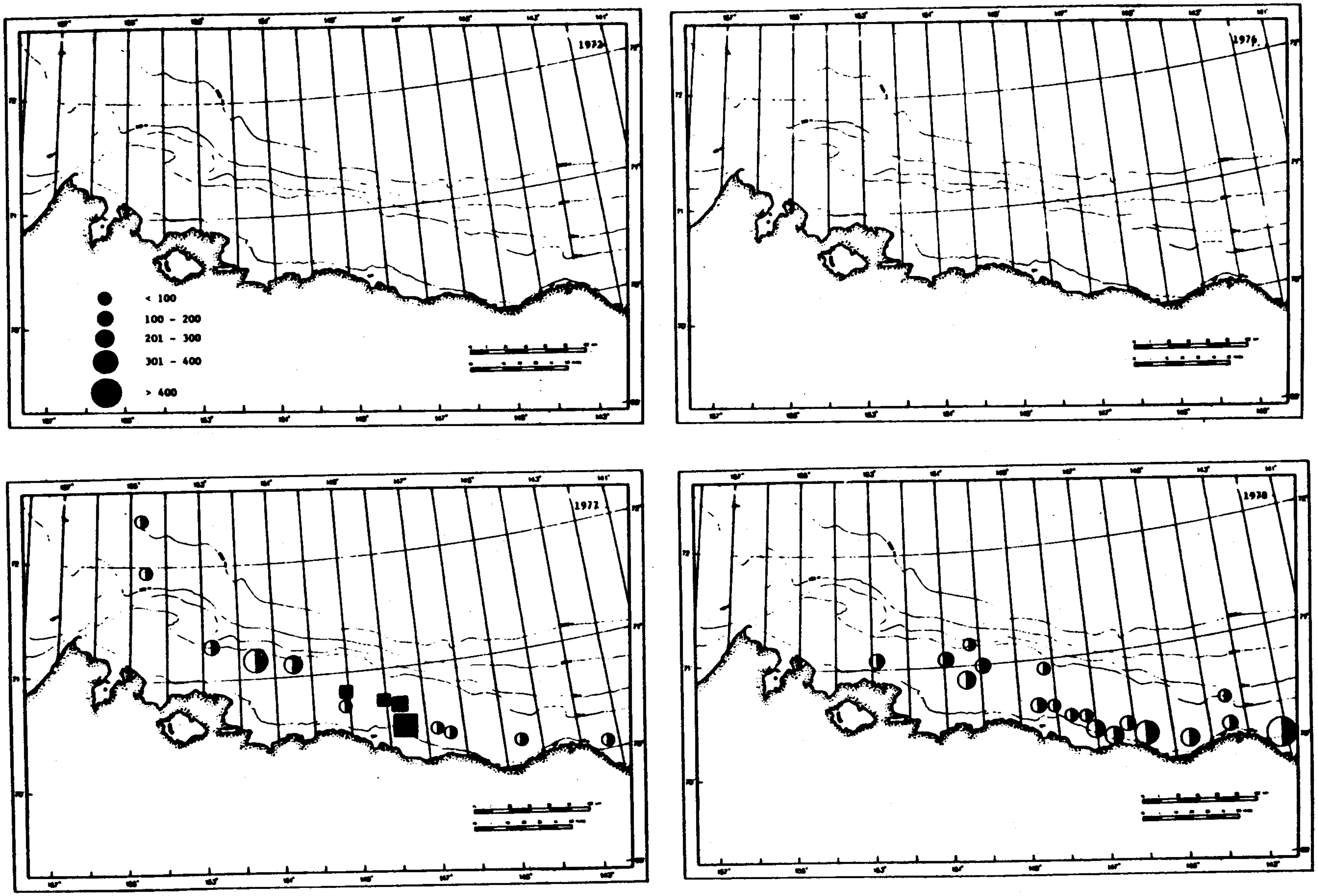


Fig. I-3. Distribution of *Catablema* spp.

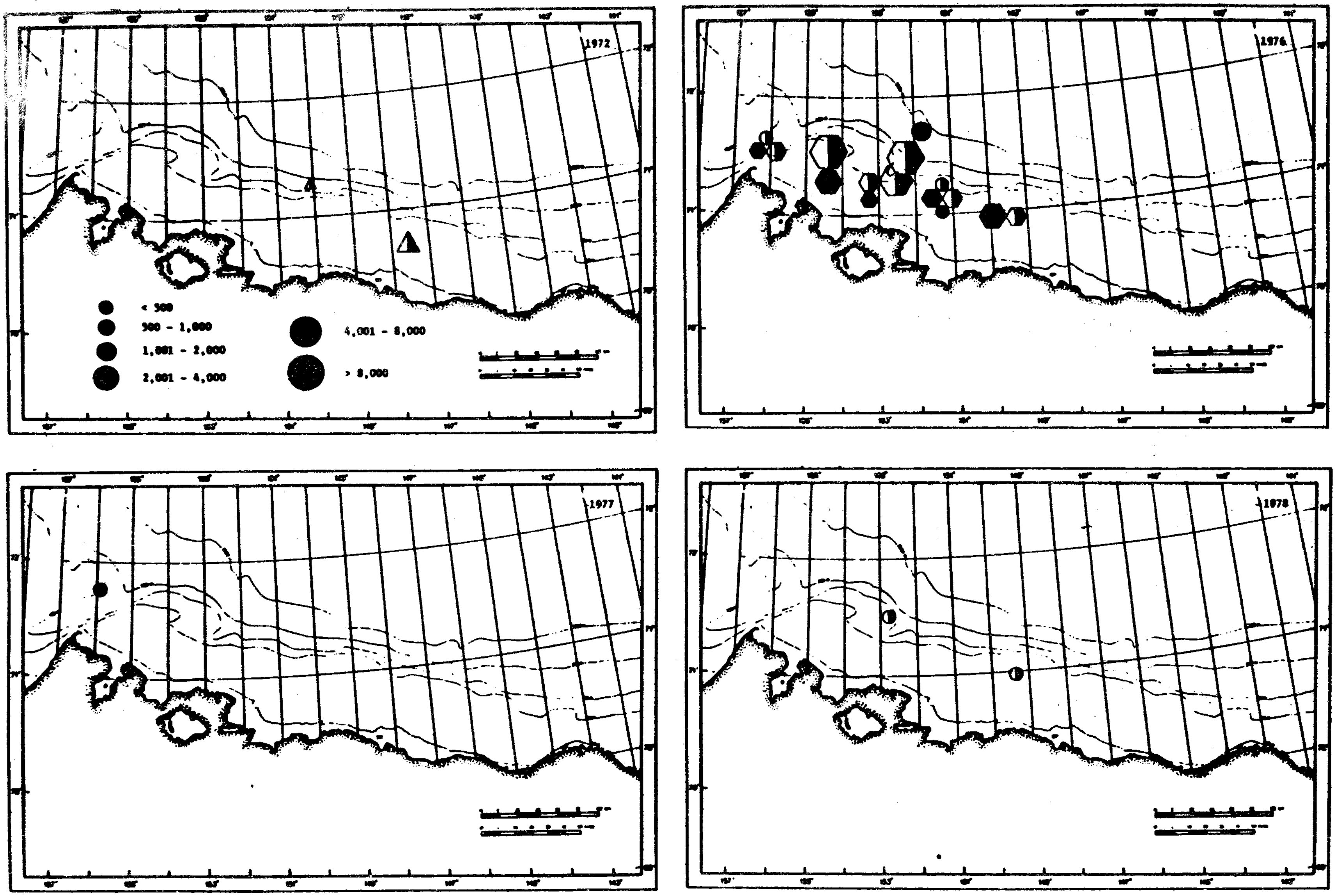


Fig. I-4. Distribution of *Rathkea* spp.

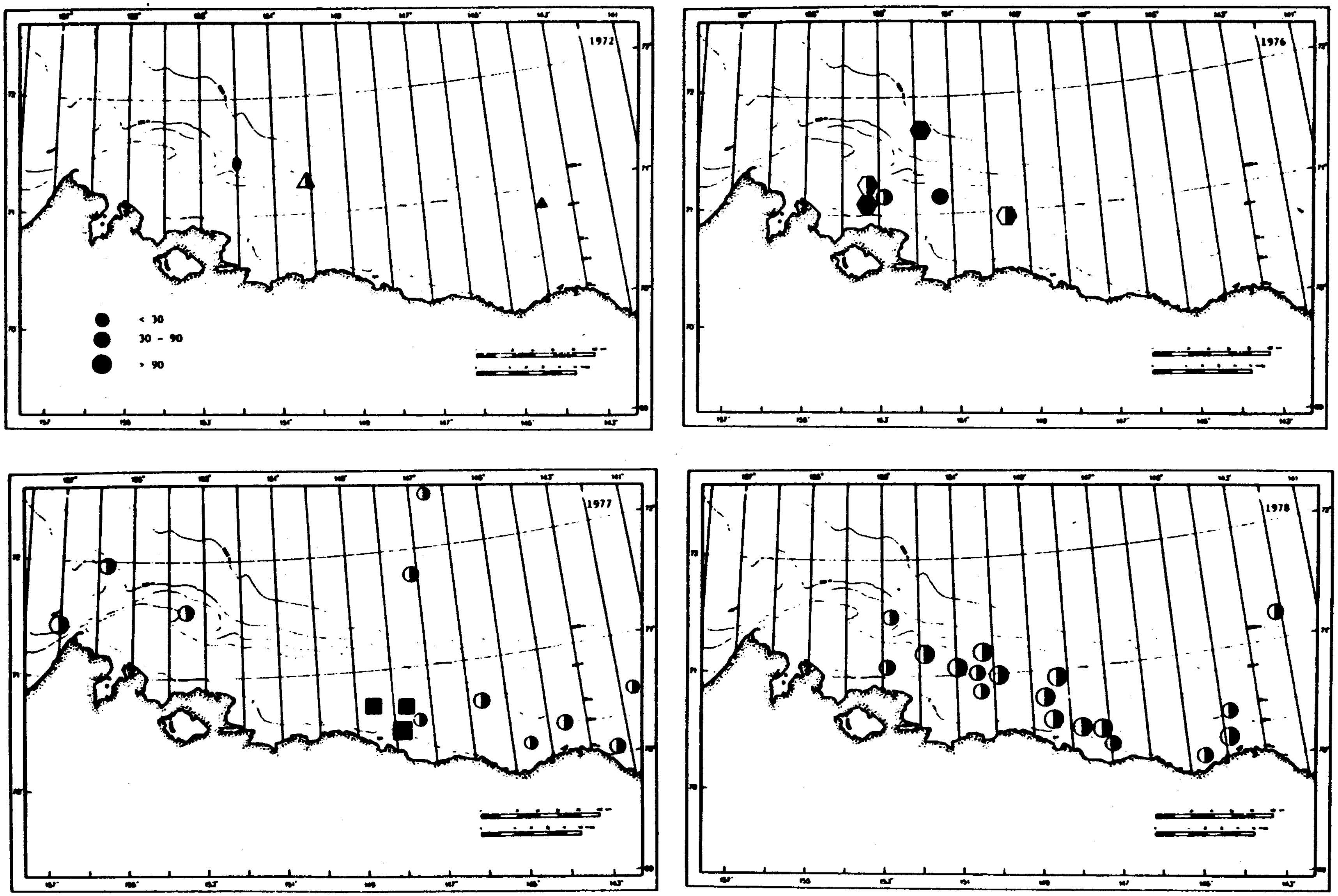


Fig. I-5. Distribution of Ctenophora.

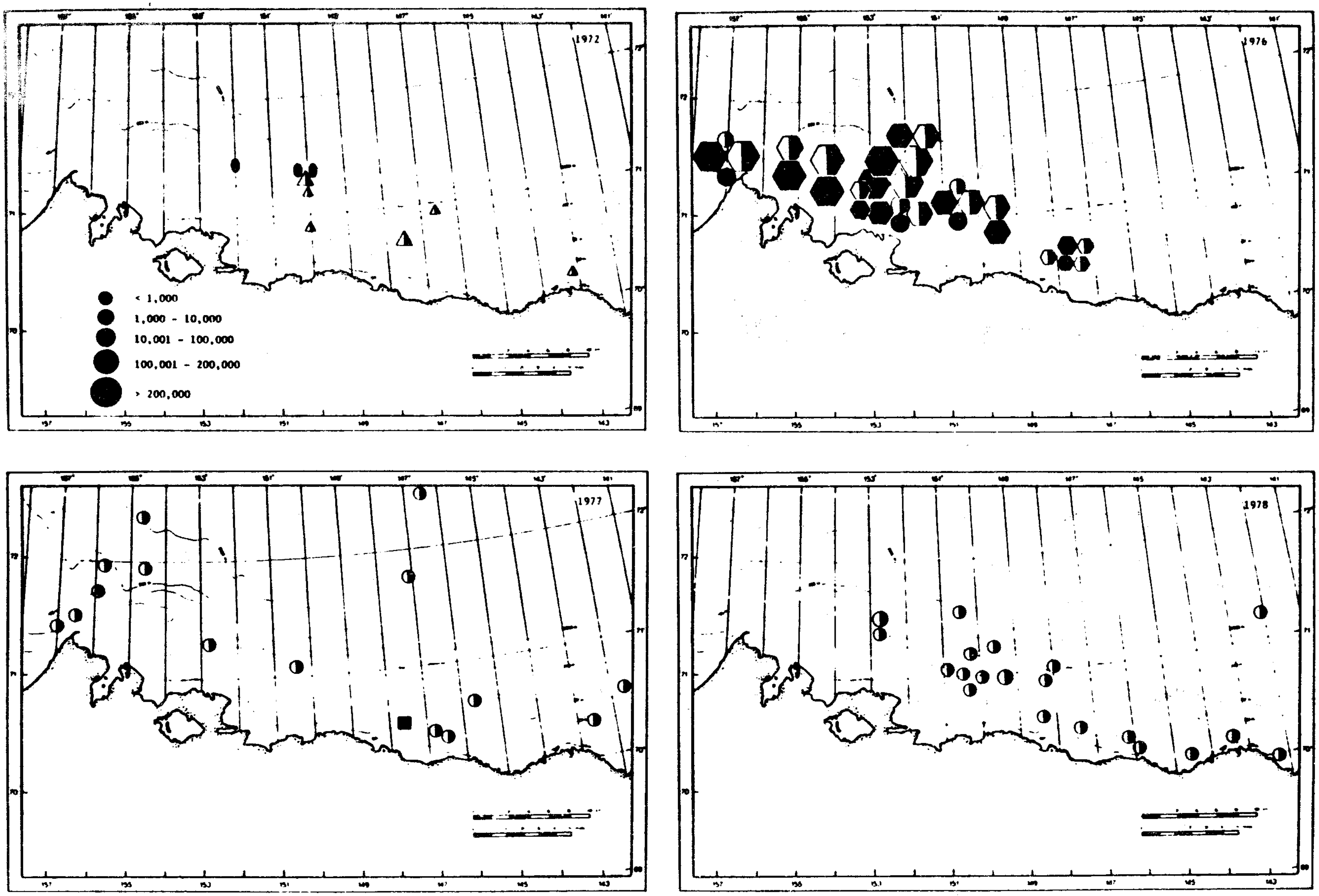


Fig. I-6. Distribution of polychaete larvae.

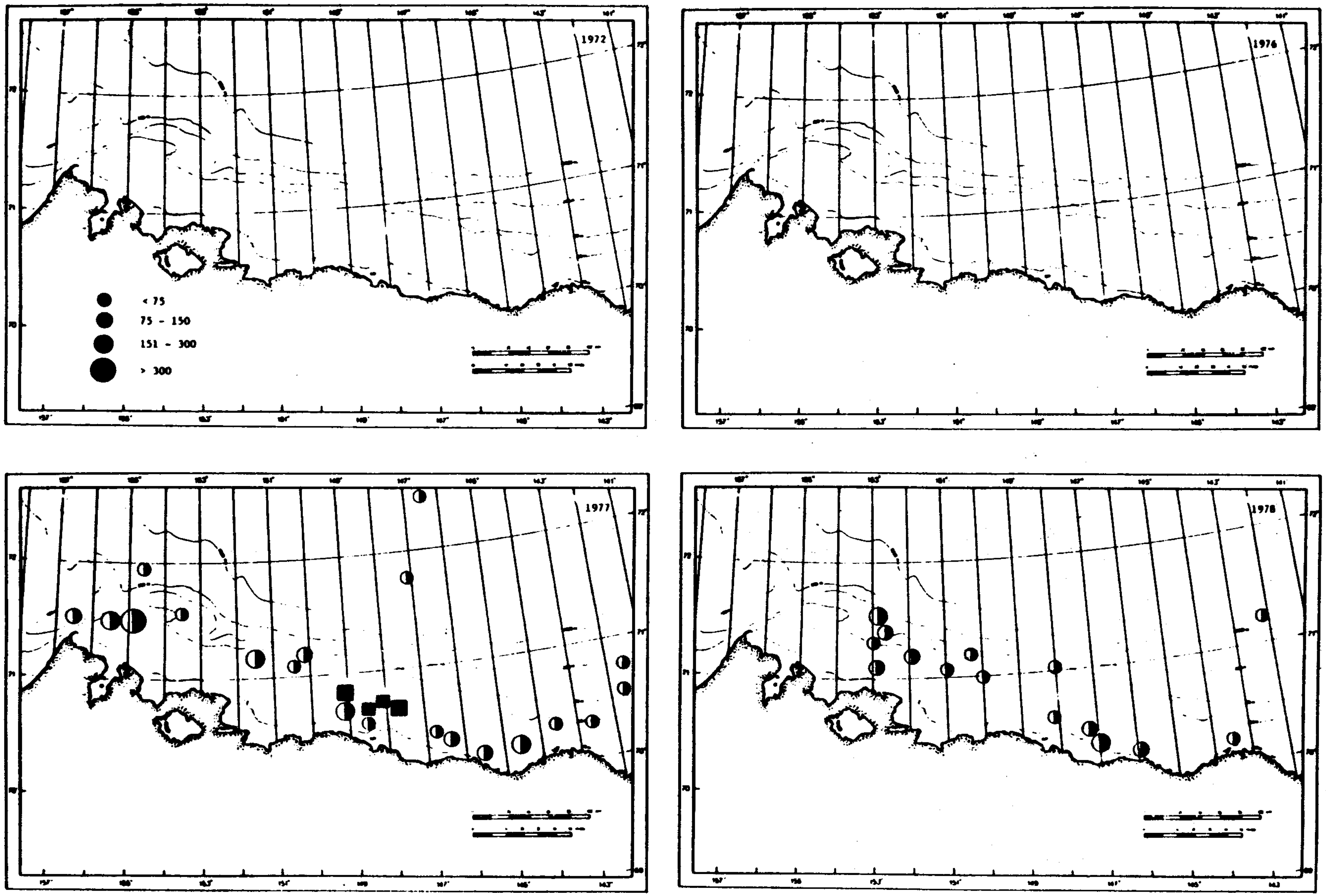


Fig. I-7. Distribution of *Clione limacina*.

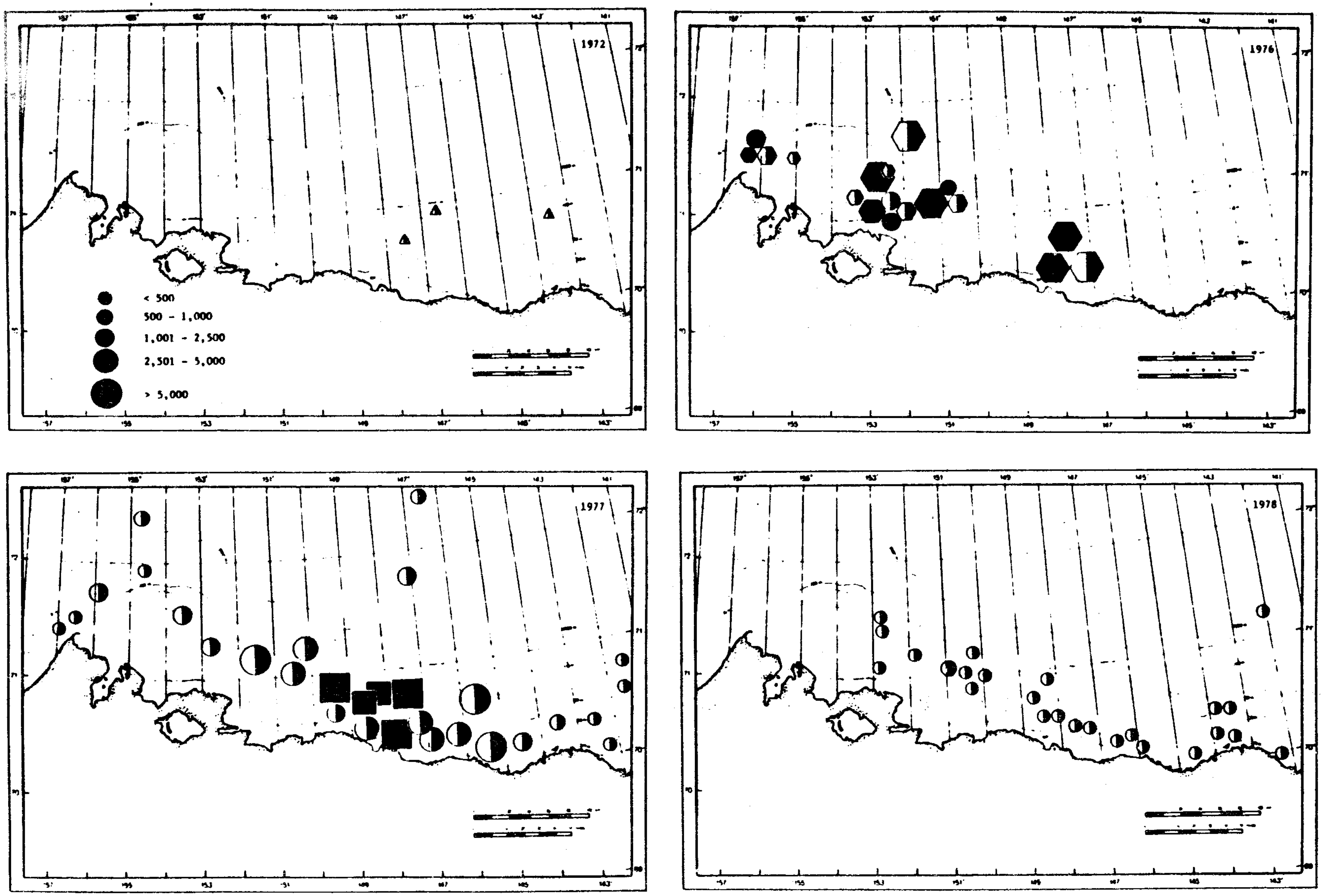


Fig. I-8. Distribution of *Limacina helicina*.

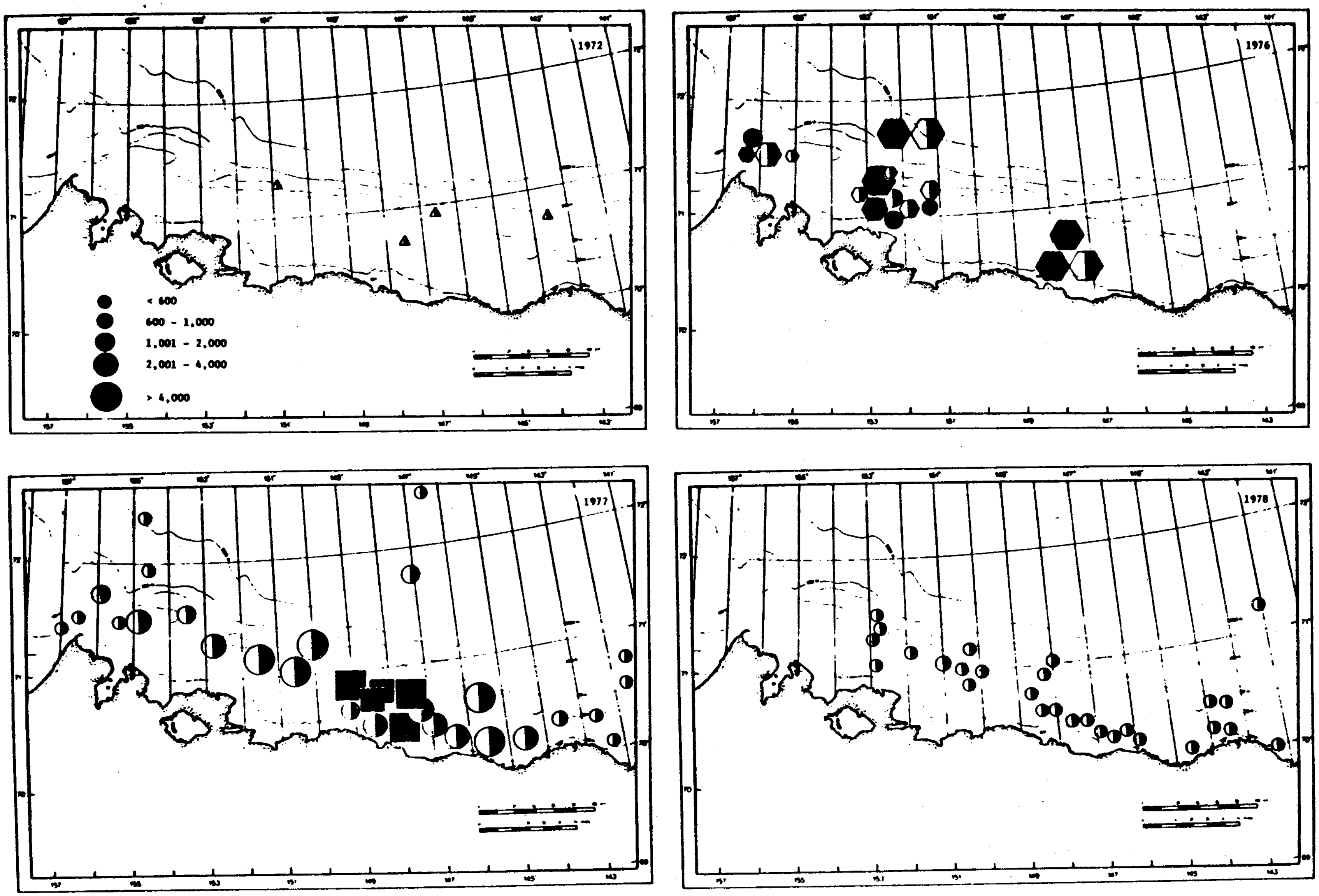


Fig. I-9. Distribution of all pteropods.

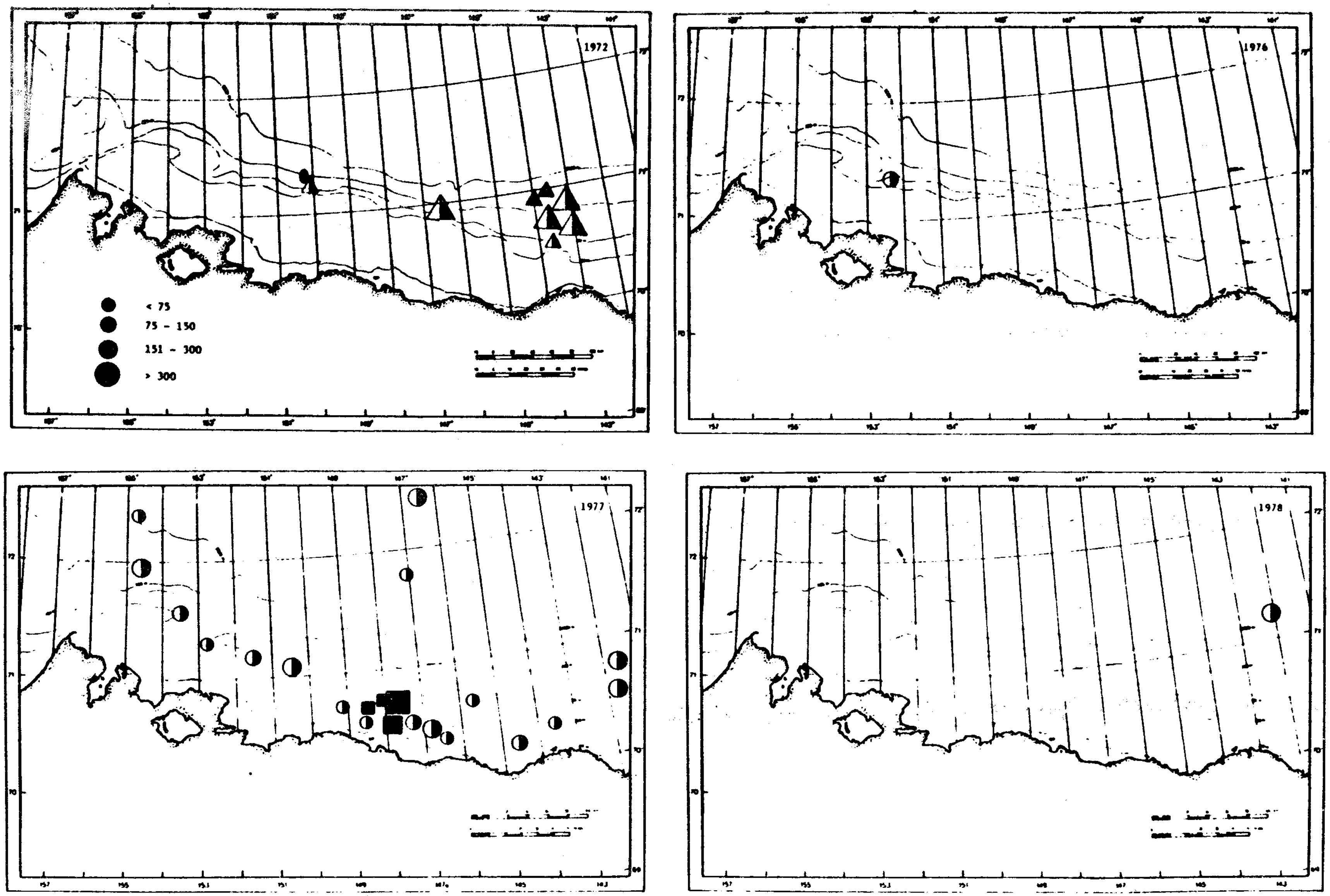


Fig. I-10. Distribution of Ostracoda.

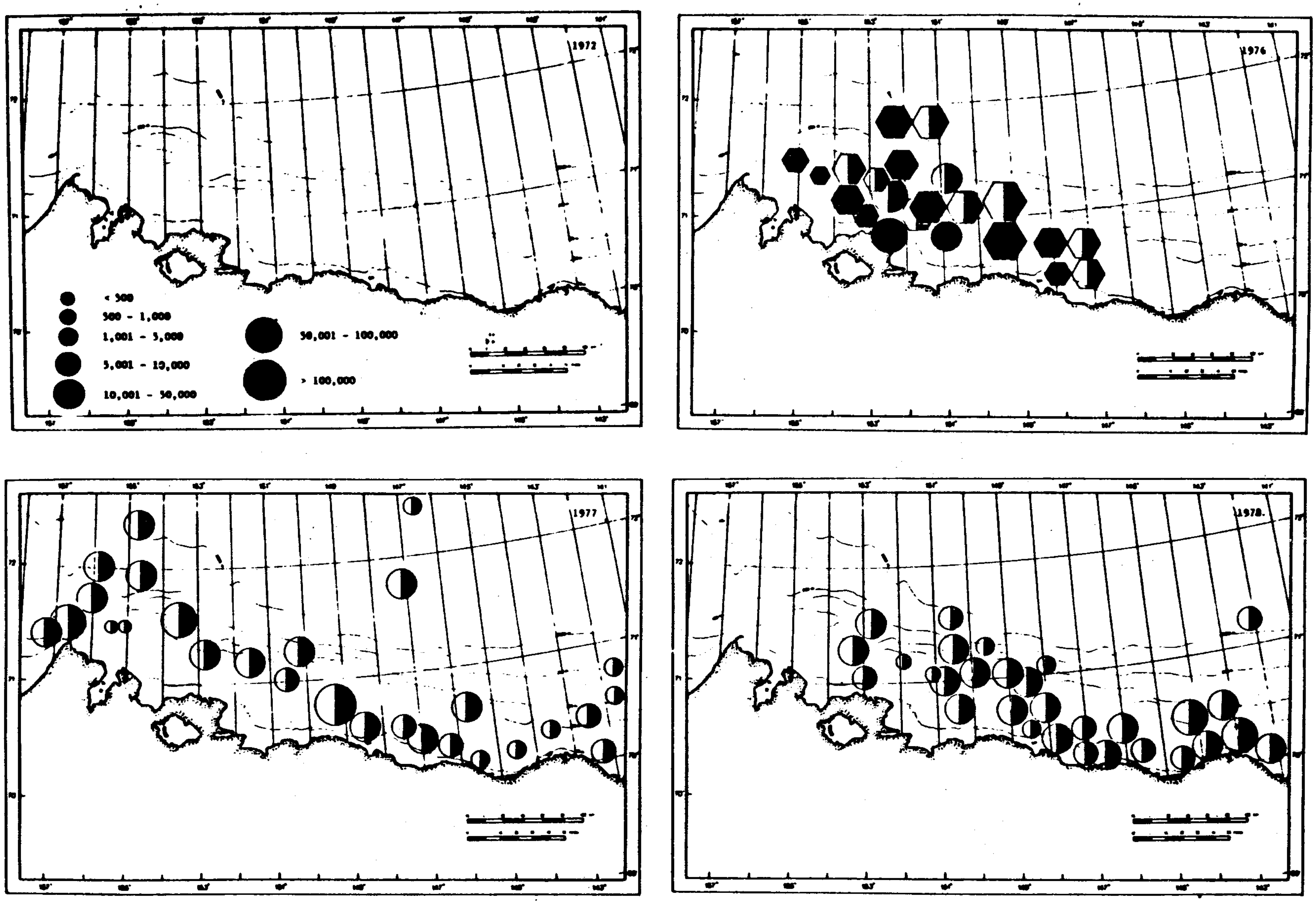


Fig. I-11. Distribution of *Calanus glacialis*.

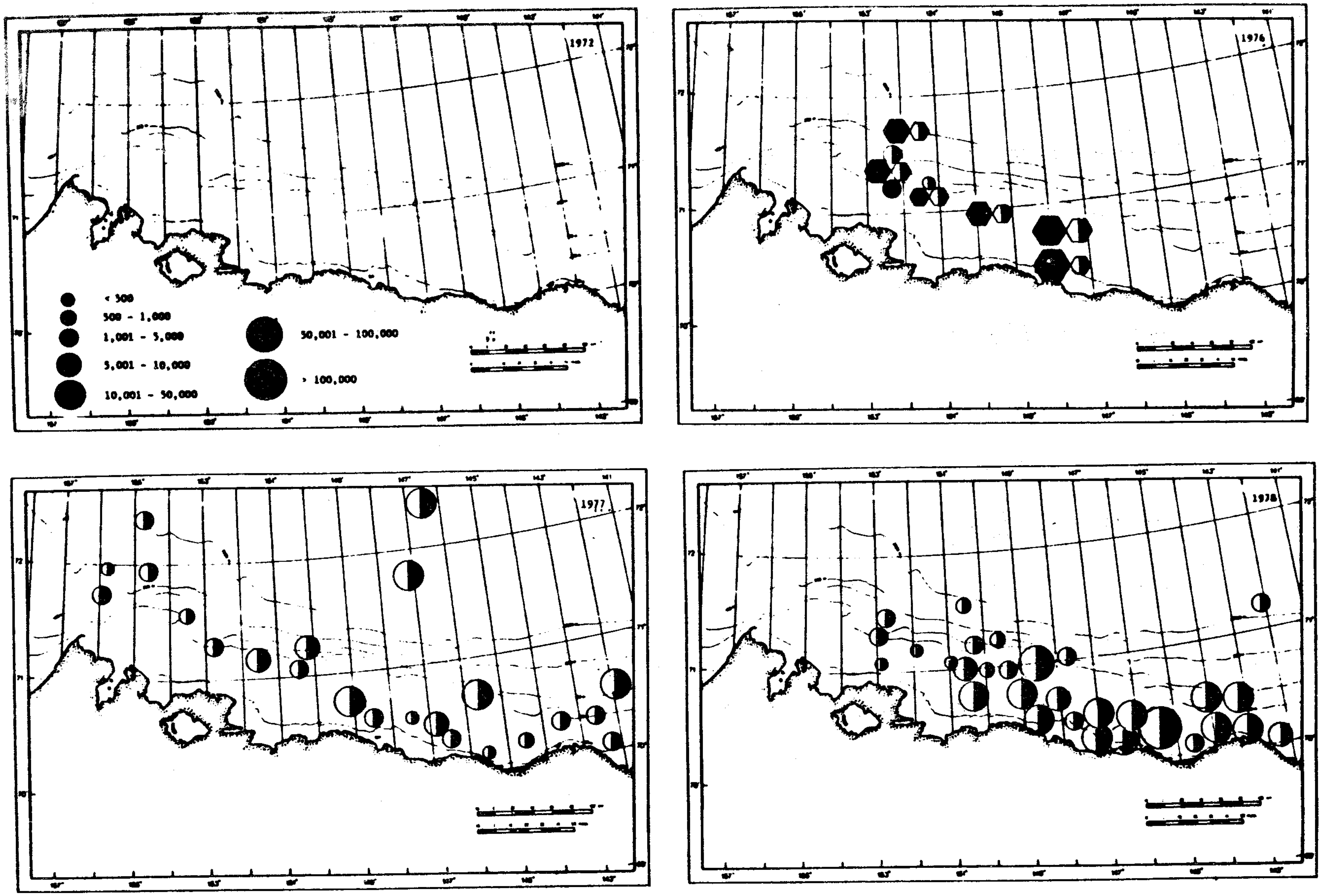


Fig. I-12. Distribution of *Calanus hyperboreus*.

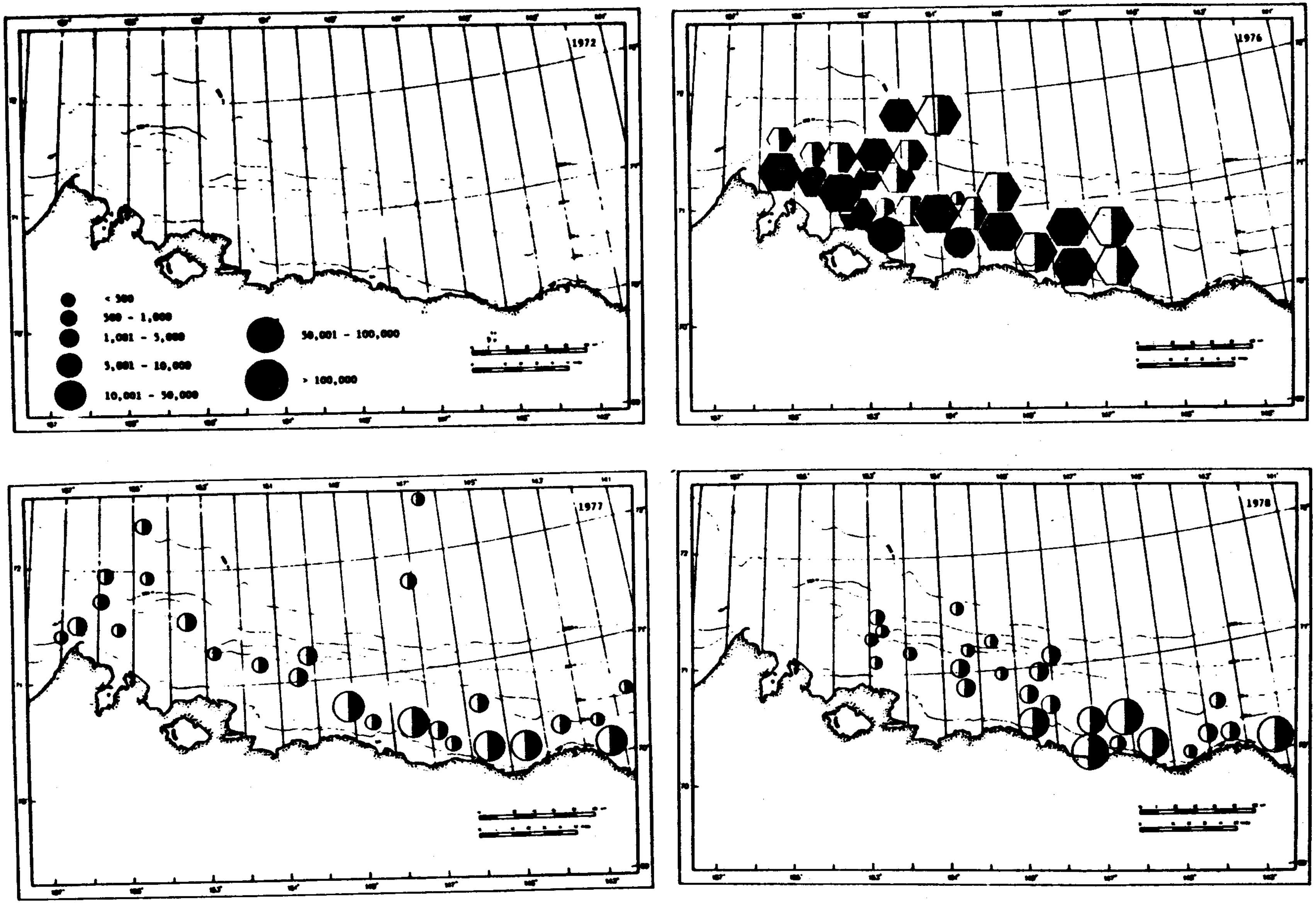


Fig. I-17. Distribution of *Pseudocalanus* spp.

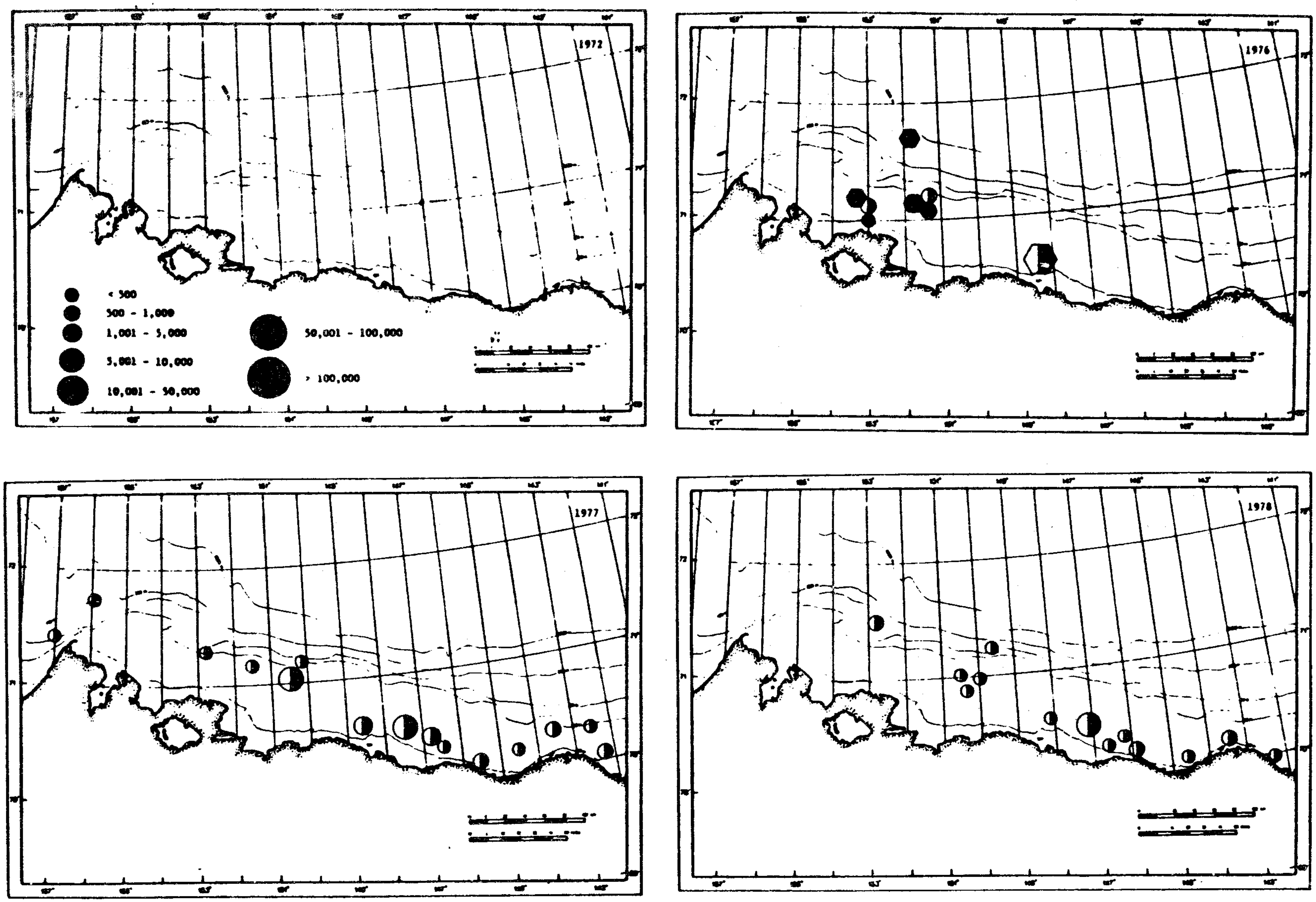


Fig. I-13. Distribution of *Derjuginia tolli*.

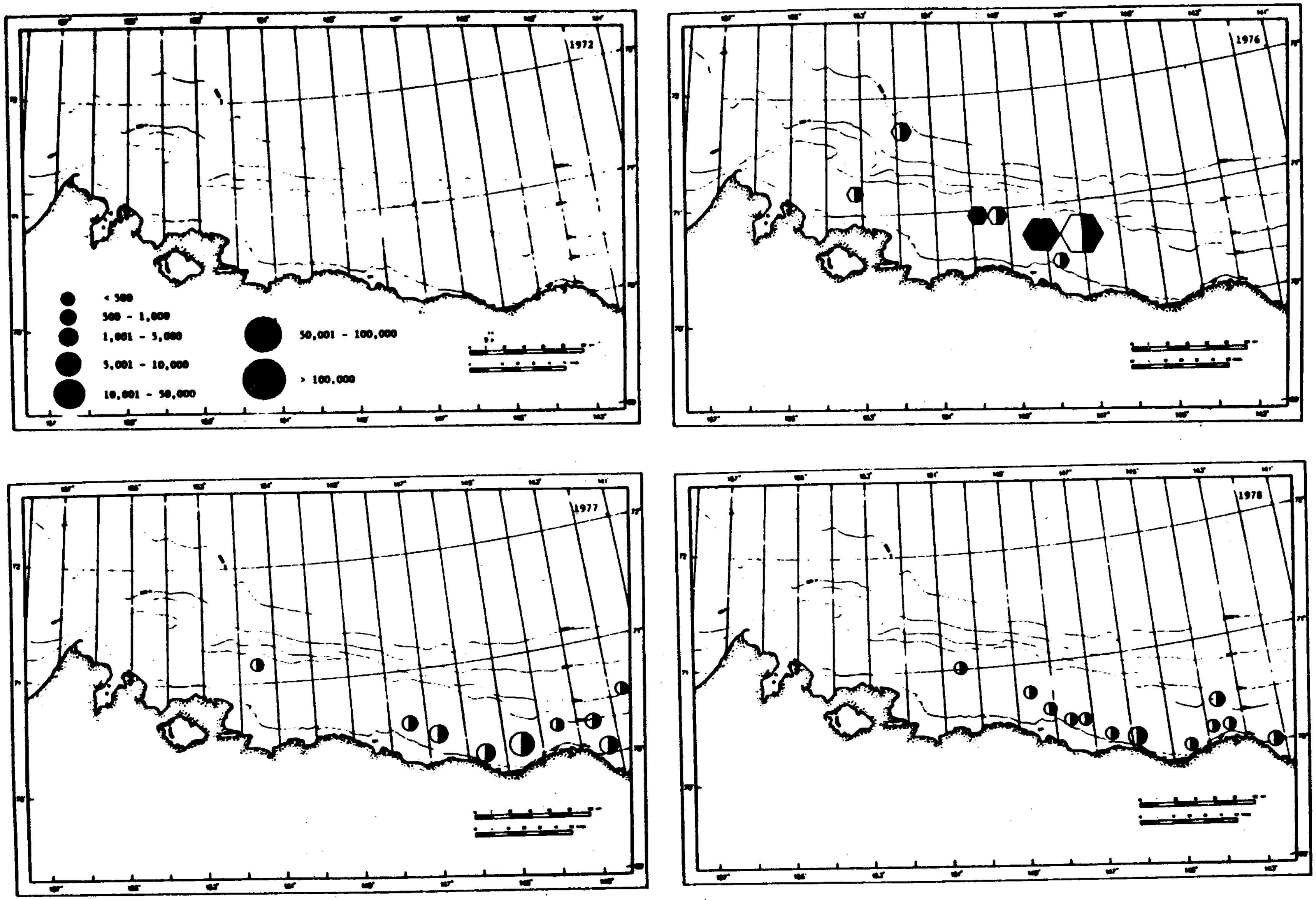


Fig. I-14. Distribution of *Limnocalanus macrurus*.

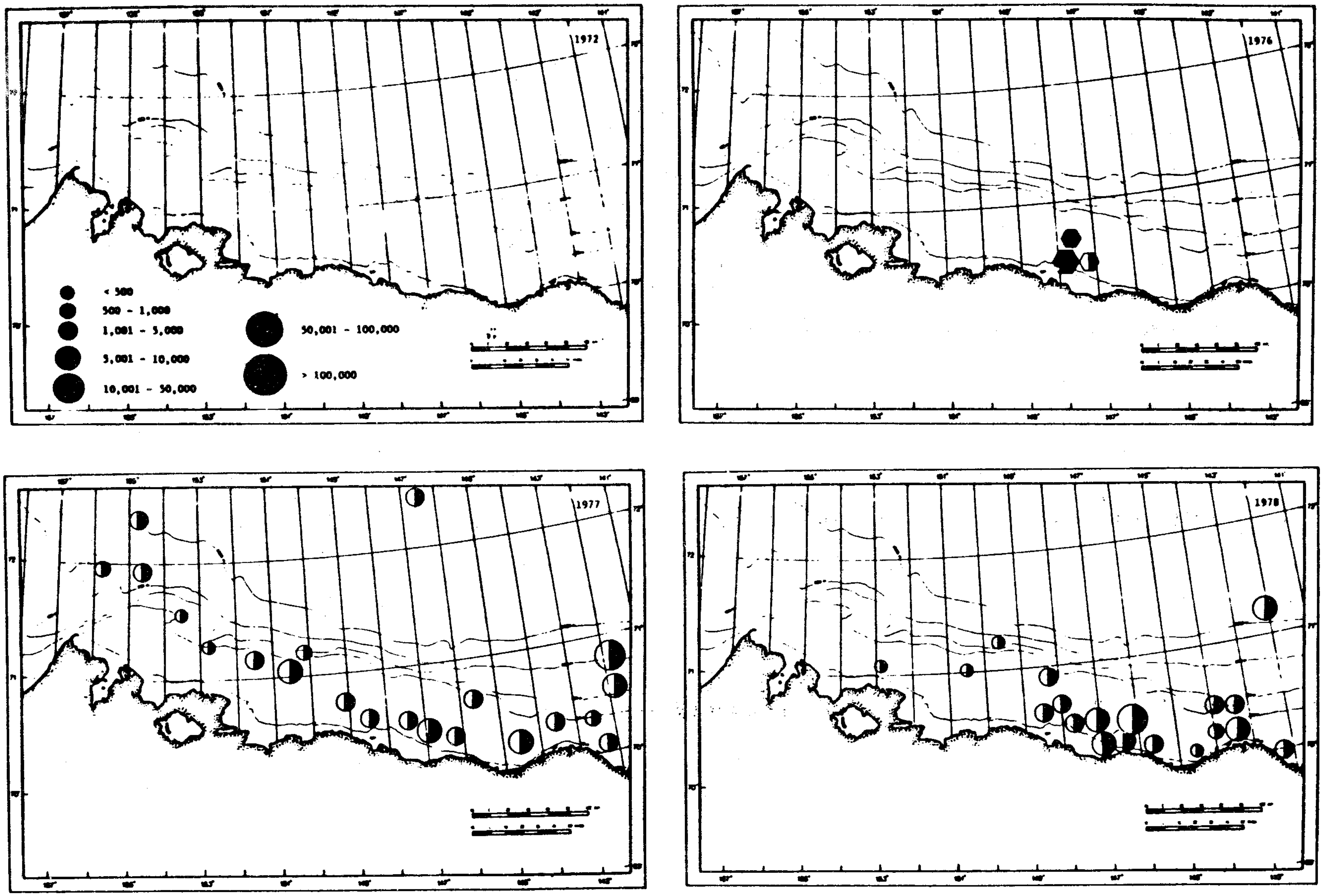


Fig. I-15. Distribution of *Metridia longa*.

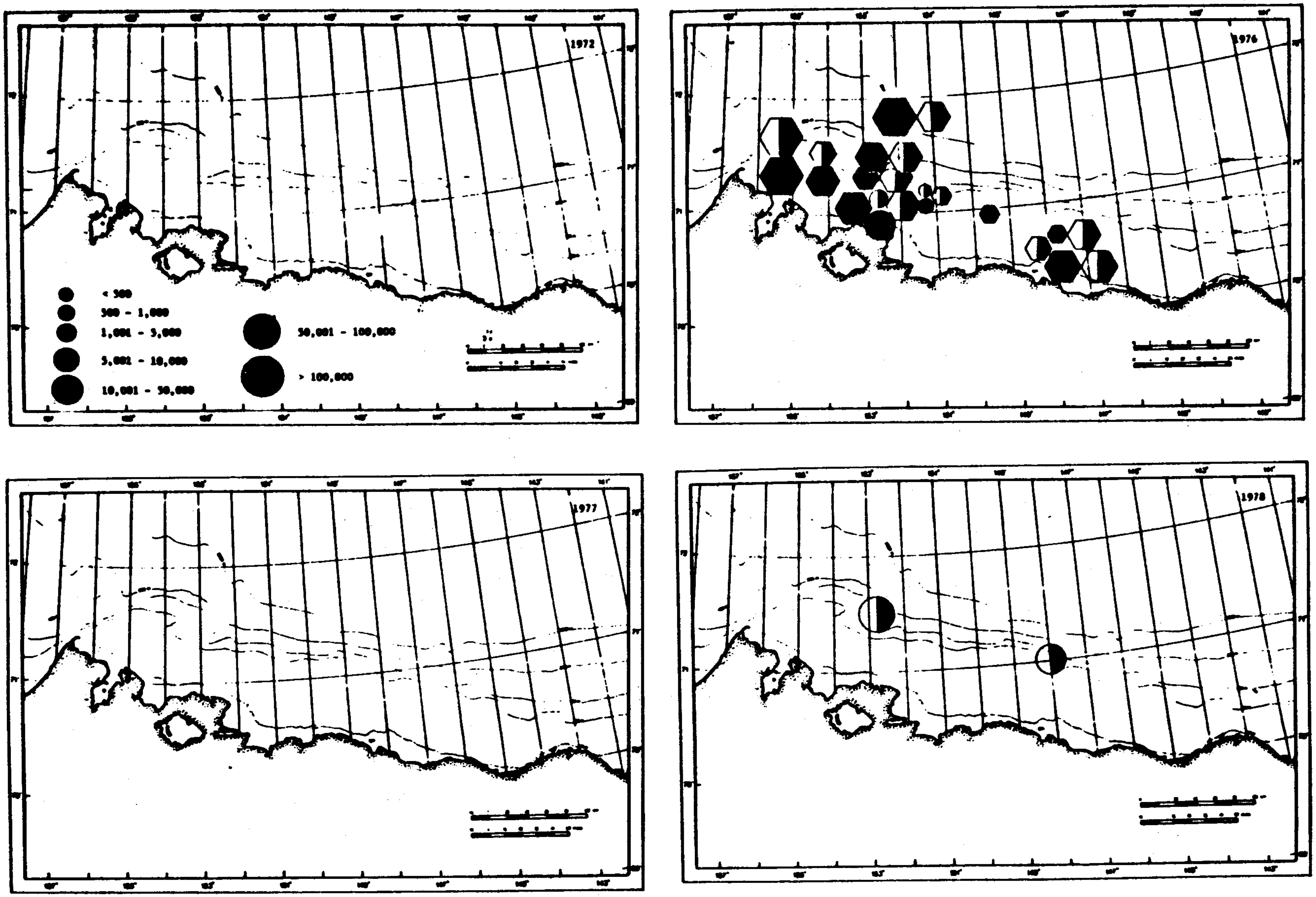


Fig. I-16. Distribution of *Oithona similis*.

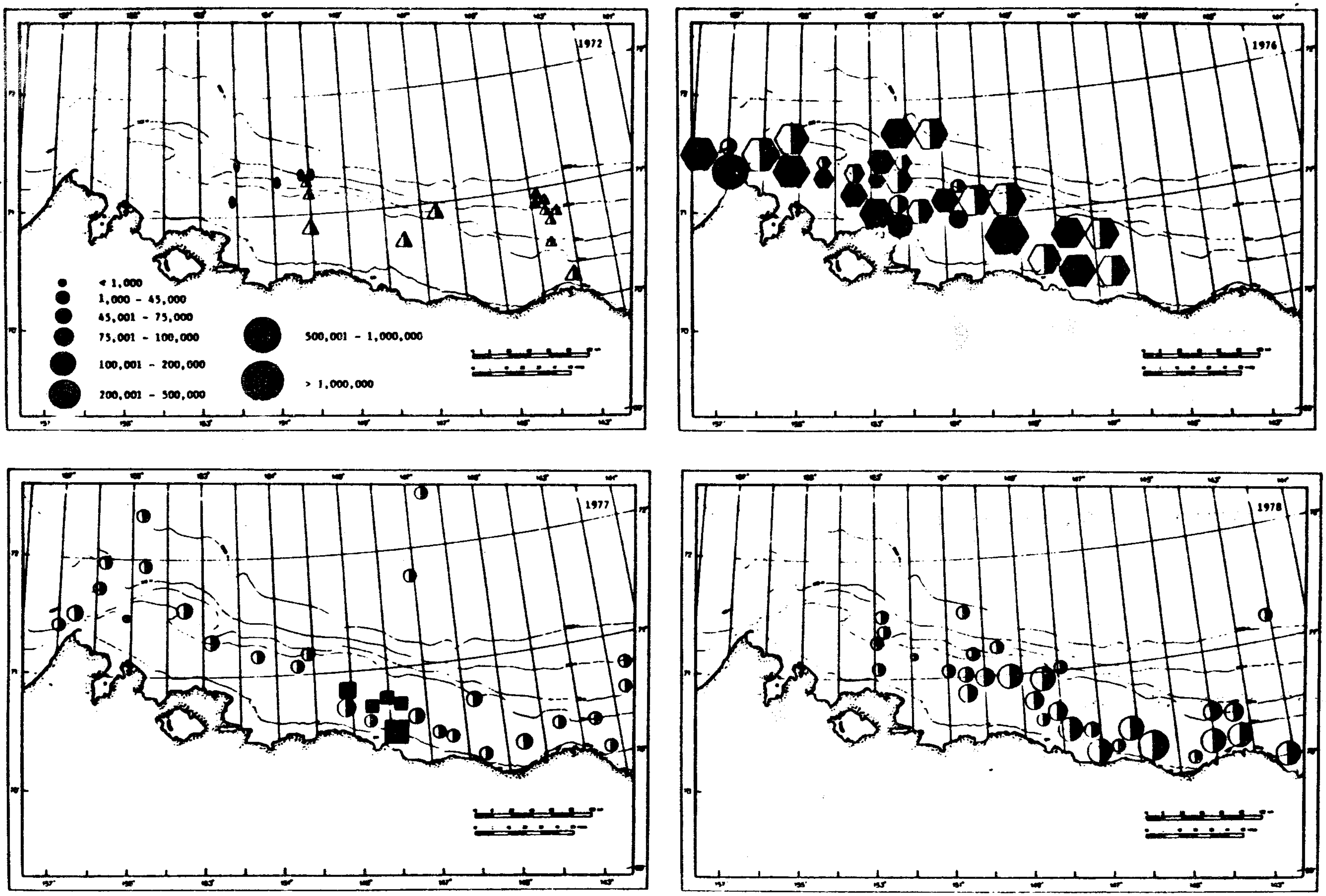


Fig. I-18. Distribution of total Copepoda.

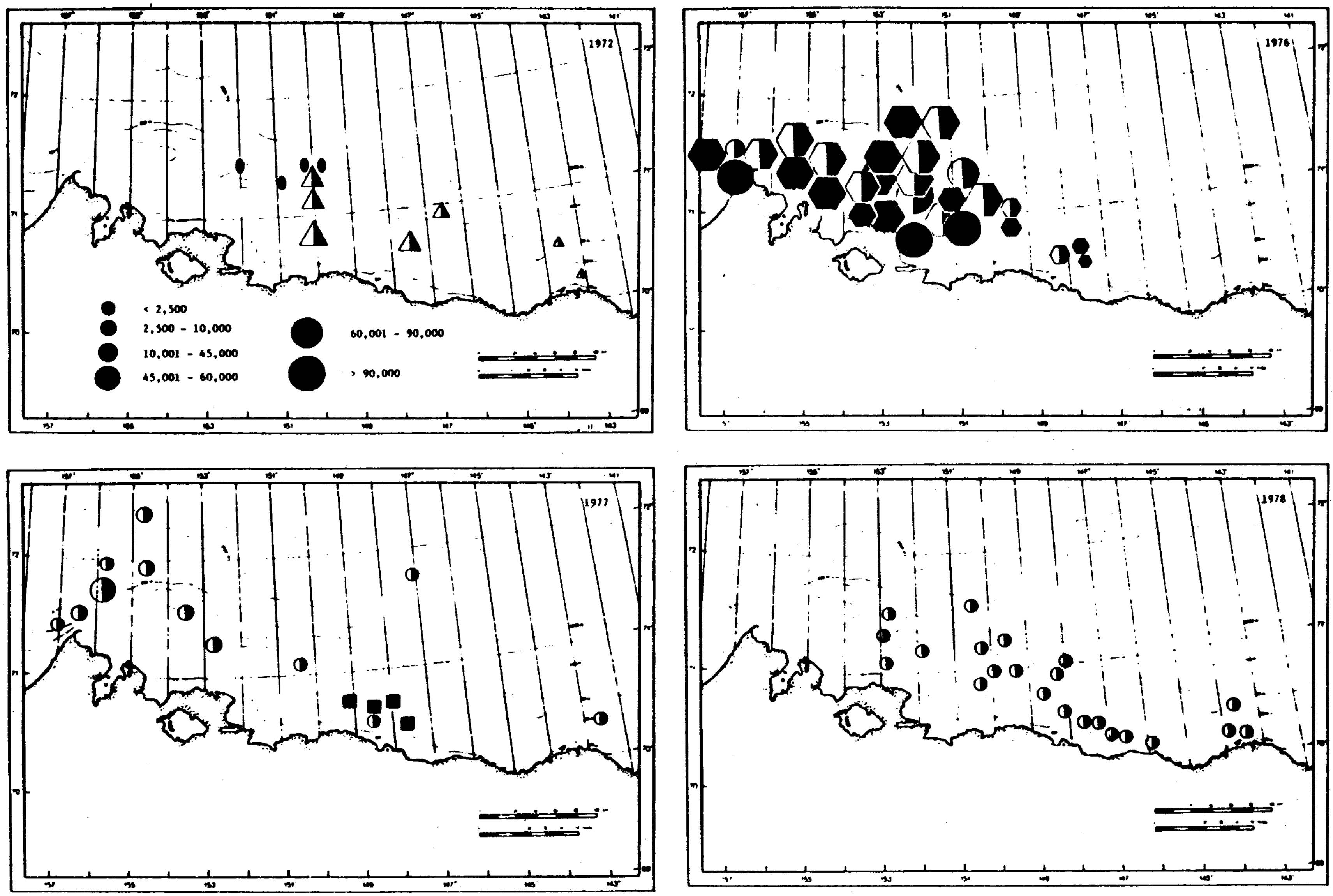


Fig. I-19. Distribution of barnacle nauplii.

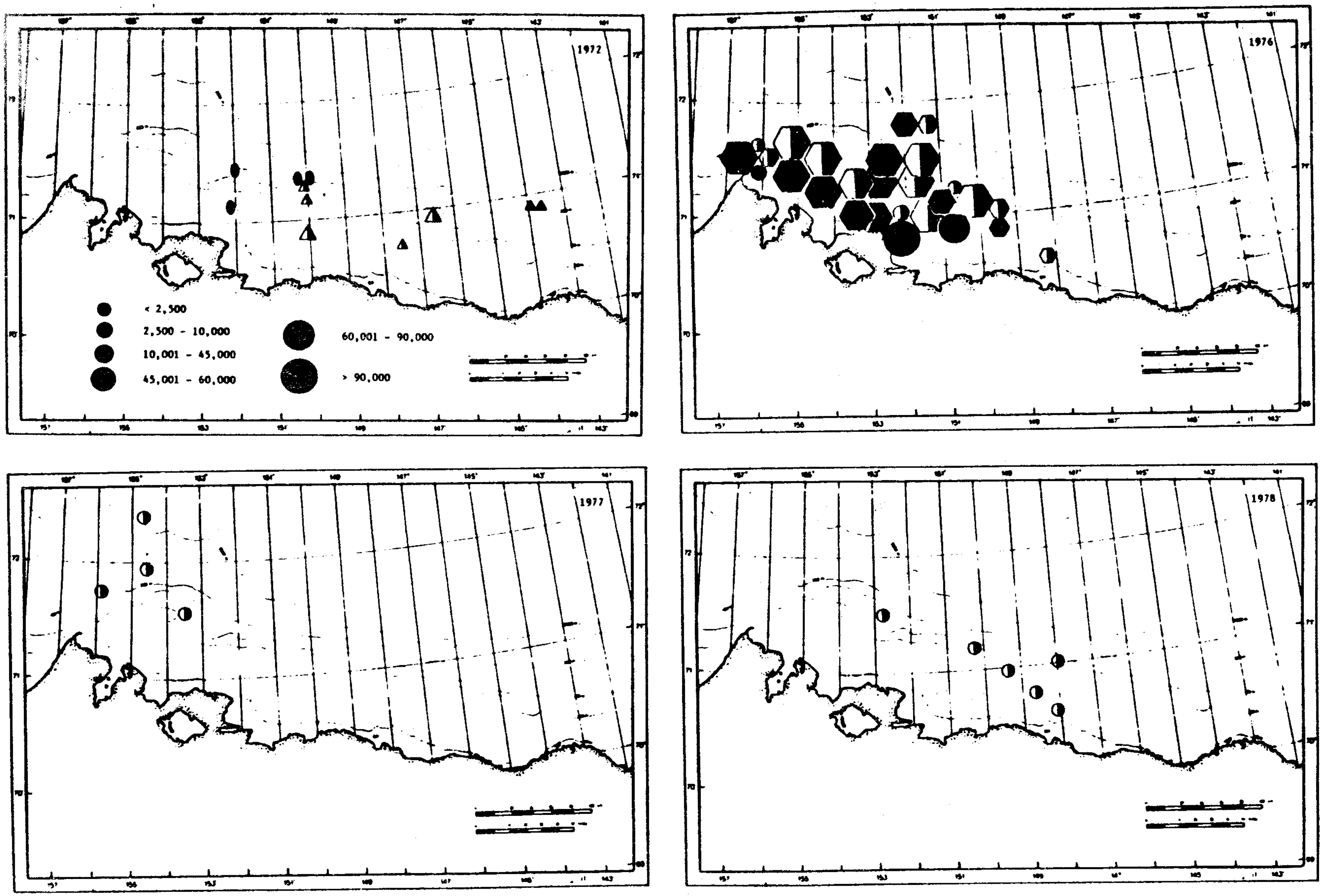


Fig. I-20. Distribution of barnacle cyprids.

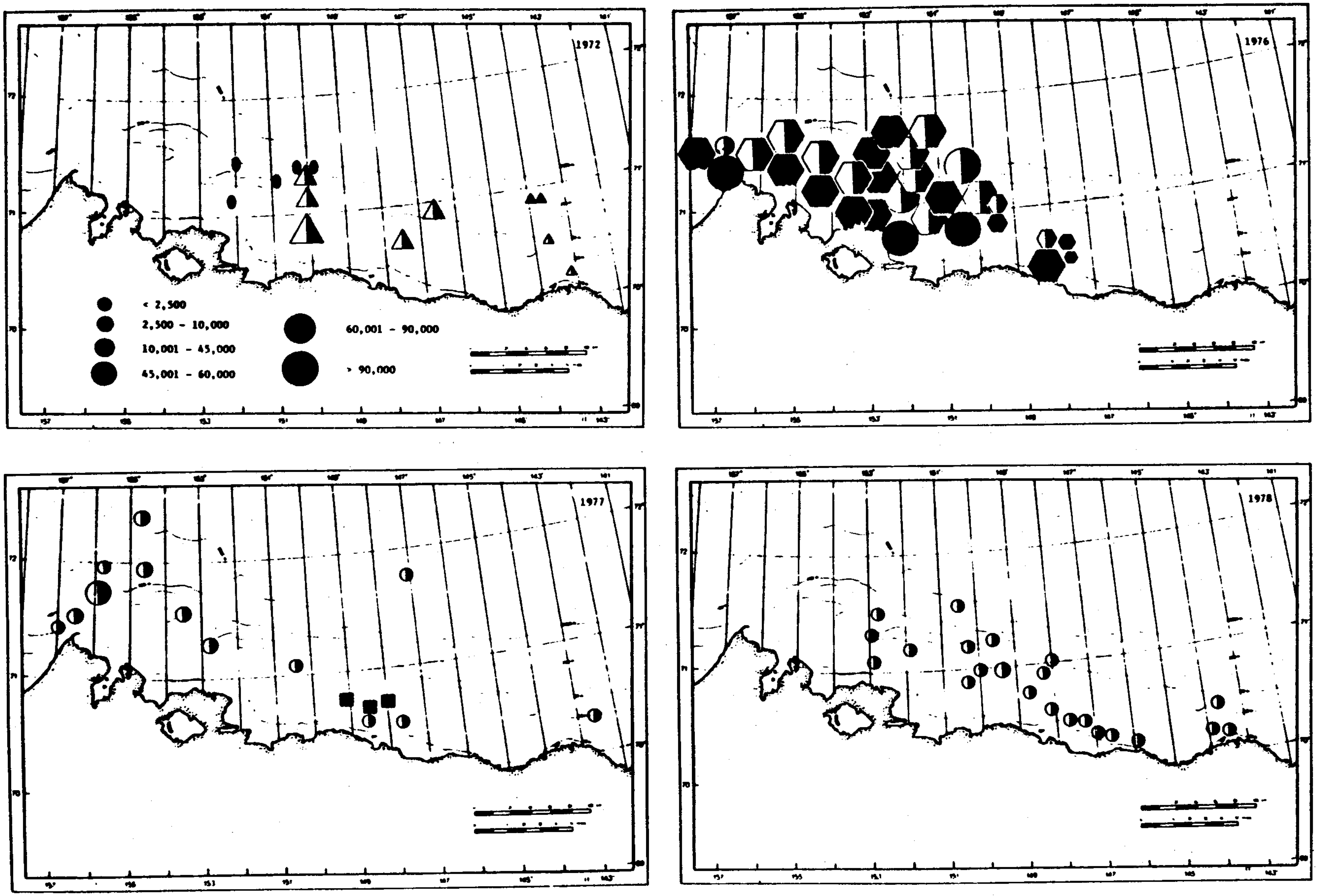


Fig. I-21. Distribution of total barnacle larvae.

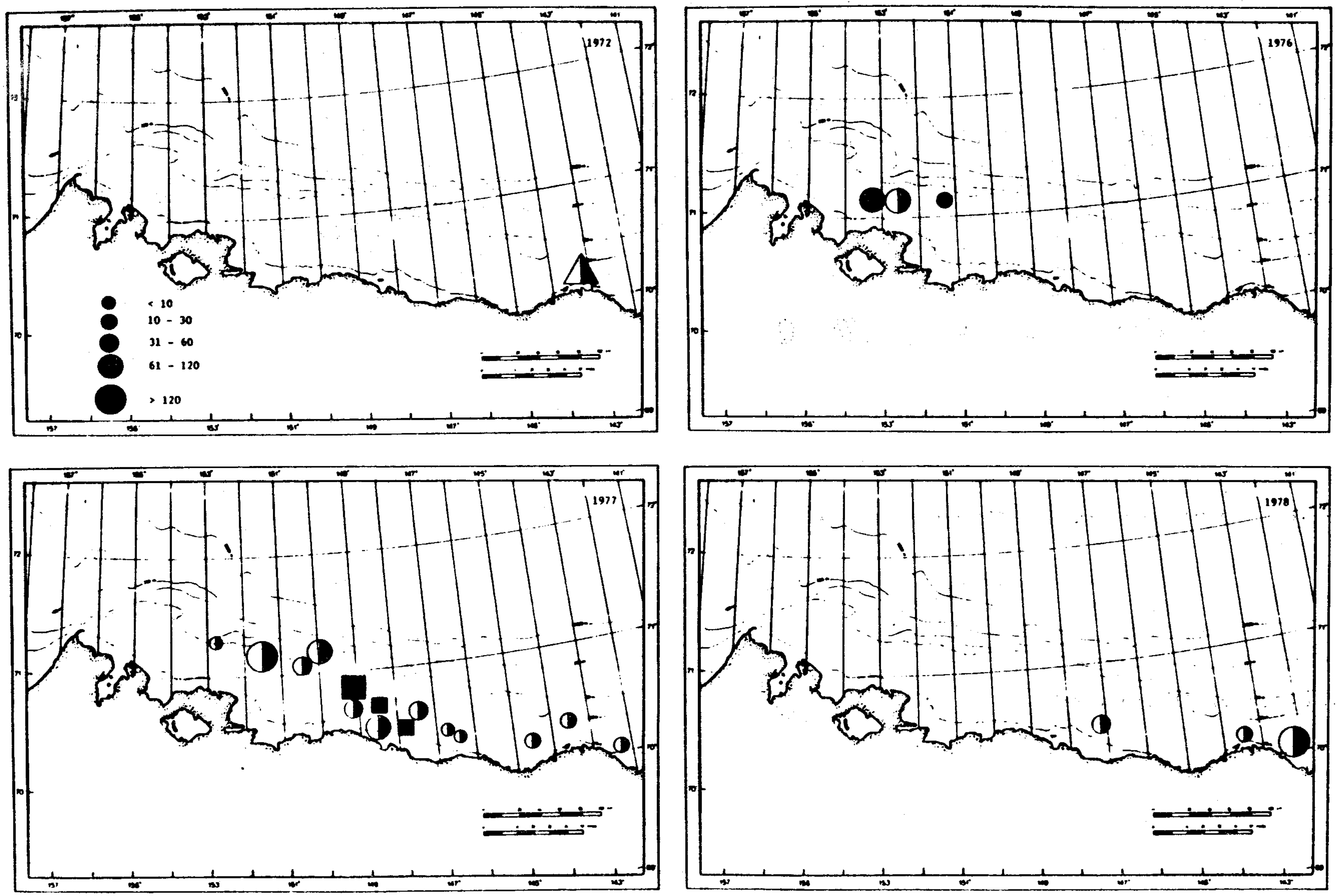


Fig. I-22. Distribution of *Mysis litoralis*.

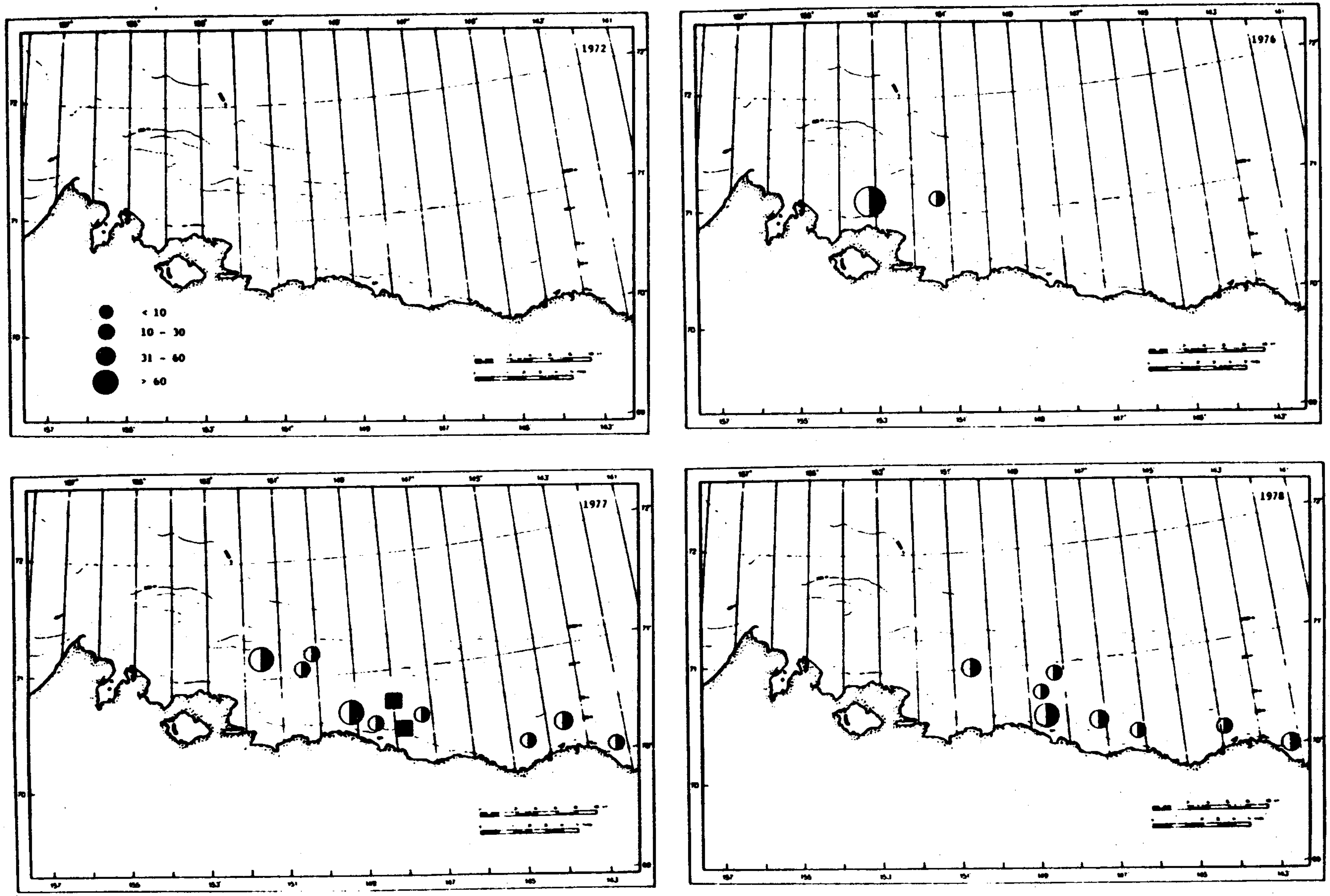


Fig. I-23. Distribution of *Mysis oculata*.

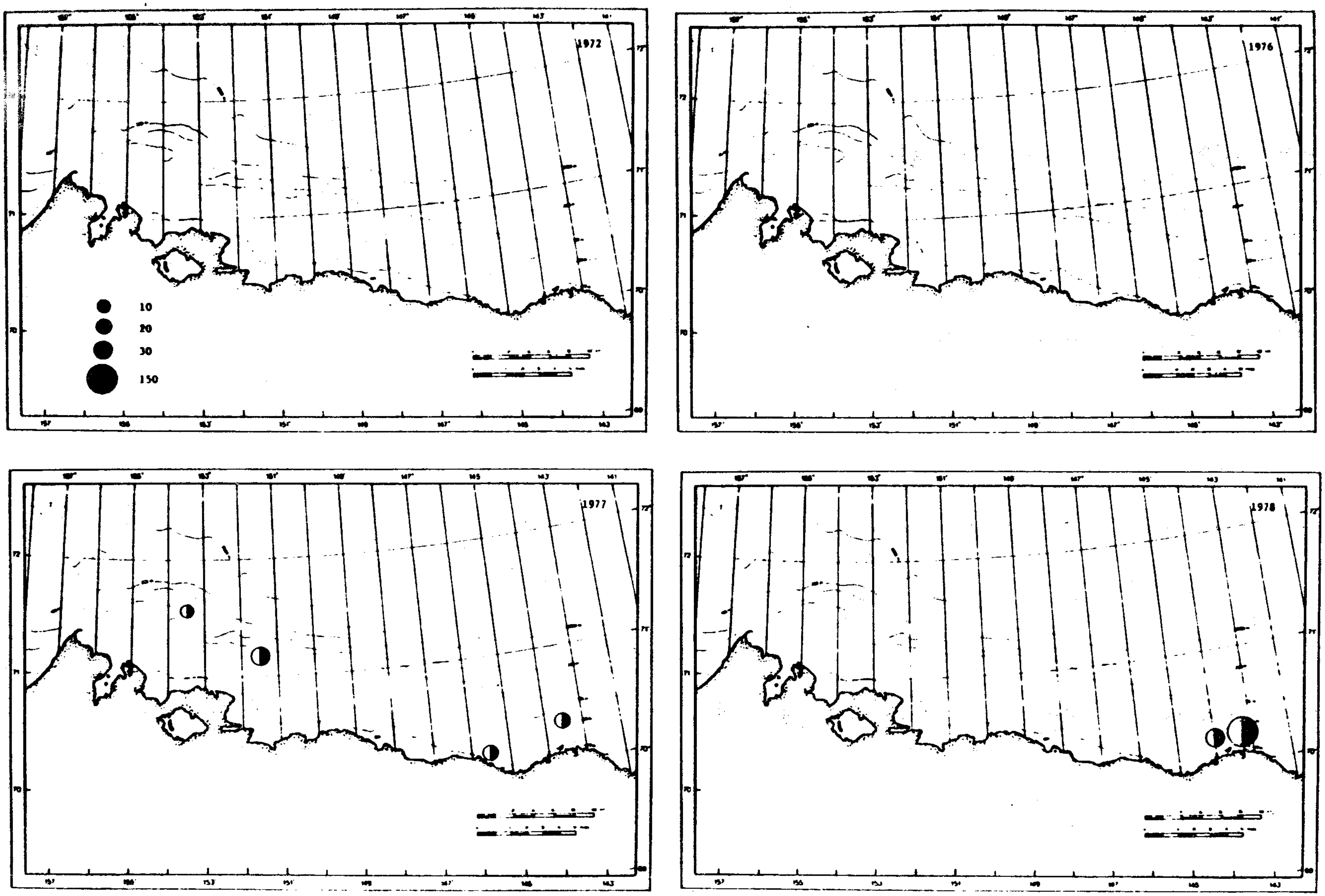


Fig. I-24. Distribution of *Mysis relicta*.

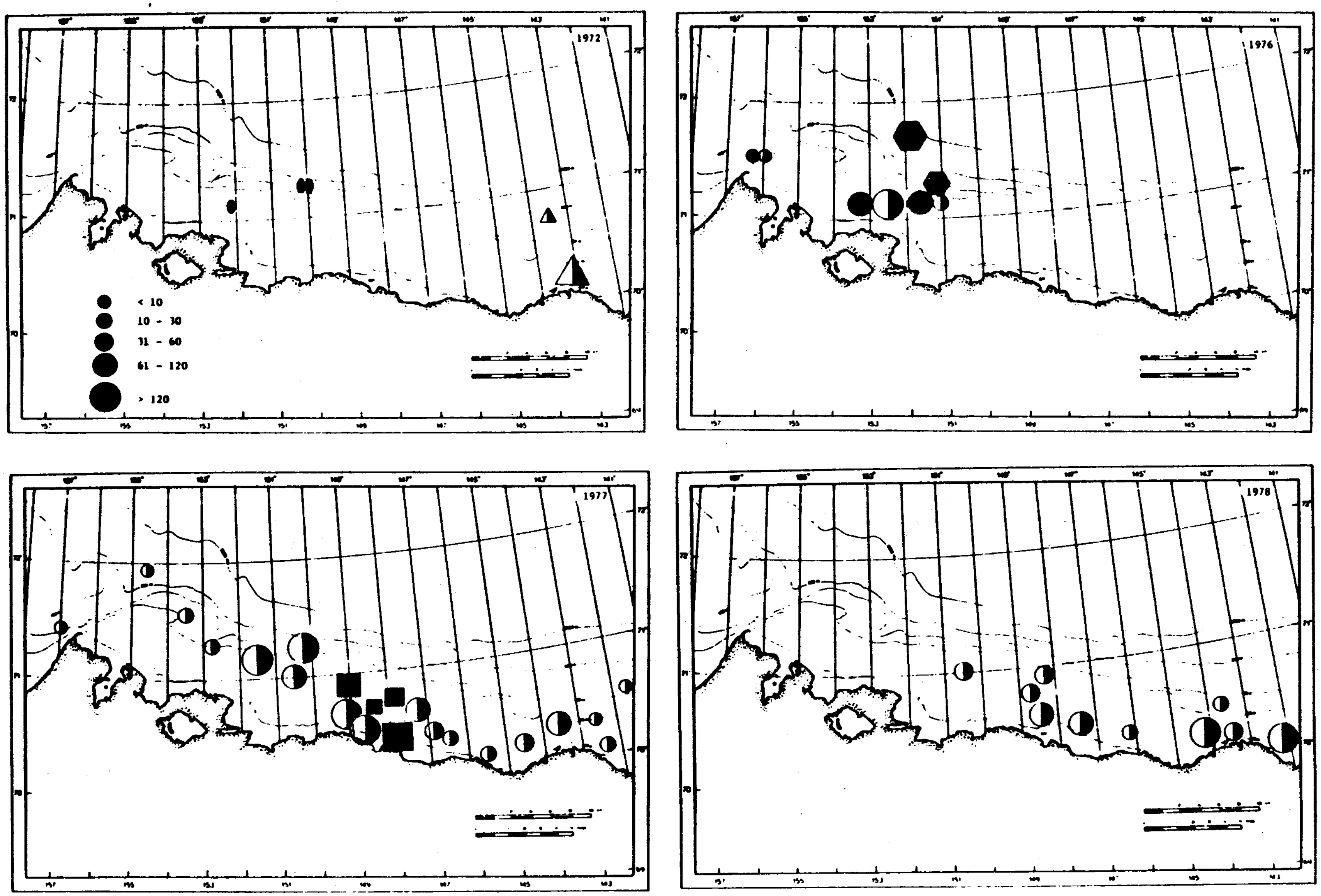


Fig. I-25. Distribution of all Mysidacea.

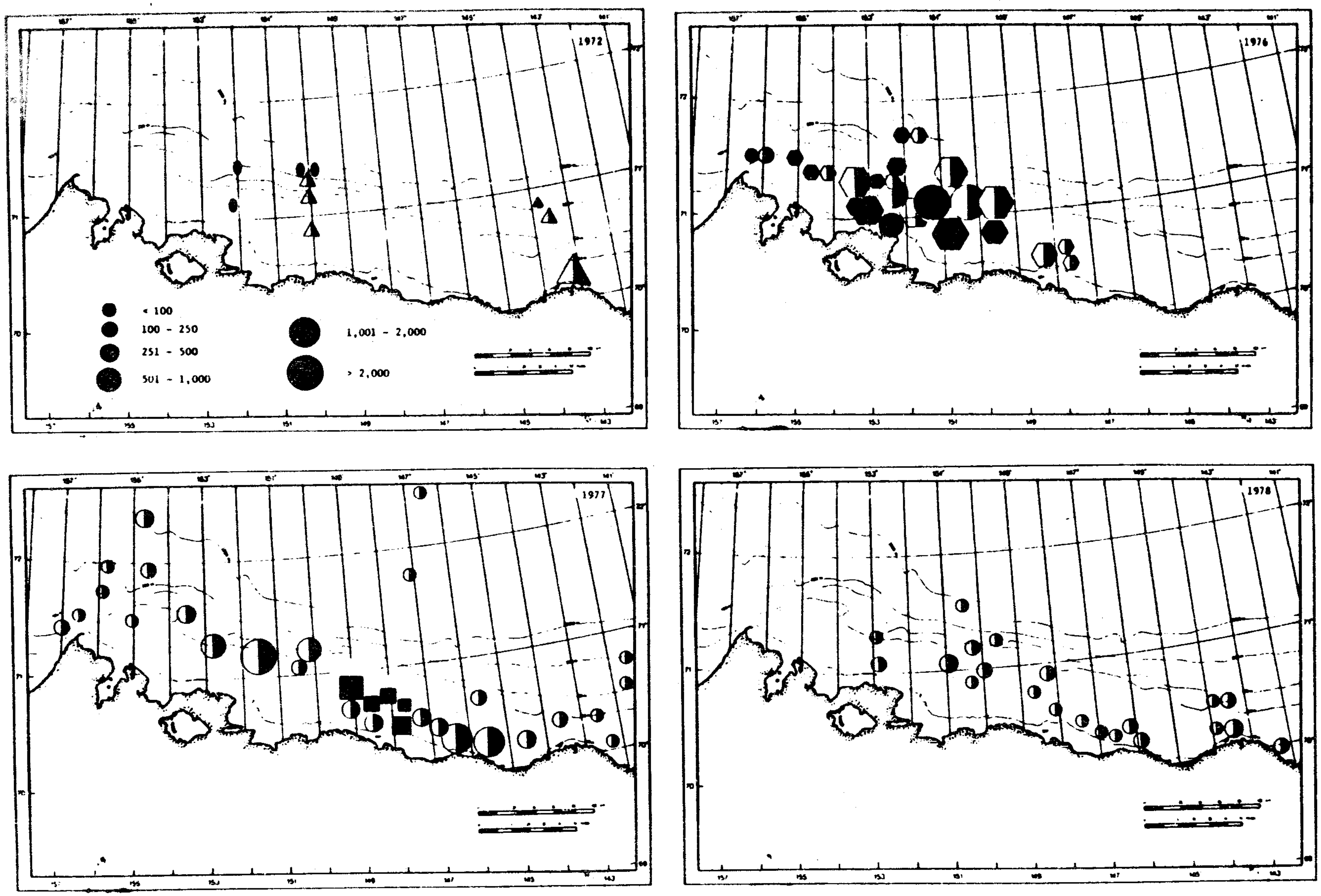


Fig. I-26. Distribution of all Gammaridea.

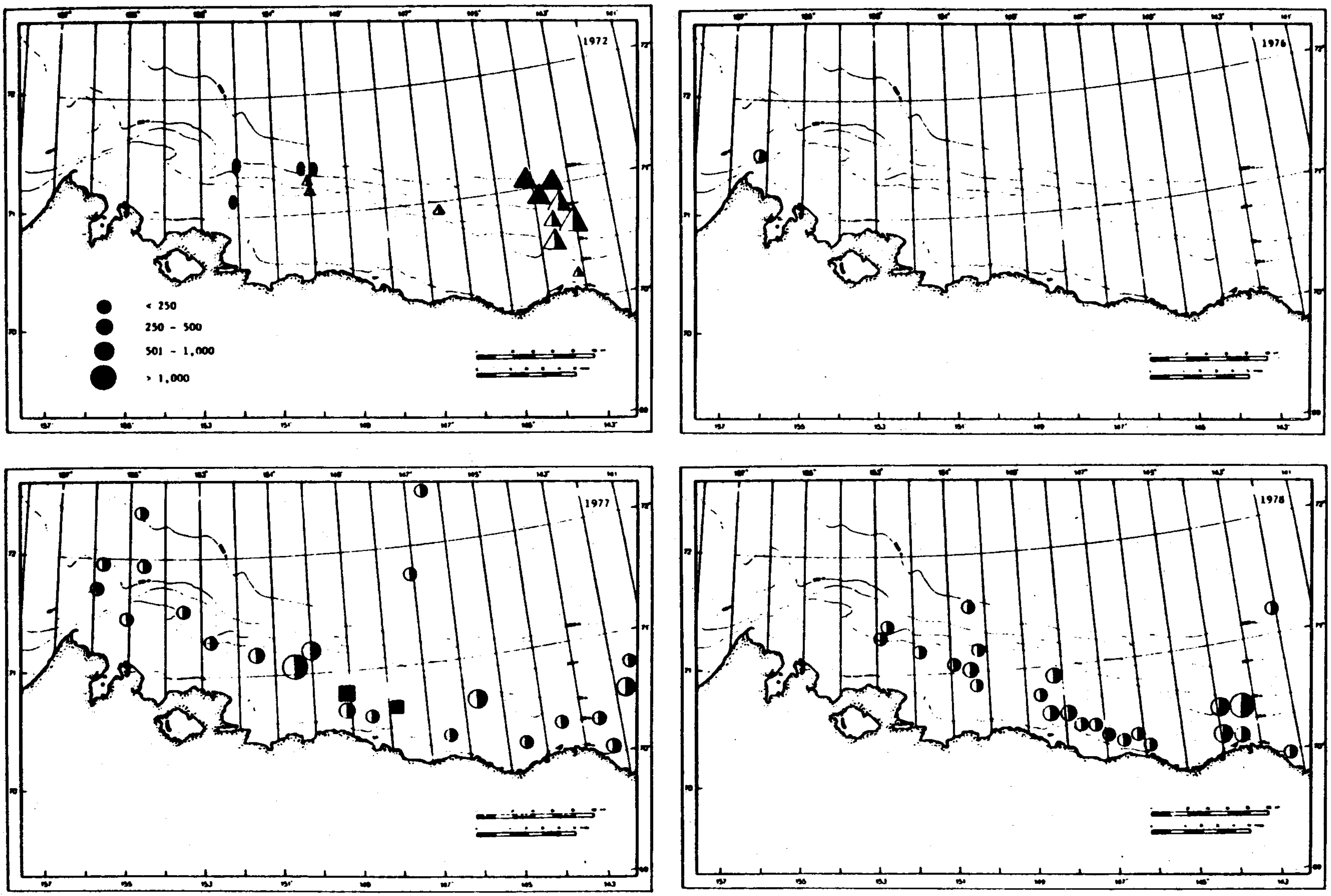


Fig. I-27. Distribution of *Parathemisto abyssorum*.

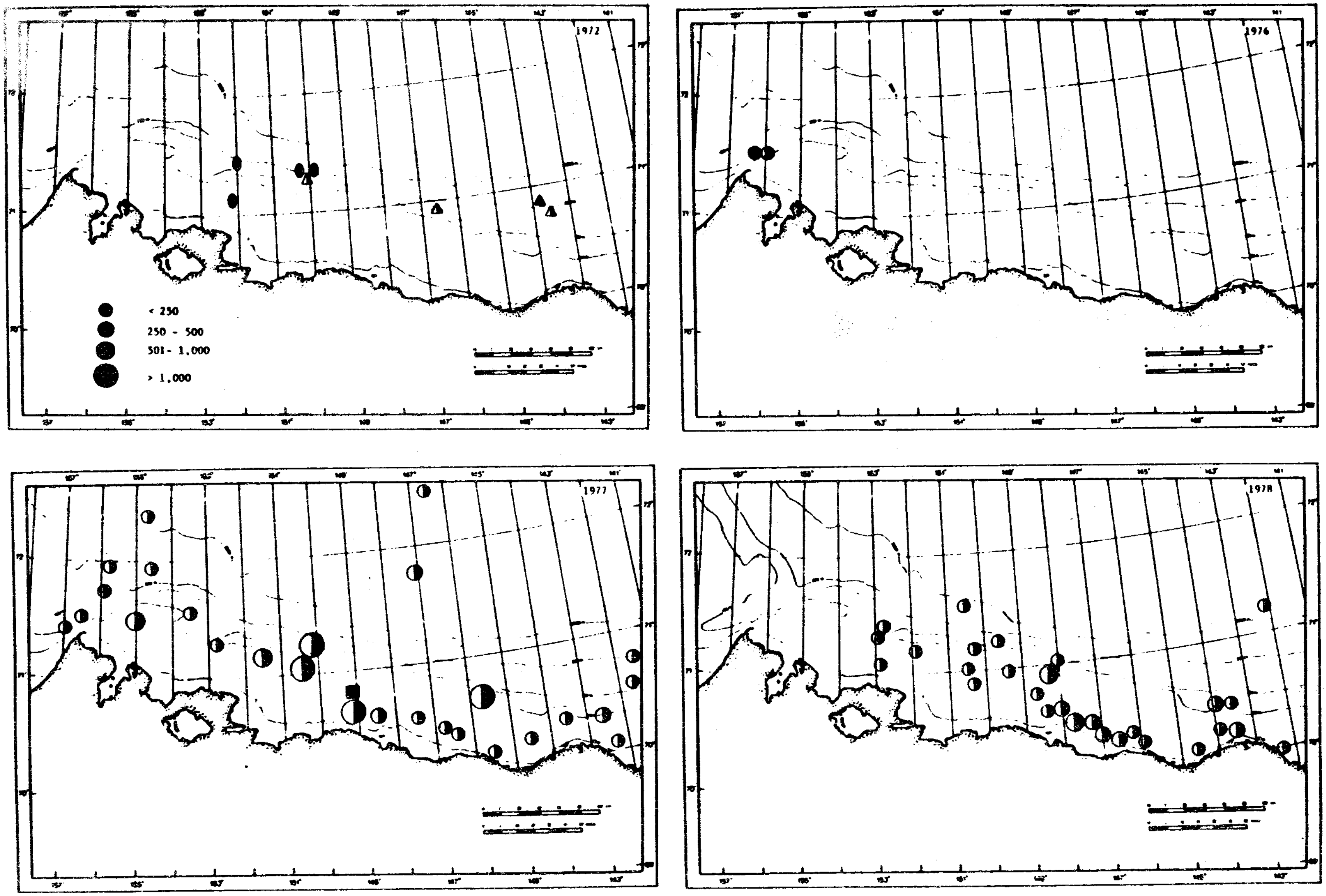


Fig. I-28. Distribution of *Parathemisto libellula*.

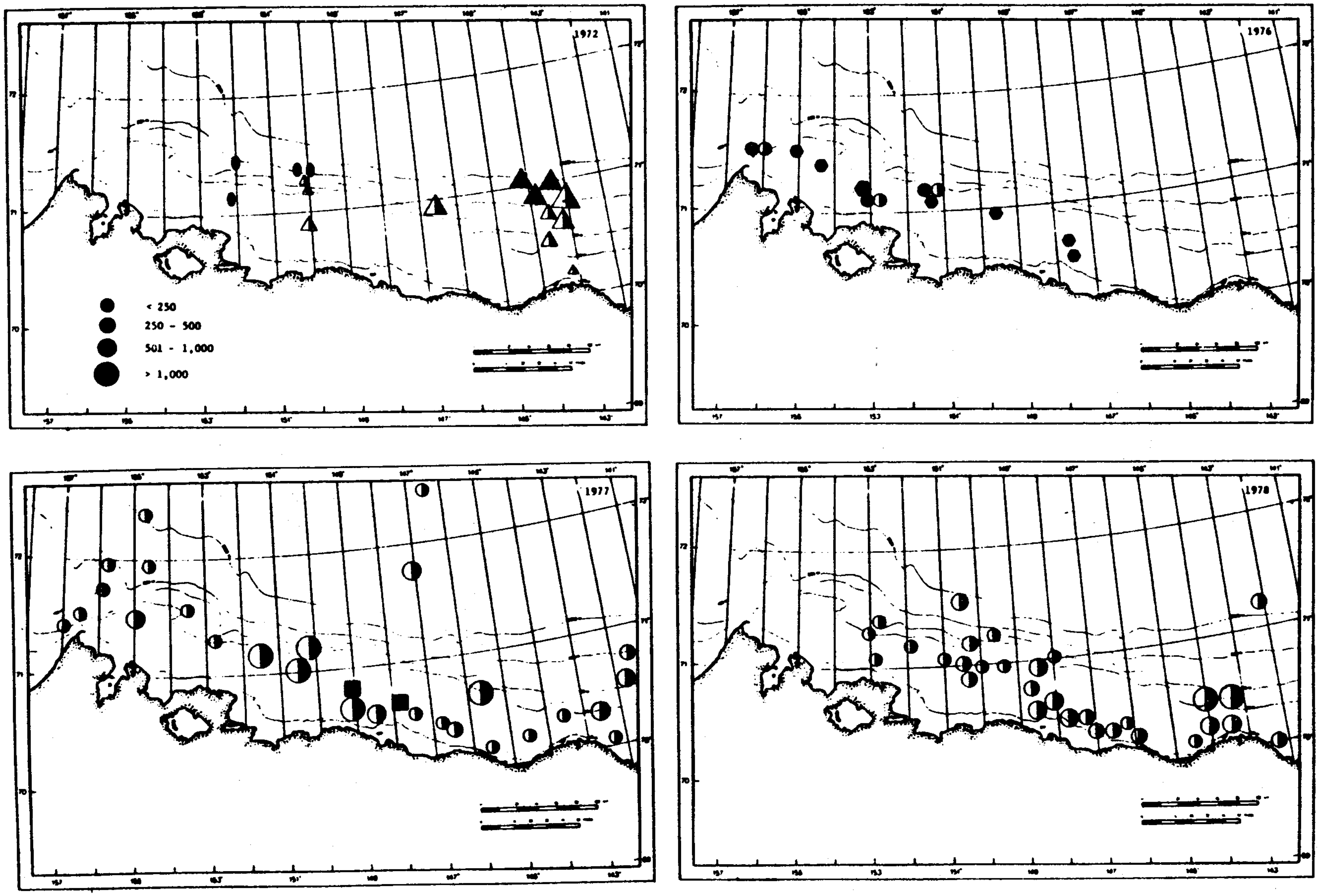


Fig. I-29. Distribution of all Hyperiidea.

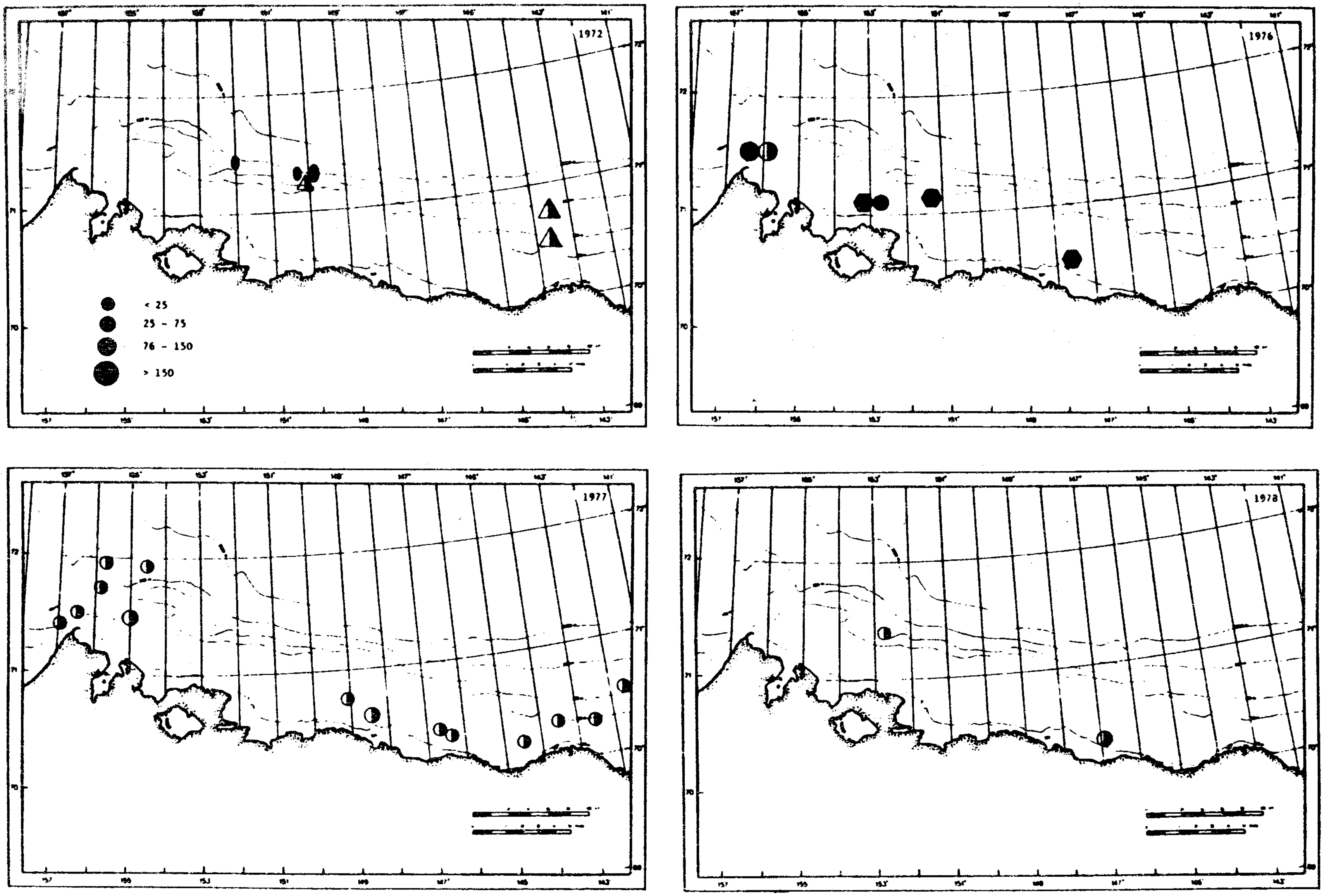


Fig. I-30. Distribution of *Thysanoëssa inermis*.

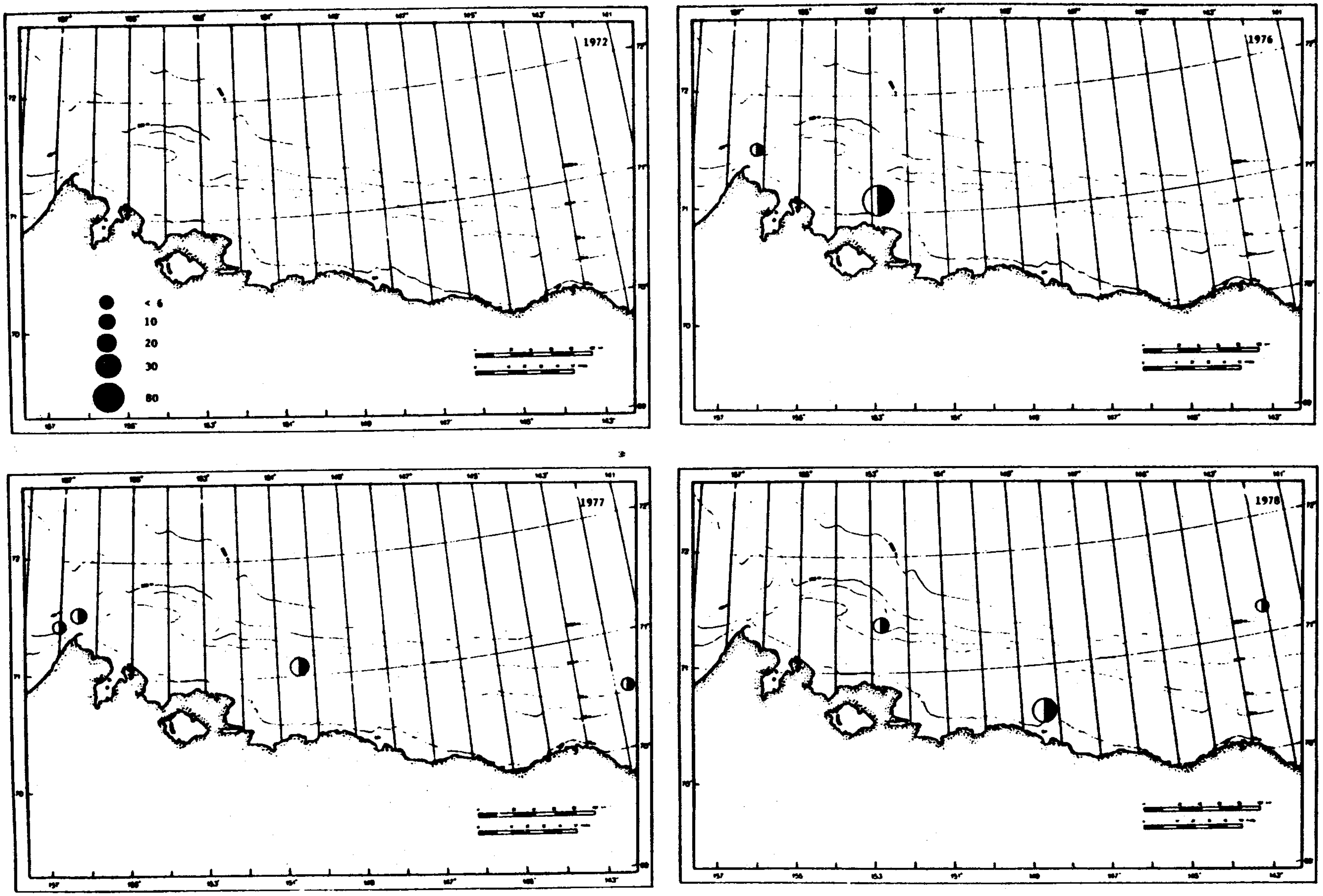


Fig. I-31. Distribution of *Thysanoëssa longipes*.

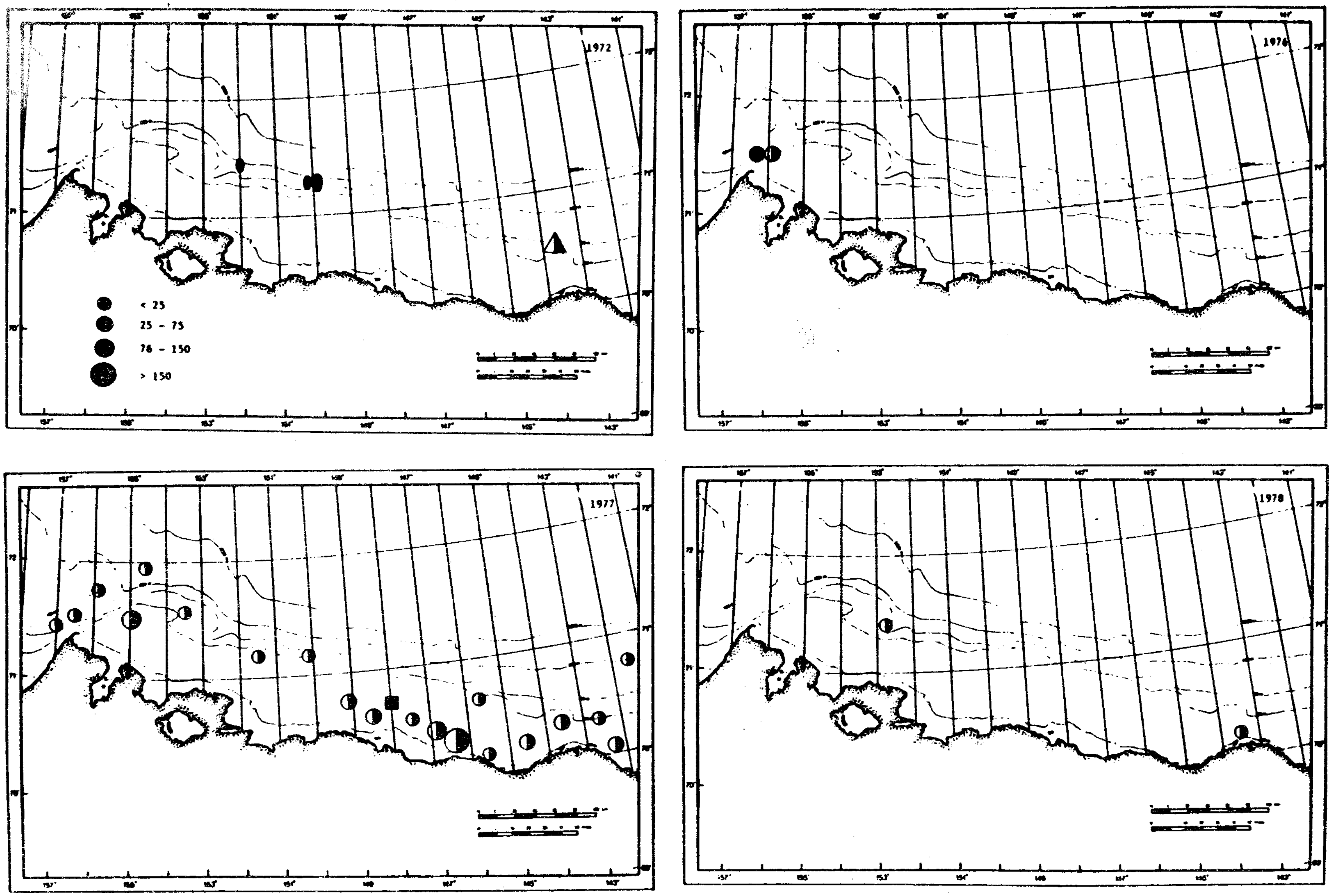


Fig. I-32. Distribution of *Thysanoëssa raschi*.

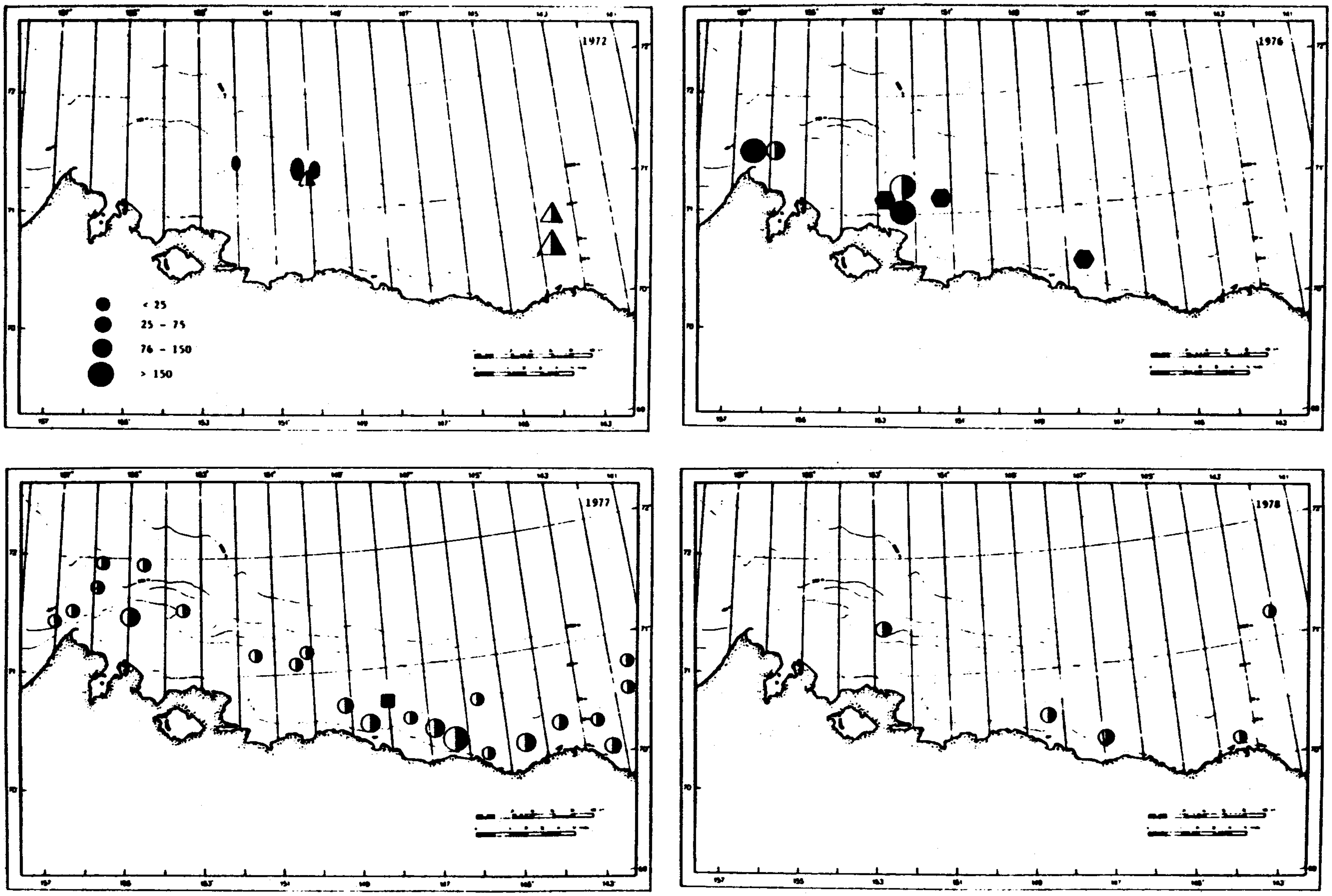


Fig. I-33. Distribution of all *Thysanoëssa* spp.

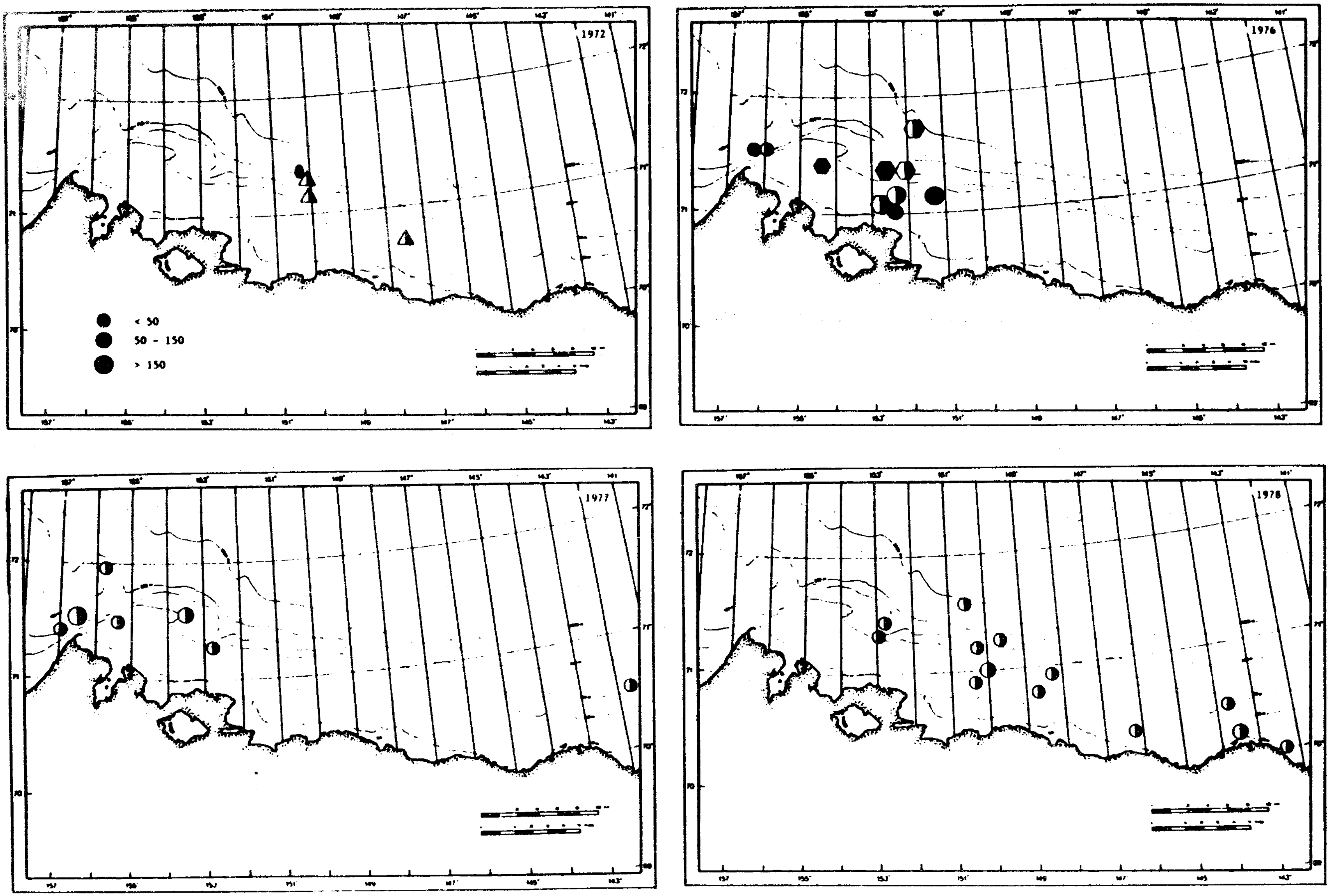


Fig. I-34. Distribution of Euphausiacea larvae.

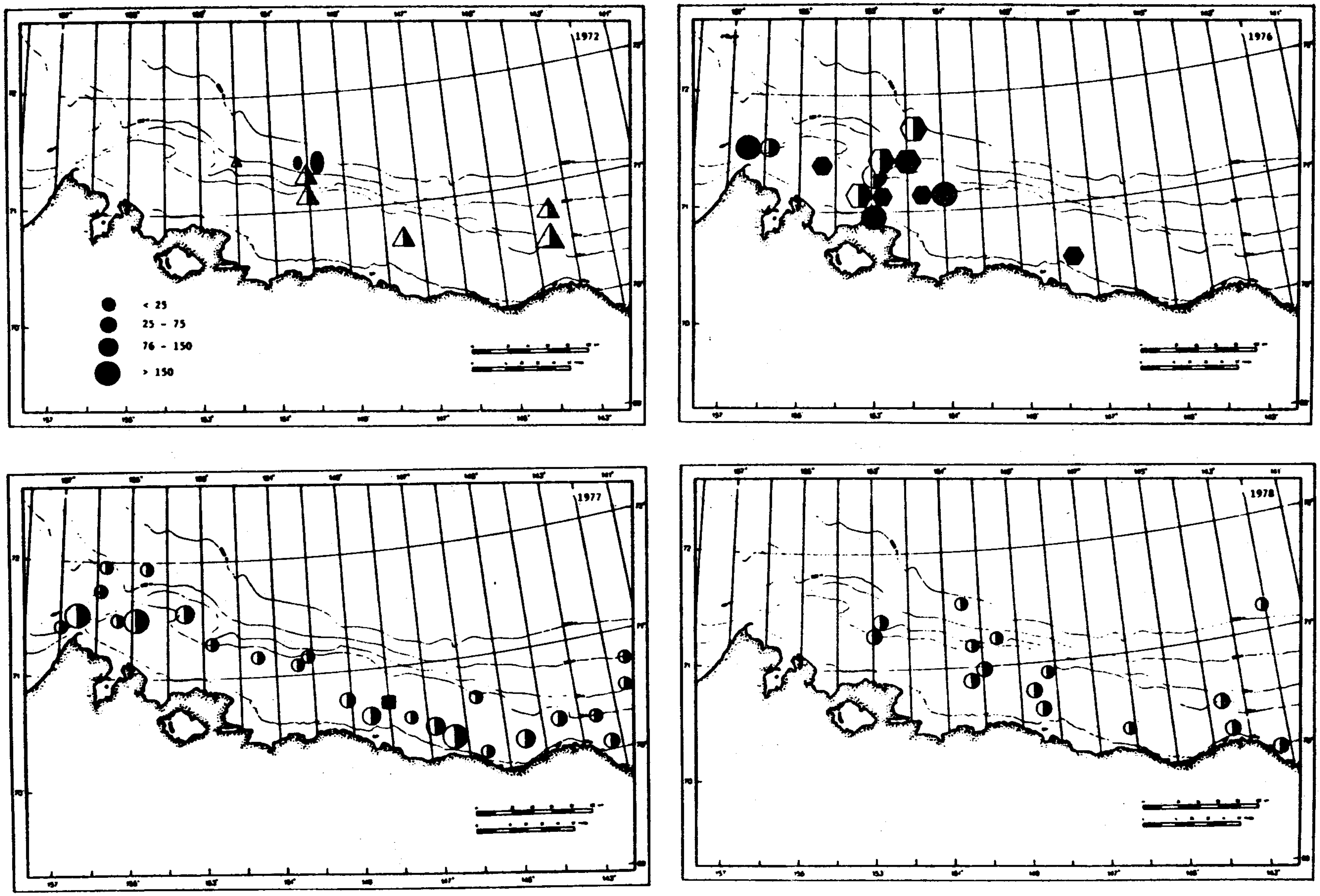


Fig. I-35. Distribution of all Euphausiacea.

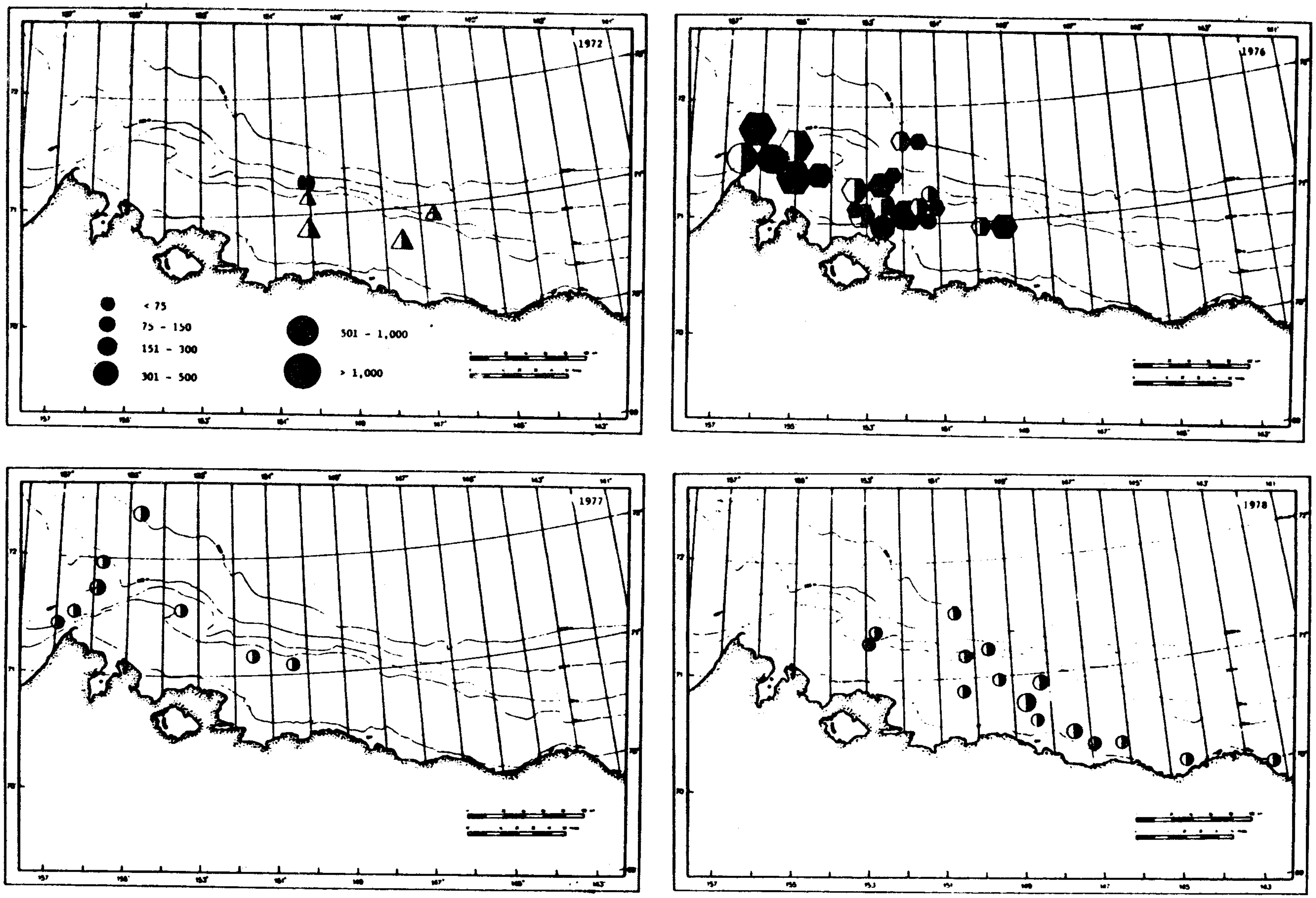


Fig. I-36. Distribution of all Anomura.

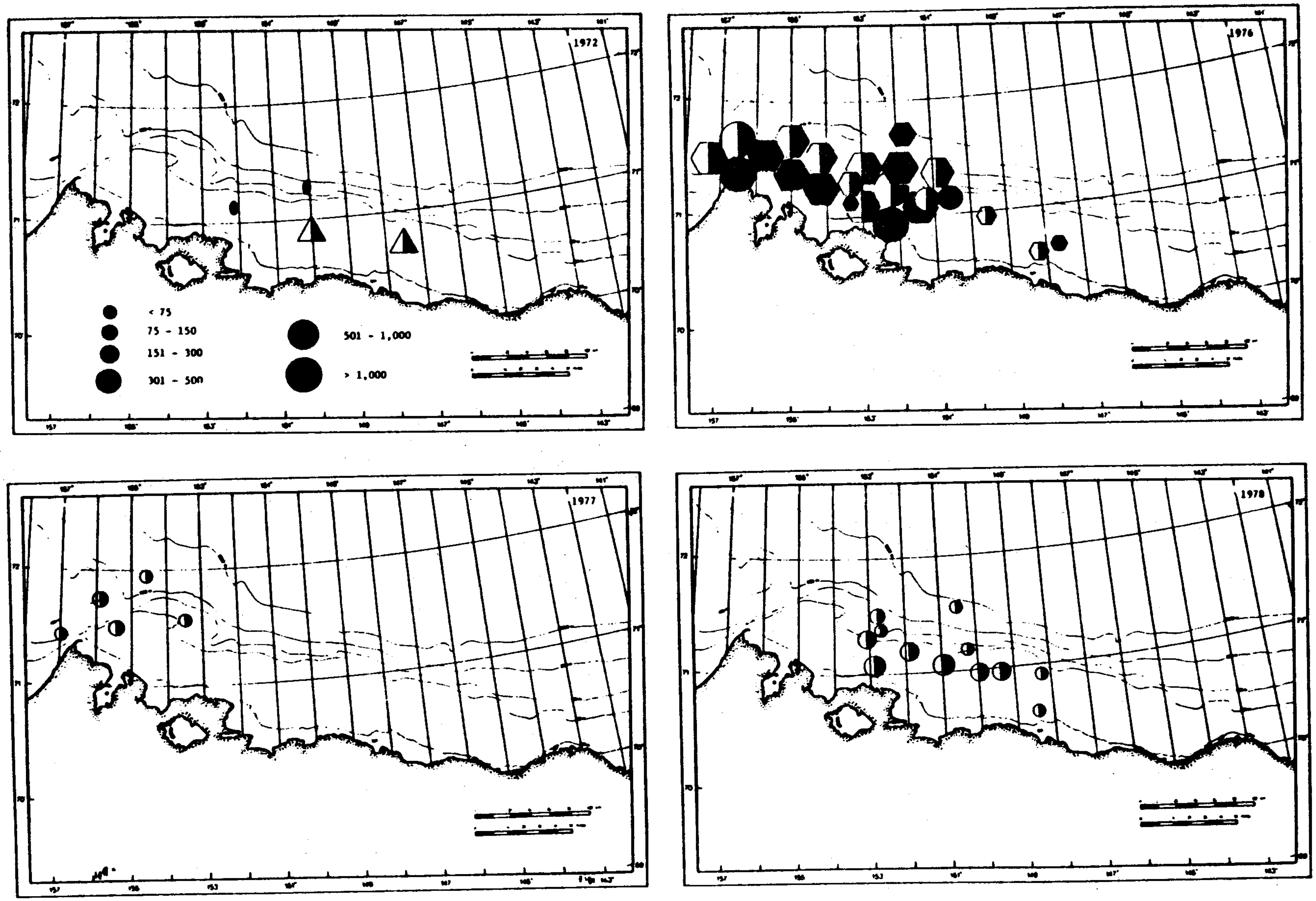


Fig. I-37. Distribution of all Brachyura.

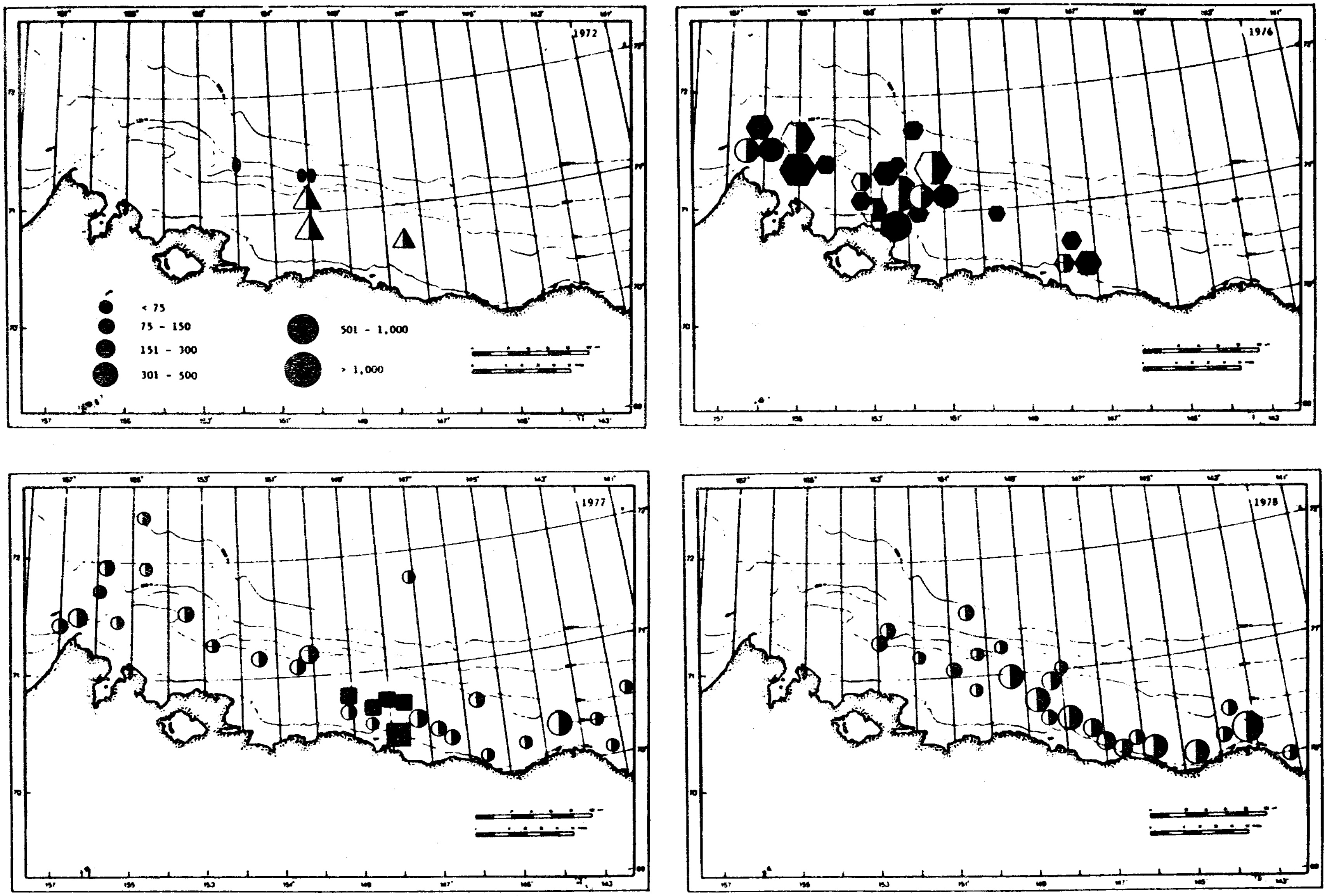


Fig. I-38. Distribution of all Caridea.

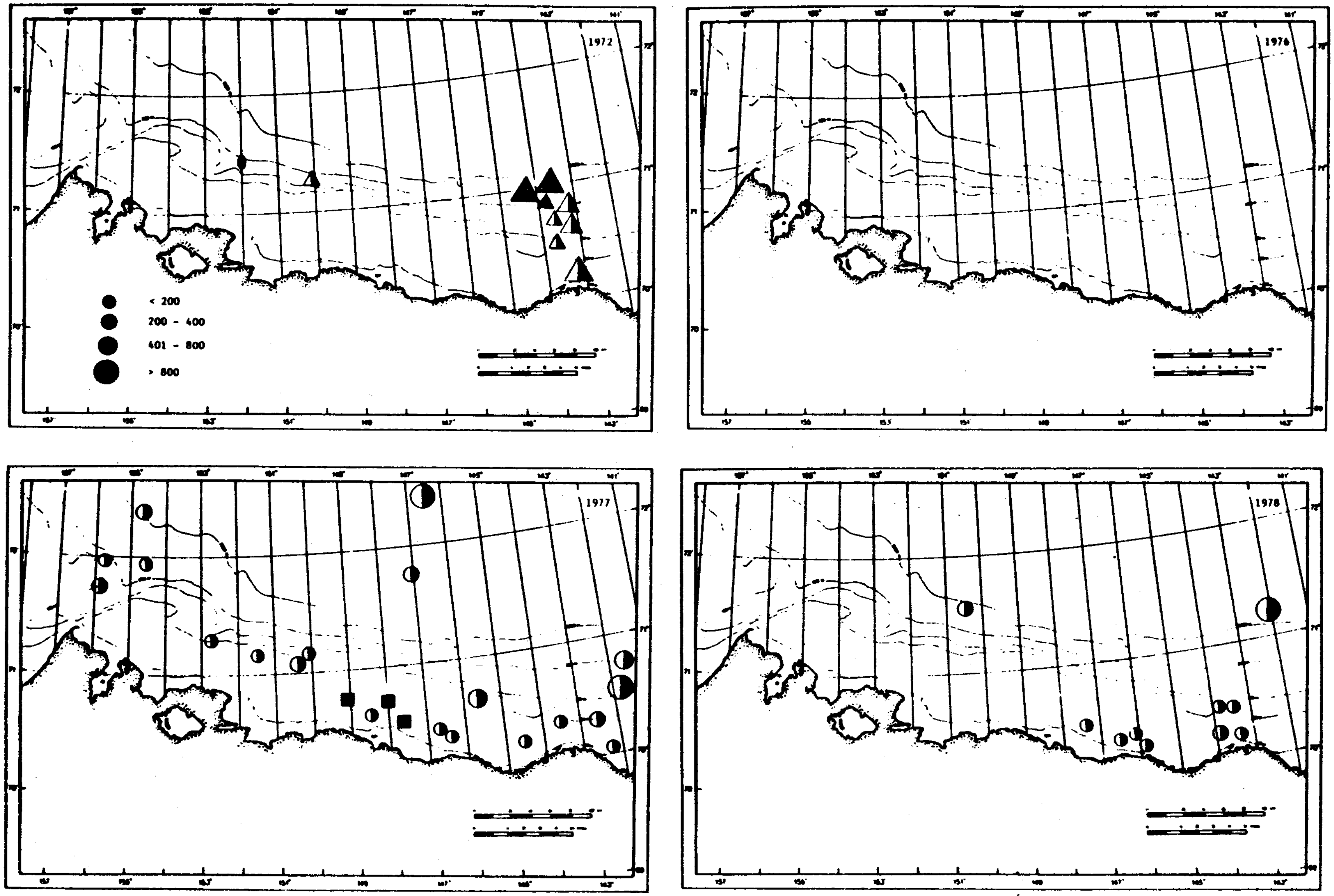


Fig. I-39. Distribution of *Eukrohnia hamata*.

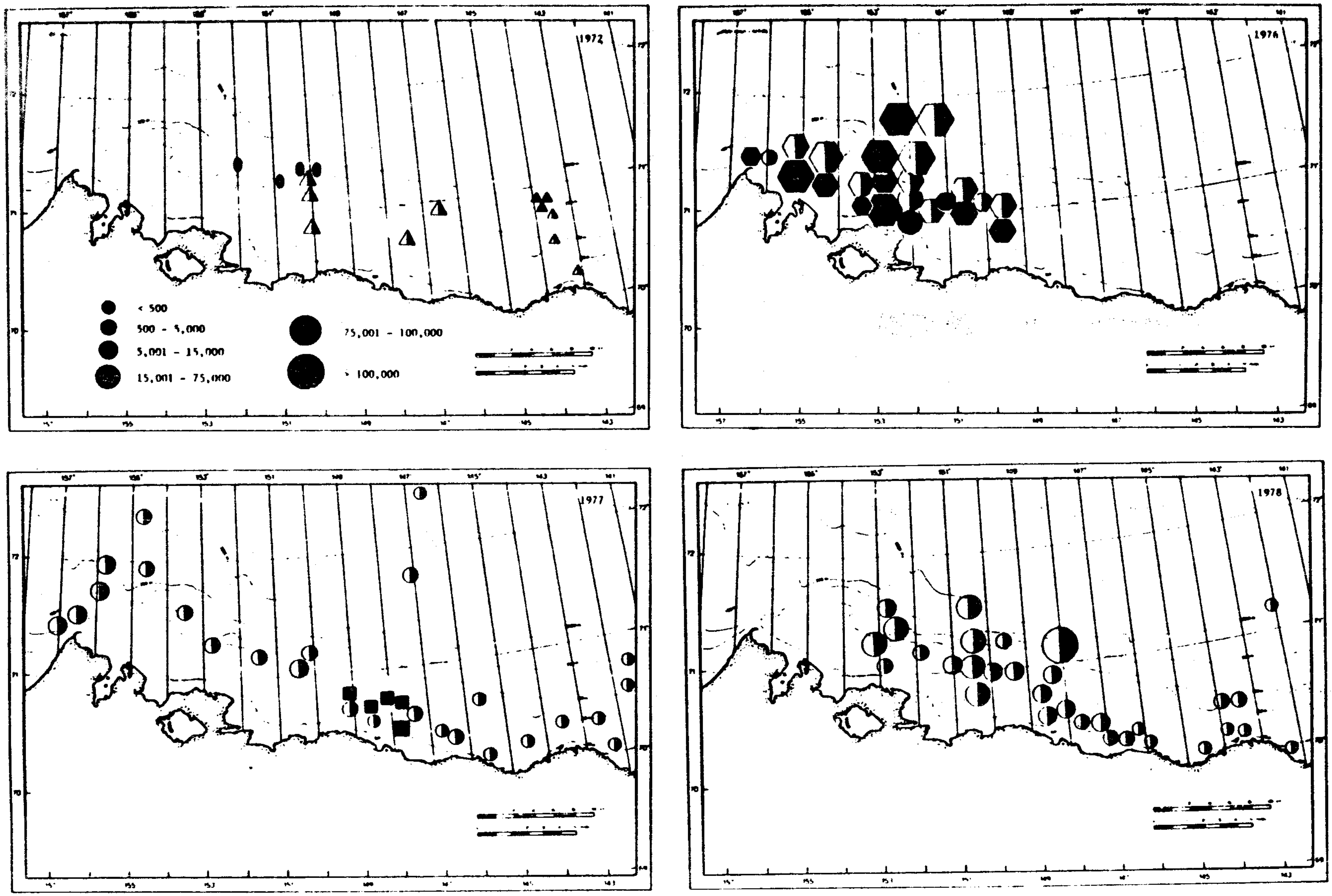


Fig. I-40. Distribution of *Sagitta elegans*.

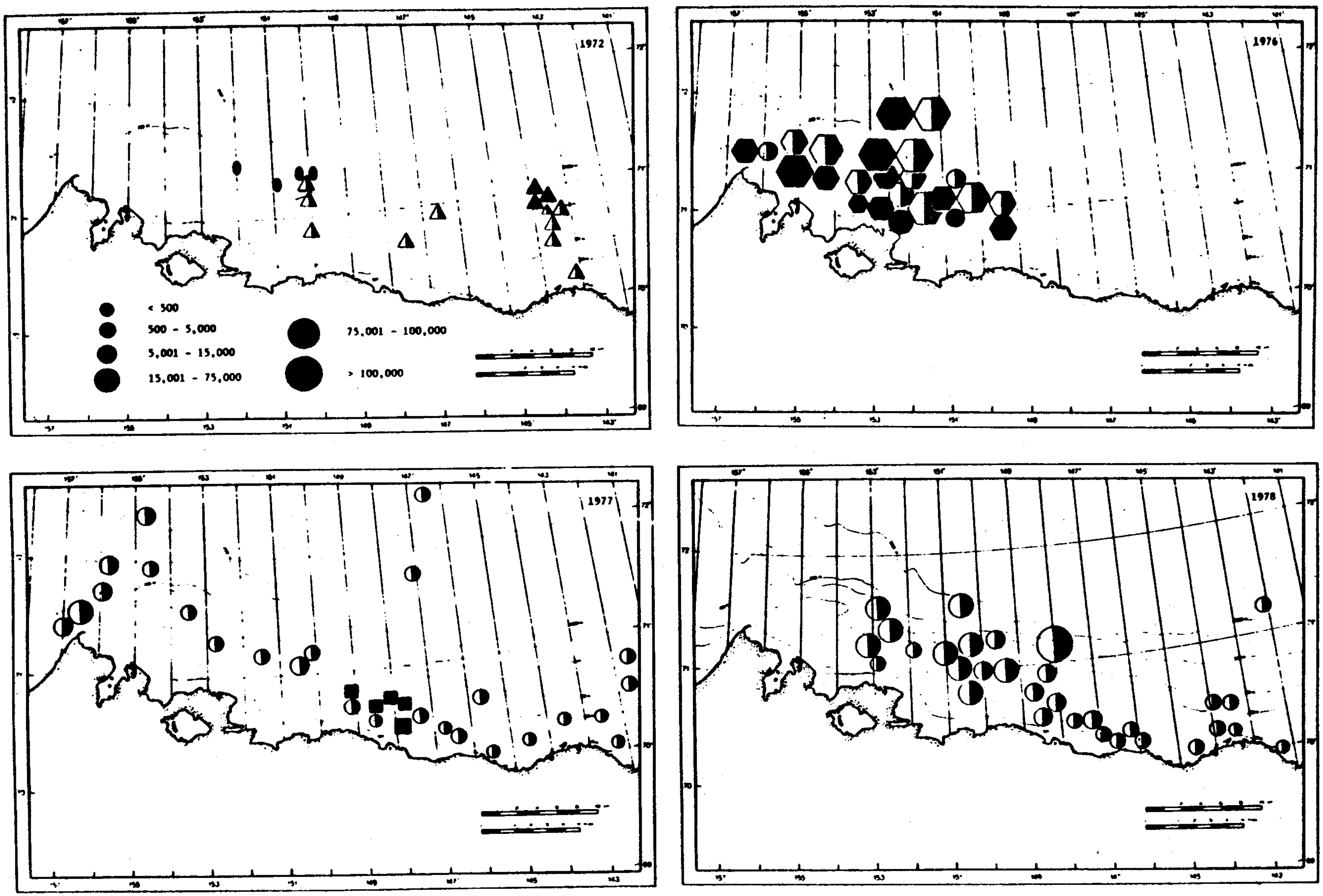


Fig. I-41. Distribution of all Chaetognatha.

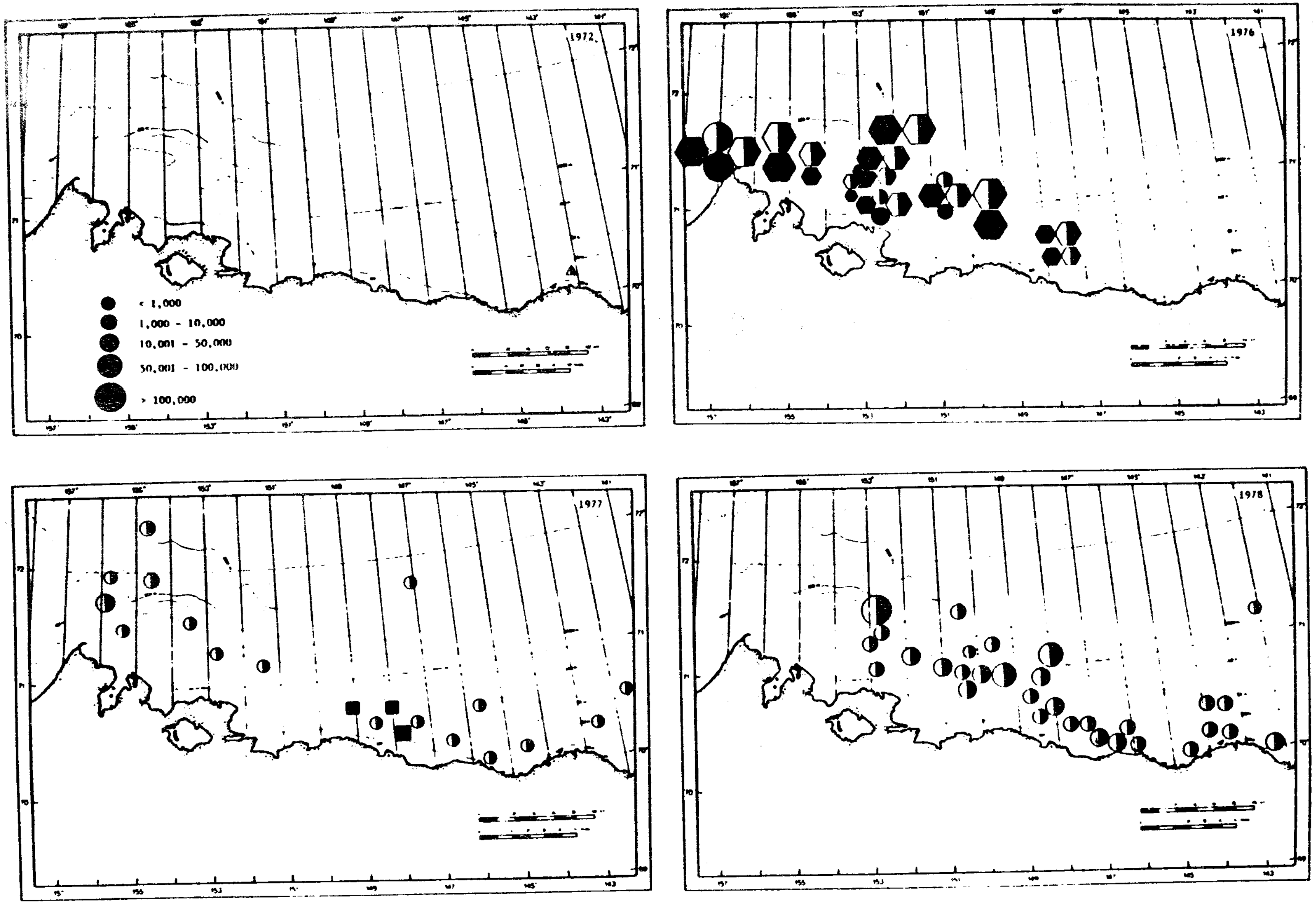


Fig. I-42. Distribution of all *Fritillaria* spp.

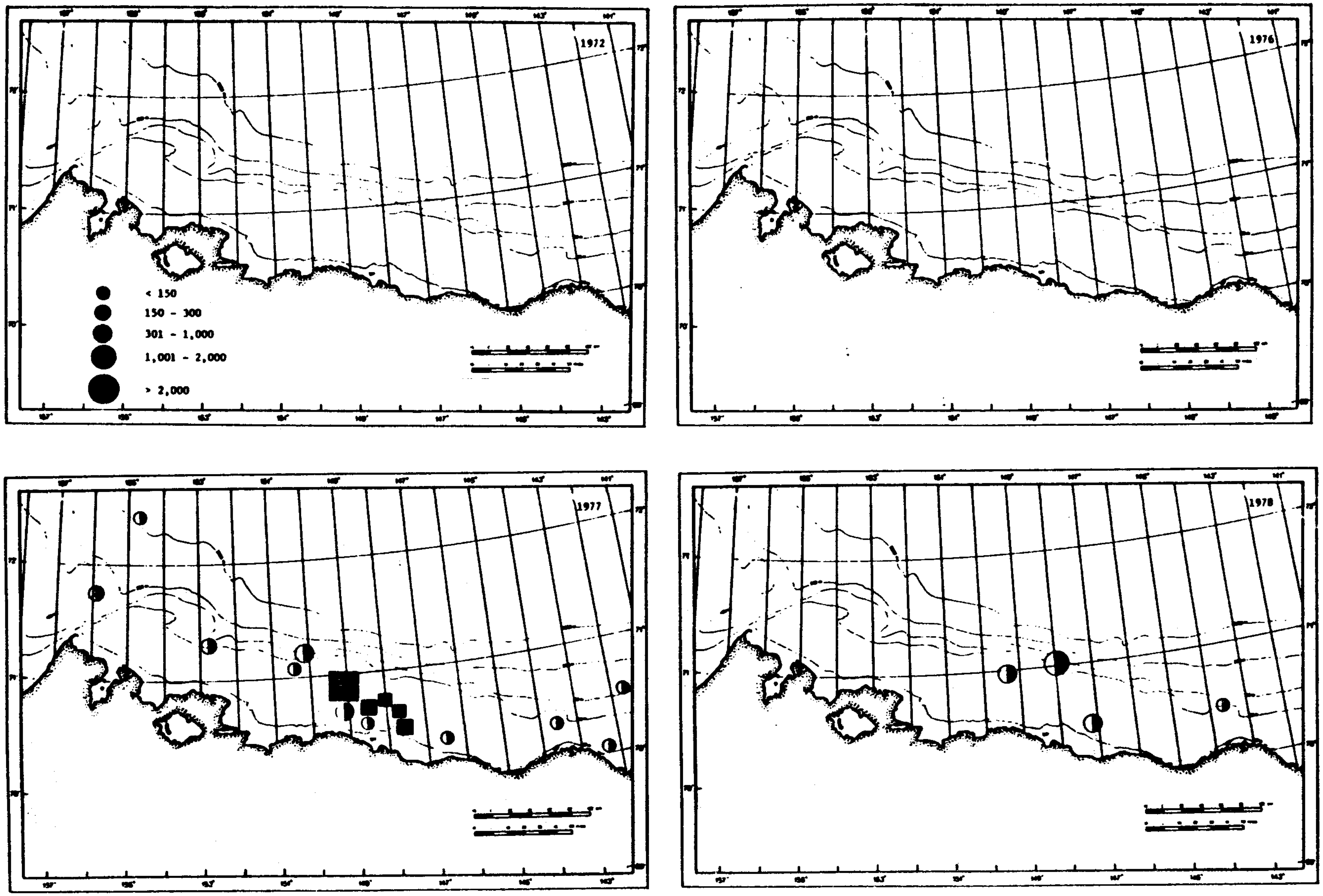


Fig. I-43. Distribution of *Oikopleura labradoriensis*.

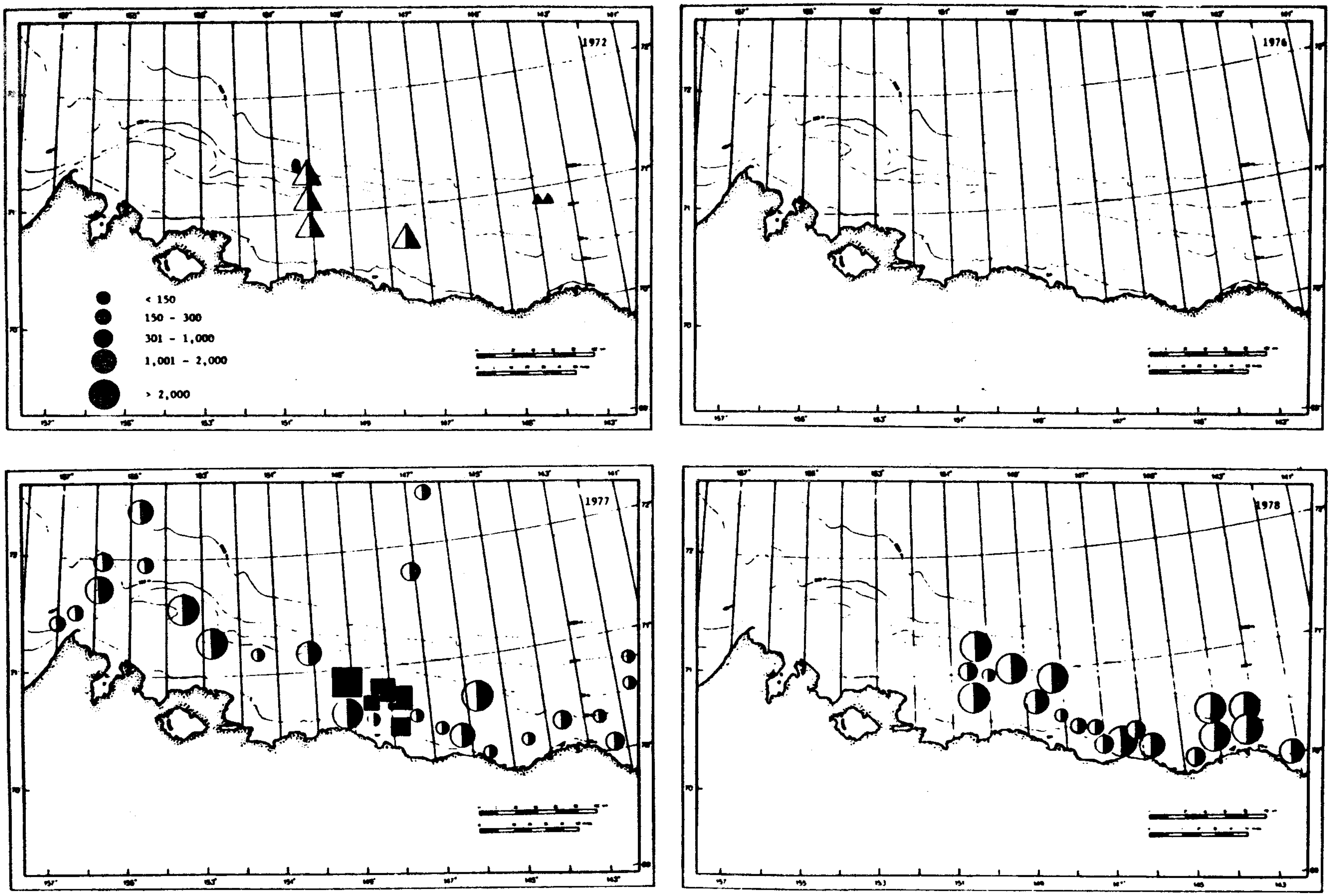


Fig. I-44. Distribution of *Oikopleura vanhöffeni*.

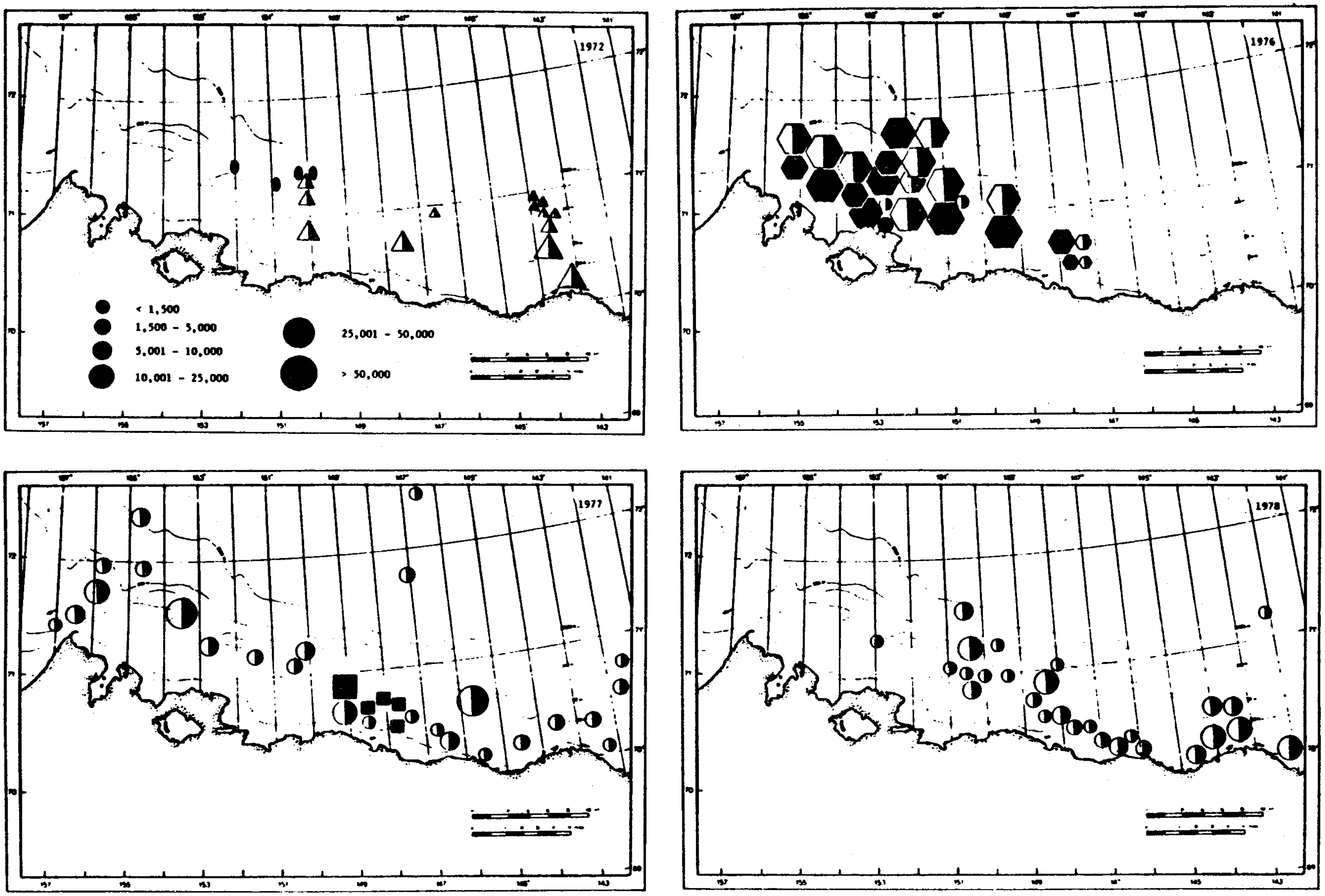


Fig. I-45. Distribution of *Oikopleura* spp.

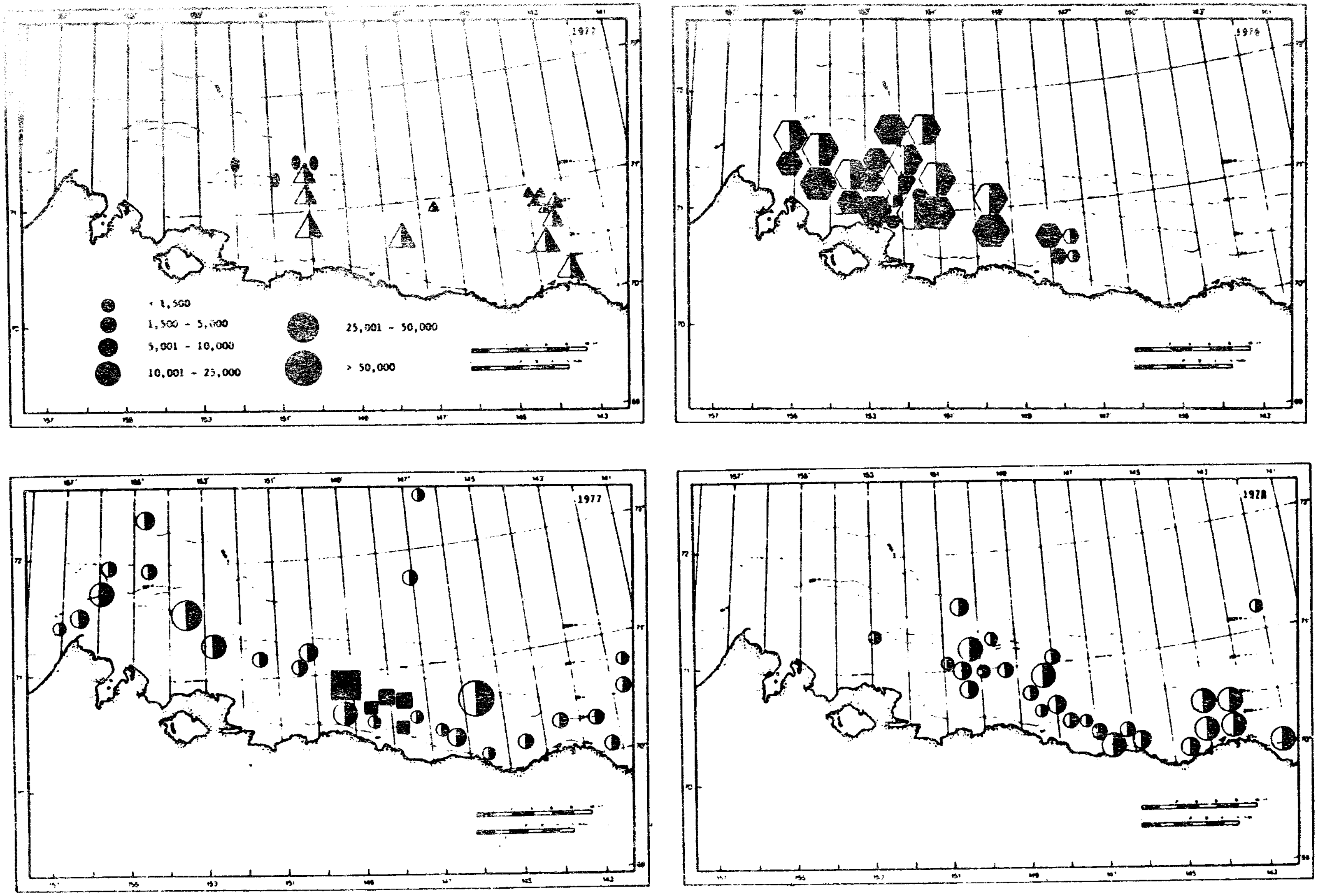


Fig. I-46. Distribution of all *Oikopleura* spp.

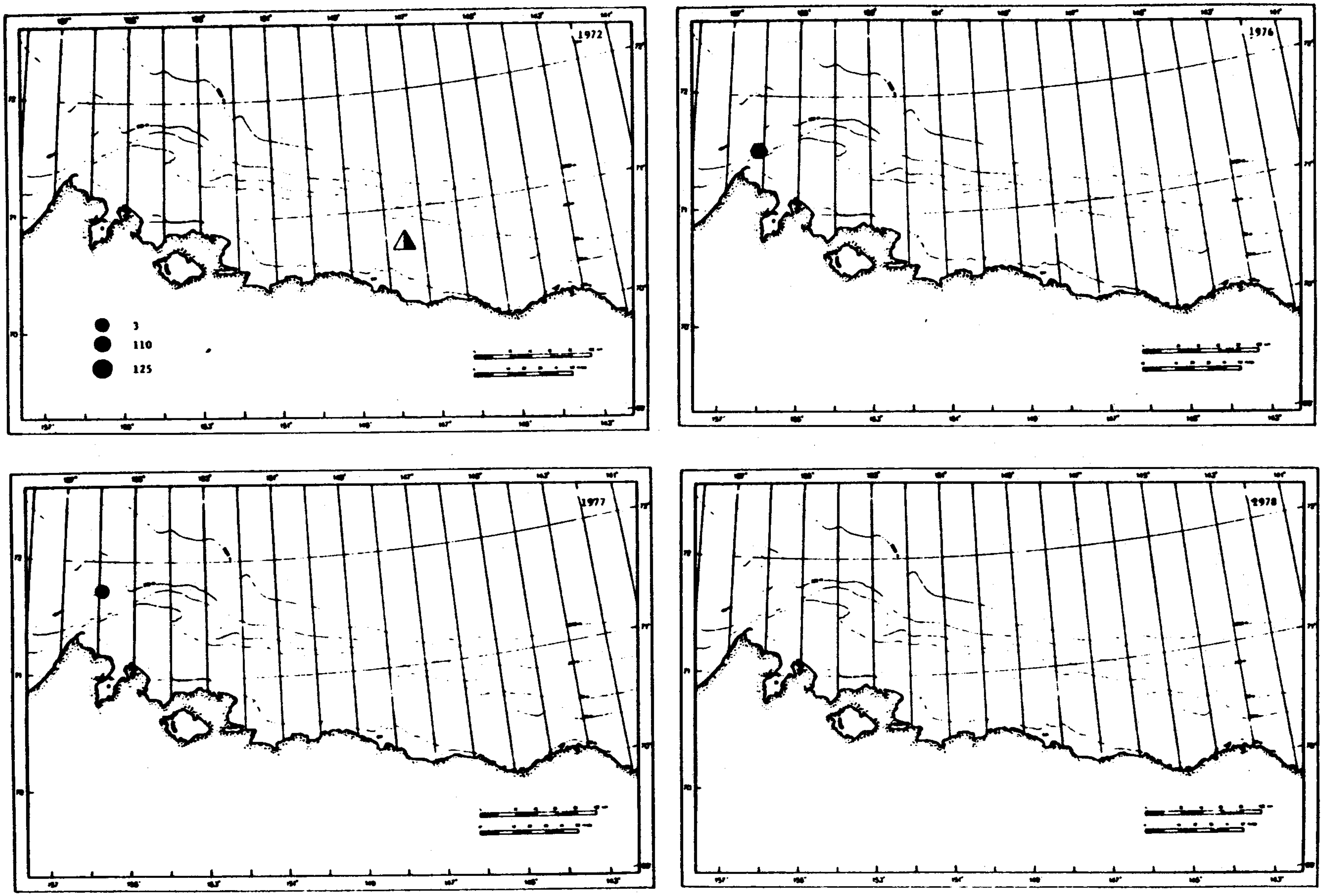


Fig. I-47. Distribution of *Hippoglossoides robustus* eggs.

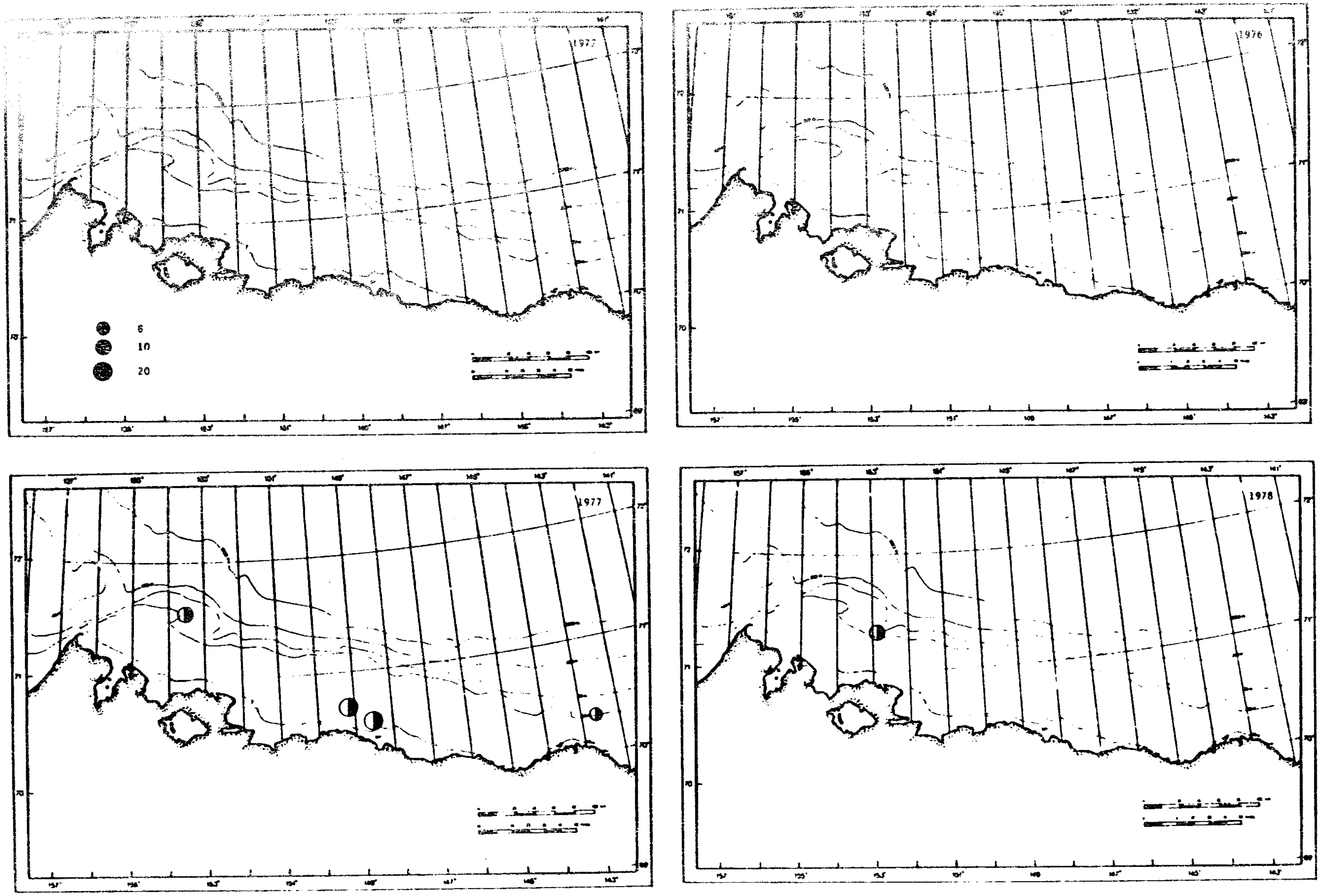


Fig. I-48. Distribution of all Cottidae.

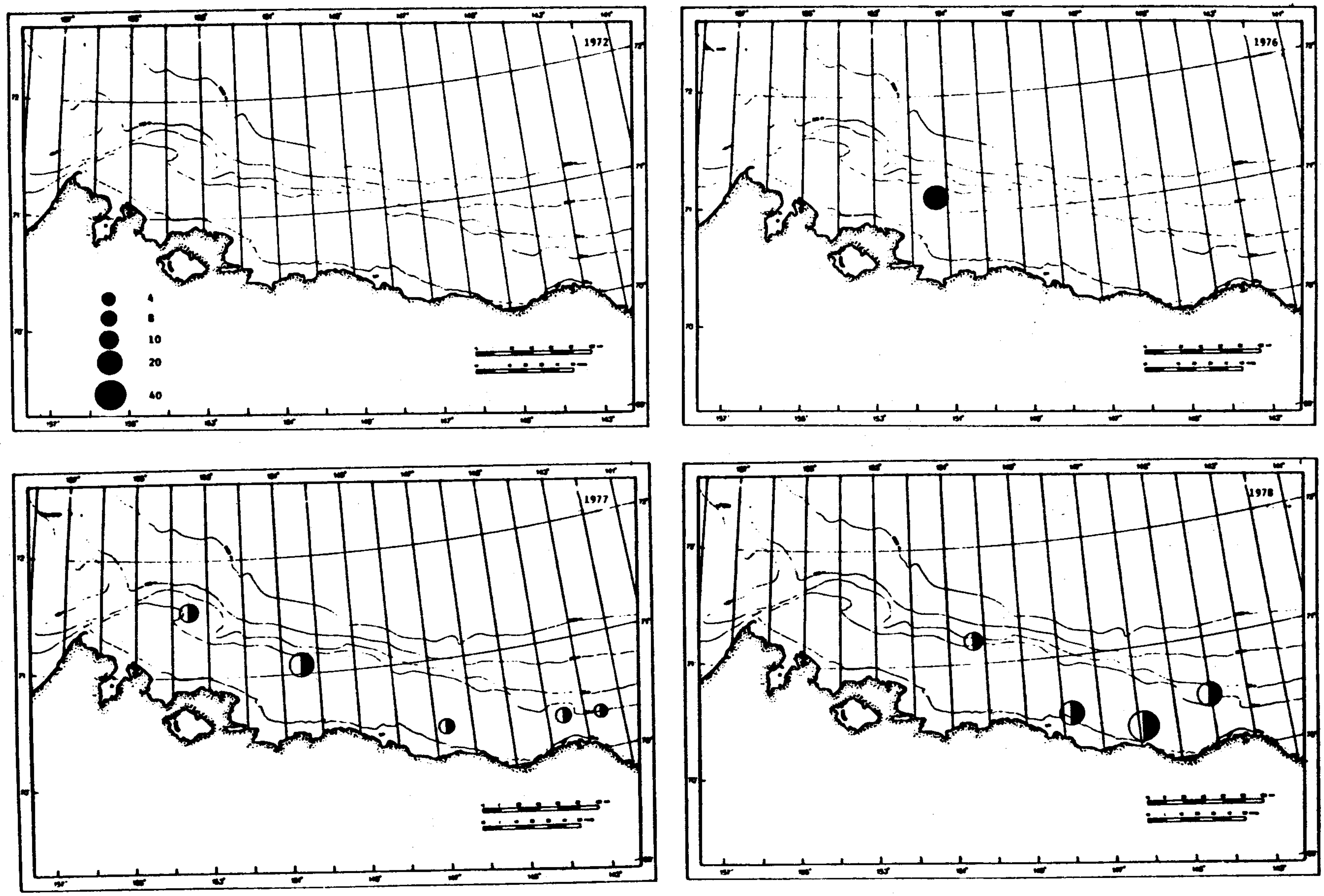


Fig. I-49. Distribution of all Cyclopteridae.

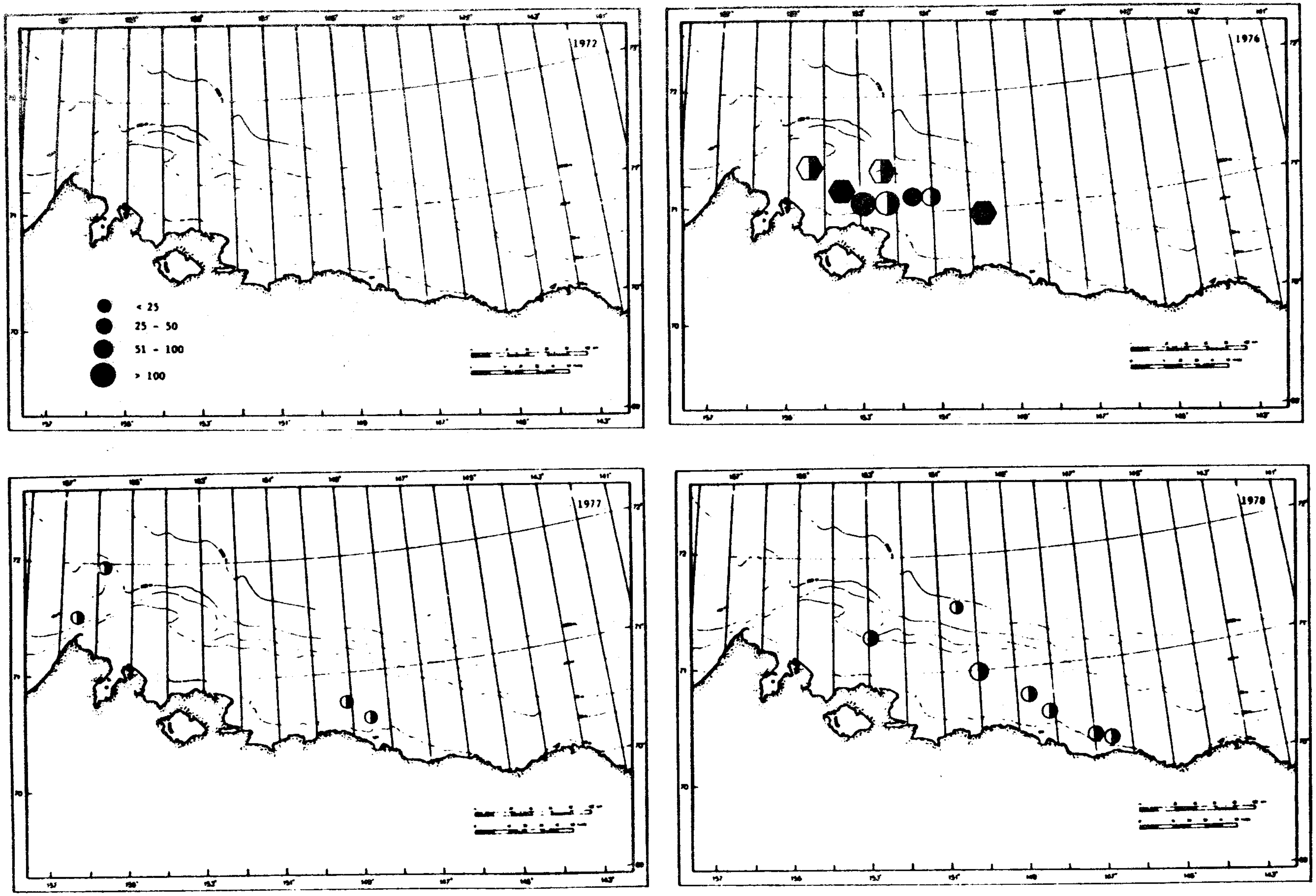


Fig. I-50. Distribution of *Boreogadus saida*.

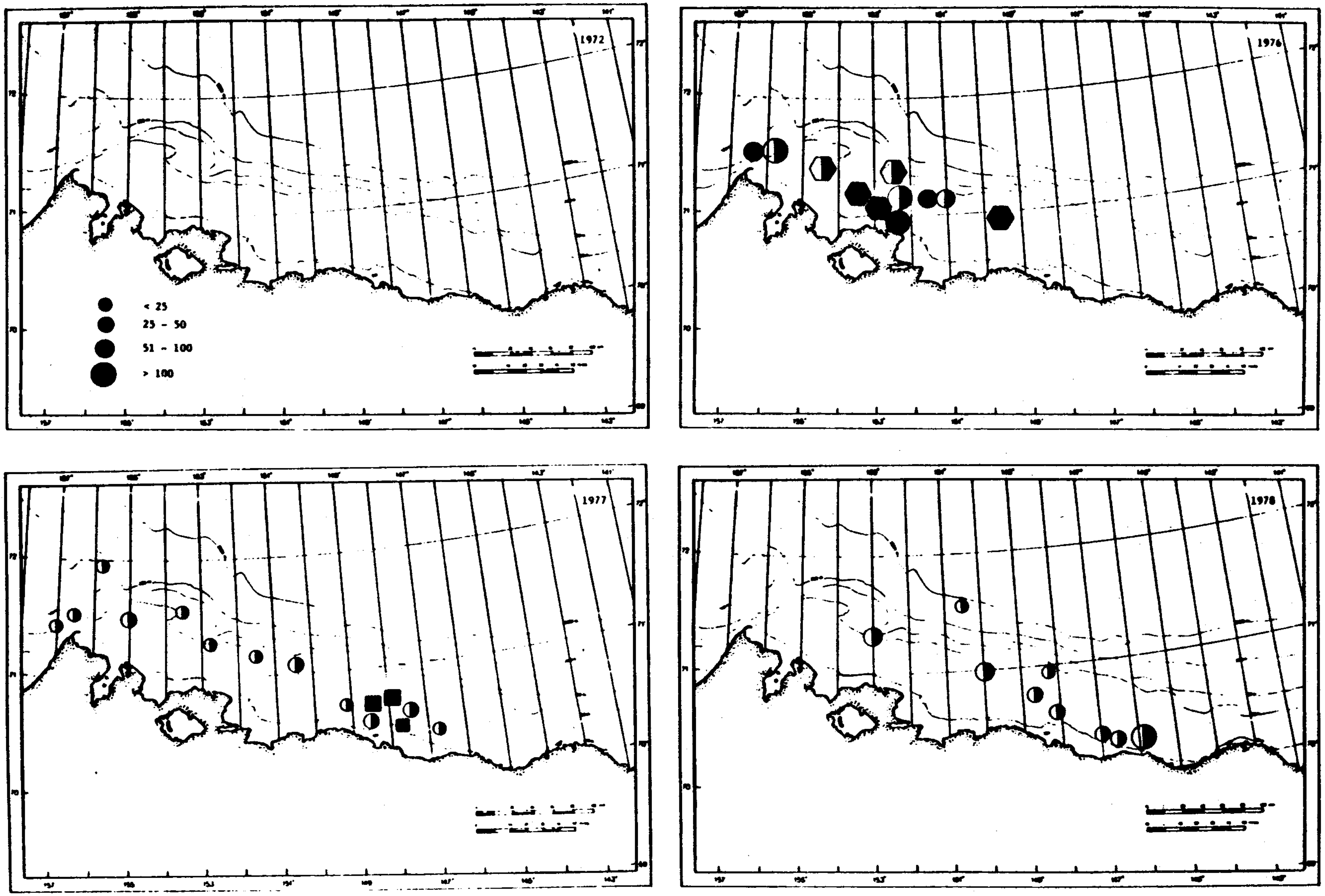


Fig. I-51. Distribution of all Gadidae.

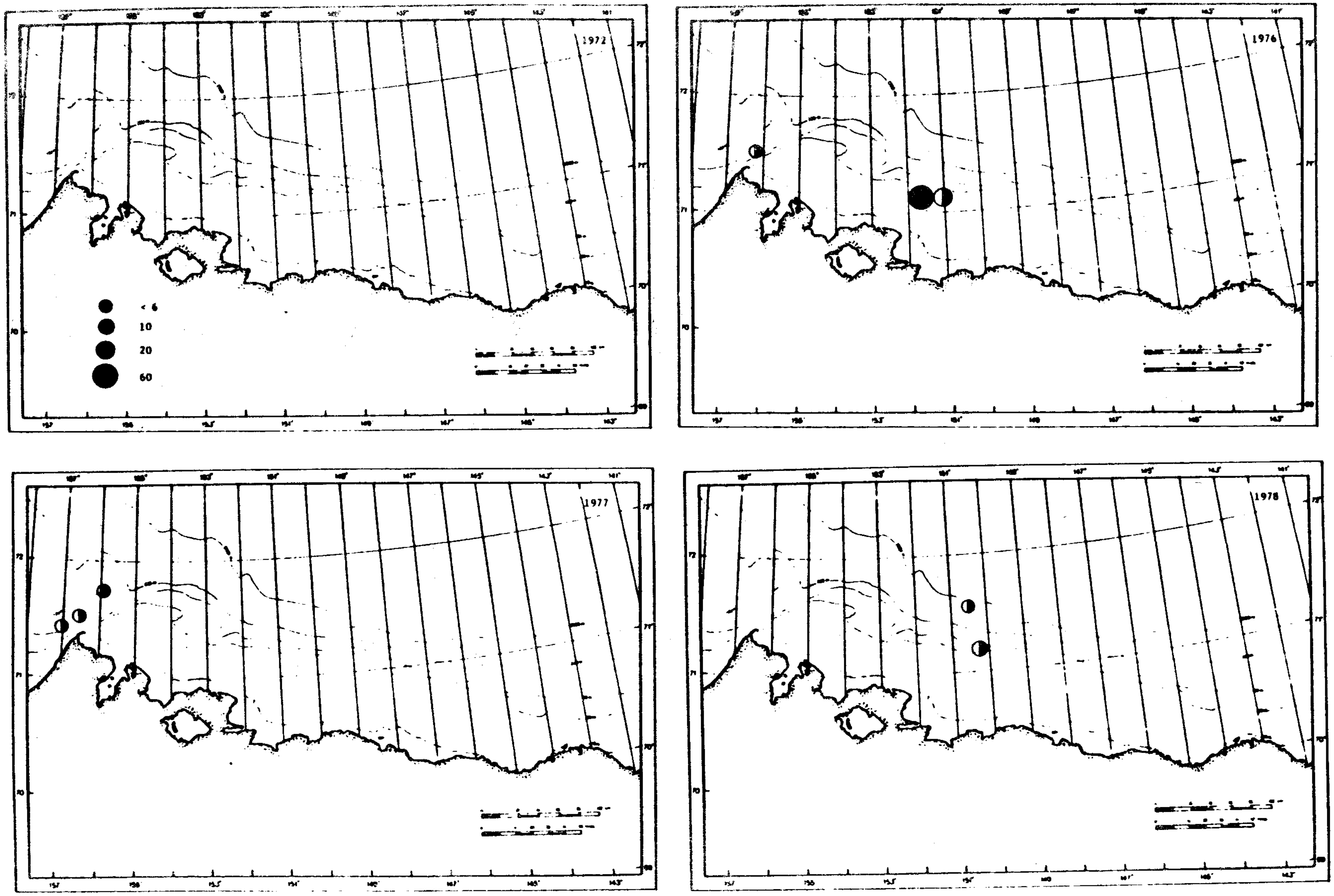


Fig. I-52. Distribution of all Stichaeidae.

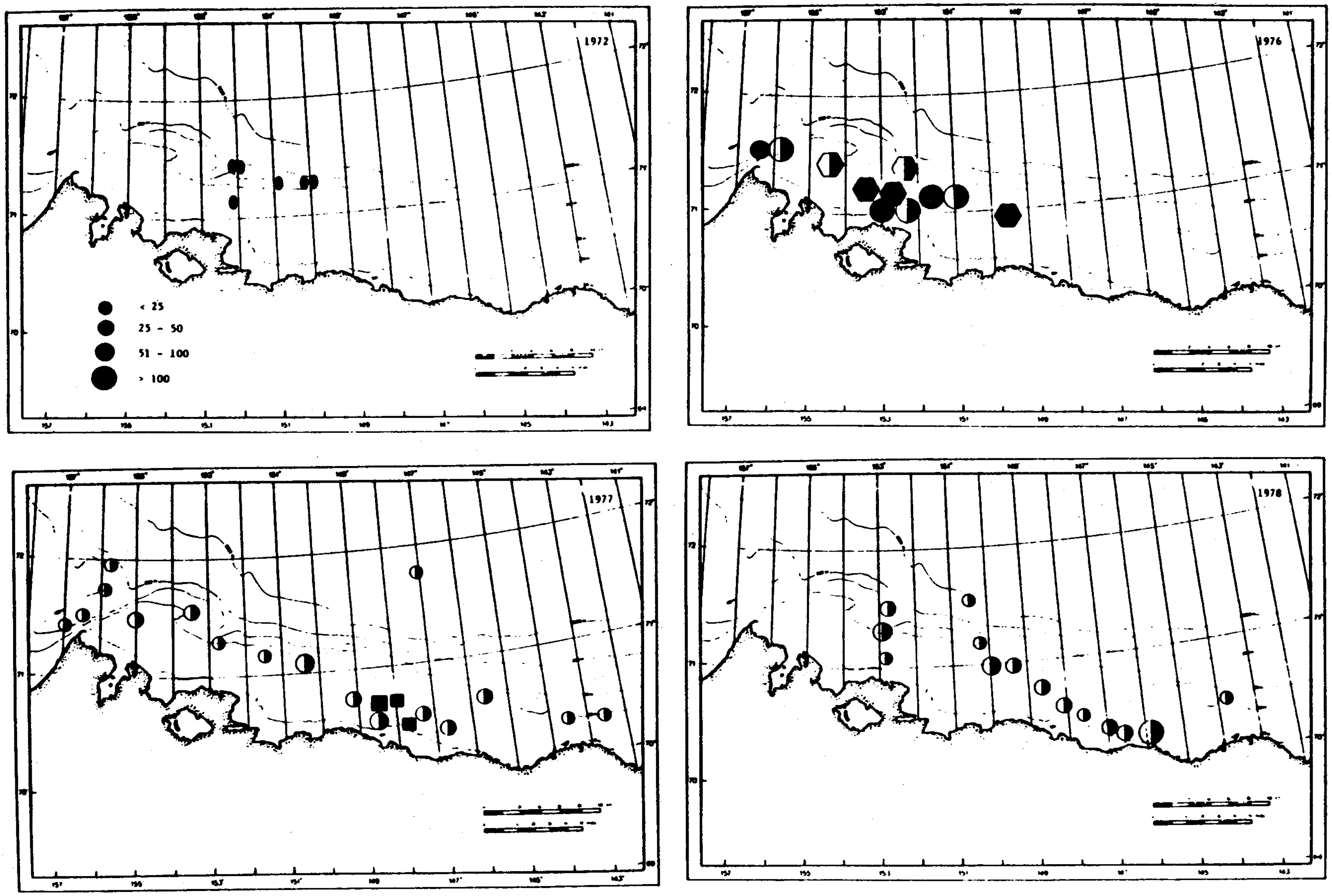


Fig. I-53. Distribution of all fish larvae.

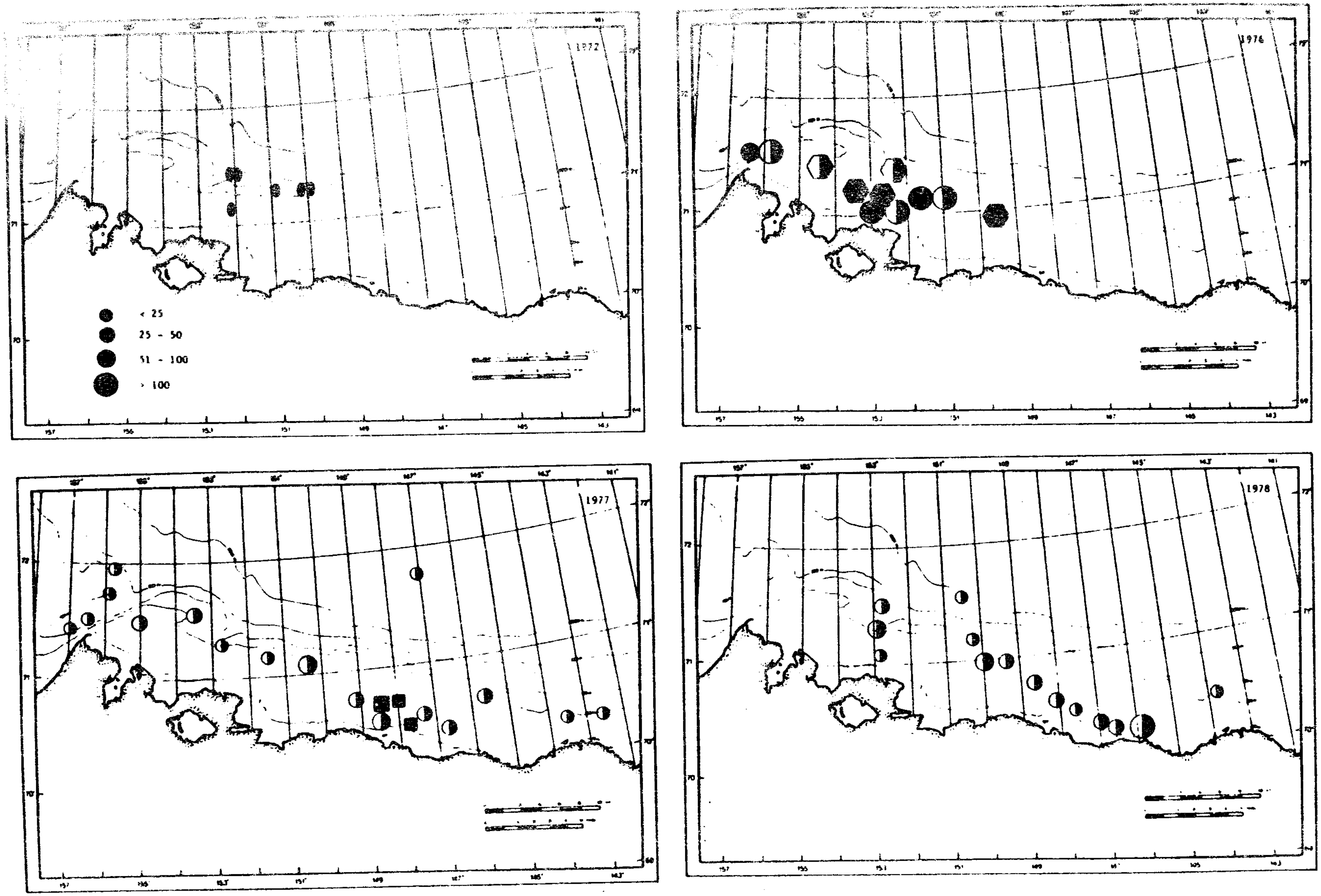


Fig. I-53. Distribution of all fish larvae.

INFLUENCE OF PETROLEUM ON EGG FORMATION AND EMBRYONIC DEVELOPMENT IN SEABIRDS

by

D.G. Ainley[1], C.R. Grau[2], and S.H. Morell[1], Principal Investigators, and

T.E. Roudybush[2], R.R. LeValley[1], H.R. Huber[1], C.S. Strong[1], and T.A. Wootton[2]

Submitted as the Final Report for Research Unit 423

OUTER CONTINENTAL SHELF ENVIRONMENTAL ASSESSMENT PROGRAM
Sponsored by

U.S. Department of Interior
Bureau of Land Management
through the U.S. Department of Commerce
National Oceanic and Atmospheric Administration
Bering Sea - Gulf of Alaska Project Office
P.O. Box 1808, Juneau, Alaska 99802

31 May 1979

1. Point Reyes Bird Observatory, 4990 Shoreline Highway, Stinson Beach, CA 94970.

2. Department of Avian Sciences, University of California, Davis, CA 95616.

I. Summary of objectives, conclusions and implications with respect of OCS oil and gas development.

A. Summary of objectives

Our general objectives were to appraise the effects that brief, sublethal exposure to an oil spill would have on the reproduction of Cassin's Auklets (*Ptychoramphus aleuticus*) and Western Gulls (*Larus occidentalis*) nesting on the Farallon Islands, California. These species are representative of many birds breeding in Alaska and the lower Pacific Coast states that are at risk from oil pollution during the reproductive period. The auklet is, in fact, a rather abundant species that nests on islands from Western Alaska to Northern Baja, California.

The specific objectives were to determine the effects of a single oral dose of bunker C fuel oil and Prudhoe Bay crude oil on the egg production, hatching success, fledging success, egg yolk structure, and yolk composition of Cassin's Auklet. We dosed the female during the period of rapid yolk formation and obtained field data on reproductive success. Laboratory studies were designed to determine effects on yolk qualities and composition and embryonic changes in response to the oil, based on experience with Japanese quail as a model bird.

B. Summary of conclusions

During the 1977 breeding season on Southeast Farallon Island, 251 female Cassin's Auklets were force-fed gelatin capsules that were empty or contained 300 mg or 600 mg bunker C oil. During the 1978 breeding season, 219 female auklets were force-fed gelatin capsules that contained 1.0 g of bunker C oil or 1.0 g of Prudhoe Bay crude oil. Birds were sexed by measurement of the bill (length:depth); the smaller bird of a pair was the female. These birds were all sexed and banded before the nesting season. Dosing occurred just as the population began to lay eggs. After dosing, the eggs and chicks of experimental birds were observed, as were 70 birds in a control group. Egg laying was inhibited in females dosed 9 to 13 days before they should have laid eggs. Increasing dosage level appeared to increase the proportion of birds affected. Effects were similar for both types of oil. We do not know whether affected birds laid at a later time.

C. Implications with respect of OCS oil and gas development

The presence of spilled oil on the sea, from platform, pipeline, or tanker, constitutes a major hazard to birds in contact with that oil, as has been documented many times. These birds die from exposure when the oil breaks down the insulating, water-proofing qualities of the plumage. We now know, based on the work reported here, that ingestion of oil in very small amounts, not large enough to be lethal in terms of exposure can have negative repercussions as well. Ingestion can occur when birds preen small amounts of oil from plumage. Not only can oil pollution result in increased adult and post-fledging mortality but it conceivably can cause a reduction in breeding success of surviving adults. Both effects, if enough individuals are involved, can contribute to population decline. The effects of even low level pollution are thus theoretically increased.

II. Introduction

A. General nature and scope of study

The responses of marine birds to contamination by petroleum are only partly understood. Massive coating of external surfaces results in their death, but what happens when seabirds ingest small amounts of oil preened from their feathers? This project was designed to determine reproductive responses of Cassin's Auklets and Western Gulls to small doses of bunker C oil ingested by females during the period of egg formation. During the first season we found that the gulls regurgitated the oil as soon as the gelatin capsule dissolved. Following the observations of gull behavior in regurgitating oil, auklets and other birds were also studied. The auklets began eliminating the oil in their feces at a mean time of 36 minutes after being fed. Adult Japanese quail (Coturnix coturnix japonica) reared in cages and adult, pen-reared mallards (Anas platyrhynchos) deprived of food for 16 hours were compared in their responses to oil with fed birds. It took fed quail 177 minutes to eliminate oil, while unfed quail took only 29 minutes. Mallards responded differently: feeding did not affect passage time. Three Black-footed Albatross (Diomedea nigripes) and three Common Murres (Uria aalge) were also dosed. It took several hours for oil to pass in the albatross; the murres reacted violently within minutes by regurgitating and defecating oil.

Auklet eggs collected in 1977, 2 to 7 days after dosing with bunker C oil, were found to have normal yolk structure and appearance. Because chemical methods might be more useful than visual methods of detecting pollution, attempts were made to develop techniques of analysis using quail, chicken and mallard eggs for eventual use with auklets. Yolks from oil-treated quail, chickens,and mallards were found to differ from normal yolk in appearance and response to solvents. "Oil" yolks were lighter in color than normal. Denaturation and initial extraction of the thawed yolk with acetone resulted in a stringy texture as compared with the normal crumbly appearance. No major differences were found in phospholipid distribution or in ultra-violet absorption of extracts. Differences were detected in fluorescence of extracts prepared from "oil" and normal eggs after thin-layer chromatography of yolk extracts.

Gas chromatographic analyses of treated extracts of normal and "oil" eggs have been pursued vigorously but the results have not proved satisfactory. Preliminary observations of differences attributable to oil have not been confirmed.

B. Specific objectives

The approach was to identify breeding birds, feed them known amounts of Prudhoe Bay crude oil and bunker C oil at the time when yolk was being formed, and then to follow the course of their reproductive activities. We sought to determine whether ingested oil affected the timing of egg laying, the number of eggs laid, the hatching success of eggs, and the growth and fledging success of chicks. We also sought to develop techniques whereby petroleum compounds could be detected qualitatively and quantitatively in the yolk of eggs.

C. Relevance to problems of petroleum development

It is known that many seabirds are killed by becoming oiled through contact with spills. The effects of sublethal contamination, especially in relation to reproduction are not known. Because the reproductive period is one of vulnerability of adults and young, assessment of potential hazards to breeding populations is needed to evaluate the total impact of oil development and transport on avian species.

III. Current state of knowledge

Major oil slicks are relatively recent components of the marine environment, except in rare places such as Santa Barbara, California, where natural seeps occur. Seabirds, particularly the more susceptible diving and plunge-diving types (Ainley and Sanger MS), have not had contact with oil pollution long enough to have evolved or acquired defense mechanisms. Mortality of seabirds due to oiled plumage resulting from direct contact with oil slicks is thus becoming a frequent occurrence (see, for instance, Straughan 1970, 1971; Smail et al., 1972). Death in this situation has been attributed to hypothermic stress after the oil destroys the insulating properties of a bird's plumage. Ingestion of oil under these circumstances also affects intestinal absorption of water as at least one contributing cause of death (Crocker et al., 1975). In spite of information about bird survival following direct oiling, little is known about the possible effects of petroleum of physiological processes, especially reproduction, in birds. The present work is designed to evaluate the significance of oil ingestion in seabird reproduction.

Coating of laid eggs can cause embryonic mortality, probably by limiting gaseous exchange through the shell (Rittinghaus 1956, Abbott et al., 1964, Hartung 1965), but also by a toxic effect of substances absorbed through the shell. Albers (1977) reported that as little as 1 µl of fuel oil reduced the hatchability of eight-day Mallard embryos that were being incubated artificially. Ingested substances can be deposited in eggs, usually in the yolk (Shenstone 1968), but we are only beginning to understand the mechanism and effects of such incorporations. Both fat and water-soluble materials, including drugs, pesticides, toxins, and dyes have been identified in the yolk.

A recently published study of the effects of bunker C oil on egg formation and hatchability in Japanese Quail (Coturnix coturnix japonica), a pilot animal, showed that a single dose of 200 mg reduced egg production and drastically interfered with embryonic development, resulting in very poor hatchability for several days (Grau et al., 1977). It is not yet clear whether these effects represent incorporation of oil components in yolk or some indirect effect on intestinal or liver functions. Extension of this study to fractions of bunker C has shown that the primary effects lie in an isopentane-soluble fraction, not in the heavy residue. When experiments similar to these were carried out with Prudhoe Bay crude oil, fed at 400 and 800 mg levels, egg production and shell thickness were reduced, and therefore total reproduction was markedly affected, but the hatchability of fertile eggs was not reduced (Engel et al., 1977), in contrast to the results with bunker C oil.

Ingestion of petroleum hydrocarbons by seabirds and waterfowl can occur in several ways. First, a bird ingests oil while attempting to preen it from its plumage. Hartung and Hunt (1966) reported that a duck with 7 g oil on its feathers ingested 1.5 g of the oil during the first day after oiling or 2-3 g/kg body weight. Autopsies of heavily-oiled birds have disclosed oil in the alimentary tract, indicating that ingestion occurred during preening. At least twice during the past five years, up to 10% of Common Murres (Uria aalge), Pigeon Guillemots (Cepphus columba) and Western Gulls (Larus occidentalis) at their breeding grounds on the Farallon Islands have been counted with small amounts of oil on their feathers (PRBO Farallon Journal). In such instances significant amounts of oil might be ingested through preening without the birds being sufficiently coated with oil to cause death. Second, a seabird might directly eat oil. Some species, for instance large gulls (Larus) and albatross (Diomedea) feed heavily at times on pelagic barnacles (Lepas) that attach themselves to objects floating on the sea (Miller 1940, Sanger 1973). The barnacles readily attach to oil globs with a hardened outer surface; such tar balls can in some areas be quite common (Heyerdahl 1971; Ainley, personal observation). If a bird finds barnacles on a small tar ball it might ingest both tar ball and barnacle. Third, seabirds maintain fluid and salt balance by drinking seawater. They could conceivably drink water contaminated by oil. Finally, direct contact of skin with oil causes changes in tissue structure and permeability (Renden and Abbott 1973). We found recently that such contact will also affect yolk structure in the same way as does oral dosage. Similarly, we found that intraperitoneal injection of bunker C oil resulted in abnormal yolk structure (unpublished observations).

Smearing of as little as 1 ml of bunker C on the feathers and skin of the head and neck of quail resulted in formation of yolk with the same abnormal structure as was observed when 200 mg was given in a capsule by mouth. From this experiment it was not possible to determine whether the effect was a direct one on the skin, or whether the bird preened and thereby ingested the oil.

Recently developed approaches to the study of yolk structures and its relation to nutrition and other environmental factors have been made possible through new methods of fixation, staining and analysis of eggs (Grau 1976). After freezing whole eggs to alter lipoproteins, the yolk can be fixed in formalin and stained to reveal rings of yolk that can be related to the time the egg was laid. Frozen, unfixed yolks can be cut in half and material isolated from particular parts of the yolk can be analyzed chemically. Thus the composition of yolk deposited during a known period of 8 to 12 hours can be related to environmental pollution by oil or other materials without maintaining the female in captivity.

IV. Study area

Field studies were carried out on the Farallon Islands, which lie 45 km west of San Francisco, California (Figure 1). They are the site of the largest seabird breeding colony in the contiguous 48 states of the U.S. and a National Wildlife Refuge. Since 1968 the Point Reyes Bird Observatory (PRBO) has maintained a year round research station on Southeast Farallon, the largest island of the chain. Based on our earlier studies, we concluded that Cassin's Auklet (Ptychoramphus aleuticus) would be our major study subject (Figure 2). This bird is abundant at the Farallones, its ecology has been intensively studied there, it easily lends itself to the proposed studies and, lastly and very importantly, it is a member of that seabird family (the Alcidae) that world-round has been most heavily impacted by oil pollution. Futhermore, these auklets breed as far north as the Kodiak Island area of Alaska (Udvardy 1963) and thus occur in important lease areas (Figure 3). Study of the species at the Farallones meant a minimum of logistics arrangements and problems.

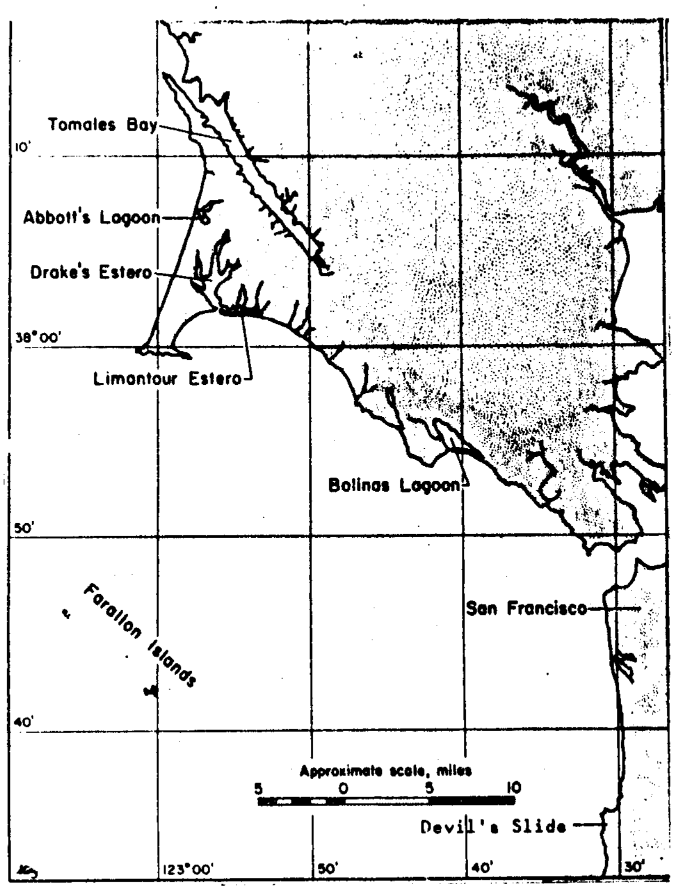


Figure 1. The Farallon Islands in relation to the California coast and San Francisco Bay. Southeast Farallon is the largest island.

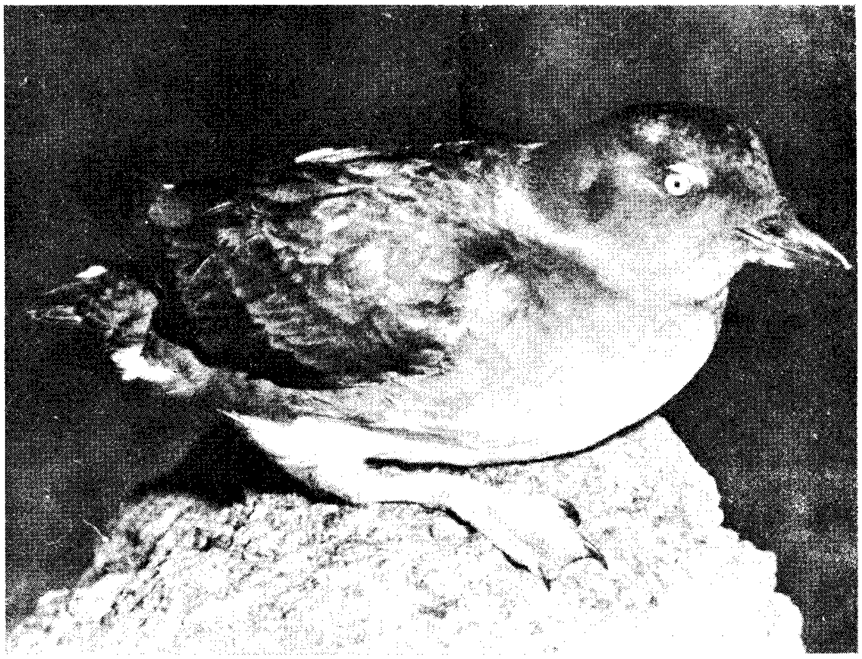


Figure 2. Adult Cassin's Auklet. (Photograph by Bill Parsons)

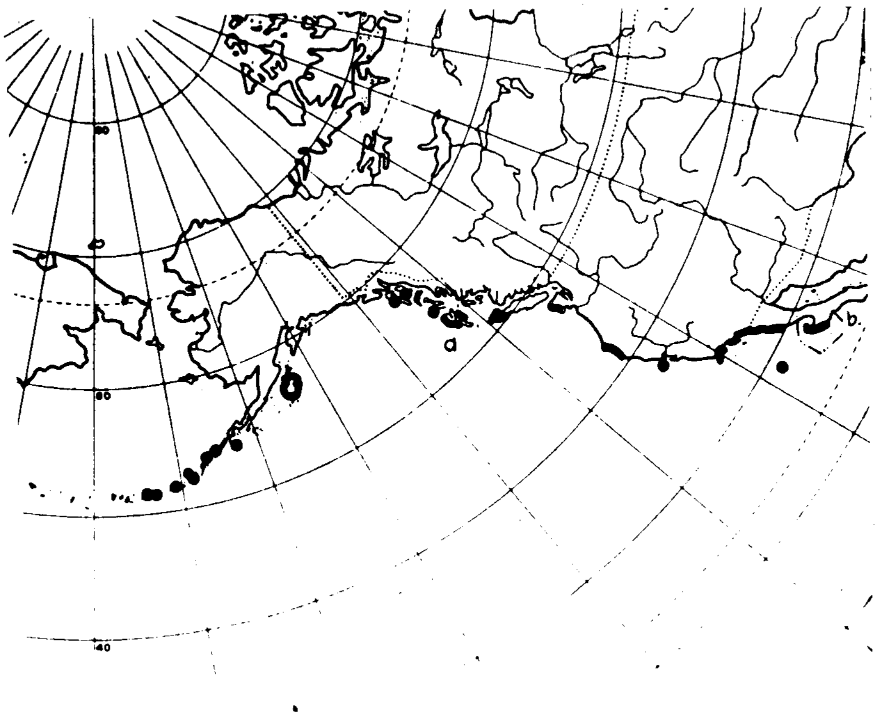


Figure 3. Breeding range of Cassin's Auklet (From Udvardy 1963)

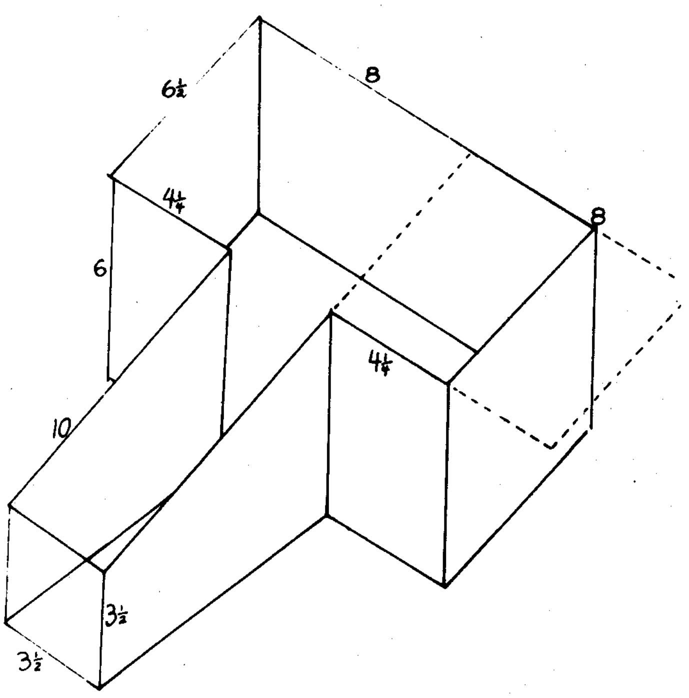


Figure 4. Diagram of wood nest box for Cassin's Auklets. Dimensions are given in inches. The floor is drained by drilled holes. The entrance tunnel and left part of the box are covered with a nailed-down cover. The right side has a removable cover. In use, most of the box is below ground level.

V. Sources, methods and rationale of data collection

<u>Auklet field study</u>. In January and early February 1977, 300 Cassin's Auklet burrows were selected and altered to allow human access. An additional 80 control burrows, studied since 1972 and in which birds were not given oil or capsules, were used to compare the effects of force feeding. Beginning in mid-March, all burrows were checked every other day until the first egg was found. On the night of 31 March we began our program of dosing at least 30 female auklets per night.

Each study burrow was checked until a pair of birds was found. We sexed the pair by measuring the bills with calipers. This method was proved reliable by analysis of specimens in museums. If the bill lengths were not distinctly different (an uncommon event), the bill depth was also measured. The bird with the smaller bill of each pair was assumed to be the female. She was force fed one of three possible experimental doses - empty capsules or capsules containing a total of 300 or 600 mg of bunker C. After banding, both members of the pair were returned to their burrow, (females were banded on the left leg, males on the right). The type of dose was alternated in sequence (600 mg, 300 mg, empty capsule) so that equal numbers of each treatment were administered each night. Dosing was completed on 7 April after eight successive nights of work. Due to limited time only about 30 pairs of auklets were banded during 1977.

All experimental burrows were checked daily for eggs through 14 April, after which they were checked every four days. The control burrows were checked every other day throughout the study. When an egg was found, the burrow was not checked again for 38 days (to determine incubation period and/or hatching weight) or 42 days (to determine hatching success). Hatching weight was measured to the nearest 0.5 gram with a Pesola spring scale which was checked daily for accuracy with an electronic balance. After hatching, at least 10 chicks from each group were weighed daily (when alone) until fledging, others were weighed beginning shortly before fledging and others were checked only to determine fledging success. In all comparisons of times, weights, and success, only the first egg laid is considered and only if it was laid on at least the second day <u>after</u> a selected experimental dose was administered.

Procedures in 1978 were similar with the following exceptions (detailed below):

(1) nest boxes were used in addition to natural burrows,
(2) Prudhoe Bay crude oil was used in addition to bunker C oil, and
(3) higher doses of oil were administered, along with euphausiids (their natural food) in an attempt to slow down the passage of oil in the gut.

During the late summer and fall of 1977, 270 wood nest boxes were constructed and put in place in Southeast Farallon Island. These box components were cut from exterior-grade 3/8" plywood, painted with dull grey paint, and assembled on the island, according to the plan shown in Figure 4. The boxes were well accepted by auklets, as we knew they would be based on our previous experience with them. At the same time, 35 identical boxes were installed for use by the control group of auklets; and 8 boxes installed the previous year were inspected for habitability. In January 1978, 130 natural burrows in the same areas where boxes for experimental birds had previously been installed, were also selected and altered to allow human access. Likewise, 41 burrows monitored in previous years were checked and included in the control group. This gave us a potential 400 pairs of experimental birds and 84 controls. In March, birds were sexed and banded with stainless steel leg bands. Of the possible 400 pairs, 330 pairs were successfully sexed and banded. It was felt that having birds sexed and identified before the onset of breeding would greatly facilitate oil dosing once egg laying commenced.

Beginning on 10 March 1978, a sample of the nest sites was checked every day for eggs until the first eggs were found, on 13 April. That night we began our program of force-feeding female Cassin's Auklets with oil in gelatin capsules. Each one fed oil was also fed whole fresh-frozen euphausiids (thawed before use) to simulate conditions of being exposed to oil while feeding at sea. From the data we collected in 1977, we felt that the auklets were coming ashore with empty stomachs at this stage of the breeding season, and that such a condition could have caused more rapid elimination of the petroleum oil than would be the case with birds feeding at sea, where exposure to oil would most likely occur.

Each experimental nest site was checked until the banded female or pair of birds was found. Each banded female was dosed with euphausiids and either 1000 mg of PBCO or BC and then returned to her nest site. When pairs of unbanded birds were found, they were sexed by bill measurement and the male was immediately returned to his nest site. The female was fed, dosed, and then returned. Doses of PBCO and BC were alternated. In this manner, 107 females were dosed with PBCO and 112 were dosed with BC before they laid eggs.

All experimental nest sites were checked daily for eggs after the first eggs were found, while control burrows were checked every other day. In those experimental nests where the female laid an egg before she was dosed with oil, the egg was removed and the female was dosed a few days before we expected her to lay her second egg. Females in this group were either fed 1000 mg of BC and euphausiids (36 females) in a manner identical to that already described, or else were smeared with 100 mg of BC on the left brood patch (21 females). No euphausiids were fed to females that were smeared with oil. Females in these groups were expected to lay second eggs. When possible, the females were redosed if they did not lay the second eggs within one week. The only difference with redosing was that females having oil smeared on them were smeared the second time on the right brood patch. Oil smearing was done as another attempt to closely approximate exposure to oil at sea. It was felt that birds exposed to non-lethal amounts of oil at sea would likely ingest some oil while cleaning themselves through preening, or as in quail they would absorb petroleum compounds through their skin (Grau unpublished).

When an egg was found in an experimental or control nest site, it was not checked again until we expected the egg to hatch. For the control nests, we checked for hatching at 38 days in order to determine incubation period. However, for all experimental nests we did not check for hatching until day 42, since we felt that in 1977, through repeated checks for hatching, we might have caused some experimental birds to abandon eggs which could have otherwise hatched. In 1977, we found no difference in incubation period or hatching weight among the various groups, and so this year we hoped to keep disturbance to a minimum and focus our attention on hatching and fledging success. After hatching, at least 10 chicks (if possible) from each group were weighed daily (when alone) until fledging, while other chicks were checked only to determine fledging success.

The following definitions apply to this study:

Incubation period is the time between the day the egg is found and the day before the chick is found free of its egg shell;

Nestling period is the time between the day the chick is found and the day the chick is fledged;

Hatching weight is the weight of a chick on the first day it is found (within 24 hours of hatching);

Fledging weight is the weight of a chick on the last day it is in its burrow before fledging;

Maximum number of eggs possible equals the number of females dosed minus the number of burrows that collapsed before an egg was laid; and

Maximum number of eggs possible to hatch equals the number of eggs laid minus the number of eggs collected and the number of burrows collapsed, filled in, or where checking was discontinued.

Gull field study. The field observations on the effects of the oil on gulls were based on the 1976 results. Dosing was the principal problem. In 1977, capsules containing oil were coated with hydrogenated vegetable oil to lengthen time of capsule solution, and the capsules were sewn inside small squid. The squid was then hidden under a board to which a long line was attached, thus permitting the researcher to reveal the squid to the particular gull for which the dose was prepared.

A few gulls were snared and smeared with oil or were injected intraperitoneally with oil. In some nests, the first egg laid was covered with bunker C oil, and after the female incubated it overnight, thus coating the brood patch with oil, the egg was removed. Eggs laid subsequently were collected for chemical analysis and observation of yolk structure.

Oil ingestion and elimination study. To determine the time required for elimination of oil from the guts of auklets, birds were captured at random at night and placed in cardboard boxes covered with netting. The auklets were fed 600 mg of bunker C oil and observed until the oil was passed in their feces. Adult Japanese Quail reared in cages and adult pen-reared Mallards deprived of food for 16 hours (overnight) were compared in their responses to oil with fed birds. Black-footed Albatross and Common Murres that were being cared for in preparation for release were also dosed.

Structural and chemical examination of yolks. Auklet eggs collected 2 to 7 days after dosing with bunker C oil were frozen, fixed in formalin, and examined for structural changes such as those observed in eggs laid by quail after being dosed with bunker C (Grau et al., 1977). Eggs of quail and chickens that had been given single doses of bunker C oil were treated and extracted, and various techniques were used to detect compounds that might be unique to petroleum-fed birds. The richness of egg yolk in triglycerides, phospholipids, sterols, and pigments complicates the extraction and treatment processes, and makes difficult the detection of hydrocarbons and their metabolites in extracts prepared from yolks. Frozen, thawed egg yolks were denatured and extracted with acetone. Phospholipid distribution was studied by thin-layer chromatography or by ultraviolet absorption of extracts containing primarily triglycerides or phospholipids.

We attempted to follow the lead of other laboratories (Ehrhardt 1972; Neff and Anderson 1975; Warner 1976) by saponifying and cleaning with florosil extracts of egg yolk, and then subjecting the extract to ultraviolet absorption and gas chromatographic analysis. We have also used thin-layer chromatography to separate natural yolk components from those that might have oil contributions.

Several methods of treatment were used for the physical partitioning of yolk extracts. For one method, a 500 mg sample of frozen yolk was dried in a vacuum oven at 60° for 8 hours, or alternatively, a sample of yolk that has been fixed in 4% formalin after freezing (Grau 1976) was used without drying. The sample was extracted by agitation and a beaker with 15 ml of petroleum ether, then with 15, 10, and 10 ml portions, and the extract was filtered into a flask. A mixture of 750 mg aluminum oxide G (E. Merck) and 750 mg silica gel (Absorbosil-3) both washed twice with petroleum ether, were evaporated, and transferred with isopentane to one spot on an activated silica gel plate scored with vertical grooves to prevent cross contamination. The plate was developed with isopentane: isopropanol: chloroform (100: 1: 0.2) and observed in ultraviolet light (254 nm).

A recent modification was found to be useful for detecting eggs from oil-fed ducks (available through the courtesy of W.N. Holmes, University of California, Santa Barbara). The duck eggs were frozen and formalin-fixed as above. The slices of yolk (3 mm thick) were dried in a vacuum at 60^{o} for one hour, extracted with 25 ml petroleum ether, broken up with a glass rod, and extracted twice with 25 ml petroleum ether. The combined extracts were filtered through Whatman No. 1 paper and the solvent evaporated at room temperature. Silica-gel, thin-layer plates predeveloped with chloroform and dried, were spotted with 5 µl of the solvent-free extract. The plates were developed with isopentane: isopropanol: chloroform (100: 0.05: 0.1) and observed in ultraviolet light (254 nm).

Chickens were dosed with 1 g bunker C and quail with 200 mg bunker C, and yolks of eggs collected 3 to 4 days later were frozen, fixed, sliced, and extracted with petroleum ether. Extracts and elutions from preparative thin-layer chromatographic plates were analyzed by gas-liquid chromatography, ultraviolet absorption, and spectrophotofluorometry. Some extracts were treated as were the ducks, above. Others were treated with activated florosil, and some of these were saponified with 5% potassium hydroxide in 95% extract at 80^{o} for one hour, and reextracted with petroleum ether.

Gas-liquid chromatography was carried out with a Hewlett-Packard model 1157A and Packard model 427 gas-liquid chromatographs equipped with flame ionization detectors. The columns were glass capillaries, 5 or 10 meters long, coated with SP2100 as the liquid phase. Programmed setting which started at 100^{o} were increased 2^{o} per minute to 250^{o} or 290^{o} and then held for 30 minutes. The injector and detector ports were kept at 290^{o} or 300^{o}. The carrier and makeup gases were nitrogen. A flow rate of 10m/sec with a 10 to 1 split ratio was used. Samples were dissolved in dichloromethane for injection. All GC work was done in the laboratory of Dr. W.G. Jennings, Department of Food Science and Technology.

Ultraviolet absorption studies were performed with a Beckman Acta III Spectrophotometer, scanned from 205 to 327 nm, at 2nm/sec. Samples were dissolved in spectral quality solvents.

Spectrophotofluorometry used an Amino-Bowman instrument capable of scanning emission or excitation. For most work, excitation was set at 290 or 300 nm, and emission was scanned. Samples were dissolved in spectral-grade hexane or isopentane, or in reagent-grade petroleum ether in 2 ml quartz cuvettes, and compared with suitable solvent controls.

VI. Results

<u>Auklet study</u>. Breeding history data are summarized in Tables 1 and 2. One basic point shown by these is that if our experimental procedures affected reproduction, then they did so equally for all groups. In fact, we found no differences between experimental controls (empty capsules), and disturbance controls (received a bare minimum of our attention) in such comparisons as incubation period, hatching weight, fledging success, and other comparisons.

There was little difference statistically between treatment groups, although lower values for various measurements in Table 1 for higher dosage groups suggested an effect. When presented graphically, these data show that ingestion of oil

Table 1. A summary of nesting success for various groups of auklets in 1977 and 1978.

			Dosage Group[1]				
	CONT.	CONT.	Bunker C Fuel Oil				Prudhoe Bay Crude
	1977	1978	0mg	300mg	600mg	1000mg	1000mg
# Dosed	79	84	74	64	71	105	106
# Laid	75	77	72	62	70	87	82
# Hatched	62	66	52	51	48	60	65
# Fledged	55	53	48	49	47	53	55
% Laid	94.9	91.7	97.3	96.9	98.6	82.9	77.4*
% Hatched	82.7	85.7	72.2	82.3	68.6	69.0*	79.3
% Fledged[2]	73.3	68.8	66.7	79.0	67.1	60.9	67.1
% Fledged[3]	69.6	63.1	64.9	76.6	66.2	50.5	51.9

1 1000mg dosages administered in 1978, others in 1977.
2 Based on eggs laid.
3 Based on nests occupied during nesting season.
* Significant difference, P<0.01 (test for difference between two percentages, Sokal and Rohlf 1969: 608), between this group and control.

Table 2. A summary of growth and development measurements for auklet chicks in 1977 and 1978.[1]

	CONT. 1977	CONT. 1978	Bunker C Fuel Oil 0mg	300mg	600mg	1000mg	Prudhoe Bay Crude 100mg
Incubation Period, d.	38 ± 1 55	-	39 ± 2 10	38 ± 1 16	39 ± 1 12	-	-
Hatching Weight, g.	-	-	18 ± 1 9	20 ± 2 14	18 ± 2 10	-	-
Fledging Period, d.	41 ± 3 48	43 ± 5 49	43 ± 4 9	42 ± 2 11	44 ± 2 11	42 ± 3 10	40 ± 1 10
Fledging Weight, g.	152 ±14 48	145 ±16 49	153 ±10 9	149 ±12 12	150 ±13 11	151 ±11 10	151 ±11 10

1 1000 mg dosages were administered in 1978, the others in 1977.

Figure 5

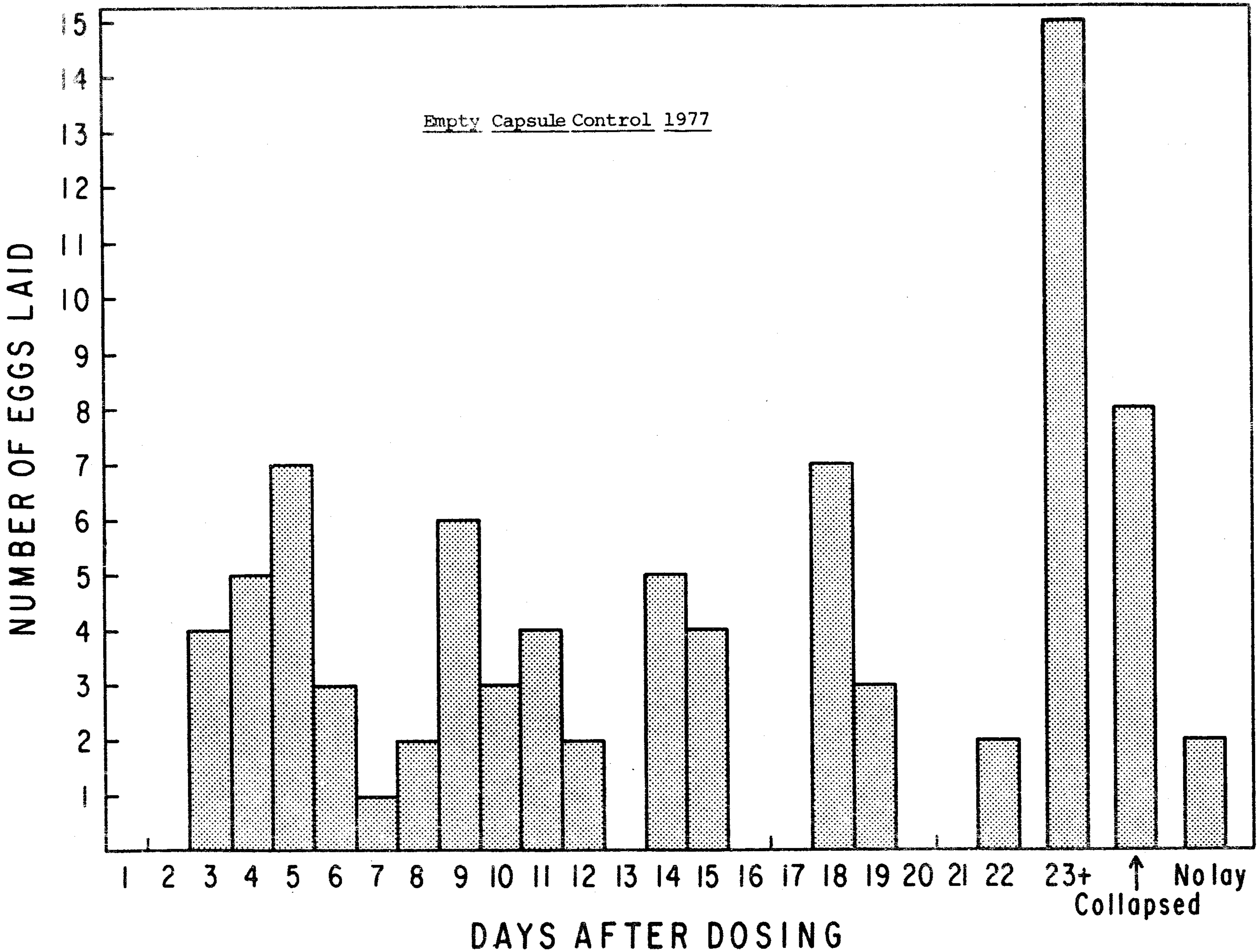
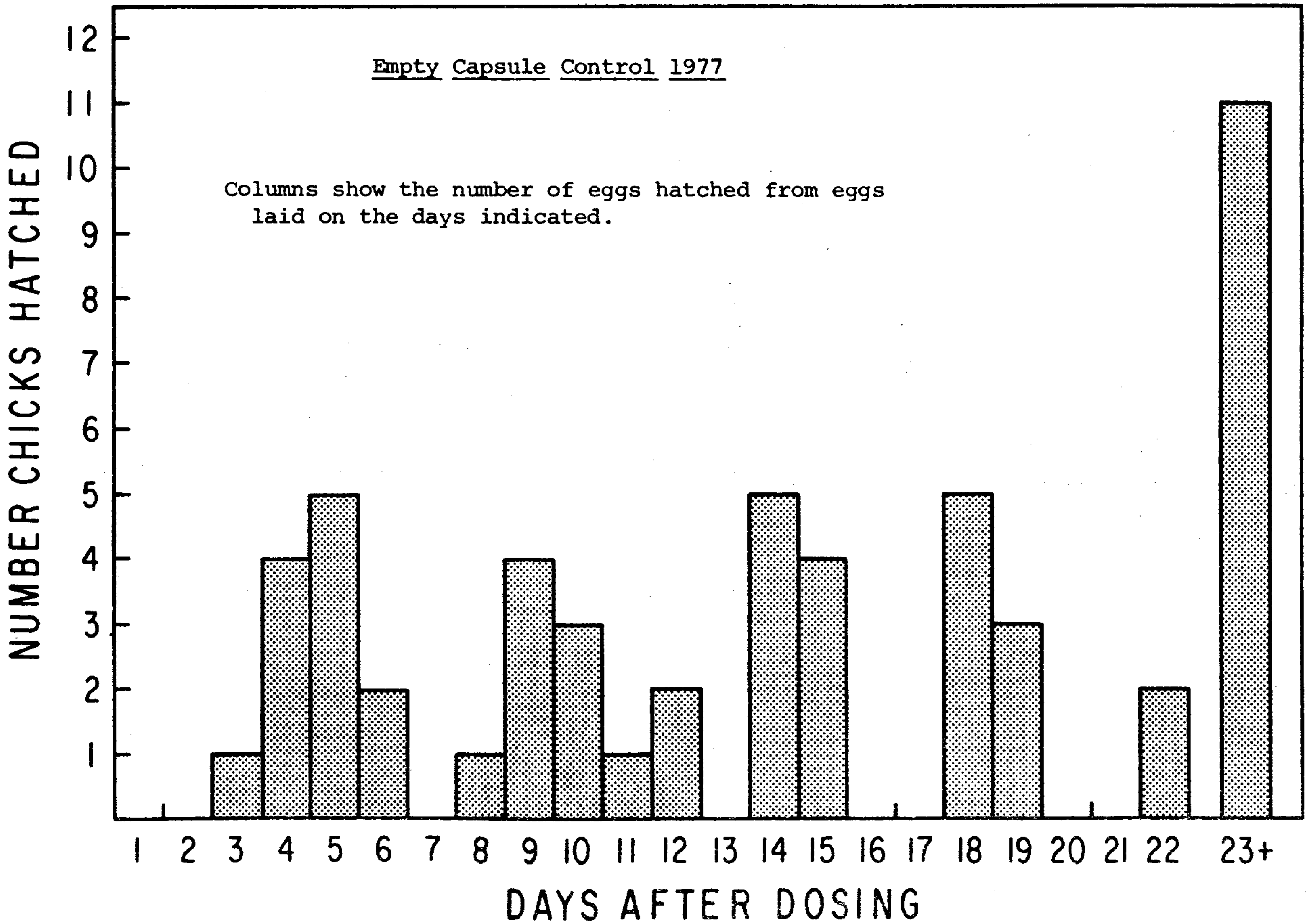

Empty Capsule Control 1977
NUMBER OF EGGS LAID
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23+
Collapsed
No lay
DAYS AFTER DOSING

Figure 6



Empty Capsule Control 1977
Columns show the number of eggs hatched from eggs laid on the days indicated.
NUMBER CHICKS HATCHED
1
2
3
4
5
6
7
8
9
10
11
12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23+
DAYS AFTER DOSING

Figure 7

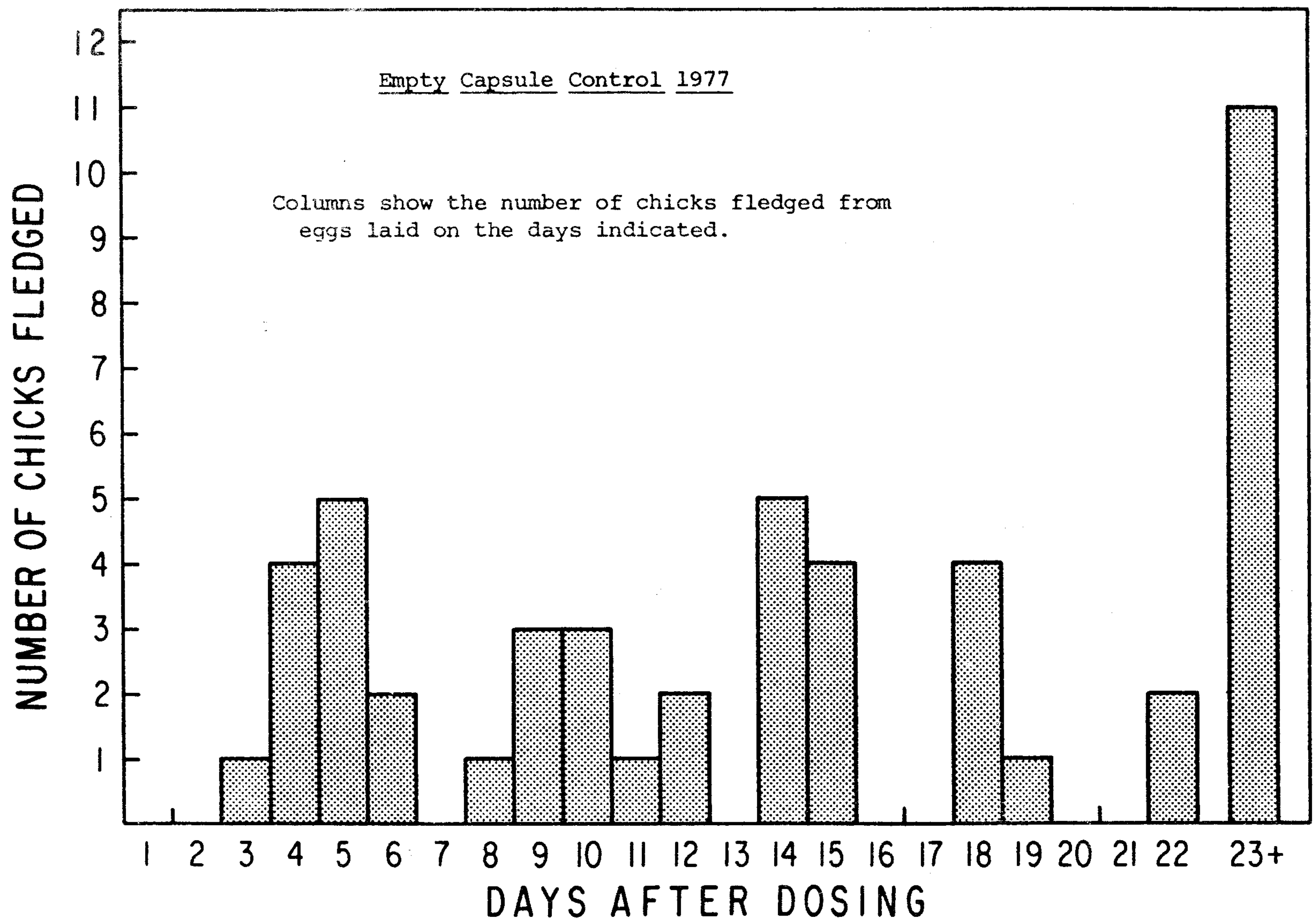

Empty Capsule Control 1977
Columns show the number of chicks fledged from eggs laid on the days indicated.
NUMBER OF CHICKS FLEDGED
12
11
10
9
8
7
6
5
4
3
2
1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23+
DAYS AFTER DOSING

Figure 8

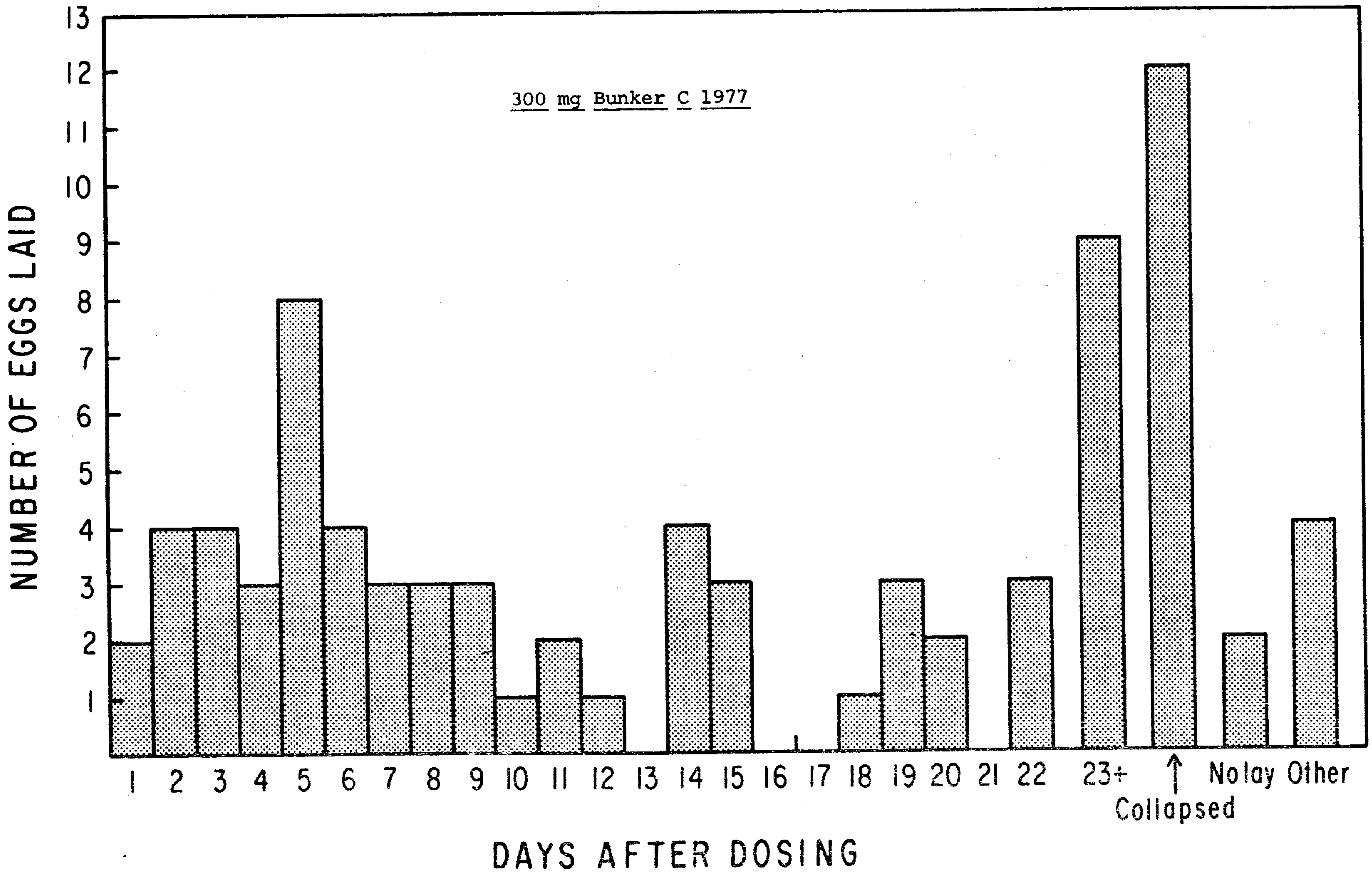
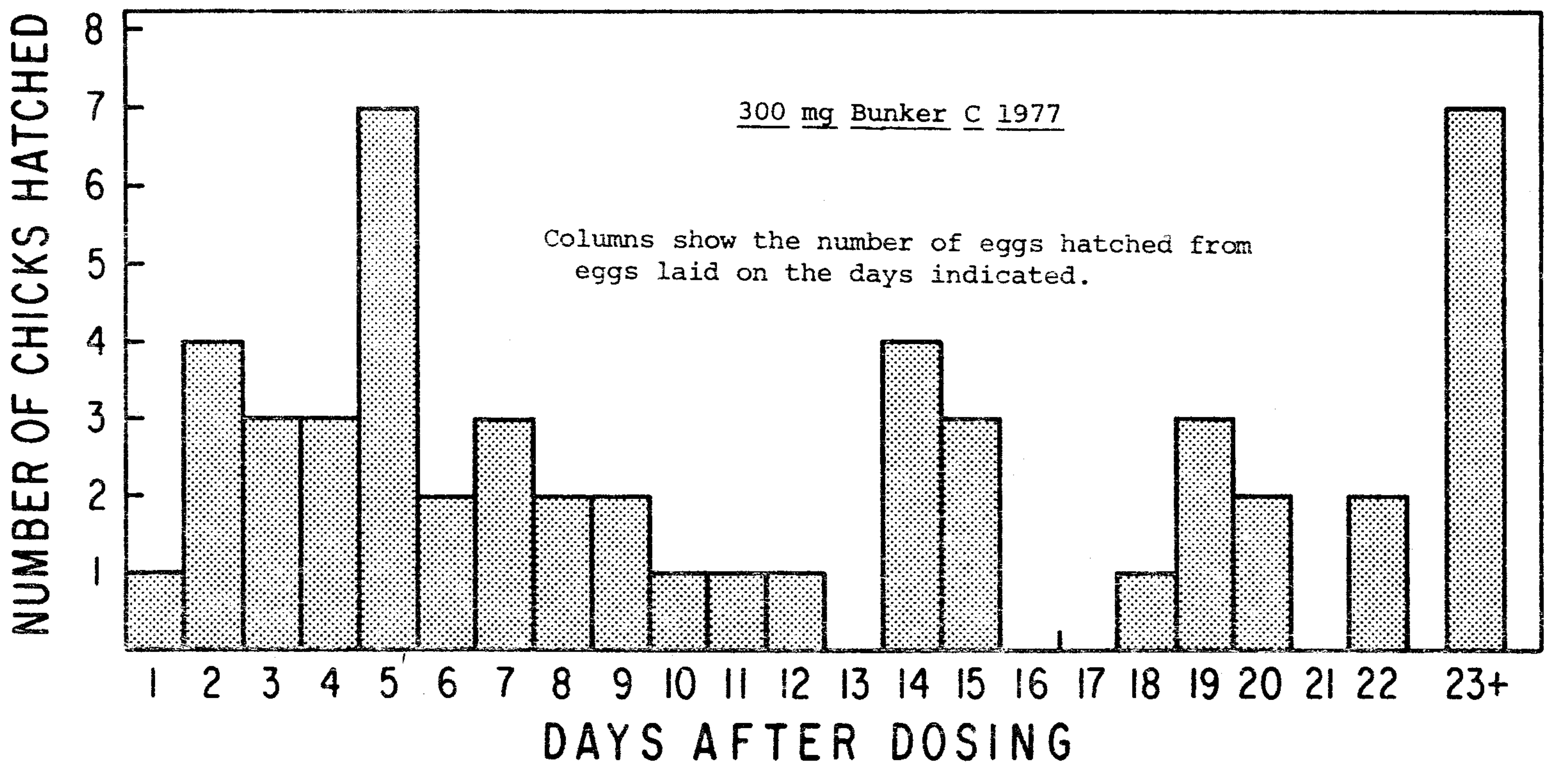

300 mg Bunker C 1977
NUMBER OF EGGS LAID
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23+
Collapsed
No lay
Other
DAYS AFTER DOSING

Figure 9



300 mg Bunker C 1977
Columns show the number of eggs hatched from eggs laid on the days indicated.
NUMBER OF CHICKS HATCHED
1
2
3
4
5
6
7
8
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23+
DAYS AFTER DOSING

Figure 10

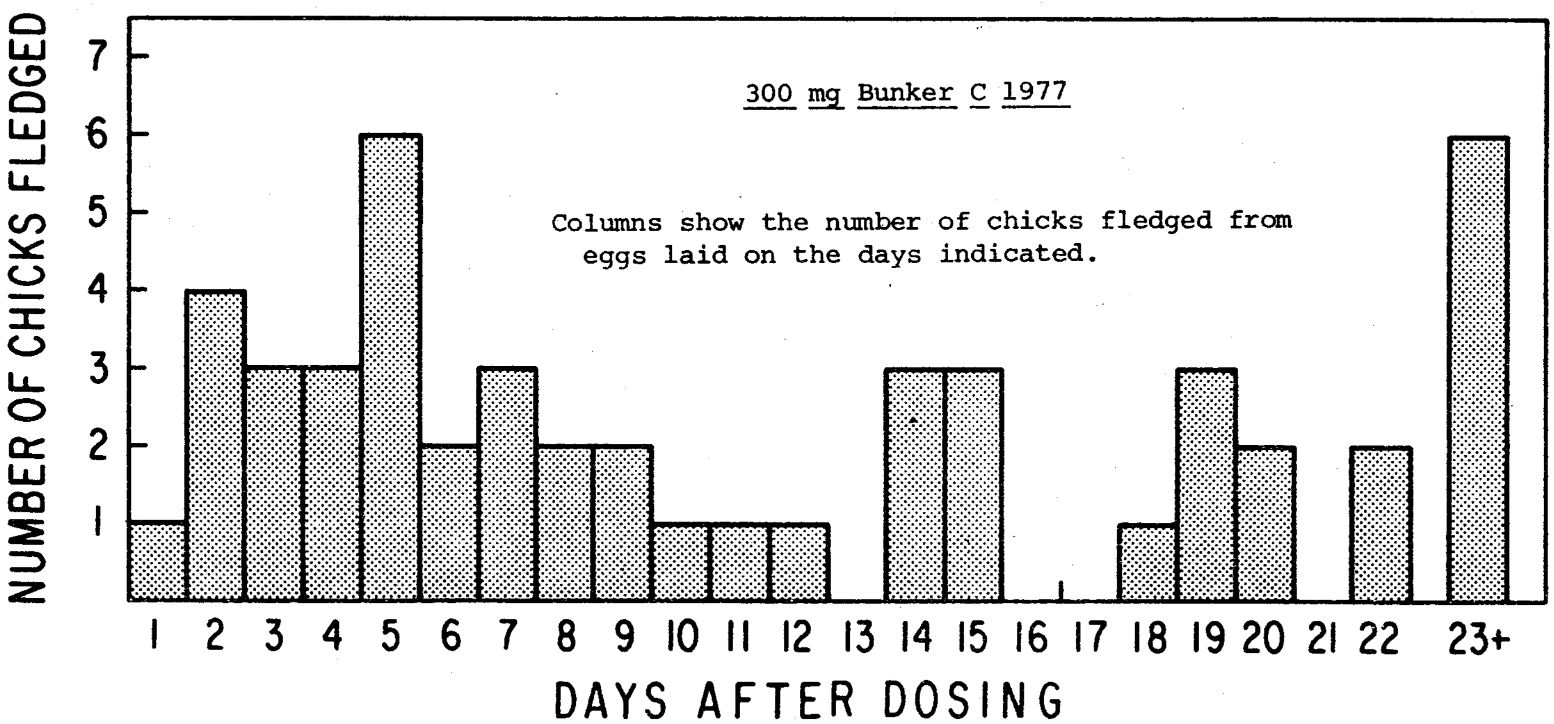

300 mg Bunker C 1977
Columns show the number of chicks fledged from eggs laid on the days indicated.
NUMBER OF CHICKS FLEDGED
1
2
3
4
5
6
7
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23+
DAYS AFTER DOSING

Figure 11

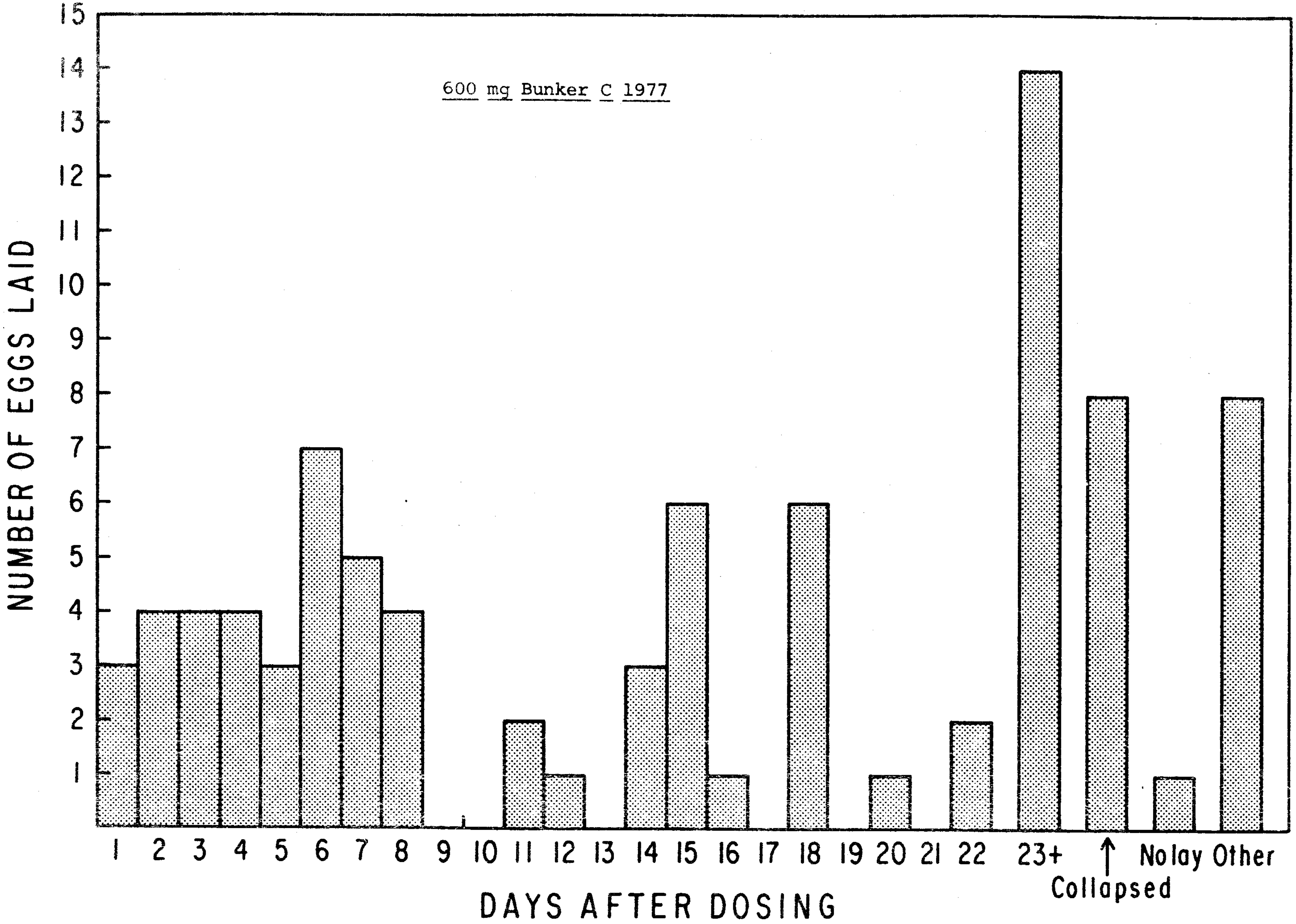

600 mg Bunker C 1977
NUMBER OF EGGS LAID
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23+
Collapsed
No lay
Other
DAYS AFTER DOSING

Figure 12

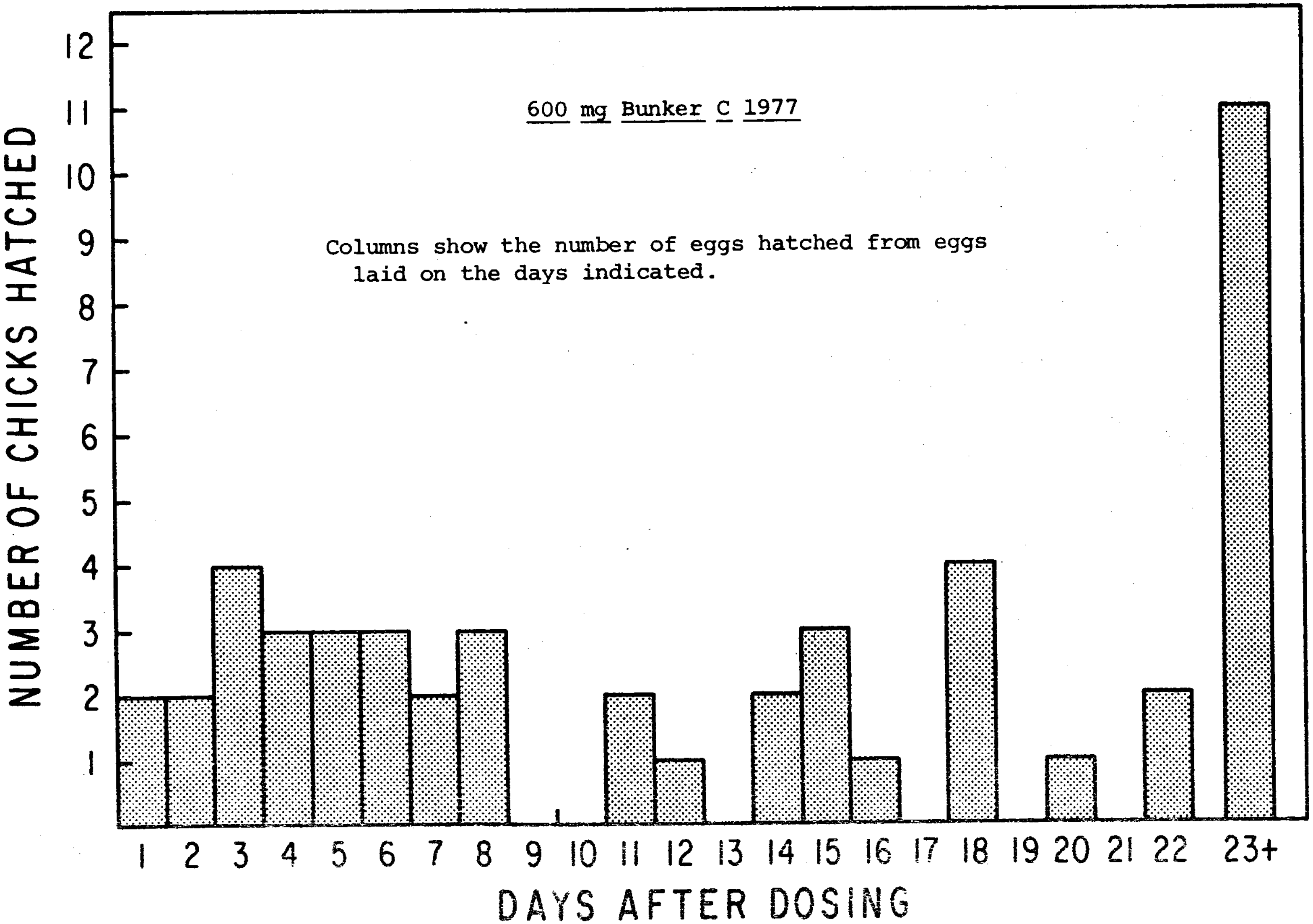
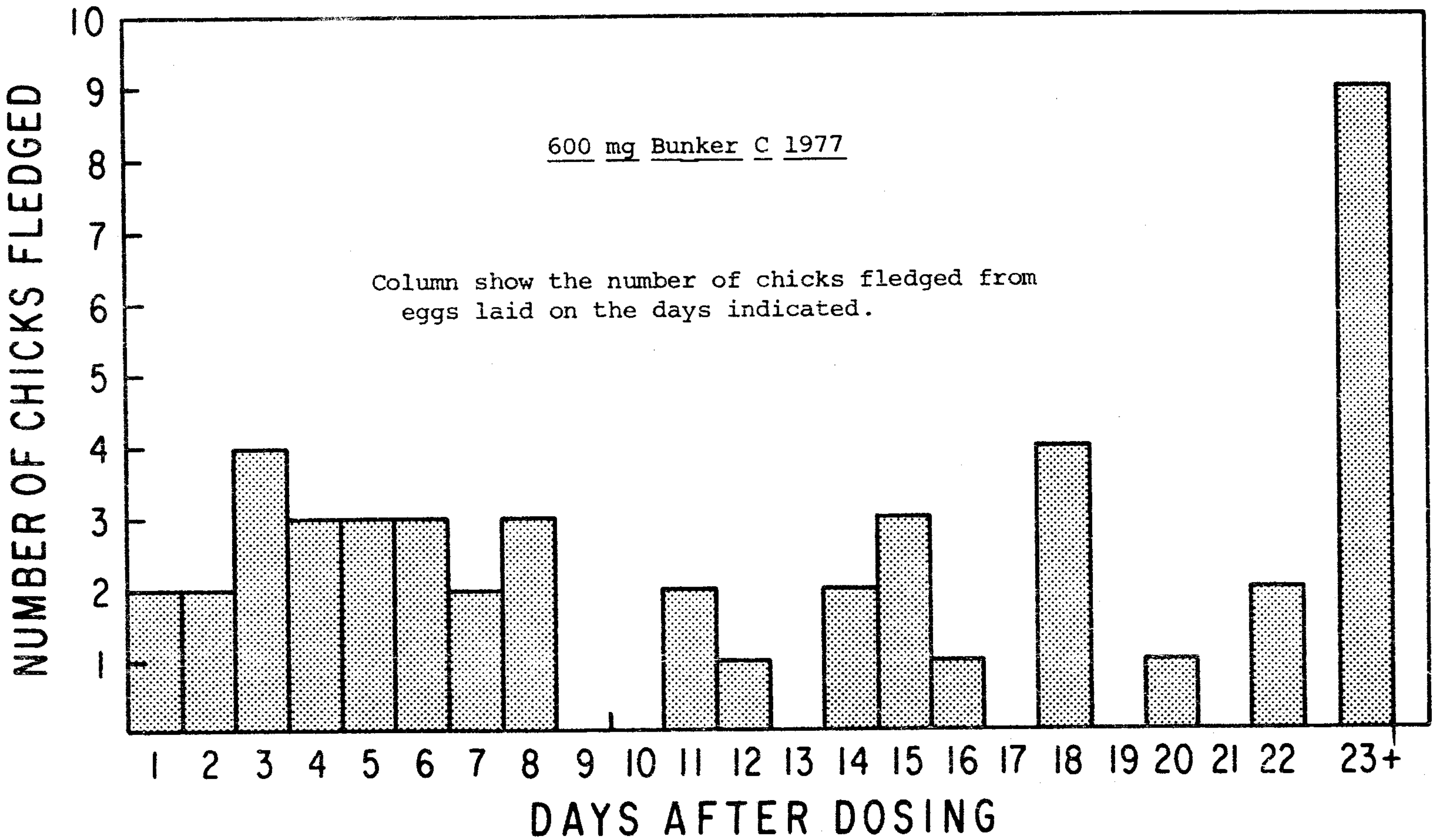
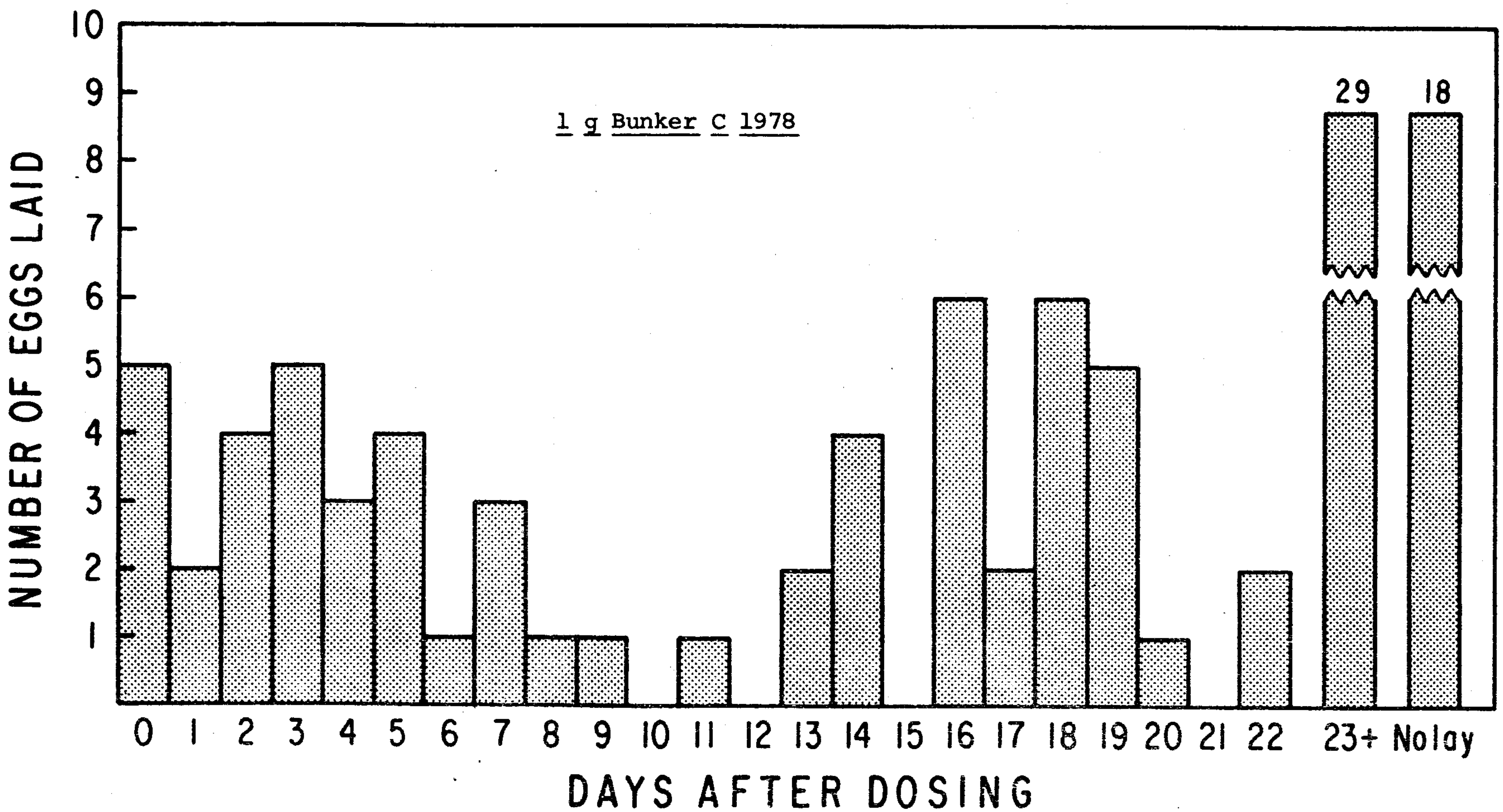

600 mg Bunker C 1977
Columns show the number of eggs hatched from eggs laid on the days indicated.
NUMBER OF CHICKS HATCHED
1
2
3
4
5
6
7
8
9
10
11
12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23+
DAYS AFTER DOSING

Figure 13



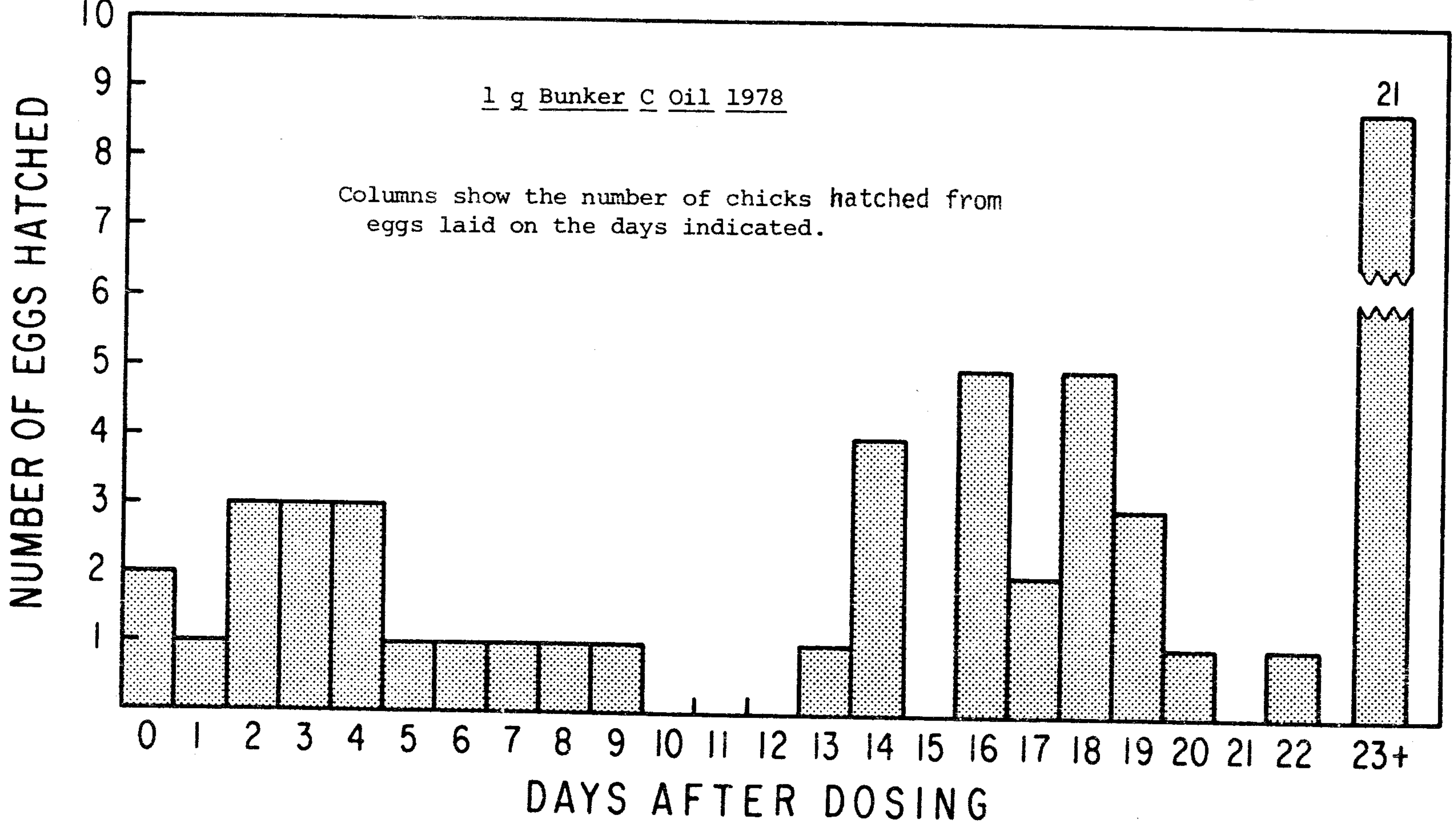
336

Figure 14



1 g Bunker C 1978
NUMBER OF EGGS LAID
0 1 2 3 4 5 6 7 8 9 10
DAYS AFTER DOSING
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23+ No lay
29
18

Figure 15



338

Figure 16

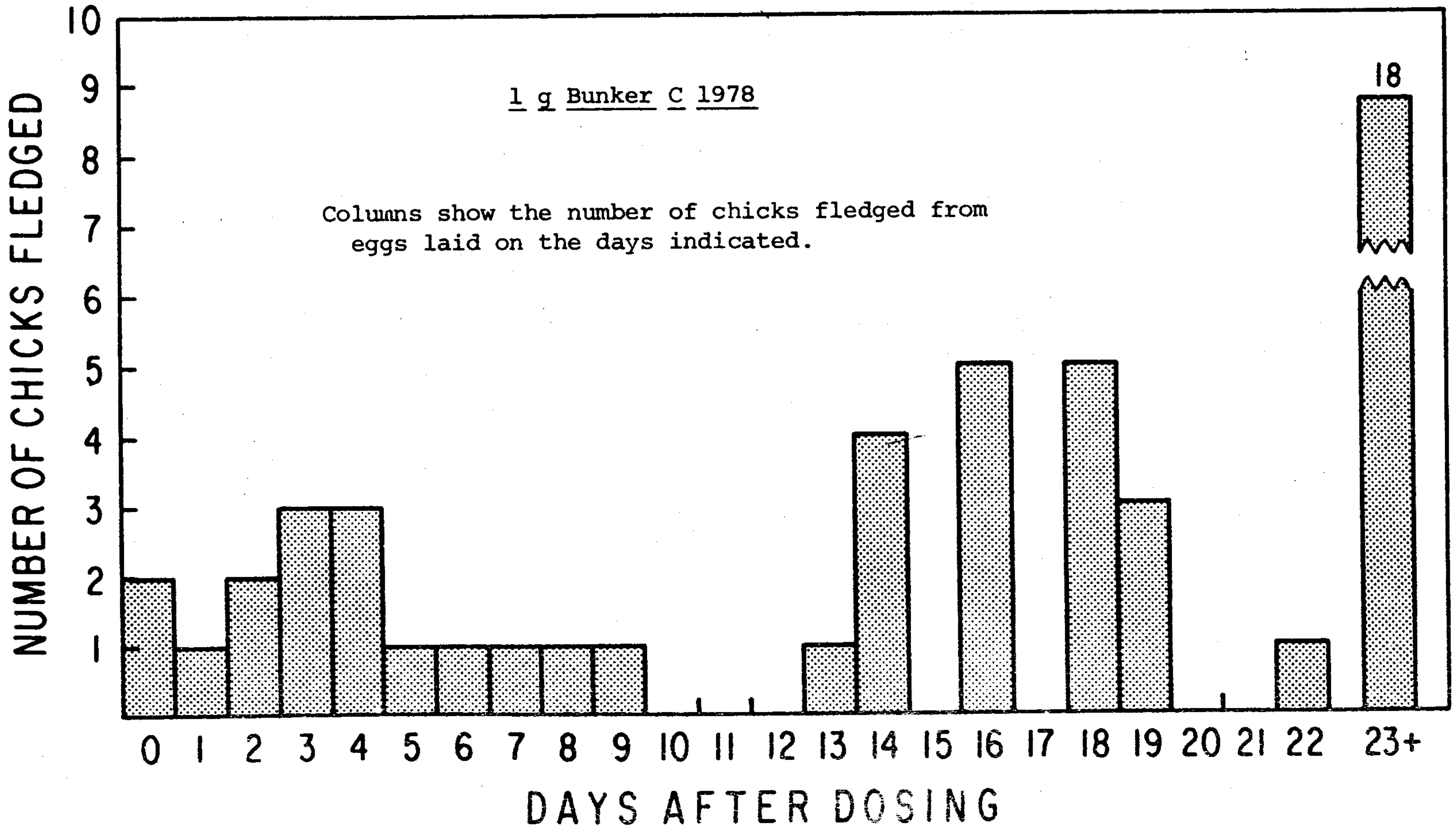
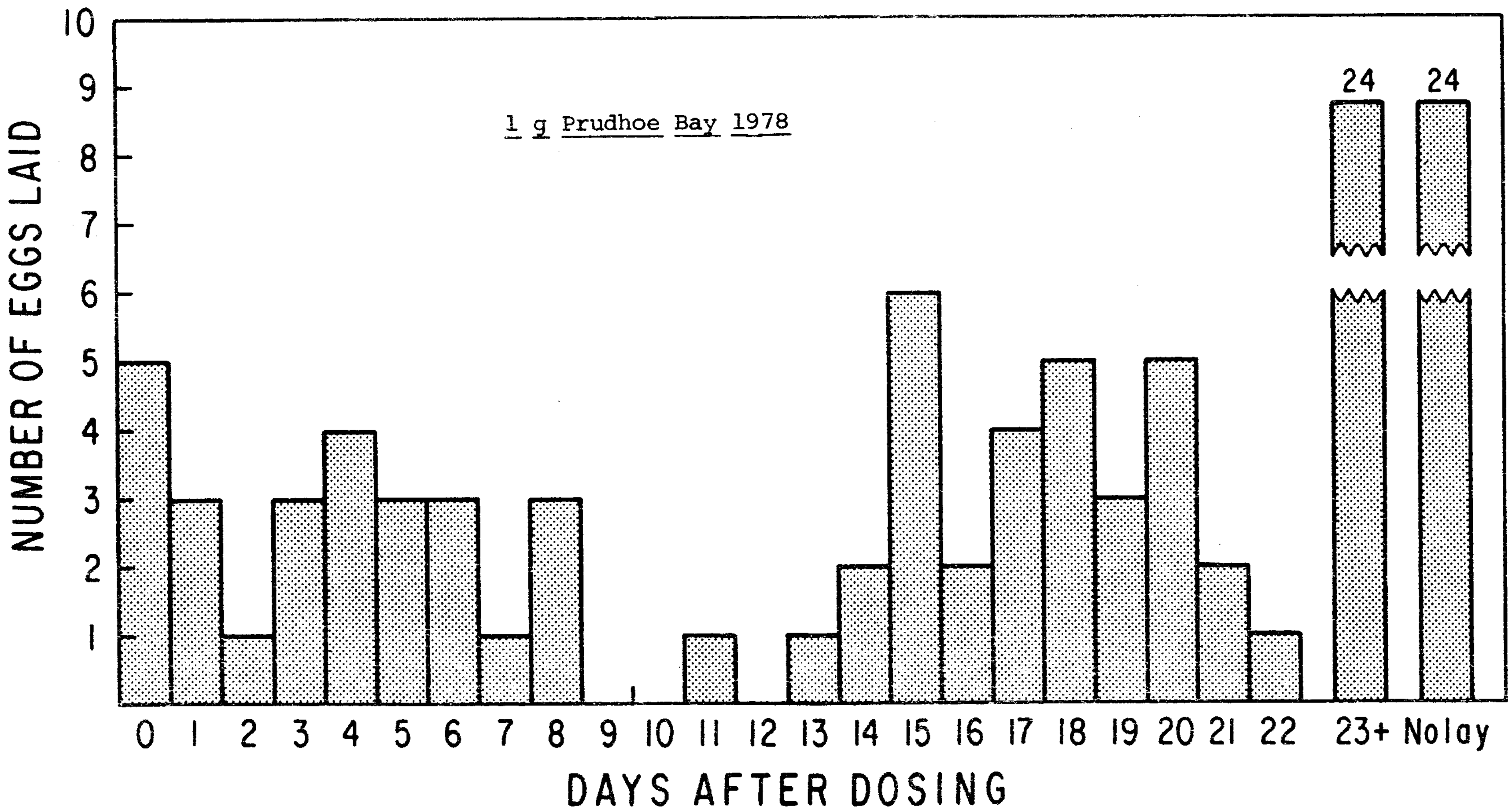

1 g Bunker C 1978
Columns show the number of chicks fledged from eggs laid on the days indicated.
NUMBER OF CHICKS FLEDGED
10
9
8
7
6
5
4
3
2
1
18
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23+
DAYS AFTER DOSING

Figure 17



1 g Prudhoe Bay 1978
NUMBER OF EGGS LAID
10
9
8
7
6
5
4
3
2
1
24
24
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23+ No lay
DAYS AFTER DOSING

Figure 18

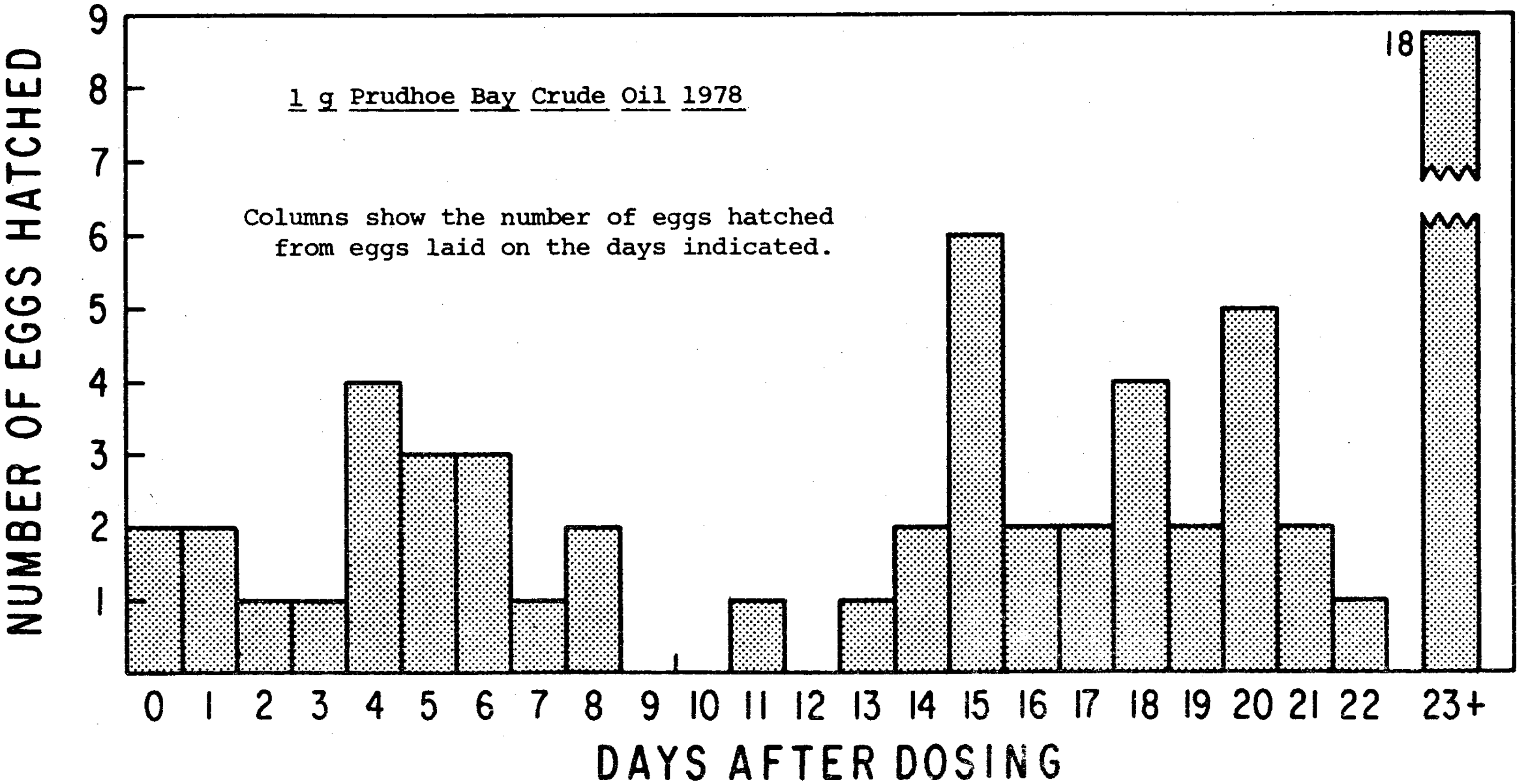

1 g Prudhoe Bay Crude Oil 1978
Columns show the number of eggs hatched from eggs laid on the days indicated.
NUMBER OF EGGS HATCHED
DAYS AFTER DOSING
1 2 3 4 5 6 7 8 9
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23+
18

Figure 19

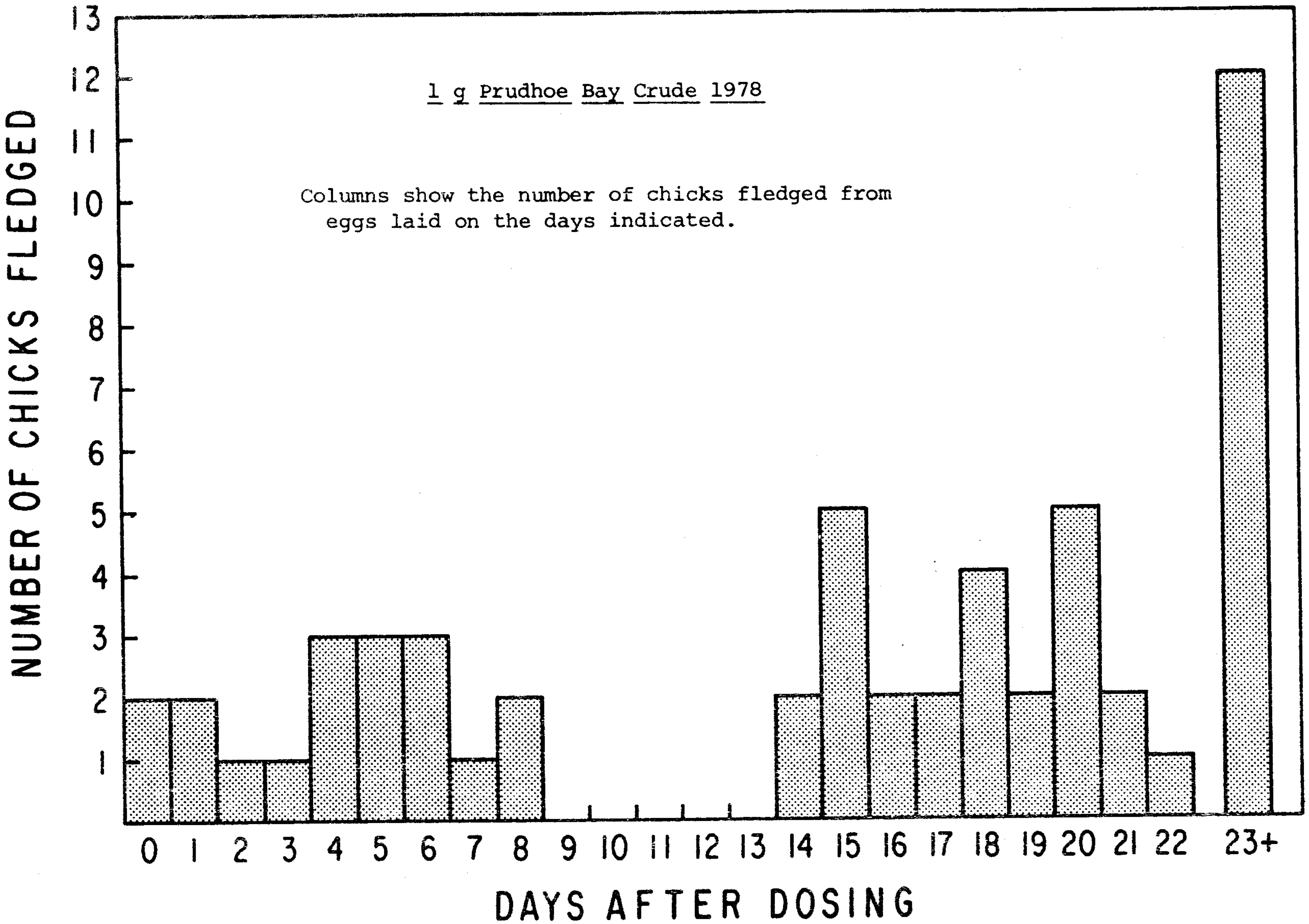

1 g Prudhoe Bay Crude 1978
Columns show the number of chicks fledged from eggs laid on the days indicated.
NUMBER OF CHICKS FLEDGED
1
2
3
4
5
6
7
8
9
10
11
12
13
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23+
DAYS AFTER DOSING

Figure 20

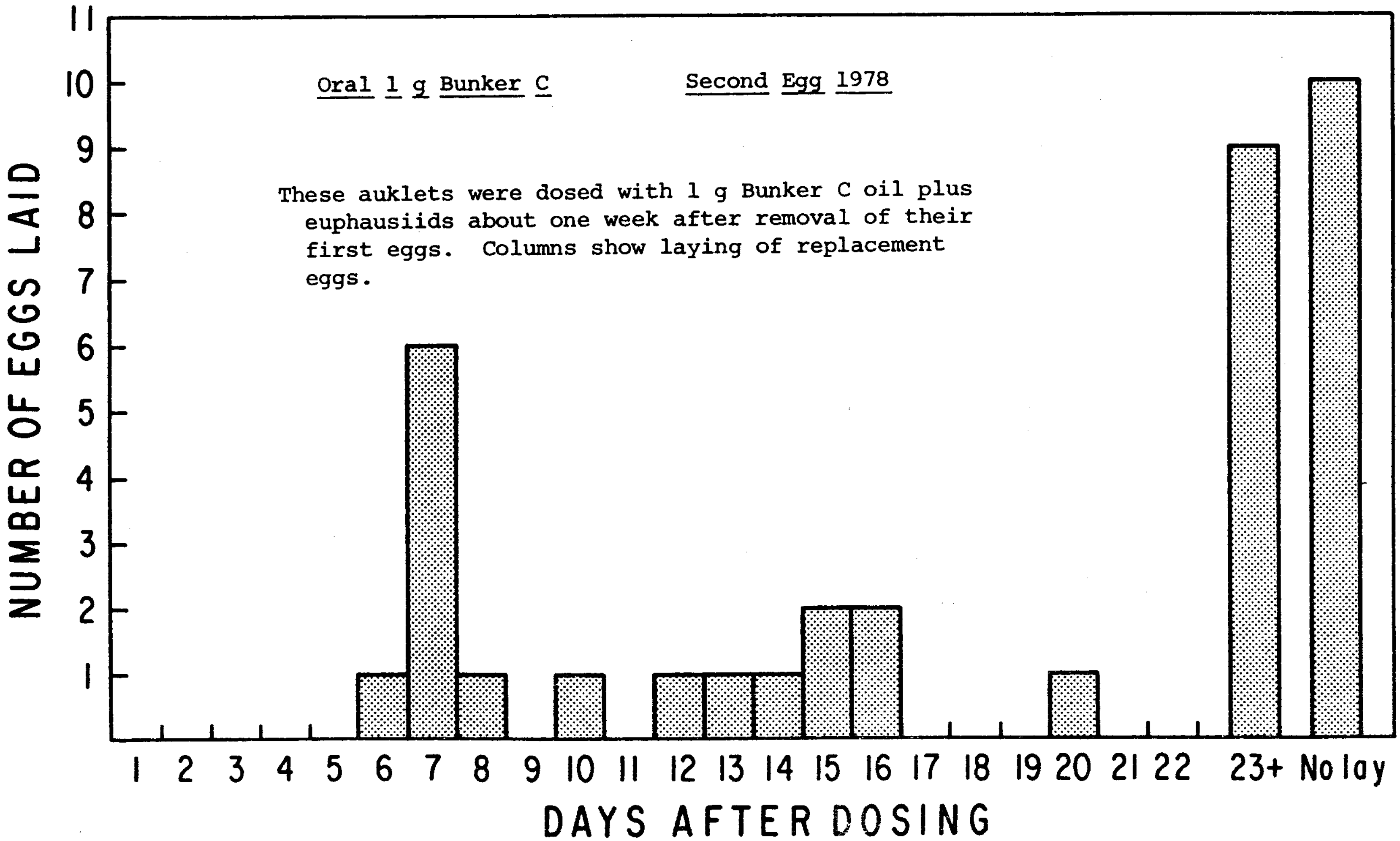

Oral 1 g Bunker C
Second Egg 1978
These auklets were dosed with 1 g Bunker C oil plus euphausiids about one week after removal of their first eggs. Columns show laying of replacement eggs.
NUMBER OF EGGS LAID
1
2
3
4
5
6
7
8
9
10
11
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23+ No lay
DAYS AFTER DOSING

Figure 21

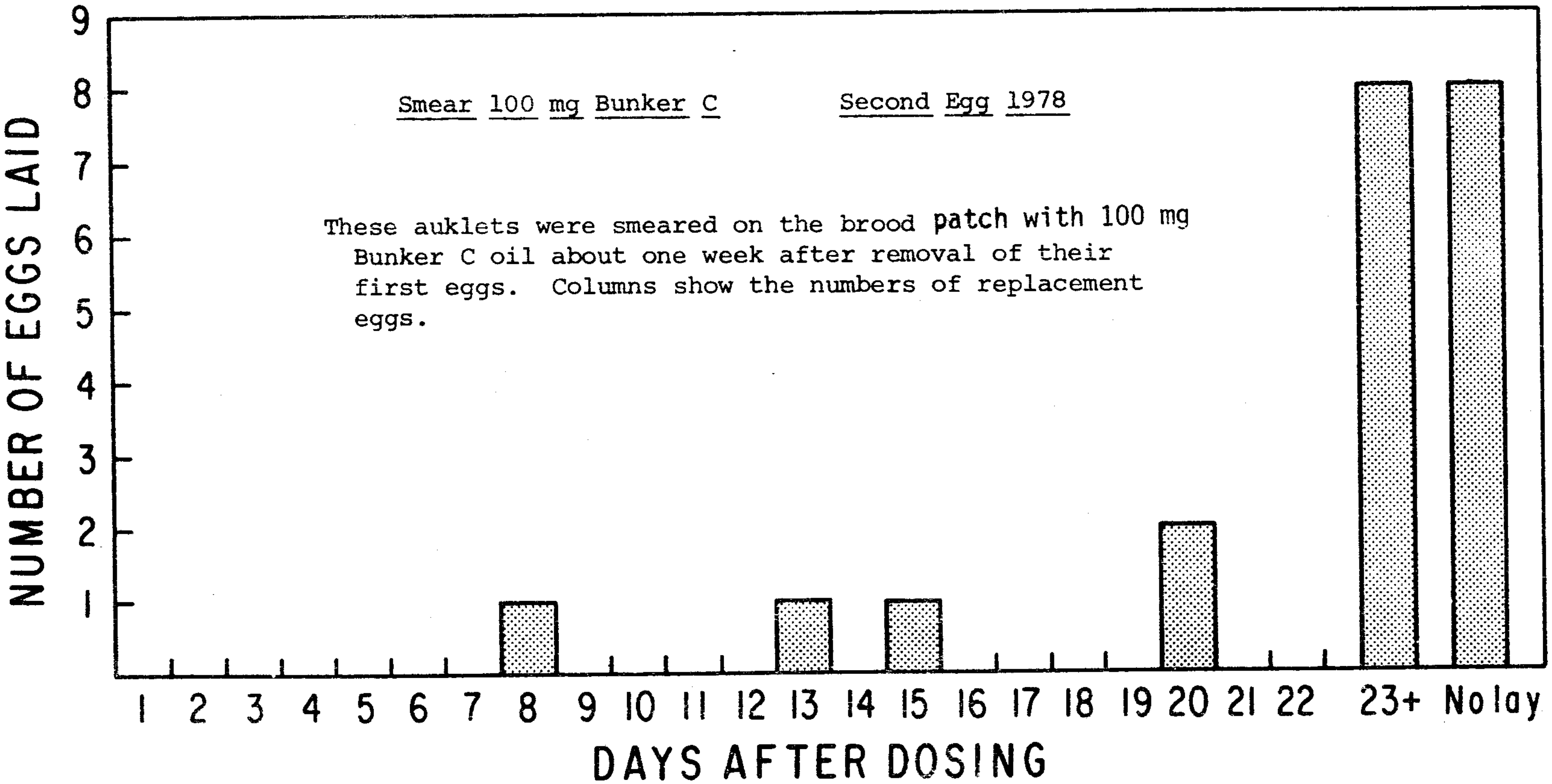
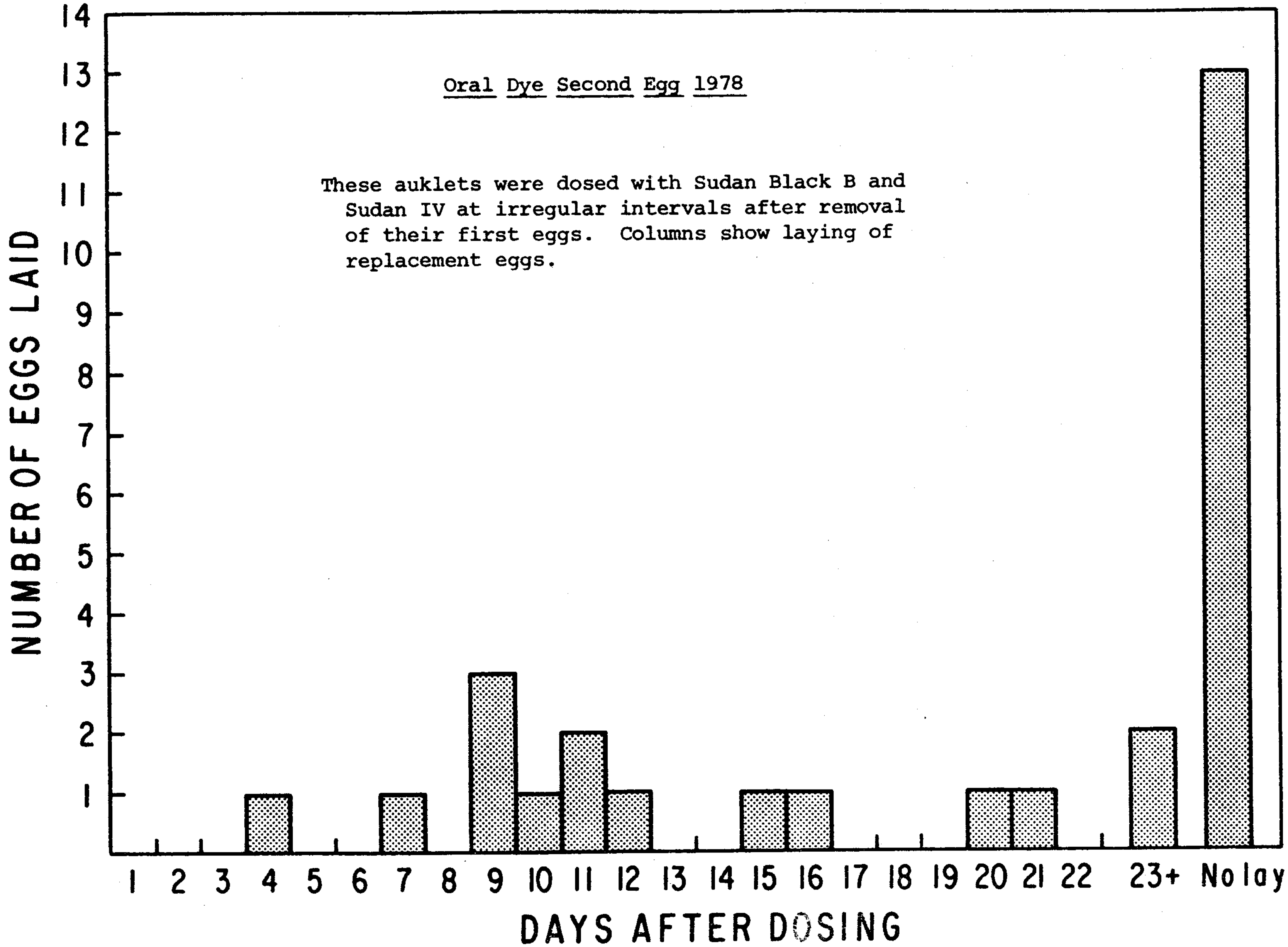

Smear 100 mg Bunker C
Second Egg 1978
These auklets were smeared on the brood patch with 100 mg Bunker C oil about one week after removal of their first eggs. Columns show the numbers of replacement eggs.
NUMBER OF EGGS LAID
9
8
7
6
5
4
3
2
1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23+ No lay
DAYS AFTER DOSING

Figure 22



345

definitely had an effect. The fate of birds in their reproductive efforts are shown as a function of days after dosing (Figures 5 to 13 for experiments in 1977, and Figures 14 to 19 for 1978). No discernible pattern is apparent in Figures 5 to 7 which show laying, hatching, and fledging histories for burrows in which the female received an empty gelatin capsule. The females which received 300 mg of bunker C oil (Figures 8 to 10) the pattern is not completely clear, but a decrease in production occurs at days 10 to 13 post-dosing. When the dose was increased to 600 mg, a decrease during days 9 to 13 occurred (Figures 11 to 13) and, in fact, there was an almost bimodal distribution with the low points centered among days 9 to 13. At a dosage of 1000 mg, the bimodal curve was even more apparent for bunker C oil (Figures 14 to 16), as well as for Prudhoe Bay crude oil doses (Figures 17 to 19). For birds dosed before they laid their second egg, given oil either orally (Figure 20) or as a smear on the skin (Figure 21), or for birds fed capsules containing dye (for other studies on egg formation), no patterns were discernible. These data together suggest the main effect to be on egg-laying, an effect which then carries on through hatching and fledging.

The graphs of smearing oil on the brood patches of auklets after removal of their first eggs and of giving oral doses of oil after removal of the first eggs do show one interesting difference, however. The delay of laying after dosing is much longer in auklets smeared with oil than in auklets dosed with oil orally, in spite of the smeared auklets being exposed to only 10% as much oil as the orally dosed auklets. This may be of significance if seabirds are exposed to chronic small oil spills from drilling platforms, oil pipelines, or tanker traffic.

When data compared in this way (relative to days post-dosing) are subjected to statistical testing, the differences are shown to be significant ($p<0.01$). We, however, could only compare days 1 to 12 since during this time period all laying dates were known to the nearest day. After that, nests were checked at 2 to 4 day intervals in 1977. Comparison of the number of eggs laid during days 1 to 8 and 9 to 12 in 1977 produces the following x^2 tables:

		dose			
		0	300	600	
time	1-8	22	31	30	83
	9-12	15	7	3	25
		37	38	33	108

which becomes,

	0	300	600
1-8	28.44	29.20	25.36
9-12	8.56	8.80	7.64

$$x^2 = 1.458 + .111 + .849 + 4.845 + .368 + .2818 = 10.449$$

$$0.01 < p < 0.005$$

Similar statistical results occurred with hatching and fledging in 1977, and when 1978 data was compared to 1977 controls. This follows naturally because egg production was depressed at about 9 to 13 days after dosing in 1978, as well as in 1977. In addition, the numbers of chicks hatched or fledged from eggs laid on specific days after dosing was largely a function of the number of eggs laid: hatching and fledging were both nearly 100% of the eggs laid. This means that graphs of laying, hatching, and fledging are approximately the same shape for a specific treatment.

No differences were apparent in timing of egg laying during 1977 following treatment for any of the three treatment groups (Table 3). However, when date of egg laying was considered (Table 4), there appeared to be a slight delay in onset of laying as the oil dosage was increased. This could not be considered significant. Egg laying in the group given empty capsules and in the control group were similar. The first egg for the control group was laid on 3 April, while the first eggs (after treatment) for the three groups dosed were -- empty capsule, 3 April ; 300 mg, 5 April; 600 mg, 2 April (second egg in this group laid 7 April). The discrepancy in onset of egg laying disappeared within the first two weeks.

Correlations between the phase of the moon and egg laying were examined graphically to detect possible responses of auklets to this variable. Since auklets were dosed only on moonless nights when they come ashore in large numbers such a correlation might bias our data. However, no correlation was found.

Samples of eggs that failed to hatch were taken to Davis for examination of egg contents. Most of the embryos were macerated or decomposed. No pattern of time or cause of death was found.

Gull Study. Gulls readily ate the squid containing its hidden oil capsule when the board hiding the squid was pulled away. As soon as the capsule dissolved and the oil was released, the squid, now covered with oil, was regurgitated, and was eaten by the mate or by another bird. Within a few seconds it was regurgitated again. Sometimes this was repeated several times. None of the 15 oil doses were actually retained by the gulls. Gulls that were snared and smeared with oil or injected intraperitoneally abandoned their nests. When first-laid eggs were smeared with oil and the female brooded it overnight, almost all the oil was removed from the egg, presumably to her brood patch. That egg was removed, as were subsequent eggs, for laboratory observations. No oil patches could be seen on the shell surface by observation under ultraviolet light, except on the egg that was originally smeared. Laboratory studies did not reveal any characteristic changes in yolk structure that could be attributed to oil. Chemical analyses have not been performed because of delays in adaptation of gas chromatographic methods to eggs. The attempts to dose gulls by capsule to observe reproductive effects were judged to be futile, and this part of the research was terminated.

Fate of ingested oil. Following the observations of gull behavior in regurgitating oil, auklets and other birds were also studied. The auklets began eliminating the oil at a mean time of 36 minutes after being fed (Table 5).

Adult Japanese quail and adult Mallards deprived of food overnight were compared in their responses to oil with fed birds, with the results also shown in Table 4. It will be noted that fed quail took a mean of 177 minutes before eliminating oil while unfed quail took only 29 minutes. Mallards responded differently: feeding did not affect passage time.

Black-footed Albatross and Common Murres that were dosed were few and two of the albatross were found later to be infected by bacteria, but their responses appeared to be different from the other birds studied. The murres reacted violently to the oil dose.

Table 3. Timing of egg laying by Cassin's Auklets following treatment.

Dose	Total # Eggs Laid		Number of Days Between Dosing and Egg Laying 2-7	8-13	14-19	20-25	26-31	32-37	38+	Un-Known
empty capsule	80	# eggs	21	22	19	4	7	1	4	2
		% of total	26	28	24	5	9	1	5	3
		cumulative %	26	54	78	83	92	93	98	-
300 mg bunker C	72	# eggs	27	18	12	8	1	3	0	3
		% of total	38	25	17	11	1	4	-	4
		cumulative %	38	63	80	91	92	96	96	-
600 mg bunker C	77	# eggs	25	17	15	8	4	2	2	4
		% of total	32	22	20	11	5	3	3	5
		cumulative	32	54	74	85	90	93	96	-

Table 4. Cumulative percent of total number of first eggs laid by auklets.

		Empty Capsule (N=80)	300 mg Bunker C (N=72)	600 mg Bunker C (N=77)	Control (N=75)
April	1-2	-	-	1	-
	3-4	3	-	-	1
	5-6	4	6	-	8
	7-8	8	17	7	11
	9-10	14	32	25	18
	11-12	27	42	39	34
	13-14	38	52	44	45

Table 5. Responses of several bird species to dosing with capsules containing bunker C oil.

Species	Number of Birds	Time Between Dosing and Regurgitation Mean	Regurgitation Range	Fecal Elimination Mean	Fecal Elimination Range
Cassin's Auklet[1] (*Ptychoramphus aleuticus*)	10	-	-	36min.	12-82min.
Western Gull[1] (*Larus occidentalis*)	15	*	0-35min.	-	-
Common Murre[2] (*Uria aalge*)	3	10min.	7-13min.	18min.	7-33min.
Black-footed Albatross[2] (*Diomedea nigripes*)	3	-	-	10hrs.	6-20hrs.
Japanese Quail[3] (*Coturnix coturnix japonica*)	6 fed	-	-	177min.	143-226min.
	5 unfed	-	-	29min.	11-67min.
Mallard[3] (*Anas platyrhynchos*)	6 fed	-	-	52min.	20-145min.
	6 unfed	-	-	46min.	31-79min.

* Upon contact with oil. Some oil was hidden in bait.
1 Dosed on Southeast Farallon Island.
2 Dosed at International Bird Rescue Research Center, Berkeley, California.
3 Dosed at University of California, Davis, California.

We observed by aspiration that no food was present in auklet stomachs at night. This information, together with data on passage time of oil in fed and unfed quail and mallards indicates that if auklets are similar to quail, then oil may have passed through the auklets too quickly to affect their eggs.

The cooperation of Alice Berkner of the International Bird Rescue Research Center is gratefully acknowledged.

If the same relationship between oil retention times in fed and unfed quail holds for fed and unfed auklets, fed auklets would be expected to retain oil for three hours before beginning to eliminate it. This would greatly extend the time of the auklet's exposure to oil and would expose the auklet at a time when it is actively absorbing nutrients. This may increase the toxicity of oil to both the auklet and any egg which it is forming at the time of exposure. Based on these suppositions we fed euphausiids to auklets in 1978 at the same time we fed oil. The only difference in results could have been expected based on the larger oil doses alone given in 1978.

Structural examination of yolks. No characteristic features of yolk of dosed auklets could be detected, in contrast to our previous experience with quail, chickens, and geese (Grau, et al., 1977). Tentatively, we attribute these results to elimination of the oil before an effect was obtained, but no substantiating data are available.

Chemical examination of yolks. Because petroleum hydrocarbons or their metabolites have not been reported to occur in avian yolk, and information of this kind would be important in evaluating responses of breeding birds to oil exposure, considerable effort has been made to determine whether oil components were present in eggs from birds fed oil. Most of the work has been done with quail and chickens fed bunker C: the former because of the known effects of oil on reproduction, and the latter because of the ease of obtaining samples. Yolks from Mallards fed crude oil-containing diets were also studied.

Ultraviolet visualization of the developed thin-layer plates indicated that there were differences between normal yolk and yolk from hens that had been fed oil. Control egg extracts exhibited a dull orange band close to the front. Frequently, this was so faint that it could barely be seen. Eggs from oil-fed hens fluoresced deep blue in this region. This deep blue color faded after a day and appeared more white than blue. The dull orange band seen on control yolk extracts also changed, appearing whiter in color, however, differences between oil and control chromatographed extracts were still apparent. Some control quail eggs exhibited the blue fluorescence characteristic of experimental bird eggs, but this was not observed in control chicken or duck eggs.

No consistent difference in the lower part of the TLC plates has appeared in ultraviolet visualization. When exposed to sulfuric acid charring or iodine vapors, there was a very dark line at the front, a large dark "cloud" of material (which appeared translucent when unstained plates were held up to a light) just below the front, a large brown area below that, a fairly clean area about 2-3 cm above the origin, and two or three dark bands on or above the origin. No differences were found between extracts of "oil" eggs and control eggs when sulfuric acid charring, iodine vapor exposure, or formalin sulfuric acid spray, which stains polynucleur aromatic compounds, were used.

When attempts were made to saponify the yolk extracts with alcoholic KOH and then chromatograph the ethyl ether extractable nonsaponifiable material, the TLC plates looked identical. In fact, there were quite a few more fluorescent bands after saponification in both oil and control chromatographs than before saponification.

Gas-liquid chromatographic analyses have been impaired by the presence of many nonvolatile or high boiling compounds in the extracts. These materials became baked on the glass walls of the splitter and deocmposed at the high temperatures of the injector port. This necessitated dismantling the column set up, changing the splitter, and running programs at high temperatures which lowered column life and increased column bleed.

No consistent differences were found between experimental and control chromatographs from any of the extracts. When the brightly fluorescent portion of some experimental thin layer chromatographs were eluted and compared with controls, there were, in four cases of experimental extracts, alkane peaks between C_{22} and C_{32}, but subsequent attempts to reproduce this failed. Similar chromatographs were produced with oil-spiked eggs however, and we suspect the earlier observations were probably caused by laboratory contamination. No C_{16} peaks were found by GC when yolk extracts were made after quail were given 200 mg hexadecane. Ultraviolet absorption measurements of extracts and TLC eluates did not show any differences between experimental and control eggs.

Spectrophotofluorometry of eluates from the plates proved to be the only method by which quantitative differences between experimental and control eggs were obtained. The shape of the spectra emitted over the range of 200 to 800 nm did not appear different between the two types of eggs. When excited at 290 or 300 nm, a broad peak appeared between 320 and 500 nm. Extracts of "oil" eggs showed a greater peak than control extracts. Some quail yolk extracts that emitted a blue fluorescence of TLC plates appeared to be identical in response to extracts from experimental (oil) yolks. Duck and chicken eggs have not exhibited this tendency.

Several auklet eggs from dosed and control birds have been extracted and examined for fluorescence, but no differences have been found. Because the number of eggs was low, the results cannot be considered as conclusive.

VII. Discussion

In our annual report for 1977 (Ainley et al., 1978) our attention was directed to hatching and fledging success, incubation period and fledging weight in the group of burrows where eggs were laid 2 to 7 days after dosing. Since yolk formation in the Cassin's Auklet takes eight days (Roudybush et al., MS), we felt that the effects of various treatments would be most apparent in this group. However, no major differences were found. The incubation periods, fledging times and fledging weights were comparable in all groups and were also comparable with the findings of Manuwal (1972) from his studies on Southeast Farallon in 1969 to 1971. Still convinced of the importance of egg laying during days 2 to 7 post-dosing, we felt that we could generate an effect by increasing the dose and feeding euphausiids simultaneously in our 1978 field studies. It was not until that work was completed when almost fortuitously we discovered that the period 9 to 13 days post-dosing was the seemingly critical one. This led us to work in 1979 (not funded by NOAA) in which we attempted to learn more about the duration of egg formation including events other than those concerning the yolk. By feeding fat-soluble dyes we were able to determine the time between the end of yolk deposition and oviposition in auklets. This time was found to be four days as compared to one day in chickens and quail. This time added to the eight days of yolk formation in auklets means that twelve days elapsed between the onset of rapid yolk deposition and oviposition. It is at about the time of initiation of yolk deposition that oil ingestion causes some change in the normal reproductive pattern of auklets, since egg laying is depressed 9 to 13 days later, or at the time when eggs initiated when oil was fed should have been laid. This narrows down the timing of the acute effect of oil ingestion. We were also led to completely re-analyze our 1977 findings. Readers will thus find little similarity between the conclusions in this and those in our 1978 report, at least as concerns the auklet dosing.

Although there is little doubt that ingestion of small doses of bunker C oil and Prudhoe Bay crude oil had a depressing effect on auklet reproductive success, we do not know what the effect was. We do know that it pertained to egg laying and not apparently to hatchability of eggs or development of chicks. We do not know whether the birds which failed to lay as a result of ingesting oil laid eggs later in the spring or whether they did so even the next year. Additional work would have been interesting. We would have learned more if we had discovered the days 9 to 13 period earlier in our work but such is the way things happen when new ground is being broken in research. Another year of study would indeed be fruitful.

Depending on the severity of the process which inhibited laying, the significance to auklets could change in degree. In all ways, reproductive potential would be reduced. If the effects of ingested oil merely "caused" (or allows) auklets to lay later in the same season there would be little chance that late hatching chicks would have survived (based on PRBO unpublished data). If the affected auklets failed to lay at all that season, that would have reduced outright the number of young fledged from the population. If somehow they became permanently sterilized then they might occupy a nest site unproductively for the remainder of their lives, thus making the reduced breeding potential a longer term problem.

Definitive chemical analyses of auklet eggs for presence of oil components have been delayed until techniques are developed using quail and other laboratory birds. Development of suitable chemical methods has not progressed as rapidly as had been hoped. Differences in fluorescence of extracts after thin-layer chromatography are established for ducks and probably for chickens. Some quail give a false positive response; that is, some control quail that have not ever been exposed to oil show fluorescence. There have not been any false negative responses.

There are several possible reasons for failure to find petroleum hydrocarbons in yolk after birds were dosed with oil. Some of these are as follows:

(1) Hydrocarbons may act primarily on the gut, altering capacity to withstand stress.
(2) Hydrocarbons may be poorly absorbed, making identification in eggs difficult.
(3) Toxicity may be high, thus making difficult the detection of small amounts needed to have an effect.
(4) Hydrocarbons may affect synthesis or metabolism of fluorescent compounds not usually present in chicken and duck eggs, thus increasing these compounds in the egg.
(5) Hydrocarbons may be easily volatilized from drying yolk or from TLC plates, thus possibly falling below detectable levels.

VIII. Conclusions

In this combined field and laboratory study of the effect of oil on reproduction, three dose levels of bunker C fuel oil and one dose level of Prudhoe Bay crude oil were given orally by gelatin capsules to randomly chosen groups of female Cassin's Auklets, and compared with control groups given an empty capsule or no capsule at all. The field work was done on Southeast Farallon Island, California; the laboratory study of some of the eggs produced was done at Davis. There were 72 to 106 females per group. Production of eggs, hatching success, chick weight, survival, and fledging were compared among the treatment groups. We found that egg laying was inhibited in some females, particularly those that should have laid 9 to 13 days after dosing. Such an effect would reduce the reproductive success of auklets.

Attempts to dose gulls with bait enclosing capsules containing oil were unsuccessful, because the gulls regurgitated the bait as some of the capsule dissolved, in half an hour or less. Auklets were then dosed with oil to determine the fate of the dose. None regurgitated, but elimination in the feces was rapid, with a mean time of 36 minutes. Adult Japanese Quail reared in cages and adult, pen-reared Mallards deprived of food for 16 hours were compared in their responses to oil with fed birds. It took fed quail 177 minutes to eliminate oil, while unfed quail took only 29 minutes. Mallards responded differently; feeding did not affect passage time. Three Black-footed Albatross and three Common Murres were also dosed. It took several hours for oil to pass in the albatross; the murres reacted violently within minutes by regurgitating and defecating oil.

IX. Auxiliary Material

A. References

Abbott, U.K., R.M. Craig, and J.O. Keith; 1964. Effects of malathion spray on embryonated chicken eggs exposed under field conditions at Tuolumne Meadow, Yosemite National Park. Poultry Sci. 43: 1297.

Ainley, D.G., G.A. Sanger (in press). Seabird trophic relationships in the northeastern Pacific Ocean and Bering Sea. In (J.C. Bartonek, D.N. Nettleship, and W.B. King, eds.). Conservation of seabirds in western North America. U.S. Fish Wildlife Service, Wildl. Res. Rept.

Albers, P.H.; 1977. Effects of external applications of fuel oil on hatchability of mallard eggs. In "Fate and Effects of Petroleum Hydrocarbons in Marine Organisms and Ecosystems", D.A. Wolfe, ed. Pergamon; pp. 158-163.

Crocker, A.D., J. Cronshaw, and W.N. Holmes; 1974. The effect of a crude oil on intestinal absorption in ducklings (*Anas platyrhynchos*). Environ. Pollution 7: 165.

Erhardt, M.; 1972. Petroleum hydrocarbons in oysters from Galveston Bay. Environ. Pollution 3: 257.

Engel, S.W., T.E. Roudybush, J.C. Dobbs, and C.R. Grau; 1977. Depressed food intake and reduced reproduction in Japanese Quail following a single dose of Prudhoe Bay crude oil. Presented at the 17th Hanford Biology Symposium, Richland, Washington; October 17-19, 1977.

Grau, C.R.; 1976. Ring structure of avian egg yolk. Poultry Sci. 55:1418-1422.

Grau, C.R., T. Roudybush, J. Dobbs and J. Wathen; 1977. Altered yolk structure and reduced hatchability of eggs from birds fed single doses of petroleum oils. Science 195: 779-781.

Hartung, R.; 1965. Some effects of oiling on reproduction in ducks. J. Wildlife Management 29: 872-874.

_______, and G.S. Hunt; 1966. Toxicity of some oils to waterfowl. J. Wildlife Management 30: 564-570.

Heyerdahl, T.; 1971. The Ra Expeditions, New York; Doubleday and Company, Incorporated.

Manuwal, D.A.; 1972. The population ecology of Cassin's Auklets on Southeast Farallon Island, California. Ph.D. Dissertation, UCLA; p. 298.

Miller, L.; 1940. Observations on the Black-footed Albatross. Condor 42: 229-238.

Neff, J.M., and J.W. Anderson. 1975. In Proceedings of the 1975 Conference on Prevention and Control of Oil Pollution. p. 469. American Petroleum Institute, Washington, D.C.

Renden, J., and U.K. Abbott. 1973. The response of avian skin to an oil-based pesticide and its carrier. Poultry Sci. 52: 2077.

Rittinghaus, H. 1956. Etwas über die "indirekte" Verbreitung der Ölpest in einem Seevogelschutzgebeite. Ornithol. Mitt., Lubeck 3: 43-46. (Quoted by Nelson-Smith, A. 1972. Oil Pollution and Marine Ecology, Paul Elek, London.)

Roudybush, T., C.R. Grau, M.R. Peterson, D.G. Ainley, K.V. Hirsch and A.I. Gilman. MS. Yolk formation in some charadriiforme birds. Condor In Press.

Sanger, G.A. 1973. Pelagic records of Glaucous-winged and Herring Gulls in the North Pacific Ocean. Auk 90: 384-393.

Shenstone, F.A. 1968. The gross composition, chemistry and physio-chemical basis of organization of the yolk and white. Chapter 2 in Egg Quality - A Study of the Hen's Egg. T.C. Carter, ed. Oliver and Boyd, Edinburgh (1968).

Smail, J., D.G. Ainley, and H. Strong. 1972. Notes of birds killed in the 1971 San Francisco oil spill. Calif. Birds 3: 25-32.

Sokal, R.R., and F.J. Rohlf. 1969. Biometry. W. H. Freeman & Co., San Francisco.

Straughan, D. 1970. Ecological effects of the Santa Barbara oil spill. Sympos. ed. by R. W. Holmes and F. A. DeWitt, Santa Barbara, California. pp. 173-182.

________. 1971. Oil pollution and sea birds. In (D. Straughan, comp.) Biological and oceanographical survey of the Santa Barbara Channel oil spill 1969-1970. Vol. 1., Allan Hancock Foundation, U. of S. California. pp. 307-312.

Udvardy, M. D. F. 1963. Zoogeographical study of the Pacific Alcidae. Tenth Pacific Science Conference (1961). Bishop Museum Press. pp. 85-111.

Warner, J. S. 1976. Determination of aliphatic and aromatic hydrocarbons in marine organisms. Anal. Chem. 48:578.

B. Papers in preparation or print

Ainley, D. G., C. R. Grau, S. H. Morrell, T. E. Roudybush, R. R. LeVallay and H. R. Huber. 1978. Influence of petroleum on egg formation and embryonic development in seabirds. Final Rept., NOAA, Juneau.

Grau, C. R., T. A. Wootton, T. E. Roudybush, W. N. Holmes, J. A. Cronshaw and D. G. Ainley. MS. Detection of eggs from oil-fed birds by ultraviolet fluorescence of yolk extracts. Soc. Petroleum Industry Biol., Proc. I: In Press.

C. Oral presentations

1. "Influence of petroleum on egg formation and embryonic development in seabirds."

   Seattle, Washington. 29 November - 1 December 1977.

2. "Reproductive responses of Cassin's Auklets to orally administered bunker C oil and eliminative responses in seabirds."

   Fourth Annual Meeting, Pacific Seabird Group, Victoria, B.C. 19-21 January 1978.

3. "Studies on seabirds at the Farallon Islands."

   Thirteenth Annual Meeting, Point Reyes Bird Observatory, Bolinas, California. 5 February 1978.

4. "Egg formation in seabirds".

   Fifth Annual Meeting, Pacific Seabird Group, Pacific Grove, California. 12-15 December 1978.

FINAL REPORT

Contract No.:	R7120825
Research Unit No.:	RU551
Number of Pages:	393

SEASONAL COMPOSITION AND FOOD WEB RELATIONSHIPS OF MARINE ORGANISMS IN THE NEARSHORE ZONE - INCLUDING COMPONENTS OF THE ICHTHYOPLANKTON, MEROPLANKTON, AND HOLOPLANKTON

Co-Principal Investigators

Jean R. Dunn, Arthur W. Kendall, Jr.,

Robert J. Wolotira, Jr.

with

John H. Bowerman, Jr., Douglas B. Dey,
Ann C. Matarese and J. Eric Munk

Northwest and Alaska Fisheries Center
2725 Montlake Boulevard East
Seattle, Washington 98112

February, 1980

TABLE OF CONTENTS

	Page
LIST OF TABLES	360
LIST OF FIGURES	366
ABSTRACT	383
INTRODUCTION	384
Purpose and Scope of the Study	384
Description of the Study Area	385
Current Knowledge of Hydrography	386
Current Knowledge of Plankton	387
MATERIALS AND METHODS	390
Field Gear and Station Procedures	390
Sample Processing	392
Data Processing	393
Data Analysis	393
Grid Stations	393
Diel Series	395
RESULTS AND DISCUSSION	396
Hydrography	396
Fall 1977	396
Spring 1978	397
Summer 1978	397
Fall 1978	398
Winter 1979	398

TABLE OF CONTENTS (CONT'D)

	Page
Seasonal Summary	398
Seabed Drifter Recoveries	400
Invertebrate Zooplankton	400
Plankton Volumes	401
Distribution and Discussion of Selected Taxa	402
Natantia and Reptantia	411
Relative Importance of Individual Species or Species Groups	
Discussion of Selected Taxa	413
Summary of Decapod Larvae Information	425
Ichthyoplankton	427
Distribution and Discussion of Selected Taxa	427
Summary of Seasonal and Geographical Ichthyoplankton Distributions	443
Diel Migration and Depth Distribution	445
SUMMARY	456
ACKNOWLEDGMENTS	459
LITERATURE CITED	460

LIST OF TABLES

Table 1. --Summary of previous plankton sampling surveys relevant to the Kodiak Island shelf area.

Table 2. --Number of plankton samples collected and associated measurements made on OCSEAP plankton cruises, October 1977 - March 1979.

Table 3. --OCSEAP plankton cruises of the inshore region of Kodiak Island shelf area. Dates and numbers of samples by gear type.

Table 4. --Data sets used in analyses of decapod larvae collected during OCSEAP offshore and inshore plankton cruises.

Table 5. --Grid station numbers used for comparison of catches in nearshore, midshelf, and slope regions and trough and bank areas.

Table 6. --Seabed drifter release and recovery locations and dates, number of days out, and estimated direction and distance of drift.

Table 7. --Mean settled plankton volumes from bongo net tows on OCSEAP plankton cruises in ml/m^3.

Table 8. --Seasonal distribution and abundance of major invertebrate zooplankton groups from bongo net tows on OCSEAP plankton cruises based on mean number of animals/1000 m^3.

Table 9. --Seasonal distribution and abundance of Euphausiacea from bongo net tows on OCSEAP plankton cruises based on mean number of animals/1000 m^3.

Table 10.--Weights and lengths of principal species of Euphausiacea from bongo net tows on OCSEAP plankton cruises.

Table 11.--Day and night vertical distributions of Euphausiacea from Tucker trawl tows on OCSEAP plankton cruises.

Table 12.--Reptantia and Natantia decapod crustacea larvae encountered during OCSEAP inshore and offshore plankton cruises.

Table 13.--Rank order by frequency of occurrence (percent of plankton samples examined for decapod larvae) of Natantia and Reptantia larval taxa in inshore and offshore OCSEAP plankton cruises. Bongo net data.

Table 14.--Density (numbers/1000 m^3) of hippolytid shrimp larvae, Hippolytidae, by subarea, cruise, and season from the OCSEAP inshore plankton cruises. Bongo net data.

Table 15.--Density (numbers/1000 m^3) of hippolytid shrimp larvae, Hippolytidae, by subarea, cruise, and season from the OCSEAP offshore plankton cruises. Bongo net data.

Table 16.--Occurrence of larval stages of hippolytid shrimp larvae, Hippolytidae, by cruise, and season from the OCSEAP inshore plankton cruises. Data from all gear types.

Table 17.--Density (numbers/1000 m^3) of crangonid shrimp larvae, Crangonidae, by subarea, cruise, and season from the OCSEAP inshore plankton cruises. Bongo net data.

Table 18.--Density (numbers/1000 m^3) of crangonid shrimp larvae, Crangonidae, by subarea, cruise, and season from the OCSEAP offshore plankton cruises. Bongo net data.

Table 19.--Occurrence of larval stages of crangonid shrimp larvae, Crangonidae, by cruise, and season from the OCSEAP inshore plankton cruises. Data from all gear types.

Table 20.--Density (numbers/1000 m^3) of pink shrimp larvae, Pandalus borealis, by subarea, cruise, and season from the OCSEAP inshore plankton cruises. Bongo net data.

Table 21.--Density (numbers/1000 m^3) of pink shrimp larvae, Pandalus borealis, by subarea, cruise, and season from the OCSEAP offshore plankton cruises. Bongo net data.

Table 22.--Occurrence of larval stages of pink shrimp, Pandalus borealis, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.

Table 23.--Density (numbers/1000 m^3) of anomuran crab larvae, Anomura, by subarea, cruise, and season from the OCSEAP inshore plankton cruises. Bongo net data.

Table 24.--Density (numbers/1000 m^3) of anomuran crab larvae, Anomura, by subarea, cruise, and season from the OCSEAP offshore plankton cruises. Bongo net data.

Table 25.--Occurrence of larval stages of anomuran crab, Anomura, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.

Table 26.--Density (numbers/1000 m^3) of cancer crab larvae, Cancer I, by subarea, cruise, and season from the OCSEAP inshore plankton cruises. Bongo net data.

Table 27.--Density (numbers/1000 m^3) of cancer crab larvae, Cancer I, by subarea, cruise, and season from the OCSEAP offshore plankton cruises. Bongo net data.

Table 28.--Occurrence of larval stages of cancer crab, Cancer I, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.

Table 29.--Density (numbers/1000 m^3) of pea crab larvae, Pinnotheridae, by subarea, cruise, and season from the OCSEAP inshore plankton cruises. Bongo net data.

Table 30.--Density (numbers/1000 m^3) of pea crab larvae, Pinnotheridae, by subarea, cruise, and season from the OCSEAP offshore plankton cruises. Bongo net data.

Table 31.--Occurrence of larval stages of pea crabs, Pinnotheridae, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.

Table 32.--Density (numbers/1000 m^3) of Tanner crab larvae, Chionoecetes bairdi, by subarea, cruise, and season from the OCSEAP inshore plankton cruises. Bongo net data.

Table 33.--Density (numbers/1000 m^3) of Tanner crab larvae, Chionoecetes bairdi, by subarea, cruise, and season from the OCSEAP offshore plankton cruises. Bongo net data.

Table 34.--Occurrence of larval stages of Tanner crab, Chionoecetes bairdi, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.

Table 35.--Density (numbers/1000 m^3) of Dungeness crab larvae, Cancer magister, by subarea, cruise, and season from the OCSEAP inshore plankton cruises. Bongo net data.

Table 36.--Density (numbers/1000 m^3) of Dungeness crab larvae, Cancer magister, by subarea, cruise, and season from the OCSEAP offshore plankton cruises. Bongo net data.

Table 37.--Occurrence of larval stages of Dungeness crab, Cancer magister, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.

Table 38.--Density (numbers/1000 m^3) of red king crab larvae, Paralithodes camtschatica, by subarea, cruise, and season from the OCSEAP inshore plankton cruises. Bongo net data.

Table 39.--Density (numbers/1000 m^3) of red king crab larvae, Paralithodes camtschatica, by subarea, cruise, and season from the OCSEAP offshore plankton cruises. Bongo net data.

Table 40.--Occurrence of larval stages of red king crab, Paralithodes camtschatica, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.

Table 41.--Number of occurrences and mean density (number/1000 m^3) of fish eggs and larvae collected in neuston tows during the five OCSEAP plankton cruises.

Table 42.--Total numbers ($\log_{10}$) of eggs and larvae of each taxon of fish estimated from catches in bongo tows during the five OCSEAP plankton cruises.

Table 43.--Seasons and areas of major occurrences of the most abundant taxa of fish eggs (E) and larvae (L) in the Kodiak Island shelf area based on five OCSEAP plankton cruises, fall 1977-winter 1979.

Table 44.--Abundance of fish larvae and eggs taken during seven diel-vertical distribution series off Kodiak Island, Alaska.

Table 45.--Catches of Hemilepidotus spp. at 2-hr intervals based on number/100 m^3 for three selected depths. Stations D33A-L (Diel 1), fall 1977.

Table 46.--Catches of Pleurogrammus monopterygius larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D33A-L (Diel 1), fall 1977.

Table 47.--Catches of Hexagrammos decagrammus larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D33A-L (Diel 1), fall 1977.

Table 48.--Catches of Hemilepidotus spp. larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D35A-L (Diel 2), fall 1977.

Table 49.--Catches of Hemilepidotus spp. larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D45A-L (Diel 3), spring 1978.

Table 50.--Catches of Hexagrammos decagrammus larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D45A-L (Diel 3), spring 1978.

Table 51.--Catches of Ammodytes hexapterus larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D45A-L (Diel 3), spring 1978.

Table 52.--Catches of Theragra chalcogramma eggs at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D63A-L (Diel 4), spring 1978.

Table 53.--Catches of Theragra chalcogramma larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D63A-L (Diel 4), spring 1978.

Table 54.--Catches of Hexagrammos decagrammus larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D63A-L (Diel 4), spring 1978.

Table 55.--Catches of Ammodytes hexapterus larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D63A-L (Diel 4), spring 1978.

Table 56.--Catches of Lyconectes aleutensis larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D63A-L (Diel 4), spring 1978.

Table 57.--Catches of Lepidopsetta bilineata larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D63A-L (Diel 4), spring 1978.

Table 58.--Catches of Hemilepidotus spp. larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D63A-L (Diel 4), spring 1978.

Table 59.--Catches of Bathymaster spp. larvae at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-L (Diel 5), summer 1978.

Table 60.--Catches of Ronquilus jordani larvae at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-L (Diel 5), summer 1978.

Table 61.--Catches of Sebastes spp. larvae at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-L (Diel 5), summer 1978.

Table 62.--Catches of Psettichthys melanostictus larvae at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-L (Diel 5), summer 1978.

Table 63.--Catches of Isopsetta isolepis larvae at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-L (Diel 5), summer 1978.

Table 64.--Catches of Lepidopsetta bilineata larvae at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-L (Diel 5), summer 1978.

Table 65.--Catches of Hippoglossoides elassodon larvae at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-L (Diel 5), summer 1978.

Table 66.--Catches of Bathymaster spp. larvae at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D69A-L (Diel 6), summer 1978.

Table 67.--Catches of *Sebastes* spp. larvae at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D69A-L (Diel 6), summer 1978.

Table 68.--Catches of *Microstomus pacificus* eggs at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D69A-L (Diel 6), summer 1978.

Table 69.--Catches of *Pleurogrammus monopterygius* larvae at 4-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-G (Diel 7), fall 1978.

Table 70.--Catches of *Hemilepidotus* spp. larvae at 4-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-G (Diel 7), fall 1978.

Table 71.--Catches of *Hexagrammos decagrammus* larvae at 4-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-G (Diel 7), fall 1978.

Table 72.--Catches of *Hexagrammos lagocephalus* larvae at 4-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-G (Diel 7), fall 1978.

Table 73.--Catches of *Hexagrammos octogrammus* larvae at 4-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-G (Diel 7), fall 1978.

Table 74.--Catches of *Leuroglossus schmidti* larvae at 4-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-G (Diel 7), fall 1978.

Table 75.--Catches of *Leuroglossus schmidti* eggs at 4-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-G (Diel 7), fall 1978.

Table 76.--Summary of the diel-vertical distribution, abundance, and size of the seven most abundant taxa of fish collected during seven diel-vertical distribution series off Kodiak Island, Alaska.

LIST OF FIGURES

Figure 1.-- Kodiak Island study area depicting general bathymetry and principal bays and inlets (after Science Applications, Inc., MS 1979a).

Figure 2.-- Speculative summary of surface currents of the Kodiak Island shelf area (from Science Applications, Inc., MS 1979b).

Figure 3.-- Cruise track (top) and station numbers (bottom) for cruise 4MF77, fall 1977.

Figure 4.-- Cruise track (top) and station numbers (bottom) for cruise 4DI78, spring 1978.

Figure 5.-- Cruise track (top) and station numbers (bottom) for cruise 2MF78, summer 1978.

Figure 6.-- Cruise track (top) and station numbers (bottom) for cruise 1WE78, fall 1978.

Figure 7.-- Cruise track (top) and station numbers (bottom) for cruise 1MF79, winter 1979.

Figure 8.-- Locations of diel sampling series.

Figure 9.-- Bays and sampling locations of the inshore bay regions of the Kodiak Island study area.

Figure 10.--Diagram of data management system used for reduction and analysis of OCSEAP plankton data.

Figure 11.--Offshore region subareas of the Kodiak Island study area identified for the decapod larvae section of this report.

Figure 12.--Surface temperature in ^{o}C (top) and salinity in $^{o}/oo$ (bottom) fall 1977 (Data from Schumacher, et al., 1979).

Figure 13.--Temperature in ^{o}C (top) and salinity in $^{o}/oo$ (bottom) at 50 m, fall 1977 (Data from Schumacher, et al., 1979).

Figure 14.--Temperature in ^{o}C (top) and salinity in $^{o}/oo$ (bottom) at bottom (or 200 m), fall 1977 (Data from Schumacher, et al., 1979).

Figure 15.--Surface temperature in ^{o}C (top) and salinity in $^{o}/oo$ (bottom) spring 1978.

Figure 16.--Temperature in ^{o}C (top) and salinity in $^{o}/oo$ (bottom) at bottom (or 200 m), spring 1978.

Figure 17.--Surface temperature in ^{o}C (top) and salinity in $^{o}/oo$ (bottom) summer 1978.

Figure 18.--Temperature in ^{o}C (top) and salinity in $^{o}/oo$ (bottom) at 50 m, summer 1978.

Figure 19.--Temperature in ^{o}C (top) and salinity in $^{o}/oo$ (bottom) at bottom (or 200 m), summer 1978.

Figure 20.--Surface temperature in ^{o}C (top) and salinity in $^{o}/oo$ (bottom) fall 1978.

Figure 21.--Temperature in ^{o}C (top) and salinity in $^{o}/oo$ (bottom) at 50 m, fall 1978.

Figure 22.--Temperature in ^{o}C (top) and salinity in $^{o}/oo$ (bottom) at bottom (or 200 m), fall 1978.

Figure 23.--Surface temperature in ^{o}C (top) and salinity in $^{o}/oo$ (bottom) winter 1979.

Figure 24.--Temperature in ^{o}C (top) and salinity in $^{o}/oo$ (bottom) at 50 m, winter 1979.

Figure 25.--Temperature in ^{o}C (top) and salinity in $^{o}/oo$ (bottom) at bottom (or 200 m), winter 1979.

Figure 26.--Release and recovery locations of seabed drifters deployed in the Kodiak Island area during OCSEAP plankton cruises.

Figure 27.--Distribution and abundance of Copepoda in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.

Figure 28.--Distribution and abundance of Copepoda in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

Figure 29.--Distribution and abundance of Copepoda in bongo tows from the winter 1979 OCSEAP plankton cruise.

Figure 30.--Distribution and abundance of Euphausiacea larvae in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.

Figure 31.--Distribution and abundance of Euphausiacea larvae in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

Figure 32.--Distribution and abundance of Euphausiacea larvae in bongo tows from the winter 1979 OCSEAP plankton cruise.

Figure 33.--Distribution and abundance of Euphausiacea juveniles in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.

Figure 34.--Distribution and abundance of Euphausiacea juveniles in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

Figure 35.--Distribution and abundance of Euphausiacea juveniles in bongo tows from the winter 1979 OCSEAP plankton cruise.

Figure 36.--Distribution and abundance of *Euphausia pacifica* in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.

Figure 37.--Distribution and abundance of *Euphausia pacifica* in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

Figure 38.--Distribution and abundance of *Euphausia pacifica* in bongo tows from the winter 1979 OCSEAP plankton cruise.

Figure 39.--Distribution and abundance of *Thysanoessa inermis* in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.

Figure 40.--Distribution and abundance of *Thysanoessa inermis* in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

Figure 41.--Distribution and abundance of *Thysanoessa inermis* in bongo tows from the winter 1979 OCSEAP plankton cruise.

Figure 42.--Distribution and abundance of *Thysanoessa longipes* in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.

Figure 43.--Distribution and abundance of *Thysanoessa longipes* in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

Figure 44.--Distribution and abundance of *Thysanoessa longipes* in bongo tows from the winter 1979 OCSEAP plankton cruise.

Figure 45.--Distribution and abundance of *Thysanoessa spinifera* in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.

Figure 46.--Distribution and abundance of *Thysanoessa spinifera* in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

Figure 47.--Distribution and abundance of *Thysanoessa spinifera* in bongo tows from the winter 1979 OCSEAP plankton cruise.

Figure 48.--Lengths of *Euphausia pacifica* collected in bongo net tows from the five offshore OCSEAP plankton cruises.

Figure 49.--Lengths of *Thysanoessa inermis* collected in bongo net tows from the five offshore OCSEAP plankton cruises.

Figure 50.--Lengths of Thysanoessa longipes collected in bongo net tows from the five offshore OCSEAP plankton cruises.

Figure 51.--Distribution and abundance of Chaetognatha in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.

Figure 52.--Distribution and abundance of Chaetognatha in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

Figure 53.--Distribution and abundance of Chaetognatha in bongo tows from the winter 1979 OCSEAP plankton cruise.

Figure 54.--Distribution and abundance of Cnidaria in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.

Figure 55.--Distribution and abundance of Cnidaria in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

Figure 56.--Distribution and abundance of Cnidaria in bongo tows from the winter 1979 OCSEAP plankton cruise.

Figure 57.--Distribution and abundance of Cirripedia nauplii in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.

Figure 58.--Distribution and abundance of Cirripedia nauplii in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

Figure 59.--Distribution and abundance of Cirripedia nauplii in bongo tows from the winter 1979 OCSEAP plankton cruise.

Figure 60.--Distribution and abundance of Cirripedia cyprids in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.

Figure 61.--Distribution and abundance of Cirripedia cyprids in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

Figure 62.--Distribution and abundance of Cirripedia cyprids in bongo tows from the winter 1979 OCSEAP plankton cruise.

Figure 63.--Distribution and abundance of Amphipoda in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.

Figure 64.--Distribution and abundance of Amphipoda in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

Figure 65.--Distribution and abundance of Amphipoda in bongo tows from the winter 1979 OCSEAP plankton cruise.

Figure 66.--Average density (numbers per 1000 m^3) by cruise, season, bay, subarea, and region for hippolytid shrimp larvae, Hippolytidae, in the Kodiak Island study area. 1977-1979 OCSEAP plankton cruises. Bongo net data.

Figure 67.--Average density per station (numbers per 1000 m^3) of hippolytid shrimp larvae, Hippolytidae, in bongo tows from the spring 1978 OCSEAP inshore plankton cruises.

Figure 68.--Average density per station (numbers per 1000 m^3) of hippolytid shrimp larvae, Hippolytidae, in bongo tows from the summer 1978 OCSEAP inshore plankton cruises.

Figure 69.--Average density per station (numbers per 1000 m^3) of hippolytid shrimp larvae, Hippolytidae, in bongo tows from the late winter 1979 OCSEAP inshore plankton cruise.

Figure 70.--Distribution and relative abundance of hippolytid shrimp larvae, Hippolytidae, during the spring (top) and summer (bottom) 1978 OCSEAP offshore plankton cruises. Bongo net data.

Figure 71.--Distribution and relative abundance of hippolytid shrimp larvae, Hippolytidae, during the fall 1978 OCSEAP offshore plankton cruise. Bongo net data.

Figure 72.--Percent of total numbers caught by depth stratum per time interval and cruise, and density by time and cruise of hippolytid shrimp larvae, Hippolytidae, at diel stations in the inshore region. Tucker trawl data. D = day, N = night.

Figure 73.--Percent of total numbers of hippolytid shrimp larvae, Hippolytidae, caught by time interval per depth stratum during spring and summer 1978 diel studies in the offshore region. Tucker trawl data. d = mean density (no./1000 m^3) for all time periods per depth stratum.

Figure 74.--Average density (numbers per 1000 m^3) by cruise, season, bay, subarea, and region for crangonid shrimp larvae, Crangonidae, in the Kodiak Island study area. 1977-1979 OCSEAP plankton cruises. Bongo net data.

Figure 75.--Average density per station (numbers per 1000 m^3) of crangonid shrimp larvae, Crangonidae, in bongo tows from the spring 1978 OCSEAP inshore plankton cruises.

Figure 76.--Average density per station (numbers per 1000 m^3) of crangonid shrimp larvae, Crangonidae, in bongo tows from the summer 1978 OCSEAP inshore plankton cruises.

Figure 77.--Distribution and relative abundance of crangonid shrimp larvae, Crangonidae, during the spring (top) and summer (bottom) 1978 OCSEAP offshore plankton cruises. Bongo net data.

Figure 78.--Percent of total numbers caught by depth stratum per time interval and cruise, and density by time and cruise of crangonid shrimp, Crangonidae, at diel stations in the inshore region. Tucker trawl data. D = day, N = night.

Figure 79.--Average density (numbers per 1000 m^3) by cruise, season, bay, subarea, and region for pink shrimp larvae, Pandalus borealis, in the Kodiak Island study area. 1977-79 OCSEAP plankton cruises. Bongo net data.

Figure 80.--Average density per station (numbers per 1000 m^3) of pink shrimp larvae, Pandalus borealis, in bongo tows from the spring 1978 OCSEAP inshore plankton cruises.

Figure 81.--Distribution and relative abundance of pink shrimp larvae, Pandalus borealis, during the spring (top) and summer (bottom) 1978 OCSEAP offshore plankton cruises. Bongo net data.

Figure 82.--Percent of total numbers caught by depth stratum per time interval and cruise, and density by time and cruise of pink shrimp larvae, Pandalus borealis, at diel stations in the inshore region. Tucker trawl data. D = day, N = night.

Figure 83.--Percent of total numbers of pink shrimp larvae, Pandalus borealis, caught by time interval per depth stratum during summer 1978 diel studies in the offshore region. Tucker trawl data. d = mean density (no./1000 m^3) for all time periods per depth stratum.

Figure 84.--Average density (numbers per 1000 m^3) by cruise, season, bay, subarea, and region for anomuran crab larvae, Anomura, in the Kodiak Island study area. Bongo net data.

Figure 85.--Average density per station (numbers per 1000 m^3) of anomuran crab larvae, Anomura, in bongo tows from the spring 1978 OCSEAP inshore plankton cruises.

Figure 86.--Average density per station (numbers per 1000 m^3) of anomuran crab larvae, Anomura, in bongo tows from the summer 1978 OCSEAP inshore plankton cruises.

Figure 87.--Average density per station (numbers per 1000 m^3) of anomuran crab larvae, Anomura, in bongo tows from the fall 1978 OCSEAP inshore plankton cruise.

Figure 88.--Average density per station (numbers per 1000 m^3) of anomuran crab larvae, Anomura, in bongo tows from the late winter 1979 OCSEAP inshore plankton cruise.

Figure 89.--Distribution and relative abundance of anomuran crab larvae, Anomura, during the spring (top) and summer (bottom) 1978 OCSEAP offshore plankton cruises. Bongo net data.

Figure 90.--Distribution and relative abundance of anomuran crab larvae Anomura, during the fall 1978 (top) and winter 1979 (bottom) OCSEAP offshore plankton cruises. Bongo net data.

Figure 91.--Percent of total numbers caught by depth stratum per time interval and cruise, and density by time and cruise of anomuran crab larvae, Anomura, at diel stations in the inshore region. Tucker trawl data. D = day, N = night.

Figure 92.--Percent of total numbers of anomuran crab larvae, Anomura, caught by time interval per depth stratum during summer 1978 diel studies in the offshore region. Tucker trawl data. d = mean density (no./1000 m^3) for all time periods per depth stratum.

Figure 93.--Average density (numbers per 1000 m^3) by cruise, season, bay, subarea, and region for cancer crab larvae, Cancer I, in the Kodiak Island study area. 1977-1979 OCSEAP plankton cruises. Bongo net data.

Figure 94.--Average density per station (numbers per 1000 m^3) of cancer crab larvae, Cancer I, in bongo tows from the spring 1978 OCSEAP inshore plankton cruise.

Figure 95.--Average density per station (numbers per 1000 m^3) of cancer crab larvae, Cancer I, in bongo tows from the summer 1978 OCSEAP inshore plankton cruises.

Figure 96.--Distribution and relative abundance of cancer crab larvae, Cancer I, during the summer 1978 OCSEAP offshore plankton cruise. Bongo net data.

Figure 97.--Percent of total numbers caught by depth stratum per time interval and cruise, and density by time and cruise of cancer crab larvae, Cancer I, at diel stations in the inshore region. Tucker trawl data. D = day, N = night.

Figure 98.--Percent of total numbers of cancer crab larvae, Cancer I, caught by time interval per depth stratum during summer 1978 diel studies in the offshore region. Tucker trawl data. d = mean density (no./1000 m^3) for all time periods per depth stratum.

Figure 99.--Average density (numbers per 1000 m^3) by cruise, season, bay, subarea, and region for pea crab larvae, Pinnotheridae, in the Kodiak Island study area. Bongo net data.

Figure 100.--Average density per station (numbers per 1000 m^3) of pea crab larvae, Pinnotheridae, in bongo tows from the spring 1978 OCSEAP inshore plankton cruises.

Figure 101.--Average density per station (numbers per 1000 m^3) of pea crab larvae, Pinnotheridae, in bongo tows from the summer 1978 OCSEAP inshore plankton cruises.

Figure 102.--Distribution and relative abundance of pea crab larvae, Pinnotheridae, during the summer 1978 OCSEAP offshore plankton cruise. Bongo net data.

Figure 103.--Percent of total numbers caught by depth stratum per time interval and cruise, and density by time and cruise of pea crab larvae, Pinnotheridae, at diel stations in the inshore region. Tucker trawl data. D = day, N = night.

Figure 104.--Percent of total numbers of pea crab larvae, Pinnotheridae, caught by time interval per depth stratum during summer 1978 diel studies in the offshore region. Tucker trawl data. d = mean density (no./1000 m^3) for all time periods per depth stratum.

Figure 105.--Average density (numbers per 1000 m^3) by cruise, season, bay, subarea, and region for Tanner crab larvae, Chionoecetes bairdi, in the Kodiak Island study area. Bongo net data.

Figure 106.--Average density per station (numbers per 1000 m^3) of Tanner crab larvae, Chionoecetes bairdi, in bongo tows from the spring 1978 OCSEAP inshore plankton cruises.

Figure 107.--Average density per station (numbers per 1000 m^3) of Tanner crab larvae, Chionoecetes bairdi, in bongo tows from the summer 1978 OCSEAP inshore plankton cruises.

Figure 108.--Distribution and relative abundance of Tanner crab larvae, Chionoecetes bairdi, during the summer 1978 OCSEAP offshore plankton cruise. Bongo net data.

Figure 109.--Percent of total numbers caught by depth stratum per time interval and cruise, and density by time and cruise of Tanner crab larvae, Chionoecetes bairdi, at diel stations in the inshore region. Tucker trawl data. D = day, N = night.

Figure 110.--Percent of total numbers of Tanner crab larvae, Chionoecetes bairdi, caught by time interval per depth stratum during summer 1978 diel studies in the offshore region. Tucker trawl data. d = mean density (no./1000 m^3) for all time periods per depth stratum.

Figure 111.--Average density (numbers per 1000 m^3) by cruise, season, bay, subarea, and region for Dungeness crab larvae, Cancer magister, in the Kodiak Island study area. Bongo net data.

Figure 112.--Average density per station (numbers per 1000 m^3) of Dungeness crab larvae, Cancer magister, in bongo tows from the spring 1978 OCSEAP inshore plankton cruises.

Figure 113.--Average density per station (numbers per 1000 m^3) of Dungeness crab larvae, Cancer magister, in bongo tows from the summer 1978 OCSEAP inshore plankton cruises.

Figure 114.--Distribution and relative abundance of Dungeness crab larvae, Cancer magister, during the summer 1978 OCSEAP offshore plankton cruise. Bongo net data.

Figure 115.--Percent of total numbers caught by depth stratum per time interval and cruise, and density by time and cruise of Dungeness crab larvae, Cancer magister, at diel stations in the inshore region. Tucker trawl data. D = day, N = night.

Figure 116.--Percent of total numbers of Dungeness crab larvae, Cancer magister, caught by time interval per depth stratum during summer 1978 diel studies in the offshore region. Tucker trawl data. d = mean density (no./1000 m^3) for all time periods per depth stratum.

Figure 117.--Average density (numbers per 1000 m^3) by cruise, season, bay, subarea, and region for red king crab larvae, Paralithodes camtschatica, in the Kodiak Island study area. Bongo net data.

Figure 118.--Average density per station (numbers per 1000 m^3) of red king crab larvae, Paralithodes camtschatica, in bongo tows from the spring 1978 OCSEAP inshore plankton cruises.

Figure 119.--Average density per station (numbers per 1000 m^3) of red king crab larvae, Paralithodes camtschatica, in bongo tows from the summer 1978 OCSEAP inshore plankton cruises.

Figure 120.--Percent of total numbers caught by depth stratum per time interval and cruise, and density by time and cruise of red king crab larvae, Paralithodes camtschatica, at diel stations in the inshore region. Tucker trawl data. D = day, N = night.

Figure 121.--Percent of total numbers of red king crab larvae, Paralithodes camtschatica, caught by time interval per depth stratum during summer 1978 diel studies in the offshore region. Tucker trawl data. d = mean density (no./1000 m^3) for all time periods per depth stratum.

Figure 122.--Distribution and abundance of Mallotus villosus larvae in neuston (top) and bongo (bottom) tows from the fall 1977 OCSEAP plankton cruise.

Figure 123.--Distribution and abundance of Mallotus villosus larvae in neuston tows from the spring 1978 OCSEAP plankton cruise.

Figure 124.--Distribution and abundance of Mallotus villosus larvae in neuston (top) and bongo (bottom) tows from the fall 1978 OCSEAP plankton cruise.

Figure 125.--Distribution and abundance of Mallotus villosus larvae in neuston (top) and bongo (bottom) tows from the winter 1979 OCSEAP plankton cruise.

Figure 126.--Distribution and abundance of *Leuroglossus schmidti* eggs in bongo tows from the fall 1977 OCSEAP plankton cruise.

Figure 127.--Distribution and abundance of *Leuroglossus schmidti* larvae in bongo tows from the summer 1978 OCSEAP plankton cruise.

Figure 128.--Distribution and abundance of *Leuroglossus schmidti* eggs (top) and larvae (bottom) in bongo tows from the fall 1978 OCSEAP plankton cruise.

Figure 129.--Distribution and abundance of *Leuroglossus schmidti* eggs (top) and larvae (bottom) in bongo tows from the winter 1979 OCSEAP plankton cruise.

Figure 130.--Distribution and abundance of *Stenobrachius leucopsarus* larvae in bongo tows from the spring (top) and summer (bottom) 1978 OCSEAP plankton cruises.

Figure 131.--Distribution and abundance of *Stenobrachius leucopsarus* larvae in bongo tows from the fall 1978 (top) and winter 1979 (bottom) OCSEAP plankton cruises.

Figure 132.--Distribution and abundance of *Protomyctophum thompsoni* larvae in bongo tows from the fall 1977 (top) and fall 1978 (bottom) OCSEAP plankton cruises.

Figure 133.--Distribution and abundance of *Theragra chalcogramma* eggs in neuston (top) and bongo (bottom) tows from the fall 1977 OCSEAP plankton cruise.

Figure 134.--Distribution and abundance of *Theragra chalcogramma* eggs in neuston (top) and bongo (bottom) tows from the spring 1978 OCSEAP plankton cruise.

Figure 135.--Distribution and abundance of *Theragra chalcogramma* larvae in bongo tows from the spring (top) and summer (bottom) 1978 OCSEAP plankton cruises.

Figure 136.--Distribution and abundance of Macrouridae eggs in bongo tows from the summer (top) and fall (bottom) 1978 OCSEAP plankton cruises.

Figure 137.--Distribution and abundance of *Sebastes* spp. larvae in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.

Figure 138.--Distribution and abundance of *Hexagrammos octogrammus* larvae in neuston tows from the fall 1977 (top) and fall 1978 (bottom) OCSEAP plankton cruises.

Figure 139.--Distribution and abundance of _Hexagrammos octogrammus_ larvae in neuston tows from the winter 1979 OCSEAP plankton cruise.

Figure 140.--Distribution and abundance of _Hexagrammos lagocephalus_ larvae in neuston tows from the fall 1977 (top) and fall 1978 (bottom) OCSEAP plankton cruises.

Figure 141.--Distribution and abundance of _Hexagrammos decagrammus_ larvae in neuston tows from the fall 1977 OCSEAP plankton cruise.

Figure 142.--Distribution and abundance of _Hexagrammos decagrammus_ larvae in neuston (top) and bongo (bottom) tows from the spring 1978 OCSEAP plankton cruise.

Figure 143.--Distribution and abundance of _Hexagrammos decagrammus_ larvae in neuston tows from the summer 1978 OCSEAP plankton cruise.

Figure 144.--Distribution and abundance of _Hexagrammos decagrammus_ larvae in neuston tows from the fall 1978 OCSEAP plankton cruise.

Figure 145.--Distribution and abundance of _Hexagrammos decagrammus_ larvae in neuston (top) and bongo (bottom) tows from the winter 1979 OCSEAP plankton cruise.

Figure 146.--Distribution and abundance of _Hexagrammos stelleri_ larvae in neuston (top) and bongo (bottom) tows from the fall 1977 OCSEAP plankton cruise.

Figure 147.--Distribution and abundance of _Hexagrammos stelleri_ larvae in neuston tows from the spring 1978 OCSEAP plankton cruise.

Figure 148.--Distribution and abundance of _Hexagrammos stelleri_ larvae in neuston tows from the summer 1978 OCSEAP plankton cruise.

Figure 149.--Distribution and abundance of _Hexagrammos stelleri_ larvae in neuston (top) and bongo (bottom) tows from the fall 1978 OCSEAP plankton cruise.

Figure 150.--Distribution and abundance of _Hexagrammos stelleri_ larvae in neuston tows from the winter 1979 OCSEAP plankton cruise.

Figure 151.--Distribution and abundance of _Ophiodon elongatus_ larvae in neuston tows from the summer 1978 OCSEAP plankton cruise.

Figure 152.--Distribution and abundance of _Pleurogrammus monopterygius_ larvae in neuston (top) and bongo (bottom) tows from the fall 1977 OCSEAP plankton cruise.

Figure 153.--Distribution and abundance of _Pleurogrammus monopterygius_ larvae in neuston tows from the spring 1978 OCSEAP plankton cruise.

Figure 154.--Distribution and abundance of _Pleurogrammus monopterygius_ larvae in neuston (top) and bongo (bottom) tows from the fall 1978 OCSEAP plankton cruise.

Figure 155.--Distribution and abundance of _Pleurogrammus monopterygius_ larvae in neuston (top) and bongo (bottom) tows from the winter 1979 OCSEAP plankton cruise.

Figure 156.--Distribution and abundance of _Anoplopoma fimbria_ larvae in neuston tows from the summer 1978 OCSEAP plankton cruise.

Figure 157.--Distribution and abundance of _Hemilepidotus_ spp. larvae in neuston (top) and bongo (bottom) tows from the fall 1977 OCSEAP plankton cruise.

Figure 158.--Distribution and abundance of _Hemilepidotus_ spp. larvae in neuston (top) and bongo (bottom) tows from the spring 1978 OCSEAP plankton cruise.

Figure 159.--Distribution and abundance of _Hemilepidotus_ spp. larvae in neuston tows from the summer 1978 OCSEAP plankton cruise.

Figure 160.--Distribution and abundance of _Hemilepidotus_ spp. larvae in neuston (top) and bongo (bottom) tows from the fall 1978 OCSEAP plankton cruise.

Figure 161.--Distribution and abundance of _Hemilepidotus_ spp. larvae in neuston (top) and bongo (bottom) tows from the winter 1979 OCSEAP plankton cruise.

Figure 162.--Distribution and abundance of _Hemilepidotus hemilepidotus_ larvae in neuston tows from the summer 1978 OCSEAP plankton cruise.

Figure 163.--Distribution and abundance of _Hemilepidotus jordani_ larvae in neuston tows from the summer 1978 OCSEAP plankton cruise.

Figure 164.--Distribution and abundance of _Bathymaster_ spp. larvae in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.

Figure 165.--Distribution and abundance of _Bathymaster_ spp. larvae in neuston tows from the fall 1978 OCSEAP plankton cruise.

Figure 166.--Distribution and abundance of _Bathymaster_ spp. larvae in neuston tows from the winter 1979 OCSEAP plankton cruise.

Figure 167.--Distribution and abundance of Stichaeidae larvae in bongo tows from the spring (top) and summer (bottom) 1978 OCSEAP plankton cruises.

Figure 168.--Distribution and abundance of _Lyconectes aleutensis_ larvae in neuston tows from the spring 1978 OCSEAP plankton cruise.

Figure 169.--Distribution and abundance of Lyconectes aleutensis larvae in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.

Figure 170.--Distribution and abundance of Ammodytes hexapterus larvae in neuston (top) and bongo (bottom) tows from the spring 1978 OCSEAP plankton cruise.

Figure 171.--Distribution and abundance of Ammodytes hexapterus larvae in neuston tows from the summer 1978 OCSEAP plankton cruise.

Figure 172.--Distribution and abundance of Ammodytes hexapterus larvae in bongo tows from the winter 1979 OCSEAP plankton cruise.

Figure 173.--Distribution and abundance of Atheresthes stomias larvae in bongo tows from the winter 1979 (top) and spring 1978 (bottom) OCSEAP plankton cruises.

Figure 174.--Distribution and abundance of Glyptocephalus zachirus eggs in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.

Figure 175.--Distribution and abundance of Glyptocephalus zachirus larvae in bongo tows from the summer 1978 OCSEAP plankton cruise.

Figure 176.--Distribution and abundance of Hippoglossoides elassodon eggs in neuston (top) and bongo (bottom) tows from the spring 1978 OCSEAP plankton cruise.

Figure 177.--Distribution and abundance of Hippoglossoides elassodon eggs in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.

Figure 178.--Distribution and abundance of Hippoglossoides elassodon larvae in bongo tows from the summer 1978 OCSEAP plankton cruise.

Figure 179.--Distribution and abundance of Isopsetta isolepis eggs in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.

Figure 180.--Distribution and abundance of Isopsetta isolepis larvae in bongo tows from the summer 1978 OCSEAP plankton cruise.

Figure 181.--Distribution and abundance of Lepidopsetta bilineata larvae in bongo tows from the spring (top) and summer (bottom) 1978 OCSEAP plankton cruises.

Figure 182.--Distribution and abundance of Limanda aspera eggs in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.

Figure 183.--Distribution and abundance of Microstomus pacificus eggs in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.

Figure 184.--Distribution and abundance of Microstomus pacificus larvae in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.

Figure 185.--Distribution and abundance of Psettichthys melanostictus larvae in bongo tows from the summer 1978 OCSEAP plankton cruise.

Figure 186.--Distribution and abundance of Pleuronectidae eggs in neuston (top) and bongo (bottom) tows from the spring 1978 OCSEAP plankton cruise.

Figure 187.--Distribution and abundance of Pleuronectidae eggs in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.

Figure 188.--Lengths of Theragra chalcogramma larvae collected in bongo net tows from the OCSEAP plankton cruises from spring and summer 1978.

Figure 189.--Lengths of Mallotus villosus larvae collected in neuston net tows from the OCSEAP plankton cruises from fall 1977, fall 1978, winter 1979 and spring 1978.

Figure 190.--Lengths of Hexagrammos decagrammus larvae collected in neuston net tows from the five OCSEAP plankton cruises.

Figure 191.--Lengths of Hexagrammos lagocephalus larvae collected in neuston net tows from the OCSEAP plankton cruises from fall 1977 and fall 1978.

Figure 192.--Lengths of Hexagrammos octogrammus larvae collected in neuston net tows from the OCSEAP plankton cruises from fall 1977 and 1978 and winter 1979.

Figure 193.--Lengths of Hexagrammos stelleri larvae collected in neuston net tows from the OCSEAP plankton cruises from fall 1977 and 1978, winter 1979 and spring 1978.

Figure 194.--Lengths of Pleurogrammus monopterygius larvae collected in neuston net tows from the OCSEAP plankton cruises from fall 1977, spring and fall 1978 and winter 1979.

Figure 195.--Lengths of Hemilepidotus spp. larvae collected in neuston net tows from the five OCSEAP plankton cruises.

Figure 196.--Lengths of Lyconectes aleutensis larvae collected in neuston net tows from the OCSEAP plankton cruises in spring and summer 1978.

Figure 197.--Lengths of Ammodytes hexapterus larvae collected in bongo net tows (winter 1979 and spring 1978) and neuston net tows (summer 1978) from the OCSEAP plankton cruises.

Figure 198.--Lengths of Glyptocephalus zachirus larvae collected in bongo net tows from the OCSEAP plankton cruise from summer 1978.

Figure 199.--Lengths of Hippoglossoides elassodon larvae collected in bongo net tows from the OCSEAP plankton cruise from summer 1978.

Figure 200.--Lengths of Isopsetta isolepis larvae collected in bongo net tows from the OCSEAP plankton cruise from summer 1978.

Figure 201.--Lengths of Lepidopsetta bilineata larvae collected in bongo net tows from the OCSEAP plankton cruises from spring and summer 1978.

Figure 202.--Lengths of Microstomus pacificus larvae collected in bongo net tows from the OCSEAP plankton cruise from summer 1978.

Figure 203.--Lengths of Psettichthys melanostictus larvae collected in bongo net tows from the OCSEAP plankton cruise from summer 1978.

Figure 204.--Ranked abundance of common fish larvae in bongo catches from the five OCSEAP plankton cruises.

Figure 205.--Depth distribution with time of day of Hemilepidotus spp. larvae at stations D33A-L (Diel 1), fall 1977. n = numbers of larvae/100 m^3 caught in all nets at each station.

Figure 206.--Depth distribution with time of day of Pleurogrammus monopterygius larvae at stations D33A-L (Diel 1), fall 1977. n = numbers of larvae/100 m^3 caught in all nets at each station.

Figure 207.--Depth distribution with time of day of Hexagrammos decagrammus larvae at stations D33A-L (Diel 1), fall 1977. n = numbers of larvae/100 m^3 caught in all nets at each station.

Figure 208.--Depth distribution with time of day of Hemilepidotus spp. larvae at stations D35A-L (Diel 2), fall 1977. n = numbers of larvae/100 m^3 caught in all nets at each station.

Figure 209.--Depth distribution with time of day of Hemilepidotus spp. larvae at stations D45A-L (Diel 3), spring 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

Figure 210.--Depth distribution with time of day of Hexagrammos decagrammus larvae at stations D45A-L (Diel 3), spring 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

Figure 211.--Depth distribution with time of day of Ammodytes hexapterus larvae at stations D45A-L (Diel 3), spring 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

Figure 212.--Depth distribution with time of day of Theragra chalcogramma eggs at stations D63A-L (Diel 4), spring 1978. n = numbers of eggs/100 m^3 caught in all nets at each station.

Figure 213.--Depth distribution with time of day of Hemilepidotus spp. larvae at stations D63A-L (Diel 4), spring 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

Figure 214.--Depth distribution with time of day of Lyconectes aleutensis larvae at stations D63A-L (Diel 4), spring 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

Figure 215.--Depth distribution with time of day of Hexagrammos decagrammus larvae at stations D63A-L (Diel 4), spring 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

Figure 216.--Depth distribution with time of day of Ronquilus jordani larvae at stations D01A-L (Diel 5), summer 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

Figure 217.--Depth distribution with time of day of Bathymaster spp. larvae at stations D01A-L (Diel 5), summer 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

Figure 218.--Depth distribution with time of day of Sebastes spp. larvae at stations D01A-L (Diel 5), summer 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

Figure 219.--Depth distribution with time of day of Bathymaster spp. larvae at stations D69A-L (Diel 6), summer 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

Figure 220.--Depth distribution with time of day of Sebastes spp. larvae at stations D69A-L (Diel 6), summer 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

Figure 221.--Depth distribution with time of day of Microstomus pacificus eggs at stations D69A-L (Diel 6), summer 1978. n = numbers of eggs/100 m^3 caught in all nets at each station.

Figure 222.--Depth distribution with time of day of Pleurogrammus monopterygius larvae at stations D01A-G (Diel 7), fall 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

Figure 223.--Depth distribution with time of day of Hemilepidotus spp. larvae at stations D01A-G (Diel 7), fall 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

Figure 224.--Depth distribution with time of day of Leuroglossus schmidti eggs at stations D01A-G (Diel 7), fall 1978. n = numbers of eggs/100 m^3 caught in all nets at each station.

Figure 225.--Salinity (S) and temperature (T) profiles for stations D33A-L (Diel 1) and D35A-L (Diel 2), fall 1977. Bold lines represent average values (M) and fine lines represent the range during the 24 stations in these series.

Figure 226.--Salinity (S) and temperature (T) profiles for stations D45A-L (Diel 3), spring 1978. Bold lines represent average values (M) and fine lines represent the range during the 12 stations in this series.

Figure 227.--Salinity (S) and temperature (T) profiles for stations D63A-L (Diel 4), spring 1978. Bold lines represent average values (M) and fine lines represent the range during the 12 stations in this series.

Figure 228.--Salinity (S) and temperature (T) profiles for stations D01A-L (Diel 5), summer 1978. Bold lines represent average values (M) and fine lines represent the range during the 12 stations in this series.

Figure 229.--Salinity (S) and temperature (T) profiles for stations D69A-L (Diel 6), summer 1978. Bold lines represent average values (M) and fine lines represent the range during the 12 stations in this series.

Figure 230.--Salinity (s) and temperature (T) profiles for stations D01A-G (Diel 7), fall 1978. Bold lines represent average values (M) and fine lines represent the range during the 7 stations in this series.

ABSTRACT

From fall 1977 through winter 1979 five offshore cruises were conducted over the continental shelf off Kodiak Island to characterize the zooplankton communities of the area with emphasis on the meroplanktonic stages of species of commercial importance; plankton and hydrographic data were collected at about 90 stations during each cruise. Results concerning decapod larvae obtained from plankton samplings during twelve 2-week cruises in four of the major bays on the eastern side of Kodiak and Afognak islands are also reported. Several types of plankton tows were made to investigate vertical-diel distributions as well as seasonal and geographic distributions and abundances.

The area was found to be complex hydrographically with offshore parts strongly influenced by the Alaska Stream and inshore parts by the Kenai Current in addition to the effects of local factors such as winds, bathymetry and freshwater inputs. Seasonal changes in hydrography were pronounced and reflected in plankton distribution.

Among the invertebrate zooplankton studied, emphausiids showed a clear relationship to seasons and hydrography. Total plankton volumes were highest in summer in all regions of the study area.

Decapod larvae were present primarily in spring and summer and were much more abundant in bays of the Kodiak area than offshore. Among the inshore bays sampled, Kiliuda Bay had highest abundances of decapod larvae; offshore, the southernmost subarea produced concentrations of only about half of what the other subareas did. The relative abundance of the various taxa of decapod larvae did not reflect well the apparent abundance of adults in the area.

Eggs and larvae of fishes were found year-round, and several species were primarily neustonic (at the sea surface). All parts of the study area were used as spawning and nursery grounds for various species of fish.

To assess the importance of this area to the reproduction and abundance of the species we studied, comparisons with their distributions in other areas must be made.

INTRODUCTION

The continental shelf off Kodiak Island supports large fisheries for several species of finfish, shrimps and crabs. As this area supports these populations in numbers sufficient for commercial harvest, it is clearly an area of generally abundant life and high biological productivity. The possibility of exploring for and extracting petroleum from the Kodiak Island shelf area has caused concern because of potential damage to this rich marine ecosystem.

Activities associated with exploration, development, and transportation of petroleum and petroleum by-products in outer continental shelf waters could pose significant hazards to the fauna of the nearshore marine environment (Malins, 1977; Wolfe, 1977). Assessment of the impact of such activities or predictions of the effects of petroleum products on the marine ecosystem require some reference point or "baseline" from which attempts to measure changes can be made.

Purpose and Scope of the Study

To establish such a baseline, the Outer Continental Shelf Environmental Assessment Program (OCSEAP) of the National Oceanic and Atmospheric Administration (NOAA), funded by the Bureau of Land Management, initiated in 1977 a multidisciplinary baseline study of the biology of the nearshore zone of Kodiak Island, Alaska. At that time significant gaps existed in the knowledge of the temporal and spatial changes in the composition of planktonic organisms of ecological or economical importance in the Kodiak Island shelf area. It was felt that a critical need in attempts to evaluate the potential impact of petroleum development on the early life history of important components of the marine ecosystem was an evaluation of which species are where, in what abundance, and during what periods their egg and larval stages are present. However, in addition, an evaluation of the food web that might indicate critical times or areas where contamination could severely impact lower and upper trophic level production and year class success of species, particularly those that are or support present or potential commercial fisheries, was also considered important.

The young of many species of fish in the Kodiak Island shelf area are neustonic, that is, they occur in the upper few centimeters of the water column as eggs, larvae or juveniles (Dunn et al., MS 1979). This surface layer is particularly vulnerable to contamination since oil spills leave residues at the sea surface which are dispersed widely from the site of the spill. Laboratory studies have shown the extreme sensitivity of early life history stages of fishes to oil and its components (Mironov, 1969; Struhsaker et al., 1974; Mazmanidi and Bazhashvili, 1975). Hence, there is importance in knowing the seasonal and spatial distribution of meroplanktonic species in waters contiguous to Kodiak Island.

One part of the Kodiak Island "food web" study, that reported here (OCSEAP RU551), consisted of five extensive offshore plankton surveys conducted from fall 1977 through winter 1979 with emphasis on determining the distribution and abundance of eggs and larvae of finfish, of larvae of shrimp and crab, and of euphausiids, all of which are planktonic components of economic importance. A parallel study of these planktonic components in bays and estuaries of Kodiak Island, was conducted simultaneously by the Fisheries Research Institute, University of Washington (OCSEAP RU553) (Rogers et al., MS 1979b). Results concerning shrimp and crab larvae from these studies are reported here.

The objectives of RU551 were to: (1) determine seasonal composition, distribution, and apparent abundance of major life-stages of selected planktonic taxa, including fish eggs and larvae, shrimp and crab larvae, and euphausiids; (2) examine observed biological distributions in relation to bathymetry and available hydrographic data; and (3) compare the abundance of planktonic organisms in nearshore, midshelf, and slope waters.

Plankton studies can provide a wealth of information about marine communities, particularly about early life history stages of larger animals which are often the stages most vulnerable to perturbations of the environment. The information presented here provides the first data on the distributions of ichthyoplankton and decapod larvae of the Kodiak Island shelf area sufficient for use as baseline data; these data can also be used to infer much about the life history and ecology of early and adult stages of these organisms. Should development of petroleum resources in the Kodiak Island shelf area occur, the data provided here will assist in evaluating the effects of environmental perturbation, and in any case, will assist resource administrators in developing strategies to manage the biological resources of this area.

Description of the Study Area

The offshore study area, generally bounded by latitudes 55°-59°N and longitudes 148°-156°W, covers about 68,000 km^2 and encompasses the continental shelf mainly southeast of Kodiak Island from approximately the 40 m contour to the 2,000 m contour (Figure 1). Stations sampled during the study extended southwestward from Portlock Bank to the Trinity Islands. The inshore study area is described by Rogers et al., (MS 1979b).

The topography of the Kodiak Island shelf area is characterized on the eastern side by a rugged configuration, consisting of relatively shallow banks separated by troughs normal to the shelf edge. The shelf is rather wide, ranging from about 69-95 km, and is cut by four major troughs: Amatuli, Stevenson, Chiniak, and Kiliuda (Figure 1). These troughs, ranging in depth from about 110-240 m, are separated by four banks: Portlock to the east, followed to the west by North, Middle, and South Albatross banks, whose depths range from about 49-91 meters. In general, the bottom is rugged and uneven, and substrate composition changes rapidly within short distances; bottom types range from soft mud and sand to hard rock. On the northwestern side of Kodiak Island the dominant feature is Shelikof Strait through which water flows from the head of the Gulf of Alaska and Cook Inlet. This latter area, the source of large volumes of fresh water moving seaward is a notable feature of the circulation near Kodiak Island area (Science Applications, Inc., MS 1979b).

The Kodiak Island shelf area is an important region of commercial fishing. Important fisheries, both domestic and foreign, are directed toward Pacific halibut Hippoglossus stenolepis; various other flatfishes; Pacific cod, Gadus macrocephalus; walleye pollock, Theragra chalcogramma; and rockfishes, Sebastes spp. Important invertebrate species which are commercially exploited include pandalid shrimps, and several species of crabs and scallops (Ronholt et al., MS 1978).

Current Knowledge of Hydrography

The continental shelf along the western side of the Gulf of Alaska trends essentially southwest/northeast for over 1,500 km. When considering the occurrence and distribution of plankton in a limited portion, such as east of Kodiak Island, one must consider temporal changes in flow upon which residence times of local forms and transit times of advected populations partially depend, as well as horizontal and vertical distributions of water properties that could influence feeding and behavioral movements.

The acquisition of indirect and direct measurements on flow in this area has increased steadily in recent years. Over a century ago Davidson (1869) in a synthesis of ship reports noted that a westward drift along the coast of the Gulf of Alaska attained speeds of 75 cm/sec (1 1/2 kn). A half century ago McEwen et al. (1930) found that although a westward geostrophic flow of 50 cm/sec did occur in this area, it was restricted to a narrow band along the shelf edge and flow shoreward of the shelf edge was considerably reduced. Recently Favorite and Ingraham (1977) have shown the continuity of this flow along the shelf edge east of Kodiak Island and reported that speeds of nearly 100 cm/sec occur.

However, recoveries from extensive drift bottle releases in the northeast Pacific Ocean by Thompson and Van Cleve (1936) in the 1930's suggested a highly organized westerly flow inshore along the coast at the head of the Gulf (Ingraham et al., MS 1976) and recent satellitetracked drift buoys have indicated speeds of 50 cm/sec close inshore east of Prince William Sound (Royer et al., 1979). Recently Ingraham (1979) has shown that discharge in this area from the Copper River can be traced seaward and southwestward along the shelf edge east of Kodiak Island; and, Schumacher and Reed (MS 1979) have identified the Kenai Current that occurs west of Prince William Sound where it flows southwestward along the coast of the Kenai Peninsula (at times in excess of 100 cm/sec) and branches into Cook Inlet and Shelikof Strait. The shelf area under investigation lies primarily between these two flows and, as indicated by Favorite and Ingraham (1977), and subsequent results of OCSEAP cruises, moored current meter, and drifting buoy studies (Royer, MS 1977; Schumacher et al., 1978; Schumacher et al, 1979; and Science Applications, Inc., MS 1979b) is characterized by weak eddies and variable flow (Figure 2). At this time it is difficult to ascertain any basic order to flow here other than that related to local winds and bathymetry.

Basic water properties in the area are perhaps better known although these data are also fragmentary. Ingraham et al. (MS 1976) presented monthly mean sea surface temperatures off Kodiak Island from 1950-75 that ranged from 0.5-12.0^{o}C, and positive or negative anomalies of 3.0^{o}C for individual months occurred frequently. Sporadic data from widely spaced lines of stations off Kodiak Island obtained during oceanic investigations stem largely from 1929 (Dodimead et al., 1963; Favorite et al., 1976) and provide some indication of seasonal changes in the water column; but, the first extensive, quasi-synoptic investigation of shelf conditions east of Kodiak Island was conducted in spring 1972 (Favorite and Ingraham, 1977). Although sea surface temperatures largely reflected a general air-sea equilibrium, surface salinities clearly indicated the inshore dilution as well as the extensive continuity of a midshelf maxima and a shelf edge minima, the latter subsequently traceable to the Copper River discharge.

Winter overturn in the water column extended to 75-100 m, and thus isothermal and isohaline conditions extended from surface to bottom over essentially all the banks. In the troughs, all of which exceed 100 m in depth, temperatures were higher and continuity with the relatively permanently 5.0°C stratum that exists at about 150-300 m in the oceanic regime was apparent. Thus, four horizontal regimes (coastal, midshelf, shelf edge and oceanic) and four horizons or layers (surface, thermocline, temperature-minimum and temperature-maximum) were observed.

Current Knowledge of Plankton

Very little was known about the seasonal composition of plankton in waters contiguous to Kodiak Island prior to initiation of the present OCSEAP sponsored studies. Although several wide-ranging plankton sampling cruises have been conducted in the general area by a number of organizations, both foreign and domestic, few have concentrated on studies of the Kodiak Island shelf area specifically; a brief historical account of studies pertinent to the Kodiak Island shelf area follows and is summarized in Table 1.

The International Pacific Halibut Commission conducted ichthyoplankton sampling in the Gulf of Alaska from 1926-34 (Thompson and Van Cleve, 1936). Their station grid included a number of stations in the Kodiak Island area, but only the occurrence of the eggs and larvae of Pacific halibut, Hippoglossus stenolepis, were reported. Eggs were found southeast of Chiniak Bay, but the majority were found east of 150°W, where sampling was more intense. Early larvae were distributed offshore on the southeast side of Kodiak Island and late larvae were apparently carried inshore to the western end of Kodiak Island and northwest of Trinity Islands (Thompson and Van Cleve, 1936).

In 1955, an international cooperative study of the North Pacific Ocean, called NORPAC, was conducted (North Pacific Committee, 1960). Multidiscipline cruises by three nations (United States, Canada and Japan) were conducted aboard 19 research vessels from 14 institutions. Only the R/V Brown Bear (University of Washington) sampled waters near Kodiak Island; ten stations were occupied from the southwest end of Kodiak Island northeastward and through Shelikof Strait using a Clark-Bumpus sampler but detailed data were not reported.

The Fisheries Research Board of Canada collected zooplankton samples in the northeast Pacific Ocean, north of 45°N and west to 160°W, from 1956-1964 but only a few stations over slope waters were occupied near Kodiak Island. LeBrasseur (MS 1965a) reported the results of vertical tows made with NORPAC nets from these cruises and he included figures showing wet weight (g/1000 m^3) of total zooplankton, copepods, euphausiids, amphipods, chaetognaths, and pteropods for all years surveyed; in addition, the size and abundance of three species of copepods, three species of euphausiids, one species of pteropod, and one species of chaetognath were reported for 1962-63. LeBrasseur (MS 1970) also reported on the identification of fish larvae collected during these surveys in 1956-59--rockfishes, Scorpaenidae, and searchers, Bathymasteridae, captured primarily during the summer, were the dominant forms found in waters near Kodiak.

Broad scale exploratory plankton sampling was conducted in the North Pacific Ocean from 1956-1977 by the Faculty of Fisheries, Hokkaido University, Japan (Faculty of Fisheries, Hokkaido University, 1979). Only a few stations were sampled in waters near Kodiak Island and, other than station data, results were not routinely reported.

Aron (MS 1960, 1962) reported the results of broad surveys of midwater plankton and nekton in the North Pacific Ocean conducted by the University of Washington in 1957 and 1958. Again, only a few stations were sampled in the vicinity of Kodiak Island.

In the early 1960's, Soviet researchers conducted plankton surveys off Kodiak Island directed toward Pacific Ocean perch, *Sebastes alutus*. Lisovenko (1964) described the catches of rockfish larvae (assumed to be *S. alutus*). *Sebastes* larvae were found over the slope in the Yakutat, Kodiak, Shumagin, and Unimak areas at concentrations up to 120/m^2 in April and May over depths of 200-700 m; other species of fish larvae collected during these surveys were not reported.

In April and May 1972, the Northwest and Alaska Fisheries Center (NWAFC) conducted a multi-discipline survey in waters contiguous to Kodiak Island. Ichthyoplankton composition was reported by Dunn and Naplin (MS 1974). There were 23 kinds of fish larvae and 12 kinds of fish eggs captured. Eggs of walleye pollock, *Theragra chalcogramma*, which accounted for 97.2% of all fish eggs captured, were most abundant just west of Kodiak Island (near 56°30'N, 156°20'W). The largest catch of walleye pollock eggs was 104,645/10 m^2 of sea surface. Eggs of flathead sole, *Hippoglossoides elassodon*, occurred at 31 stations, primarily inside the 200 m contour. Rex sole, *Glyptocephalus zachirus*, eggs occurred at eight stations between the 200-2,000 m isobaths. Walleye pollock were also the predominant larvae, constituting 62% of the total catch. They occurred at 21 stations scattered throughout shelf and slope waters; the largest catch (standardized catch of 12,118/10 m^2 of sea surface) occurred southwest of the Trinity Islands (at 55°51'N, 154°56'W) over 327 m of water. Sand lance, *Ammodytes hexapterus*, larvae accounted for 11.3% of the total catch, followed by sculpins, Cottidae, 7.5% and rock sole, *Lepidopsetta bilineata*, 6.9%. The occurrence and distribution of monstrillid copepods for this cruise was reported by Threlkeld (MS 1973, 1977). Favorite et al. (MS 1975) described environmental conditions observed during this cruise.

In 1975 and 1976, Damkaer and Dey (MS 1977) sampled zooplankton in the Gulf of Alaska, Prince William Sound and Lower Cook Inlet. Two stations in Stevenson Entrance were sampled a total of ten times from April-August, 1976. They reported the composition, distribution and abundance of a variety of invertebrate taxa but very little ichthyoplankton data.

Gosho (1977) obtained plankton samples in certain estuaries of Kodiak Island while studying the food habits of juvenile pink salmon. Harris and Hart (MS 1977) studied the pelagic and nearshore fishes in three bays (Ugak, Kaiugnak, Alitak) on the east and south coasts of Kodiak Island but their sampling equipment (tow net, herring trawl, beach seine and try net) had mesh sizes too large to sample ichthyoplankton quantitatively. They reported, however, the occurrence of "larval" fishes and based on length frequency data, the dominant larvae captured were hexagrammids (greenlings) and cottids (sculpins).

Dunn et al. (MS 1979) summarized the preliminary results of two OCSEAP supported plankton cruises in Kodiak Island waters in fall 1977 and spring 1978. In addition to depicting the distribution of fish eggs and larvae collected in these two surveys, they included preliminary plots of the distribution of four species of euphausiids, natantid and reptantid larvae, and three other zooplankton taxa. This report also represents the first detailed description of occurrence, distribution, and abundance of shrimp and crab larvae in the Kodiak Island region.

Rogers et al. (MS 1979a) summarized preliminary ichthyoplankton data collected in March-August 1978, during OCSEAP sponsored studies of four Kodiak Islands bays: Izhut, Kalsin-Chiniak, Kiliuda and Kaiugnak. They identified 20 families, 49 genera, and 31 species of fish eggs and larvae and subsequently reported data collected on a total of 12 cruises in these four bays from March 1978, to March 1979 (Rogers et al., MS 1979b).

MATERIALS AND METHODS

A series of five offshore cruises was conducted to sample plankton of the Kodiak Island shelf area (Table 2). The grid pattern of 88 stations (Figures 3-7) that extended seaward to the continental slope was modified from a stratified to a systematic centric design (Milne, 1959) after completion of the first two cruises, but occasionally, planned stations were deleted due to inclement weather or operational difficulties. On the first four cruises, diel stations were taken in addition to the regular grid stations (Figure 8). During fall 1978, additional bay stations, designated by RU553, were sampled due to inclement weather offshore.

Plankton was collected at each station using several types of nets and towing schemes to investigate depth distribution and diel migrations as well as large scale areal distribution. The use of neuston tows allowed identification of the near surface components of the plankton and integrated tows (0.6 m bongo nets) allowed estimation of biomass and determination of areal distribution of organisms. Discrete depth sampling (Tucker trawl) enabled investigation of vertical distribution and diel migration. During fall 1977 and 1978, replicate tows were made at selected stations to assess sampling variability.

To evaluate the importance of the inshore areas to recruitment of shrimp and crab larvae, zooplankton were sampled during twelve 2-week cruises (I to XII) in four bay systems along the southern and eastern shores of Kodiak and Afognak Islands by RU553 (Table 3, Figure 9). Initially, five stations were located in the central and inner portions of Izhut, Kalsin, Kiliuda and Kaiugnak Bays. Three additional stations were added to the Izhut and Kiliuda station patterns to increase sampling density in the inner portions of these bays (see Rogers et al., MS 1979b, for details). All stations within bays were sampled during each 2-week survey period, including diel observations at one of the stations in both Izhut and Kiliuda Bays. The station sampling pattern and diel observations were expected to indicate spatial occurrence and vertical migration, respectively, of decapod larvae. Diel sampling was also expected to identify changes in species diversity and abundance, by depth zone and time of day. The most seaward stations sampled during the inshore surveys (Rogers et al., MS 1979b) corresponded with nearshore sampling locations of the offshore plankton surveys of RU551.

Field Gear and Station Procedures

Field sampling generally followed standard MARMAP procedures (Smith and Richardson, 1977). Three types of gear were routinely used at grid stations: (1) a Sameoto sampler (Sameoto and Jaroszynski, 1969) with a mouth opening of 0.3 m high by 0.5 m wide and a 0.505 mm mesh net, for collecting neuston samples; (2) an aluminum MARMAP bongo sampler, 0.6 m inside diameter, with one net of 0.505 mm mesh and the other of 0.333 mm mesh; and (3) a 1.0 m square mechanical opening-closing Tucker trawl (Clark, 1969) with three nets of 0.505 mm mesh.

At each regular grid station a neuston tow was taken first, followed by a CTD cast, a double oblique bongo tow, and at certain stations a Tucker trawl set. The neuston net was lowered until the frame was submerged approximately halfway while maintaining a vessel speed of ca 2.0 knots (1.03 m/sec); it was then towed for 10 minutes. The CTD was taken to near bottom, or over deeper water, to a maximum depth of 300-500 m (variable over the five cruises). Bongo nets were lowered at a rate of 50 m of wire per minute and retrieved at a rate of 20 m per minute, sampling from surface to within 5-10 m of the bottom, normally to a maximum depth of about 200 m. During lowering and retrieval, the ship's speed (approximately 2.0 knots, or 1.03 m/sec during the tow) was adjusted to maintain a 45° wire angle. Actual sampling depths varied, depending on wire angles and, during one cruise (Discoverer cruise 4DI78), angles were particularly unacceptable due primarily to vessel size (inability to adjust speed quickly) and frequent winch failures. At about half of the regular grid stations a Tucker trawl set was taken after the bongo tow. Specific net depths were chosen using various procedures during the five cruises. During the fall 1977 and spring 1978, two net depths were selected to include the upper mixed layer in one sample and from the sea bottom to the bottom of the thermocline in the other sample. When no thermocline was present, net depths were chosen to divide the water column in half. During the summer 1978 the same procedure was used for stations with bottom depths greater than 100 m. At relatively shallow stations the upper stratum from about 28 m to the surface was sampled in one net and below 28 m to about 5 m above bottom was sampled in the other net. In fall 1978 and winter 1979 the water column was arbitrarily divided at 42 m to sample from 0-42 m in one net and from 5 m above bottom to 42 m in the other net. The Tucker trawl was lowered at a rate of 40-50 m of wire per minute to the desired depth; the net was then tripped with a messenger and towed while being retrieved at a rate of 20 m per minute. Vessel speed and wire angles were maintained in the same way as for bongo tows.

Seven diel sampling series were conducted during the first four cruises. During each of these series, we sampled with both neuston nets and Tucker trawls, at regular intervals over a 24-hr period at a fixed geographical position. Neuston tows and Tucker trawl sets followed the same procedures used for grid stations although actual depths sampled by the Tucker trawl varied during the seven series. Diel series during fall 1977 and spring 1978 involved repetitive stations consisting of a neuston tow, CTD cast and a Tucker trawl set every 2 hours. Diel sampling with the Tucker trawl was designed to sample with one net from near bottom to the bottom of the thermocline (when present), and with the other net from the thermocline to the surface. When no thermocline was present, sampling was conducted to divide the water column in half, with one net sampling from near the bottom to mid-depth, and the other sampling from mid-depth to the surface. During summer 1978, an additional Tucker trawl was taken every 2 hours enabling more discrete depth coverage. One tow sampled two strata, 71 m to 28 m and 28 m to the surface, whereas a second tow sampled the stratum below 71 m (136-71 m at Diel 5 and 95-71 m at Diel 6). Tows were made every 4 hours during fall 1978 and the CTD casts were taken on every other station. Diel sampling again included two tows with the Tucker trawl. The first tow sampled from 200-40 m and from 40 m to the surface; the second tow sampled from 400-200 m and 200 m to the surface. Additionally, bongo tows were taken in replicate to monitor on station variability. Inclement weather forced cancellation of diel series during the winter cruise in 1979.

Times during diel series were recorded in GMT. Local sunrise and sunset was determined by changing GMT to local Kodiak time and adjusting for longitude, latitude, and day of month according to procedures outlined in NOAA Tide Tables

(National Ocean Survey, 1976-78). Stations taken within a half hour of sunrise or sunset were designated as R and S, respectively. Station times were based on the time recorded for neuston tows; i.e., the first haul taken on station.

Due to towing procedures and vessel characteristics, depths for the stations within a diel series often varied. Discussions (including Tables and Figures) are based on an average depth for all stations of a particular series.

The decapod larvae portions of this report include analyses of data from the Kodiak inshore plankton studies (RU553). Details on station sampling procedures for these studies are in Rogers et al. (MS 1979b).

Sample Processing

Plankton samples were preserved in the field in a 5% Formalin-seawater mixture buffered with sodium tetraborate and returned to NWAFC. Samples were then shipped to the sorting contractor (Texas Instruments, Inc., Dallas, Texas) for initial processing. The sorting contractor determined the settled volume (Kramer et al., 1972) and removed all fish eggs and larvae (i.e., samples were not split) from the neuston, 0.505 mm bongo, and Tucker trawl samples. Fish eggs and larvae were returned to NWAFC where they were identified to lowest taxon possible using standard procedures and life history stage was recorded.

Certain larval fishes were selected for length measurement (standard length to 0.1 mm) based on their abundance and economic value (i.e., capelin, *Mallotus villosus*; walleye pollock, *Theragra chalcogramma*; all greenlings, Hexagrammidae; sablefish, *Anoplopoma fimbria*; Irish lords, *Hemilepidotus* spp.; all pricklebacks, Stichaeidae, identified to type or species; Pacific sand lance, *Ammodytes hexapterus*; and flatfishes, Pleuronectidae). Length ranges reported herein were truncated to whole millimeters.

After settled volumes were determined, zooplankton from the 0.333 mm bongo net hauls was sorted to major categories (e.g., phylum, class, or order) from an aliquot of the total catch (ca 500 organisms) and enumerated by the sorting contractor. The shrimp and crab larvae from the aliquot were then sent to the NWAFC Kodiak Facility for analysis. The contractor then took a separate subsample to yield an aliquot containing approximately 200 adult euphausiids which he identified to species, enumerated, measured lengths (Ponomareva, 1963) and determined wet weights (Weibe et al., 1975). Tucker trawl catches were subsampled for ca 200 euphausiids which were handled as above. An additional subsample of about 500 organisms from the Tucker trawl sets was taken for separation of shrimp (Natantia) and decapod crab (Reptantia) larvae. Further subsampling as necessary was conducted at the NWAFC Kodiak Facility to provide adequate numbers of decapod larvae for analysis. Selected bulk samples (i.e., that portion remaining after removal of the 500 organism aliquot) were examined and either subsamples containing a minimum of 500 Natantia were obtained, or all Natantia and Reptantia were removed from the bulk samples. The resulting shrimp and crab larvae were identified from existing reference material to the most precise taxonomic category and life history stage possible, and enumerated.

All samples are maintained at NWAFC, Seattle Laboratory, except for decapod larvae which are at the NWAFC Kodiak Facility, and voucher specimens of identified taxa which have been deposited at the California Academy of Sciences.

Data Processing

Field and laboratory data were recorded on forms that were amenable to keypunching. After they had been examined for missing and obviously incorrect entries, field data were keypunched after each cruise. Some laboratory data were keypunched by the sorting contractor; some were recorded and keypunched inhouse. After the various data records from each cruise were keypunched, they were combined into a single file by station (Figure 10). Data were reduced and products generated from this file. Data output included a tape for each cruise for NODC (National Oceanographic Data Center) in the "zooplankton-024" format. Data products to assist in analysis and reporting include listings of catches by station and species, summaries of catches on each cruise by species and gear type, geographic plots of distribution of plankton by taxon, life history stage and collecting gear, and length frequency and abundance summaries by station and selected combinations of stations. Hydrographic data were processed by PMEL (Pacific Marine Environmental Laboratory) and have not yet been incorporated into our data base.

Data Analysis

Grid Stations

Numbers of organisms in each life history stage and taxon in the aliquot (or whole sample) from each tow were recorded. These numbers were converted to biomass or density figures as follows.

Biomass (number/10 m^2):

neuston = $n \times d \times 10/(aliq \times h \times w \times \ell)$	$h = 0.15,\ w = 0.5$
bongo = $n \times d \times 10/(aliq \times (aper)^2 \times \ell \times \ell)$	$aper = 0.3$
Tucker = $n \times d \times 10/(aliq \times h \times w \times \ell)$	$h = 1.0,\ w = 1.0$

Density (number/1000 m^3):

neuston = $n \times 1000/(aliq \times h \times w \times \ell)$	$h = 0.15,\ w = 0.5$
bongo = $n \times 1000/(aliq \times (aper)^2 \times \ell \times \ell)$	$aper = 0.3$
Tucker = $n \times 1000/(aliq \times h \times w \times \ell)$	$h = 1.0,\ w = 1.0$

where

- n = number of organisms in sample
- aliq = proportion of total sample examined
- aper = radius of net opening in m
- h = effective fishing height of net opening in m
- w = width of net opening in m
- ℓ = length of tow in m (computed from flowmeter readings)
- d = depth of water sampled

Biomass figures for each taxon from the neuston and bongo catches were used to plot geographic distributions for comparisons of different areas and seasons. Biomass figures for the bongo catches were multiplied by the area of sea surface represented by each station, and these figures were summed to estimate the total number of organisms of each taxon present in the study area at the time of the cruise.

Density figures from the neuston and Tucker catches for each taxon were used to investigate the depth distribution of organisms as a function of time of day and other variables. Mean density for each cruise-taxon-stage-net combination was computed by dividing the sum of the densities by the number of occurrences.

Samples only from certain gear types were sorted for decapod larvae. A list of data sets for the various analyses of shrimp and crab larvae are presented in Table 4.

For the invertebrate (excluding decapods) and ichthyoplankton analyses the Kodiak Island shelf area was divided into several offshore regions including nearshore, midshelf and slope regions, as well as regions featuring banks and troughs to enable comparisons of catches of plankton in various bathymetric/ecologic zones. Stations included in each of these regions are listed in Table 5.

For the comparative analysis of shrimp and crab larvae the shelf study area was divided into four offshore subareas (Figure 11) which were identified as follows:

Portlock subarea -- continental shelf regions north of any inshore sampling areas, containing shelf stations north of 58^{o} 10'N latitude and including Portlock Bank.

Marmot subarea -- continental shelf regions offshore of Izhut and Chiniak Bays containing shelf stations south of 58^{o} 10'N latitude and north of 57^{o} 30'N latitude, including Stevenson Trough, North Albatross Bank, and inner Chiniak Trough.

Albatross subarea -- continental shelf regions offshore of Kiliuda and Kaiugnak Bays containing shelf stations south of 57^{o} 30'N latitude and north of 56^{o} 50'N latitude, including outer Chiniak Trough, middle Albatross Bank, and inner Kiliuda Trough.

Sitkinak subarea -- continental shelf regions south of any inshore sampling areas, containing shelf stations south of 56^{o} 50'N latitude, and including outer Kiliuda Trough, south Albatross Bank and stations near the Trinity Islands.

Diel Series

For the diel series abundances of fish eggs and larvae are based on the number of larvae or eggs per 100 m^3 (ten times the density figures as calculated in the previous section). Catches of a taxon in the various nets at a station are expressed as a per cent of the combined catch (per 100 m^3) of all the nets at the station.

Abundances for all decapod larvae diel information and figures for depth distribution are based on numbers of larvae per 1000 m^3 and per cent of total caught per depth or time interval. This information was obtained from only a few locations. In the offshore subareas, only two series during spring (Diel 3 and 4) and summer (Diel 5 and 6) contained suffficient numbers of shrimp and crab larvae for detailed analyses. Additionally, information available for the summer studies did not include samples from the middle stratum (Diel 5: 28-71 m, Diel 6: 29-71 m). In the inshore bay regions, diel-depth data were obtained from one station in Izhut and Kiliuda Bays during most of the 12 inshore cruises. In contrast to offshore diel sampling methodology (i.e., sampling two or three depth strata during twelve 2-hour time intervals), inshore information was obtained from five discrete depths (10 m, 30 m, 50 m, 70 m, and 90 m) at 12-hour intervals. Further descriptions of inshore sampling methodology are found in Rogers et al. (MS 1979b).

Salinity and temperature profiles (except for Diel 1 and 2) were produced by plotting data for all observations in a diel series and graphically determining the average and a range of values at each depth. During the fall 1977 cruise (Diel 1 and 2), the CTD did not operate properly (see Hydrography). For this cruise the salinity profile was based on analysis as above of 20 salinity profiles that were taken within 30 days and within $\pm$ 1° (latitude and longitude) of the two diel series. These data were taken with a CTD during research cruises aboard the R/V Discoverer (Schumacher et al., 1979). The temperature profile was determined in the same way except that a further comparison was made with the actual XBT data taken at our stations.

RESULTS AND DISCUSSION

Data collected during the five cruises in the Kodiak Island shelf area will be presented under the following topics: 1) hydrography, 2) invertebrate zooplankton, 3) decapod larvae (from bay sampling as well as offshore), and 4) ichthyoplankton. Because sampling was conducted at least once in each season, an annual cycle of hydrographical and biological features can be derived from these results. Fall sampling was conducted during both 1977 and 1978, so some year-to-year differences in measured parameters can be seen. In general the Kodiak shelf is found to be a complex environment which is influenced by several features outside the area. Offshore from the Kodiak shelf, the Alaska Stream impinges on the area with a characteristically oceanic plankton and relatively warm saline water. Some influence of the stream is seen in shelf waters at the east and north end of Kodiak Island, in both hydrographic and planktonic distributions. Nearshore several large bays, where generally cooler and fresher water is found, influence conditions on the shelf. In addition some planktonic forms found in nearshore areas have centers of abundance in the bays. West of the island the water moving through Shelikof Strait strongly affects conditions. The midshelf area off Kodiak contains several large banks with troughs between them (Figure 1). These topographic features lead to complex mixing of water masses and distribution of plankton. The following sections detail our contributions to an understanding of the waters of this area.

Hydrography

Fall 1977

Circulation and hydrography near Kodiak Island in September-November 1977, was discussed by Schumacher et al. (1979). We use these data herein because of CTD failures during cruise 4MF77.

Surface temperatures in October-November 1977 ranged from only 7.0°-8.0°C in the area covered by the cruise track (Figure 12). Water over the banks was relatively cool at 7.0°C, and water of this temperature extended out over the slope. Water to the northeast was warmer than to the southwest, but observations in the latter area were made two to three weeks later than those to the east and during a time when seasonal cooling was occurring (Schumacher et al., 1979). Surface salinity increased uniformly with distance from shore, ranging from 31.5°/oo nearshore to 32.5°/oo in slope waters (Figure 12). Temperatures at 50 m (Figure 13) indicated relatively warm (7.0°C) water over banks with a sharp decrease to 5.0° or 6.0°C over the slope. Salinity at 50 m (Figure 13) increased from inshore to offshore. Bottom (or 200 m) temperatures decreased uniformly from 7.0°C over banks inshore to 4.0°C over the slope (Figure 14). Bottom (or 200 m) salinity increased from 32.0°/oo over banks to 33.5°/oo over the slope (Figure 14). Tongues of relatively high salinity water (33.0°/oo) extended into Kiliuda, Chiniak and Stevenson Troughs at depth.

Schumacher et al. (1979) discussed the general oceanographic conditions observed in the fall 1977. The observed transport in the Alaska Stream off Kodiak Island was approximately 12 x 10^6 m^3 s^{-1}. They noted that weak southwestward flow extended onto the continental shelf and found gyrelike features present in the troughs. These authors found essentially homogeneous water over banks.

Spring 1978

Observations during the spring cruise (March-April 1978) showed 4.0°C surface water over North Albatross Bank (Figure 15), nearshore south of South Albatross Bank, and in the vicinity of the Trinity Islands. Warmer water near 4.5°C covered portions of Kiliuda Trough and Middle Albatross Bank. A pocket of 5.0°C water covered portions of Portlock Bank and Stevenson Trough. The 5.0°C isotherm generally paralleled the shelf break, but a tongue of warmer (5.5°-6.0°C) water was present southeast of North Albatross Bank. Surface salinities (Figure 15) were 32.2°/oo nearshore with the 32.4°/oo contour extending from near the shelf break over South Albatross Bank to shore over Middle Albatross Bank, thence southeasterly over Northern Albatross Bank. The 32.6°/oo contour virtually followed the 2000 m contour. Temperature and salinity at 50 m were essentially the same as surface measurements. Bottom (or 200 m) temperature (Figure 16) contours indicated that the 5.0°C isotherm roughly paralleled the 200 m contour; except that colder (<4.0°C) water intruded from offshore to North Albatross Bank. Bottom (or 200 m) salinity contours (Figure 16) indicated freshened (<32.4°/oo) waters encompassing much of the nearshore zone to midshelf with more saline water (up to 33.8°/oo) offshore. Less saline (<32.4°/oo) water also covered North Albatross Bank. The 33.2°/oo isohaline generally coincided with the slope break.

Schumacher et al. (1978) discussed hydrographic conditions in the Kodiak Island shelf area from March 2-10, 1977. They found two subsurface cores of warm (>6.0°C) saline (~32.5°/oo) water, one near the shelf break and one extending northwestward from the shelf break into Amatuli Trough. The 5.0°C bottom (or 200 m) isotherm in 1977 paralleled the shelf break; water warmer than 5.0°C (bottom or 200 m depth) enveloped parts of Stevenson Trough and Portlock Bank. A tongue of higher salinity (32.6-33.0°/oo) water at bottom (or 200 m) extended into Stevenson Trough.

Summer 1978

Surface temperatures in June-July 1978 showed a nearly uniform decrease from 9.0°C over slope waters to 7.0°C nearshore with most of the midshelf area covered by 8.0°-8.5°C water (Figure 17). Surface salinities decreased from 32.8°/oo over the slope to 32.2°/oo nearshore (Figure 17); a very broad area over the shelf was a uniform 32.2-32.4°/oo. Temperatures at 50 m depth (Figure 18) indicated pockets of 7.0°C water over Kiliuda Trough, Middle and North Albatross banks, and just off the slope from Middle Albatross Bank, while temperatures over most of the shelf ranged from 6.0°-6.5°C. Salinity at 50 m depth (Figure 18) was 32.4°/oo over broad areas of the shelf. Temperatures at the bottom (or 200 m) also reflected pockets of 7.0°C water over Kiliuda Trough, and Middle and North Albatross Banks, while the rest of the area was cooler down to 4.0°C offshore with 5.0°-6.0°C commonly found over the shelf (Figure 19). Bottom (or 200 m) salinity increased from about 32.4°/oo nearshore to about 33.8°/oo over the slope. The pockets of 7.0°C bottom water coincided with salinity of 32.4°/oo (Figure 19).

Fall 1978

In October-November 1978 surface temperatures over the shelf region ranged primarily between 7.0°-8.0°C with slope waters ranging between 6.0°-7.0°C (Figure 20). An area of relatively warm (8.0°C) water was present north of Portlock Bank. Surface salinity (Figure 20) increased uniformly from 32.0°/oo nearshore to 32.6°/oo over the slope. At 50 m depth, temperatures were 7.0°C over midshelf, decreasing to less than 7.0°C toward the slope region (Figure 21). Water at 50 m depth was, in general, more saline offshore than nearshore (Figure 21). Bottom (or 200 m) temperatures decreased from 7.0°C nearshore to 4.0°C over the slope, with water 6.0°-7.0°C extending into Stevenson Trough and across Portlock Bank (Figure 22). A pocket of colder (5.0°C) water intruded north of Portlock Bank. Salinity at bottom (or 200 m) increased from 32.5°/oo nearshore to 33.5°/oo over the slope (Figure 22).

Winter 1979

Surface temperatures in February-March 1979 were characterized by wide areas of 3.0°-4.0°C water over the shelf (Figure 23), and >4.0°C water over the slope. A tongue of 4.0°C water extended from offshore into Kiliuda Trough and over Middle Albatross Bank, and a pocket of 4.0°C water occurred north of Portlock Bank. Colder (0.0°-3.0°C) water was present nearshore at the west end of Kodiak Island. Surface salinity (Figure 23) over much of the shelf area was 32.0-32.4°/oo, but an extensive tongue of water 32.4-32.6°/oo intruded toward Stevenson Trough. Temperatures at 50 m were similar to surface temperatures (Figure 24). At 50 m depth, water of 32.4-32.6°/oo salinity extended over the slope and over much of North Albatross Bank and Stevenson Trough (Figure 24), whereas water of 32.2-32.4°/oo salinity covered the shelf area west of Chiniak Trough. Temperatures at bottom (or 200 m) were primarily 3.0°-4.0°C over the shelf area, but an extensive tongue of 4.0°-5.0°C water extended across Middle Albatross Bank and into Stevenson Trough (Figure 25). Salinity at bottom (or 200 m) was 32.2°/oo nearshore increasing to 32.6-32.8°/oo over the slope and resembled surface conditions in that water 32.4°/oo-32.6°/oo extended into Stevenson Trough (Figure 25).

Seasonal Summary

Winter Conditions (Figures 23-25)--Across the Kodiak Island shelf generally homogeneous temperature and salinity distributions were found in the water column above 50 m. Temperatures ranging from 3.0°-4.0°C were slightly lower than winter 1977 values reported by Schumacher et al. (1978) but salinities in the range of 32.2-32.4°/oo compared well with this earlier study. The relative lack of stratification during winter in inshore waters (<100 m) and in waters over the banks of the Kodiak Island shelf was noted by Favorite and Ingraham (1977) and attributed to winter convection overturn and stirring processes due to storms.

Bottom (or 200 m) hydrography reflected the influence of warm (5.0°C) saline (32.6°/oo) Alaska Stream water along the shelf break east of Kodiak Island and also to the north of Portlock Bank extending toward lower Cook Inlet and Shelikof Strait. Pockets and intrusions of this water on the Kodiak Island shelf were closely associated with troughs where, apparently, Alaska Stream water was advected at depth. Stratification, caused primarily by salinity, and surface cooling resulted in episodes of thermal inversion along the shelf edge and in the troughs.

Spring Conditions (Figures 15-16)--As in winter, a lack of vertical structure in the upper 50 m was evident over much of the Kodiak Island shelf area. Temperatures in the upper layer were slightly higher (4.0°-5.0°C) than in winter while surface salinity continued in the range of 32.2-32.4°/oo across the shelf. Favorite and Ingraham (1977) reported little or no stratification in the upper 100 m of the shelf area as late as May in 1972. The range of surface salinity values they found were comparable to those reported here, and they were also able to show the location and continuity of areas of maxima (midshelf) and minima (shelf edge).

Bottom (or 200 m) temperatures remained cool across the shelf with a thermal front overlying the shelf break and the influence of the warmer (5.0°C), and more saline (32.6°/oo) Alaska Stream water seen along the shelf edge and extending northwest toward lower Cook Inlet and Shelikof Strait. Bottom salinity was slightly higher than in winter across the midshelf region and salinity contours closely paralleled the bathymetry along the shelf edge and slope.

Summer Conditions (Figures 17-19)--The temperature and salinity distributions of the nearshore waters generally reflected a more stable, stratified water column presumably caused by surface warming from increasing insolation and dilution due to freshwater runoff. Nevertheless, except for local instances inshore, the warmest surface temperatures (9.0°C) were seaward of the shelf break and to the northwest of Portlock Bank as occasional mixing over the shallow banks resulted in cooler near surface layers and warmer deep layers across the shelf.

Surface and 50 m salinities generally increased seaward from Kodiak Island without evidence of regions of minima (as described for spring by Favorite and Ingraham, 1977) and fell within the range of salinities reported by Schumacher et al. (1979) for September 1977.

Bottom (or 200 m) waters along the shelf edge and seaward were cooler and more saline than shelf conditions, but as in other seasons, the influence of Alaska Stream water was evidenced by its intrusions into troughs (e.g., Figure 19, bottom, Kiliuda and Chiniak Troughs) and its presence northwest of Portlock Bank.

Fall Conditions (Figures 12-14 and 20-22)--The hydrographic distributions reported here for fall 1977 (Schumacher et al., 1979), and fall 1978, together show virtually isothermal and isohaline conditions over much of the Kodiak Island shelf. Particularly over the shallow bank regions where mixing readily occurs, there was evidence of little or no vertical structure. At the surface, warmest temperatures (8.0°-9.0°C) and highest salinities (32.0-32.5°/oo) were recorded along and seaward of the shelf break and near Portlock Bank.

As for most of the year, bottom (or 200 m) temperatures at the edge of the shelf were 4.0°-5.0°C in fall and, as in summer, bottom temperatures increased shoreward. Bottom salinity was greater along the shelf edge (33.5°/oo in fall 1977 and 1978) than over the shelf, and intrusions and pockets of high salinity bottom water were evident in Stevenson, Chiniak and Kiliuda Troughs. Reduced mixing over the deeper troughs resulted in thermal and saline stratification in these regions.

Seabed Drifter Recoveries

A total of 3536 seabed drifters was released at 16 locations during the five cruises (Table 2). Recoveries through October 1, 1979, total 48, (44 with complete recovery information), or 1.4% of those released, with most (28) recoveries occurring from releases made in the summer of 1978 (Table 6). Although some variability is evident, drifters generally were recovered inshore from their release locations; in fact, some were found well up into bays (Figure 26). The general direction of movement of most drifters was to the southwest, but recoveries from releases made in the entrance of Chiniak Trough were made at the head of the trough.

In a modest study of residual bottom drift in Kodiak Island shelf waters in 1972, Ingraham and Hastings (1974) released 475 seabed drifters of which 15 were recovered. They also noted that the general direction of movement, as indicated by drifter recovery locations, was southwest.

Invertebrate Zooplankton

Invertebrate zooplankton are important components of the environment in terms of their biomass, their roles in the ecosystem, and their probable sensitivity to the kinds of petroleum industry development and activity anticipated in the Kodiak Island shelf area. As the major grazers of phytoplankton, they are a critical trophic link between primary producers and carnivores, including commercially valuable fish. The invertebrate zooplankton include organisms which are planktonic throughout the whole of their life histories (holoplankton) as well as organisms which may be planktonic for short periods in their development (meroplankton). This latter group consists mainly of the larval stages of benthic invertebrates and may outnumber the holoplankton for brief episodes in shallow water. While zooplankton in general are important in the movement and concentration of environmental contaminants, these early life history stages are particularly sensitive to environmental perturbations (Moore, 1973; Moore et al., 1973; Lee, 1975), and even subtle changes in water quality may be detected initially by the response of these organisms. Shifts in the relative abundance and distribution of invertebrate zooplankton taxa would be a possible first response.

North of 45°N, the subarctic Pacific comprises a distinct faunal and hydrographic region. Most of the zooplankton of the upper layers are found throughout the subarctic but are not found in the central North Pacific (below 40°N), nor are many of the southern species common to the subarctic region. Plankton in the Gulf of Alaska has been studied for decades, but the efforts have been irregular and usually limited to near surface waters in summer. Consequently, while much is known regarding large scale faunal distributions in the water masses of the whole North Pacific, there is very little detailed information on seasonal distributions in specific areas within the Gulf of Alaska. Much of the information on processes in the subarctic Pacific area is extrapolated from studies at Station "P" (50°N-145°W) on the southern edge of the Gulf of Alaska. Data from Station "P" have yielded a reasonably coherent idea of seasonal cycles of plankton in general in this oceanic region, but the populations and their cycles cannot be considered equivalent to those of the Alaska shelf.

Plankton Volumes (Table 7)

Mean total plankton settled volumes were derived from double oblique bongo net tows (0.333 mm mesh size) conducted at each station during the five cruises. Grid station numbers used to compare various geographical regions off Kodiak are shown in Table 5. The entire water column (to a maximum depth of about 200 m) was sampled in each case.

The seasonal variation of plankton biomass in the general Kodiak Island shelf area compared favorably in magnitude with the well established pattern of the open Northeast Pacific. During winter at Station "P," the total zooplankton biomass down to 200 m reaches a minimum of about 10 g wet weight/ 1000 m^3. The standing stock of grazers begins to increase in spring, peaking at about 200 g wet weight/1000 m^3 by July, before sharply decreasing through the end of summer (McAllister, 1961; LeBrasseur, MS 1965b). These values have been found to vary considerably over a period of several years, however, and in any given year less than half these quantities may be encountered.

Using relationships proposed by Sheard (1947) and by Wiebe et al. (1975) for the interconversion of measures of zooplankton biomass, the winter mean density for all stations sampled in the Kodiak Island shelf area was about twice the mean plankton concentration found in the upper 200 m of the open Northeast Pacific at that time of year. However, the larger Kodiak Island shelf value was in part due to the relatively high concentrations found at shallow nearshore stations in winter. There was a slight but general increase in plankton volumes in the Kodiak area by April due to considerably higher midshelf concentrations, and an overall maximum was reached during the summer months (Table 7). This summer peak in zooplankton biomass was roughly comparable to the reported summer maximum for the upper 200 m of the open northeast Pacific at Station "P". By late fall, the plankton volumes of the Kodiak shelf area declined to values below spring concentrations. It appears that the data from these five cruises show that the general seasonal plankton concentrations in the upper 200 m of the Kodiak Island shelf area are not substantially different from those of the open Gulf waters. However, year-to-year variability in the plankton density of the Kodiak area, uncertainty as to the precise timing of plankton minima and maxima there, and questions which remain concerning the duration of high and low plankton abundance off Kodiak make it difficult at this time to speculate conclusively on the validity of any comparisons.

In analyzing the effects of bathymetrical features of the Kodiak Island shelf area on total plankton concentrations, the data indicate that throughout the year there was very little difference between the "bank" and "trough" locations, but that with the spring and summer increase in plankton biomass these midshelf regions together contributed higher concentrations of plankton than either the nearshore or slope regions (Table 7). In addition, physical processes which may seasonally influence the local distribution and abundance of plankton in the shelf area include strong coastal downwelling and onshore transport encountered during the winter months, and the summer upwelling conditions with offshore transport (June to September) reported by Ingraham et al. (MS 1976).

Distribution and Discussion of Selected Taxa

Copepoda (Table 8, Figures 27-29)

It has been estimated that copepods compose from 70-90% of the zooplankton biomass throughout the year in the northeast Pacific (LeBrasseur, MS 1965b; Gulland, 1970). In the Kodiak Island shelf area, copepods are clearly dominant among invertebrate zooplankton, and their seasonal distribution and abundance are shown in Table 8 (no. animals/1000 m^3) and in Figures 27-29 (log no./10 m^2). Among the copepods, the Calanoida are the most significant group. In biomass, as well as in number of species, they exceed by far all other zooplankton groups and copepod suborders and are important food objects for many of the major commercial fishes and for whales of the suborder Mystacoceti (Brodskii, 1950).

In winter, copepod abundance was lowest for the year with a uniform distribution over the shelf area and concentrations several times higher over the slope. By March, the abundance of copepods had increased sharply, with nearshore and midshelf areas contributing significantly higher numbers. The summer maximum brought an increase of up to fifty times the concentrations found in winter on the shelf, with a mean density of more than 750,000 copepods/1000 m^3 in the midshelf region. The overall fall concentration of copepods remained well above the winter minimum as the nearshore and midshelf regions continued to show greater abundance in general than the slope region, which was already approaching its winter low.

Euphausiacea (Tables 9-11, Figures 30-50)

The Euphausiacea are important planktonic crustaceans because of their abundance, and because they are food for a variety of fishes including herring, cod, pollock and salmon, as well as the chief food of baleen whales (Ponomareva, 1963; Parsons and LeBrasseur, 1970). Also, euphausiids may contribute substantially to the detritus (and thus the organic matter) of the oceans because they molt regularly and frequently throughout their life (Lasker, 1966). Of futher significance has been the establishment of certain euphausiid species as indicators of various water bodies (Brinton, 1962; Ponomareva, 1963; Lasker, 1966).

The seasonal distribution and abundance of euphausiid species and life history stages caught in the Kodiak Island shelf area are presented in Table 9. Contour plots further illustrating the distribution and abundance of euphausiid larvae, juveniles and four species of adults have been included (Figures 30-47), as well as additional information on wet weights and lengths of principal euphausiid species (Table 10 and Figures 48-50). Finally, the vertical distributions of Euphausiacea are discussed and day and night vertical distribution data are presented in Table 11. Of the species caught off Kodiak, six are generally considered subarctic: *Euphausia pacifica*, *Thysanoessa longipes*, *T. spinifera*, and *Tessarabrachion oculatus* are endemic to the North Pacific, and *Thysanoessa raschii* and *T. inermis* (both arctic-subarctic) are common to the North Atlantic and the North Pacific. A fourth genus present in the Kodiak area, *Stylocheiron*, in spite of the broad range of some of its species in deep waters, has been described as essentially an epipelagic tropical and subtropical genus which has achieved its maximum development in equatorial waters (Brinton, 1962).

Euphausiacea Developmental Stages (Table 9, Figures 30-35)

The simultaneous presence of subadult euphausiids at various stages of development found in the Kodiak Island shelf area throughout the year suggests that the spawning periods of the dominant euphausiid species are protracted, and that spawning itself is intermittent. Ponomareva (1963) reported that the spawning period in the genus Thysanoessa is protracted, commencing as early as March and terminating at the end of May. Off Kodiak, both the euphausiid larvae and juveniles were in greatest abundance during the summer season. The larvae increased four orders of magnitude in general abundance from a winter low of 5.1/1000 m^3, with the nearshore and midshelf regions contributing the highest concentrations (65,703.7/1000 m^3 and 92,410.0/1000 m^3, respectively). There were significant concentrations of euphausiid juveniles distributed uniformly over the shelf and slope during the winter and very likely these included individuals from late in the previous year's spawning season. In fall, limited spawning continued to produce larvae at concentrations of more than 2000/1000 m^3 in the nearshore and midshelf regions while juveniles were found at similar concentrations nearshore and midshelf but continued to outnumber the larvae over the slope.

Euphausia pacifica (Table 9, Figures 36-38)

According to Brinton (1962) E. pacifica is found primarily in the oceanic subarctic and transition zones of the North Pacific, and is the only northern Euphausia species. It occurs from the Sea of Japan eastward to the Gulf of Alaska and the California current, and is present in the southern parts of the Sea of Okhotsk and the Bering Sea. Banner (1950) found it in greatest numbers along the northern and eastern margins of the Gulf of Alaska.

In the Kodiak Island shelf area, E. pacifica was never found in great abundance during the year. Highest concentrations were consistently found in the slope region (up to 102.5/1000 m^3 in the winter) with the most notable general lack of abundance recorded from the spring cruise (less than 4/1000 m^3). As this species is considered oceanic in its distribution, these results are not not surprising, and the relatively high concentrations noted along the edge of the shelf in winter may in part be related to onshore transport processes (discussed previously) which occur during this season. In summer, fall (1978) and winter, there was particularly good correspondence between the occurrence of E. pacifica and the apparent distribution of oceanic waters at depth (bottom or 200 m) on and around the Kodiak Island shelf (Figures 19 and 37, top; 22 and 37, bottom; 25 and 38). During summer, this species was generally found in waters of salinity $\geq 32.8^{o}$/oo and of temperature $\leq 5.0^{o}C$. In fall, E. pacifica was generally caught in waters of $\geq 33.0^{o}$/oo salinity and again of temperature $\leq 5.0^{o}C$. Winter catches of E. pacifica were primarily from waters $\geq 32.6^{o}$/oo salinity, with a temperature range of 4.0^{o}-$5.0^{o}C$.

Stylocheiron species (Table 9)

Generally an epipelagic, warm water genus, Stylocheiron was reported by Brinton (1962) as far north as the Gulf of Alaska (S. maximum). Members of this genus were encountered off Kodiak on all five cruises but in very low abundance, and usually along the edge of the shelf. The highest mean density found, however, was at the midshelf stations during the spring cruise (7.6/1000 m^3).

Tessarabrachion oculatus (Table 9)

Reports of this species limit its distribution to the subarctic North Pacific. Off Kodiak Island, *T. oculatus* appeared to be uniformly distributed in low abundance along the slope throughout the year.

Thysanoessa inermis (Table 9, Figures 39-41)

This arctic-boreal species has been recorded in abundance in the North Pacific (usually above 50° N), and the North Atlantic Oceans, and in the Beaufort, Chukchi and Bering Seas. Easily the most abundant euphausiid caught in the Kodiak Island shelf area during the sampling period, this animal was found in highest concentrations in winter (over 4000/1000 m^3) at the nearshore stations. The general abundance of *T. inermis* declined considerably during the spring and summer cruises but had begun to increase, particularly at the midshelf and slope stations, by fall.

Thysanoessa inspinata (Table 9)

Closely related to *T. longipes*, this species has been collected off British Columbia (Shih et al., 1971). General abundance was low throughout the year in the Kodiak Island shelf area, with highest concentrations found in the midshelf and slope regions during fall and winter. Lowest numbers of *T. inspinata* were caught in spring.

Thysanoessa longipes (Table 9, Figures 42-44)

The horizontal distribution of this species is limited to the North Pacific and the American section of the Arctic (Brinton, 1962). The mean densities of *T. longipes* throughout the year in the Kodiak Island shelf area are given in Table 9 (no./1000 m^3) and contour plots, Figures 42-44 (log no./10 m^2) are presented. Without exception, the local abundance of this animal was far greater at any time along the slope than within the midshelf or nearshore areas. The slope concentrations were relatively high only in winter and spring, with sharply lower densities found in summer and fall.

As with *Euphausia pacifica*, there was a conspicuous correspondence between the occurrence of *T. longipes* during certain times of the year and the apparent distribution of oceanic waters at depth (bottom or 200 m) on and around the Kodiak Island shelf (Figures 16 and 42; bottom; 19 and 43, top; 25 and 44). In spring, this species was coincident with waters of salinity $\geq 32.8^{\circ}/oo$ which were seaward of the 4.5°C isotherm. During summer, *T. longipes* was most often found in waters $\geq 32.8^{\circ}/oo$ salinity and of temperature $\leq 5.0^{\circ}C$. In winter, salinity $\geq 32.6^{\circ}/oo$ and temperature in the range of 4.0°-5.0°C characterized the water in which these euphausiids were generally caught off Kodiak Island.

Thysanoessa raschii (Table 9)

Having a latitudinal range very similar to that of *T. inermis*, this euphausiid is almost entirely restricted to neritic waters (Brinton, 1962; Ponomareva, 1963). Banner (1950) reported *T. raschii* off Kodiak Island. The highest concentrations of this species in the Kodiak Island shelf area (190.8/1000 m^3) were found during winter and at the nearshore stations. A midshelf maximum was also found during winter as well as the only occurrence for the year of *T. raschii* at slope stations. Overall spring and summer mean densities were low (less than 2/1000 m^3) with a considerable increase found in fall at the nearshore and midshelf stations.

Thysanoessa spinifera (Table 9, Figures 45-47)

Generally regarded as limited in distribution to the littoral regions of the Northeast Pacific, this species, unlike *T. raschii*, has also been caught in the oceanic Gulf of Alaska. The seasonal distribution and abundance found for *T. spinifera* in the Kodiak Island shelf area appears to confirm that this species does inhabit both the coastal and oceanic environments. Overall mean densities for *T. spinifera* remained fairly constant winter through spring, but in winter it was the nearshore stations contributing the highest values, while in spring it was the slope stations. Summer abundance was uniformly low in all regions, but in fall, maxima for all bathymetrical areas off Kodiak were reached. The fall slope stations showed the highest concentrations, over twice the mean densities found nearshore and midshelf.

Euphausiacea Weights and Lengths (Table 10, Figures 48-50)

As with other crustaceans that shed their chitinous integument when molting, the age of euphausiids is best determined by size. Information on specimen sizes can also be useful in understanding the life cycles of euphausiid species. Seasonal wet weights and lengths of principal species of euphausiids found in the Kodiak Island shelf area are presented in Table 10. Length frequencies, by cruise, for the most abundant euphausiid species (*Euphausia pacifica*, *Thysanoessa inermis*, and *T. longipes*) are shown in Figures 48-50.

In general, boreal euphausiids are believed to have biennial life cycles (Ponomareva, 1963) and quite often two size groups of adults are found (e.g., Figure 48, both fall cruises, and Figure 49, 4MF77). Among the most abundant species in the Kodiak area, the average weights and lengths of adult euphausiids were minimal, in almost all cases, in fall and winter, as presumably much of the euphausiid population consisted of newly mature individuals (Figures 48-50). With further maturation and the onset of the spawning period during spring, there was a noticeable increase in general size for most of the common species, and during the summer months mean weights and lengths increased substantially for all species. Apparently the largest and oldest (2 years) specimens perish soon after the spring-summer spawning season (Ponomareva, 1963).

Euphausiacea Vertical Distributions (Table 11)

Prior to, and during spawning in spring and summer, many widespread euphausiid species gather in enormous swarms near the surface where they may remain for days. Subsequently, the nauplii and early life history stages of these animals abound in the phytoplankton rich surface layers. In addition, the adults of some species feed mainly in the upper 50 m chiefly at night and during the morning hours (Ponomareva, 1963). For these reasons, euphausiids often make up an appreciable part of the plankton collected from the upper layers. Given the ecological importance of these crustaceans, it is worthwhile to consider their vertical distributions in order to assess, among other things, their direct vulnerability to environmental contaminants.

In Table 11, data are presented showing the day and night vertical distributions of euphausiid larvae and juveniles and of the adults of Thysanoessa inermis and T. spinifera at "diel stations" from different times of the year. Samples were collected with a Tucker trawl using a 0.505 mm mesh net and while the numbers of larvae in particular are likely to be underestimations, it is quite evident in relative terms that the highest mean concentrations of euphausiid larvae and juveniles were in the surface layer, both at night and during the day. Adults of Thysanoessa inermis, the most commonly found euphausiid species in the Kodiak Island shelf area throughout the year, were clearly most abundant in the upper 43 m during Diel 3 in April 1978 (midspawning season for the genus Thysanoessa). During Diel 4, T. inermis was found in lower concentrations at all depths with a maximum value at night in the surface layer possibly suggesting diel vertical migration. Two months later, during Diel 5, there was further evidence for the vertical migration of at least part of the population of T. inermis, as highest concentrations of this species were collected below 71 m during the day and above 27 m at night. Similarly, adults of T. spinifera, second in numbers to T. inermis in the midshelf region throughout the year (Table 9), were found in highest concentrations at the surface at night, in spring and fall (Table 11).

Chaetognatha (Table 8, Figures 51-53)

Among the invertebrate zooplankton, chaetognaths may at times be second in numbers only to the copepods, upon whom they prey. The general abundance of these animals off Kodiak remained remarkably constant from one season to the next, with the only exception being a sharp decline in mean density in the slope region in spring. During every season, however, mean density was clearly greatest at the slope stations.

Sund (1959) discussed the common forms of Chaetognatha found in the Gulf of Alaska. Eukrohnia hamata and Sagitta elagans were present in large numbers throughout most of the Gulf, while S. lyra, an oceanic form, was found in regions influenced by waters of the subarctic regions and the American coastal regions. LeBrasseur (1959) also found S. lyra in the Gulf of of Alaska in areas where the temperature at 150 m exceeded $6^{o}C$ and the salinity exceeded $33^{o}/oo$. Damkaer and Dey (MS 1977) reported the presence of Eukrohnia fowleri at a station off the shelf near Kodiak Island.

Cnidaria (Table 8, Figures 54-56)

The members of this phylum (excluding Siphonophora) were among the most numerous of the invertebrate zooplankton caught off Kodiak Island, particularly in summer and fall. During both of these seasons, the nearshore mean densities of Cnidaria were about 6000/1000 m^3 compared to several hundred/1000 m^3 in winter and spring. The general seasonal pattern for Cnidaria abundance appeared to be: relatively high concentrations over the slope in winter; a shift to a fairly even distribution across the shelf area in spring; quite a large increase in nearshore and midshelf abundance in summer; and a slight decline in nearshore and midshelf abundance by fall as concentrations increased somewhat in the region of the slope.

Cirripedia (Table 8, Figures 57-62)

The larval stages of the Cirripedia (barnacles) form an important food source for planktivorous animals, and their seasonal fluctuation in abundance in the Kodiak Island shelf area is dramatic in its range. Cirripede nauplii increased from a winter nearshore minimum to extremely high values in spring and a maximum of over 100,000/1000 m^3 in summer. Fall concentrations were still above winter values with no nauplii in evidence over the slope. Not surprisingly, the more advanced larval form, the cypris, followed the seasonal pattern of the nauplii. Winter concentrations of cyprids were very low, but by March, the nearshore and midshelf stations had sharp increases in this form, and a maximum was reached during the summer months. The fall abundance of cyprids remained relatively high as large numbers of summer nauplii continued to molt to the cypris stage.

Amphipoda (Table 8, Figures 63-65)

Among the marine planktonic Crustacea, the amphipods generally rank third in numerical abundance, behind the copepods and euphausiids (Bowman, 1960). While pelagic amphipods are not often found in large numbers in tropical and subtropical regions, they may be extremely abundant in the cooler parts of the oceans.

Amphipods were caught in substantial numbers throughout the year in the Kodiak Island shelf area and winter and spring concentrations were nearly uniform across the shelf with a slight overall increase in abundance detected in spring. In summer, the nearshore and midshelf regions experienced moderate increases, while the slope region had a mean density of 3190.4/1000 m^3 which was an order of magnitude higher than that found in spring. In October, the abundance of amphipods nearshore and midshelf continued to increase and had doubled since summer, while concentrations in the slope region had declined by more than half.

Echinodermata-larvae (Table 8)

Almost all echinoderms have a pelagic larval stage in their development. There is great diversification in larval types, each class having its own characteristic type, wtih all larval forms abundant at times in the plankton community. During winter off Kodiak, very few echinoderm larvae were caught, but the highest numbers were found nearshore. On the one spring cruise, none of these larvae were found in the bongo net samples but by summer, abundance had increased markedly, particularly at the midshelf and slope stations. In fall, a maximum concentration for the year was found nearshore (5662.3/1000 m^3), midshelf abundance continued high (1074.3/1000 m^3), and the slope mean density was extremely low (9.4/1000 m^3).

Annelida (Table 8)

Despite their diversity and abundance in shallow seas and along shores, few annelids are regularly planktonic as adults, and even the larvae do not often make up a large part of plankton samples as spawning is usually over a short period. The annelids caught in the plankton off Kodiak Island increased in general abundance from winter, through spring and into summer when a maximum concentration of over 2500/1000 m^3 was found at the midshelf stations. In fall, abundance was sharply down with concentrations similar to those found in spring.

Hydrozoa Siphonophora (Table 8)

The holoplanktonic hydrozoans, all of which consist of polymorphic colonies built up of several kinds of hydroid and medusoid-like zooids, were found only in low abundance in the midshelf and slope regions off Kodiak in winter, spring and fall. The summer distribution was confined to the nearshore region where concentrations were relatively high (75.7/1000 m^3).

Ctenophora (Table 8)

Although found in low abundance during the sampling period of this report, ctenophores at times occur in enormous numbers and can significantly reduce the population of animals upon which they prey, including the fry of many commercial fish as well as the small planktonic crustaceans upon which many young fish depend for food (Hardy, 1970). In the Kodiak Island shelf area, the occurrence of ctenophores was limited to small concentrations found in the slope region in spring, and relatively larger densities found nearshore and midshelf in fall.

Gastropoda-larvae (Table 8)

These larvae can become common in the plankton in spring, summer and fall, with usually the majority of species occurring in the summer. Many of the gastropod larvae have a long pelagic phase. The general abundance of gastropod larvae in the Kodiak Island shelf area was lowest in winter, increased considerably by spring and remained high through summer, particularly in the nearshore and midshelf regions. In fall, the abundance was uniformly lower across the shelf but continued significantly higher than in winter.

Pteropoda (Table 8)

The seasonal distribution of pteropods off Kodiak Island was highly variable during the sampling period. In spring and summer, the highest concentrations were found at the nearshore stations (maximum: 4770.2/1000 m^3 in spring), while in fall and winter, abundance was greatest along the slope. However, in terms of general abundance in the shelf area, the spring and fall seasons had three to four times the concentrations found in summer and winter.

Cladocera (Table 8)

The distribution of cladocerans is often very patchy, as they appear to swarm in great numbers but for rather short periods. Cladocera were not collected in winter samples off Kodiak, but were present in low numbers at the midshelf stations in spring. In general, summer abundance was highest for the year (maximum at midshelf: 279.3/1000 m^3), and relatively high concentrations continued through fall at nearshore and midshelf stations.

Ostracoda (Table 8)

The ostracods, which often are not a conspicuous part of the plankton, were found to be highly abundant off Kodiak, particularly along the slope. A maximum slope concentration for the year was found during winter (3475.6/1000 m^3), with concentrations half that value in spring and summer, and a slope minimum in fall. Within each season, abundance of ostracods increased consistently as one moved offshore toward the slope stations.

Isopoda (Table 8)

While few of these crustaceans are holoplanktonic, many bottom living species are taken in plankton samples, particularly in shallow water. The highest mean concentrations of isopods found off Kodiak was at the nearshore stations during fall (444.0/1000 m^3). The abundance of these animals throughout the year was greatest in fall and winter in all shelf areas, with lower concentrations and variable distributions found in spring and summer.

Mysidacea (Table 8)

Most mysids have been found near, or on, the bottom and are particularly abundant seasonally in inshore and estuarine waters. Many are considered euryhaline. In addition, mysids tend to migrate to the surface layers at night. The greatest mean density of this crustacean was found in summer at the nearshore stations (188.8/1000 m^3). In all seasons, the highest concentrations were found nearshore, but general abundance was relatively low throughout most of the year, particularly in spring.

Cumacea (Table 8)

Cumaceans are bottom dwellers which may get swirled up into the plankton temporarily by water movements, and some are known to migrate vertically at night. The abundance of cumaceans in the plankton off Kodiak was highly variable from one area of the shelf to the next, but the highest concentrations collected were at the nearshore and midshelf stations. A maximum mean density was found in summer at the nearshore stations (410.0/1000 m^3). Throughout the year, the general abundance in the shelf area remained within a modest range.

Thaliacea (Table 8)

This class of organisms includes the pyrosomes, the doliolids and the salps but was never a major part of the invertebrate zooplankton off Kodiak during the periods sampled. Thaliacea, when present, occurred only in the slope area, increasing in abundance there from spring (15.6/1000 m^3) to fall (93.2/1000 m^3).

Larvacea (Table 8)

The larvaceans (appendicularians), whose chief representatives belong to the genus Oikopleura, are often a common element of the plankton. In the Kodiak Island shelf area, larvaceans were found in considerable abundance throughout the year, showing the conventional pattern of relatively low winter concentrations, followed by moderate spring concentrations, maximum abundance in summer and a return to moderate concentrations in fall. In spring and summer, the highest concentrations were recorded at the midshelf stations (8628.4/1000 m^3 and 15911.4/1000 m^3, respectively), while in fall and winter, the nearshore stations had the highest mean densities.

Natantia and Reptantia

This section represents an assemblage of considerable information obtained on the temporal and spatial distribution of decapod larvae in the Kodiak Island shelf area. Several factors, however, limit the precision and completeness of our findings.

In the offshore subareas, samples obtained at 3-month intervals were assumed to provide representative information on the distribution and relative density or abundance of larvae for an entire season. Offshore information was further limited by station density. A maximum of 94 stations was occupied during an offshore survey which provided a sampling density in this 68,000 km^2 area of about one station/700 km^2. Sampling intensity in the inshore bay regions was substantially greater in series of observations per season (up to five) and density of stations (one/50 km^2); however, station locations usually provided assessment of zooplankton only in deep water. Initially inshore stations were established along a median line extending down the center of each bay towards offshore. This station arrangement assumed uniform distribution and abundance of larvae from the median line shoreward. After Cruise III additional stations were added to Izhut and Kiliuda bays to investigate shallower areas.

Difficulties occurred in the comparison of diel studies between regions since inshore and offshore sampling methodology differed. Five discrete depths were sampled twice daily in the inshore bay regions whereas two or three strata were sampled at 12 time periods offshore. Although studies examined the vertical distribution of decapod larvae by time of day, these observations did not include near bottom samples or surface samples sorted for decapods. The frequent occurrence of rough bottom throughout the study area prevented extensive use of benthic sampling gear.

Incomplete sampling of the entire water column resulted in an additional problem for interpreting results of diel sampling. Occasionally a larval group would be present in substantial amounts at certain depths or times of day, yet be totally absent from sampled strata at other times. We assumed that during periods of no catch the larvae were located outside our sampling depths.

An important factor affecting larval decapod analyses was aliquot size. Dense concentrations of certain invertebrate taxa (e.g. barnacles and copepods) oftentimes "masked" detailed information for the less abundant decapods in the 500-organism (all taxa) aliquot. Several randomly selected bulk samples were entirely sorted for shrimp and crab larvae and were enumerated for total organisms and decapods. Up to 250,000 organisms were encountered in these samples; decapod larvae accounted for as little as 0.1% of the total number present. Although the aliquots appeared to provide adequate information on decapod species occurrence, seasonal distribution, and density relative to total zooplankton in the samples, they were inadequate for estimating actual abundance or biomass of larval decapod populations.

Difficulties were often encountered in determining peak time of release as information on relative abundance by life stage and time of year was not available during preparation of this report.

Despite these limitations to our analyses, it is hoped that these findings provide some general descriptions of seasonal abundance, distribution and composition of decapod larvae in this area of the Alaska continental shelf.

Relative Importance of Individual Species or Species Groups

Over 20 taxa of Natantia and Reptantia larvae were encountered during the inshore and offshore plankton surveys of the Kodiak Island shelf area (Table 12).

Several decapod species of current economic importance were frequently encountered. These include pink shrimp, Pandalus borealis; red king crab, Paralithodes camtschatica; snow or Tanner crab, Chionoecetes bairdi; and Dungeness crab, Cancer magister. Other taxa not of current economic importance comprised the majority of decapod larvae in the plankton samples. The five most abundant of these non-commercial taxa and the four species mentioned above comprised the species of principal interest in this section of the report.

Twelve taxa occurred in 5% or more of all plankton samples examined for Natantia and Reptantia larvae (Table 13). The most frequently occurring species group was hippolytid shrimps, Hippolytidae. These were found in over 40% of all samples examined. Other widely distributed and frequently occurring taxa (present in at least 15% of all samples) included: pagurid and lithodid crabs, Paguridae and Lithodidae; cancer crabs, Cancridae; pinnotherid crabs, Pinnotheridae; crangonid shrimps, Crangonidae; and Tanner crab.

The frequency of occurrence of the various taxa varied somewhat by regions. Although hippolytid shrimps and pagurid and lithodid crabs occurred in about 20% of the samples examined from the offshore subareas, their incidence in samples from the inshore bay regions was substantially greater, occurring in 43 to 87% of the samples. Other species groups with relatively low frequencies of occurrence offshore and high frequencies inshore were: cancer crabs, pinnotherid crabs and crangonid shrimps. Tanner crab displayed the most uniform incidence of occurrence, appearing in about 13% of the offshore samples and 16-19% of the samples obtained inshore.

All other taxa examined usually were present at a limited number of stations; however, most occurred more frequently in inshore samples than in offshore samples.

Discussion of Selected Taxa

Hippolytidae-Hippolytid shrimps

Hippolytid shrimps are represented by 54 species and six genera in north Pacific waters and 31 species are indigenous to the Gulf of Alaska. Adults are benthic and range in depth distribution from intertidal zones to a depth of 900 m. Although certain species occur in relatively high densities, none are commercially important. Little is known about the early life histories of hippolytid shrimp and descriptions of larvae are not well documented. Since identification of hippolytid shrimp larvae to genus and species is difficult, all members of this family were treated together.

Distribution and Relative Density by Region and Season -- Hippolytid shrimp larvae were the most frequently encountered decapod taxa in the Kodiak Island study area and were present in nearly 20% of all offshore samples and 60-90% of the samples examined from the inshore bay regions (Table 13). Overall average density per station in the inshore bay regions was substantially higher than average density offshore (Figure 66). Stations in the four bays averaged nearly 3600 organisms/1000 m^3, whereas offshore stations only contained an average of about 325/1000 m^3.

Hippolytid shrimp larvae occurred throughout most of the year in all portions of the study area. In the inshore bay regions highest densities were encountered during summer, peaking in late summer (Table 14). Izhut, Chiniak, and Kiliuda Bays had similar average densities per station, whereas average densities in Kaiugnak Bay were less than half of amounts determined for any other bay. Highest concentrations of these larvae within each bay were usually encountered at the inner-bay stations. Average relative density per station by bay and season is shown in Figures 67-69.

Relatively large amounts of hippolytid shrimp larvae were encountered in the offshore subareas of the Kodiak Island study area during both spring and summer. Spring concentrations occurred at scattered locations, but by summer high concentrations occurred throughout most of the offshore subareas. Greatest numbers were found off Kaiugnak and Kiliuda Bays, and from North Albatross Bank to Portlock Bank (Figures 70 and 71). Highest average density offshore occurred in the Albatross subarea (Table 15). The Sitkinak subarea in contrast contained the lowest average density of hippolytid shrimp larvae for the entire study period.

Diel and Depth Distribution -- The vertical distribution of hippolytid shrimp larvae by time of day apparently differed between regions of the study area. In the inshore bay regions, larvae of this species group generally were concentrated in the upper portion of the water column during the day with 60% of the individuals occurring in samples from the 10-30 m depth stratum (Figure 72). At night their vertical distribution was more dispersed and somewhat deeper with over 53% of all individuals found deeper than 30 m (50-90 m). Hippolytid shrimp larvae encountered during diel studies in the offshore region displayed the reverse of vertical distribution found inshore. Highest densities were present in the upper portion of the water column at night and in lower portions during the day (Figure 73).

The only noticeable change in diel behavior by season occurred offshore in the upper portion of the water column. During spring, nearly all organisms were encountered in the upper stratum at night. During summer relatively substantial numbers were found in this stratum throughout the 24-hour sampling period.

Time of Occurrence by Larval Stage -- Information on occurrences of larval stages for all bays of the inshore region suggests that larval release of hippolytid shrimps occurs throughout most of the year (Table 16). Stages 1 and 2 larvae were encountered during every season except fall (Cruise XI). Later larval stages 3-6 were present in samples from late spring through fall with post-larval juveniles starting to occur in mid summer (Cruise VII) and apparently continuing through winter. The simultaneous presence of various stages of larval development throughout most of our study period suggests a protracted period of larval release. However, numerous species were contained in this group.

Crangonidae-Crangonid shrimps

Crangonidae is a highly speciose shrimp family. Its distribution is circumpolar with 32 species and four genera occurring in various North Pacific waters from San Diego to Alaska and Japan. Twenty-two species inhabit Gulf of Alaska waters. Adults have been reported present from the intertidal zone to depths of nearly 5,000 m and are not commercially important. Early life history information is incomplete, making identification beyond family difficult. In this report, all Crangonidae were treated as a single group.

Distribution and Relative Density by Region and Season -- Crangonid shrimp larvae were the second most frequently encountered shrimp taxon (fifth overall among decapods) in the Kodiak Island study area. This group was present in nearly 40% of all inshore samples (range by bay, 17-47%), but in less than 5% of the samples taken offshore (Table 13). Overall average density per station in the inshore bay regions was over seven times greater than average density offshore. The combined inshore bays averaged nearly 550 organisms/1000 m^3 as compared to only 77/1000 m^3 offshore.

Peak concentrations of crangonid shrimp larvae occurred during summer in both inshore bay regions and offshore subareas (Figure 74). In the inshore bay regions, the highest density occurred in Kiliuda Bay (Table 17) with substantial numbers of this larval group present throughout summer. The overall average density for all seasons combined was about 1300/1000 m^3. Concentrations occurring in all other bays were only 1/10 to 1/3 of that found in Kiliuda Bay.

Average relative density per station for spring and summer in all bays is presented in Figures 75 and 76.

Very few crangonid shrimp larvae were encountered in the offshore subareas during spring (Figure 77). By summer, concentrations increased somewhat at scattered locations throughout shallower portions of the offshore region (Figure 77). Highest overall average densities occurred in the Marmot and Albatross subareas with somewhat fewer larvae found in the Portlock subarea and very few in the Sitkinak subarea (Table 18).

Diel and Depth Distribution -- Crangonid shrimp larvae in the inshore bay regions generally were concentrated in the upper portion of the water column during the day with over 70% of all organisms encountered in the 10-30 m depth stratum (Figure 78). At night the vertical distribution of this larval group was somewhat dispersed into deeper water with nearly 60% of all individuals present in the 50-90 m depth strata. Diel behavior did not appear to change noticeably by season in the inshore bay regions.

Crangonid shrimp larvae were not encountered in sufficient amounts at offshore diel stations to provide information on offshore vertical distribution by time of day.

Time of Occurrence by Larval Stage -- Stages 1 and 2 larvae of crangonid shrimps were present in the inshore bay regions during every season except fall (Table 19). Later larval stages 3-5 were present in samples from late spring through fall and post-larval juveniles appeared from mid-summer through the fall sampling period. These data suggest that during our study of the inshore bay regions larval release of crangonid shrimps occurred throughout most of the year. Time of peak release was not determined.

Pandalus borealis - Pink shrimp

Pandalus borealis is a circumpolar pandalid shrimp which occurs in the North Pacific from off the Oregon-Washington coast northward to the Bering Sea. Adults are found at depths ranging from less than 100 m to over 900 m, with most occurring between 100-500 m in the Gulf of Alaska. General life history information for this species is very complete. Adult forms of this species are protandric hermaphrodites, developing first as males, and after 1-2 years undergoing a sex transition to become females for the remainder of their 6-7 year lifespan (Ivanov, 1969). Larval release in the Gulf of Alaska occurs sometime during spring (Barr, 1970) and the zoeae pass through six larval stages prior to attaining a juvenile adult form (Berkeley, 1930). Pink shrimp represent an extremely important commercial fisheries resource in the Kodiak Island shelf area and several other areas throughout the North Pacific.

Distribution and Relative Density by Region and Season -- Pink shrimp larvae were the third most frequently encountered shrimp taxon (9th overall among decapods) and the second most frequently occurring species of current economic importance. This species was present in over 18% of all inshore samples (range by bay, 9-28%) and in about 3% of the samples obtained from the offshore subareas (Table 13). Overall average density per station in the inshore bay regions was 10 times greater than offshore. The combined inshore bay regions averaged about 121 individuals/1000 m^3 compared to only 11/1000 m^3 offshore.

Concentrations of pink shrimp larvae were present during early to mid-spring in all four bays of the inshore region with densities peaking earlier in Kaiugnak Bay than in other bays (Figure 79). Only small concentrations were scattered throughout the inshore bay regions in late spring, and by late summer, these larvae were absent from all inshore samples.

Chiniak Bay had the highest average density of all bays sampled with an average of about 182 pink shrimp larvae/1000 m^3 for all cruises combined (Table 20). Average overall densities for Kaiugnak, Izhut, and Kiliuda Bays were 131, 120, and 49/1000 m^3, respectively. Average relative density per station for spring surveys in all bays is shown in Figure 80.

Very few pink shrimp larvae were found during the spring in the offshore subareas and only off Sitkalidak Island in the Albatross subarea. By summer slight concentrations were encountered at scattered locations in Stevenson Trough and off Portlock Bank in the Marmot and Portlock subareas (Figure 81). Pink shrimp larvae were not encountered in any offshore subareas during fall or winter and were not found during any seasonal survey of the Sitkinak subarea (Table 21).

High relative densities of larvae in the inshore bay regions during spring and increased abundance offshore during summer indicate a possible transport of pink shrimp larvae offshore with time.

Diel and Depth Distribution -- In the inshore bay regions pink shrimp larvae appeared to have a somewhat different diel and vertical distribution than other Natantia taxa studied. During both day and night most organisms were found in mid-depth stratum (30-70 m) with about 85% of all individuals encountered at these depths during day and nearly 70% at night (Figure 82). Larvae of this species were encountered at diel stations in the offshore subareas only during summer and in the upper portion of the water column (Figure 83) with highest densities at night. Pink shrimp larvae were almost totally absent from the examined diel samples taken during daylight. It should be noted that offshore diel samples from the mid-depth stratum of 30-70 m were not available for larval decapod analysis. Since most larvae in the inshore bay regions were found at this depth interval, it seems likely that pink shrimp larvae in the offshore subareas also were present at these depths during the day.

Time of Occurrence by Larval Stage -- Stages 1 and 2 pink shrimp larvae were present in the inshore bay regions from spring to early summer (Table 22). After early summer only larval stages 4-6 and post-larval juveniles were encountered. No pink shrimp larvae or juveniles were present in samples taken in late winter (Cruise XII). These data suggest that during our studies larval release of pink shrimp occurred during a relatively brief period in the spring.

Paguridae and Lithodidae (except *Paralithodes camtschatica*) - Anomuran crabs

The anomuran crab group in this report represents members of the families Paguridae and Lithodidae (excluding *Paralithodes camtschatica*). Members of these families are found throughout the world's oceans and about 40 anomuran species occur in the Gulf of Alaska. Adults are benthic and occur from the intertidal zone to depths exceeding 4,000 m. Members of this group which were caught during the study are not commercially important in the Kodiak Island shelf area.

Life history information is varied since numerous species comprise this group; however, nearly all anomuran larvae typically pass through four zoeal stages (molts) and a glaucothe stage before attaining adult form. Lack of substantial early life history information and descriptions of larvae for numerous anomurans made it extremely difficult to identify organisms, even to a family classification. For this reason, anomuran crabs (except P. camtschatica) were treated as a single group.

Distribution and Relative Density by Region and Season -- Anomuran crab larvae were the second most frequently occurring decapod larval group in the Kodiak Island study area, and the most common crabs (Table 13). This group was present in over 20% of all offshore samples and 73% of those from inshore bay regions (range by bay, 43-78%). Overall average density in the inshore bay regions was about four times greater than offshore. The combined inshore samples averaged over 2740 individuals/1000 m^3 compared to about 607 offshore (Figure 84). This larval group however, was the second most abundant taxa encountered in the offshore subareas.

Anomuran crab larvae were present throughout the inshore bay regions during the entire study. Time of highest density varied by bay (Figure 84). In Izhut, Kiliuda, and Kaiugnak Bays, peak densities of this larval group were found during late spring-early summer, while in Chiniak Bay the peak occurred later. It should be noted that following a mid-summer density decline in most of the bays concentrations again increased somewhat in late summer.

Highest overall density of anomuran crab larvae occurred in Kiliuda Bay where stations average over 4200 organisms/1000 m^3 for the entire study period (Table 23). Izhut, Chiniak, and Kaiugnak bays averaged 3414, 1968, and 1307/1000 m^3, respectively.

Average relative density of anomuran crab larvae per station in all bays by season is shown in Figures 85-88.

Anomuran larvae were present in the offshore subareas throughout the study period but only in relatively substantial amounts during spring and summer (Figure 84). During the spring this larval group was found in low numbers throughout the more nearshore portion of the region. Amounts increased during summer, especially in the Albatross subarea off Kaiugnak Bay (Figure 89). Areas of concentration were limited in the fall, and during the following winter survey, this larval group was found only in very low concentrations and in waters adjacent to the inshore bay regions (Figure 90).

Highest overall density of anomuran larvae in the offshore subareas occurred in the Albatross subarea (Table 24). This subarea averaged almost

1038 individuals/1000 m^3 during the study. The Portlock, Marmot, and Sitkinak offshore subareas averaged 729, 459, and 204/1000 m^3, respectively.

Concentrations of anomuran crab larvae in the inshore bay regions during spring and offshore during summer suggest a possible offshore transport of this group during summer months.

Diel and Depth Distribution -- The vertical distribution of anomuran crab larvae by time of day appeared similar throughout the Kodiak Island study area. In the inshore bay regions, this larval group appeared to be concentrated in the upper portion of the water column during the day with 75% of all organisms encountered in the 10-30 m depth stratum (Figure 91). At night, they were somewhat dispersed and found in deeper waters with over 80% found at depths of 50-90 m. In the offshore subareas, anomuran larvae were encountered at diel stations only during the summer. At that time, highest relative density occurred in the upper portions of the water column during the early hours of daylight and in the lower portions at night (Figure 92).

There appeared to be no substantial change in diel behavior by season in the inshore bay regions except for during early spring (Cruises I and II). At this time of low relative density, the depth distribution of anomuran larvae did not change between day and night. Most organisms were encountered at depths of 50-70 m.

Time of Occurrence by Larval Stage -- Stage 1 larvae of anomuran crabs were present in the inshore bay regions throughout the year (Table 25). Stages 3 and 4 were encountered from late spring through summer and glaucothe were encountered throughout summer and in fall.

It is difficult to identify a principal time of larval release for the anomuran group since genera from at least two families have been combined for this analysis. The presence of early zoeal stages throughout the year suggests that larval release may be somewhat continuous. The appearance of later stages and glaucothe only during summer and fall, however, may indicate peak larval release occurring during spring.

Cancer I - Cancer crabs

Cancridae are distributed along the North Pacific rim from San Diego northward to the Bering Sea and to Japan. Five species occur in the Gulf of Alaska: *Cancer productus*, *C. gibbosulus*, *C. magister*, *C. gracilis*, and *C. oregonensis*. Two species were encountered during this study. One was identified as *C. magister* and the other was only identified as *Cancer* I.

Early life history information is not available for some Cancer species. Cancridae larvae molt through a prezoea stage, five zoeal stages, and a megalops stage before attaining adult form (Trask, 1970). Based on a comparison of Cancridae larvae distribution from this study with adult distributions and personal communications (Howard C. Feder, Institute of Marine Science, University of Alaska and Evan B. Haynes, NMFS, Auke Bay Laboratory), *Cancer* I larvae were tentatively identified as *C. oregonensis*.

Distribution and Relative Density by Region and Season -- *Cancer* I larvae were the third most frequently encountered decapod during the entire study. This species was present in 35% of the inshore samples (range by bays, 21-45%) and approximately 14% of those from the offshore subareas (Table 13). Overall average density per station in the inshore bay regions was about twice the level found offshore (3125 organisms/1000 m^3 vs. 1427). *Cancer* I, however, was the most frequently encountered taxon in the offshore subareas.

Very low concentrations of *Cancer* I larvae were found in the inshore bay regions during spring and, prior to late spring, these larvae were found only in Kiliuda Bay (Figure 93). Inshore concentrations increased substantially by mid summer when peak amounts were encountered, with Izhut Bay containing highest densities. No larvae of this species were found inshore in fall and winter samples.

Highest average densities occurred in Izhut Bay where the overall average density of *Cancer* I larvae approached 7600 organisms/1000 m^3 (Table 26). Kaiugnak and Kiliuda Bay averaged 3211 and 1778/1000 m^3, respectively, while Chiniak Bay produced the lowest average of only 803/1000 m^3. Average density per station in all bays for spring and summer is shown in Figures 94 and 95.

Cancer I larvae were encountered offshore from summer through winter but in substantial amounts only during the summer sampling period (Figure 93). During summer relatively high concentrations occurred throughout much of the offshore subareas with highest amounts being found off Kaiugnak, Ugak, and Chiniak Bays adjacent to the Trinity Islands, and south of Portlock Bank (Figure 96). During fall and winter, this species was encountered at only one offshore station.

Highest overall density in the offshore subareas occurred in the Portlock subarea where at all stations larvae averaged over 2300/1000 m^3 (Table 27); the Albatross and Sitkinak subareas averaged 1500 and about 1200 organisms /1000 m^3, respectively, and the Marmot subarea only 708/1000 m^3.

Diel and Depth Distribution -- In the inshore region, *Cancer* I larvae were concentrated in the upper portion of the water column during daylight with 97% encountered in 10-30 m depth stratum (Figure 97). This larval group usually dispersed into mid depths at night with 90% occurring at depths of 30 to 70 m. In late summer and fall, individuals of this larval group appeared to be concentrated in the shallower strata during day and night.

Cancer I larvae were found at diel stations only during summer in the offshore subareas. Very high concentrations were encountered in the lower portion of the water column (Figure 98) with highest densities occurring after sunrise and after sunset. In the upper portion, densities appeared highest around sunrise.

The vertical distribution of Cancer I larvae appeared to differ between inshore bay regions and offshore subareas during summer. When day and nighttime diel samples were combined, 73% of the larvae in the inshore bay regions were encountered at depths of 30 m or less. A similar combination of data from the offshore subareas indicated only 8% occurred at 30 m or less.

Time of Occurrence by Larval Stage -- Stages 1 and 2 of Cancer I larvae were present in the inshore bay regions from late spring through summer (Table 28) while later stages were found only during summer cruises. In fall, only megalops were encountered suggesting larval release and development had been completed by that time.

Pinnotheridae - Pea crabs

Seven genera of Pinnotheridae representing 14 species are distributed around the North Pacific rim from San Diego northward to the Bering Sea and to Kamchatka and Japan. They are found at depths from about 100 m to 1,000 m. Three species of pea crabs have been reported from the Gulf of Alaska: *Pinnixia faba*, *P. occidentalis* and *Raphonotus subquadratus*. Early life history information on this family is incomplete making identification beyond family level difficult. Based on personal communication (Howard C. Feder, Institute of Marine Science, University of Alaska) and comparison of larval and adult abundance and distribution we think that the majority of pinnotherid larvae encountered during this study may be *Pinnexia occidentalis*. Pea crabs are not of commercial importance.

Distribution and Relative Density by Region and Season -- Pea crab larvae were the fourth most frequently occurring decapod in the study area. This group was encountered in over 42% of the inshore samples (range by bay, 25-53%) and nearly 7% from the offshore subareas (Table 13). Overall average density in the inshore bay regions was over six times greater than offshore. The average density for inshore bays was over 4370 organisms/1000 m^3 compared to about 660/1000 m^3 for offshore subareas.

Pea crab larvae were initially found inshore in Kaiugnak Bay during mid-spring (Figure 99). This larval group was present in all bays by late spring with peak amounts in Kiliuda Bay at this time but later elsewhere. Few and no pea crab larvae were found in the inshore bay regions during fall and winter, respectively.

Highest average density of pea crab larvae occurred in Kiliuda Bay where the overall density exceeded 11400/1000 m^3 (Table 29). Average overall densities for Izhut, Chiniak, and Kauignak bays were 3520, 1665 and 840/1000 m^3, respectively. Average relative density per station in the inshore bays during spring and summer is presented in Figures 100 and 101.

Pea crab larvae were encountered in the offshore subareas only during summer (Figure 99). Highest numbers were found primarily on North Albatross Bank in the Marmot subarea (Figure 102). Lowest density was encountered in the southernmost Sitkinak subarea (Table 30).

Diel and Depth Distribution -- Pea crab larvae in the inshore bay regions of the study area appeared to be concentrated in the upper portion of the water column during daytime with about 80% found in the 10-30 m stratum (Figure 103). This larval group seemed more dispersed and in deeper water at night with 70% occurring between 50 and 90 m. Diel behavior did not noticeably differ by time of year.

Pea crab larvae encountered during diel sampling in the offshore subareas in summer were found in the lower portion of the water column primarily from late day until just after sunset (Figure 104). In the upper portion of the water column, highest concentrations occurred after sunrise with relatively high amounts continuing until evening. Very few organisms were found in either depth stratum during late night sampling which suggests they were outside our sampling depths.

Vertical distribution of pea crab larvae appeared to differ between regions. During summer, when data were available from both regions, day and night samples combined by depth indicated 63% of these larvae in the inshore bay regions occurred at depths of 30 m or less. Only 25% of the pea crab larvae occurred at depths less than 30 m in the offshore subareas.

Time of Occurrence by Larval Stage -- Pea crab larval stages 1 and 2 were encountered in the inshore bay regions from late spring through summer (Table 31). Stages 3-5 were found in summer and fall samples.

The occurrence of pea crab in early stages of larval development throughout summer suggests a protracted spring-summer period of larval release.

Chionoecetes bairdi - Tanner crab

Tanner crab, *Chionoecetes bairdi*, occur in the northeastern Pacific region, from British Columbia northward into the eastern Bering Sea and is the only member of the genus *Chionoecetes* which is endemic to continental shelf waters of Kodiak Island. Adults are benthic and are found from the littoral zone out to depths of 400 m (Bright, 1967). A major commerical fishery for the species occurs in the Kodiak Island shelf area as well as the eastern Bering Sea.

Life history information for *C. bairdi* is fairly complete. In the Gulf of Alaska area, mating usually occurs during spring and the resulting fertilized eggs are carried by females for about one year. (Ito, 1967; and Hilsinger, 1975). Hatching and larval release are assumed to occur primarily during the spring with the subsequent pelagic zoea progressing through four molts (prezoea, zoea 1 and 2, and megalops) before attaining adult form. Zoeal distribution in the water column proceeds towards the seabed with each progressive molt.

Distribution and Relative Density by Region and Season -- Tanner Crab larvae were the sixth most frequently encountered decapod in the Kodiak

Island study area and the most frequently occurring species of current economic importance. Larval forms of this species were encountered in nearly 18% of all inshore samples with a very uniform frequency of occurrence throughout the inshore bay regions (range by bay, 16-19%). Tanner crab larvae were present in over 13% of the samples from offshore. Overall average relative density in the inshore bay regions was about five times greater than in the offshore subareas with the combined inshore bays averaging about 570 organisms/1000 m^3 compared to 110/1000 m^3 offshore.

Seasonally, the earliest appearance of Tanner crab larvae in the inshore bay regions occurred during the final survey (February-March 1979) in late winter. However, measurable quantities of Tanner crab larvae were not present until late spring and primarily in Chiniak and Kaiugnak bays (Figure 105). Very few larvae were encountered after early summer.

Highest densities occurred in Chiniak Bay with an overall average of about 1200/1000 m^3 (Table 32). Overall average densities for Kaiugnak, Kiliuda and Izhut bays were 738, 309 and 45/1000 m^3, respectively. Average relative density per station in the inshore bay regions during spring and summer is shown in Figures 106 and 107.

Tanner crab larvae were encountered in the offshore subareas almost exclusively during summer (Figure 105) with highest concentrations occurring west of the Trinity Islands, near the shelf edge in the Sitkinak subarea, and at scattered locations off North Albatross and Portlock Banks (Figure 108). Larvae of this species were absent from almost all shelf stations from the Trinity Islands northward to North Albatross Bank. Average relative densities for Sitkinak, Portlock, Marmot, and Albatross subareas were 269, 103, 50 and 19/1000 m^3, respectively (Table 33).

<u>Diel and Depth Distribution</u> -- Most Tanner crab larvae in the inshore bay regions were found in upper portions of the water column during the day (98% between 10-50 m) and in deeper strata at night (74% between 50-90 m) as shown in Figure 109. Possible changes in diel behavior by season could not be determined since substantial numbers were found only during summer observations.

Diel observations of Tanner crab larvae in the offshore subareas indicated little change in relative density by time of day in the upper and lower portions of the water column (Figure 110). Average relative density of these larvae, however, was noticeably greater in the upper portion of the water column than in the lower portion.

<u>Time of Occurrence by Larval Stage</u> -- Early and late stages of Tanner crab larvae were encountered in the inshore region throughout most of the year (Table 34). This simultaneous presence of various stages of larval development throughout the year suggests a protracted period of larval release.

Cancer magister - Dungeness crab

Dungeness crab, Cancer magister, occur in the northeastern Pacific Ocean from Magdelena Bay, Mexico northward to the Aleutian Islands and are found from the intertidal zone to a depth of about 100 m. This member of family Cancridae has supported a major commercial fishery in the Kodiak area, although current economic importance and stock size is relatively limited.

Adults are benthic and although time of mating has not been determined in the Gulf of Alaska, the breeding season in British Columbia waters has been reported as spring and summer (Hoopes, 1973). Hatching and larval release in the Kodiak Island area usually occurs during spring and the resulting pelagic larvae undergo seven molts (prezoea, zoea 1-5, and megalops) before attaining adult form (Poole, 1966). The larvae spend as long as three months in a planktonic form before settling to the bottom (Poole, 1966).

Distribution and Relative Density by Region and Season -- Dungeness crab larvae were the tenth most frequently occurring decapod in the Kodiak Island inshore bay regions and the third most frequently encountered decapod of current economic importance. This species was present in over 17% of all inshore samples (range by bay, 3-34%) but in only 1% of those obtained offshore (Table 13). Overall relative density was quite low with the inshore average about 217 organisms/1000 m^3 and offshore about 23/1000 m^3.

Most Dungeness crab larvae occurring in the inshore bay regions were present in Kiliuda Bay during spring and summer (Figure 111). Average relative density in this bay was about 660/1000 m^3, at least six times greater than any other bay studied (Table 35). Highest densities in all bays occurred during early summer, although the times of occurrence in Izhut, Chiniak, and Kaiugnak bays were fairly short. This species occurred only during one cruise in Chiniak Bay. Average relative densities in Kaiugnak, Izhut and Chiniak bays were 105, 53 and 44/1000 m^3, respectively.

Average relative density per station for the inshore region during spring and summer are shown in Figures 112 and 113.

Dungeness crab larvae were very limited in distribution and abundance in the offshore subareas (Table 36) occurring only at three nearshore stations during summer in the Albatross and Sitkinak subareas (Figure 114). These data suggest that during our studies the larvae of this species occurred mostly in bays, with offshore distribution only adjacent to the bays.

Diel and Depth Distribution -- Dungeness crab larvae in the inshore bay regions of Kodiak Island generally were concentrated in upper strata of the water column during the day and dispersed into deeper strata at night (Figure 115). Over the entire study period about 70% of the individuals encountered during daytime sampling occurred in the 10-30 m depth stratum, while at night, slightly more than 50% were found between 50 and 90 m. It should be noted during the period of peak daytime occurrence (Cruise VII), substantial numbers were found to depths of 50 m.

During offshore diel studies, Dungeness crab larvae were found almost exclusively at night with most organisms in the deeper stratum (Figure 116). Almost no larvae were encountered in either stratum during daylight, which suggests that their location was outside our sampling depths.

Time of Occurrence by Larval Stage -- Stage 1 Dungeness crab larvae were present in the inshore bay regions from early spring through summer and during the following late winter (Table 37). Later stages of larval development were found only during mid-summer.

The occurrence of early stage larvae throughout spring and summer suggests a protracted period of larval release. The presence of later stages only during summer indicates that during our study the peak period of larval release for Dungeness crab occurred during spring or early summer.

Paralithodes camtschatica - Red king crab

Red king crab occur along the North Pacific rim from southeast Alaska to the Chukchi and Okhotsk Sea and Japan. Adults are benthic and are found from subtidal areas to depths of about 300 m in the Kodiak Island shelf area (Powell and Reynolds, 1965). This species is an extremely important commercial fishing resource throughout most areas of the Alaska continental shelf.

Life history information for this species is fairly complete. In the Gulf of Alaska region, fertilized eggs are carried by females for about one year (McMullen and Yoshihara, 1969) with hatching and subsequent larval release usually occurring during early spring (Bright, 1967). Red king crab zoeae molt through four larval stages and a glaucothe stage (about 13 days per stage) before attaining adult form (Sato, 1958). All larval stages are pelagic but zoeal distribution in the water column proceeds towards the seabed with each progressive larval stage (Bright, 1967).

Distribution and Relative Abundance by Region and Season -- Red king crab larvae were the twelfth most frequently occurring decapod and the fourth most commonly encountered species of current economic importance. Larval forms of this species were present in 13% of all inshore samples (range by bays, 6-15%) and in only about 2% of those samples obtained offshore (Table 13). Overall, the average relative density was very low in the entire survey area with the combined inshore bays averaging 63/1000 m^3. Zoeae of this species were virtually absent offshore. Samples from that region averaged only about one larva/1000 m^3.

Red king crab larvae were present in the inshore bay regions only during late winter and spring (Figure 117) with most found in Chiniak and Kiliuda bays (Table 38). Average densities in Chiniak, Kiliuda, Kaiugnak, and Izhut bays were 152, 69, 31 and 5/1000 m^3, respectively.

Average relative density per station in the inshore bay regions during spring 1978 and the following winter is shown in Figures 118 and 119.

Offshore, red king crab larvae were totally absent from the Portlock and Marmot subareas (Table 39). They were found in extremely low densities in Albatross and Sitkinak subareas, occurring at only one station per survey during the spring, summer and winter cruises. During these cruises each occurrence was at a location adjacent to an inshore bay region.

Diel and Vertical Distribution - In the inshore bay regions of the study area, red king crab larvae were usually found in shallower portions of the water column during daytime than at night (Figure 120). Nearly 85% of all individuals encountered during daylight diel sampling occurred in the 10-30 m stratum while at night 83% were found between 50 and 90 m.

Red king crab larvae were found only in the upper portions of the water column during diel investigations in the offshore subareas. In the upper stratum, larvae of this species were encountered from about sunrise until a few hours before sunset with highest relative density occurring shortly after sunrise (Figure 121). No larvae were captured during late day and most of the night suggesting that at those times they were present outside our sampling depths.

Time of Occurrence by Larval Stage -- Stage 1 red king crab larvae were encountered only during late winter and early spring in the inshore bay regions (Table 40). Later stages occurred during spring or very early summer suggesting that during our study a relatively brief period of larval release occurred for red king crab.

Summary of Decapod Larvae Information

Relative Densities -- Larval groups which had the highest average densities over the entire survey period in both regions were pea crab and *Cancer* I crab.

Larvae of decapod species of current economic importance were encountered in low density relative to other decapod species.

Geographic -- All decapod larvae groups of principal interest were found in substantially greater concentrations inshore rather than offshore. Kiliuda Bay contained the highest numbers of decapod larvae for all species combined over the entire study period. Average densities of all larval decapods combined were fairly uniform in the Portlock, Marmot, and Albatross offshore subareas. Overall, amounts present in the southernmost subarea, Sitkinak, were about half of those averaged in all other offshore subareas.

Seasonal -- Highest densities for all decapod groups combined occurred during summer throughout the study area. Time of peak occurrence for each decapod group varied through spring and summer. The succession was as follows:

Early-Mid spring - red king crab, pink shrimp
Late spring - anomuran crabs, Tanner crab, Dungeness crab
Early summer - *Cancer* I crab, crangonid shrimp
Mid summer - hippolytid shrimp, pea crab.

The occurrence of early stages of most decapod larvae from late winter through summer suggests a protracted period of decapod larvae release. Notable exceptions were pink shrimp and red king crab which were present in early larval stages during an abbreviated time period, mid- and late spring.

Diel-Vertical -- Several crab larvae (Tanner crab, red king crab, pea crabs, and anomuran crabs) displayed positive photostasis during diel studies, i.e., more organisms were encountered near the surface during day than at night. Additionally, combined day and night data from the inshore region diel work indicated that the greatest proportion of organisms for most larval groups occurred in the shallower depths sampled. A list of the larval groups and depth strata of highest densities is as follows:

Larval Group	Depth Stratum	Percentage of Combined All-Depth Catch Rate
hippolytid shrimp	30 m	>40%[1]
crangonid shrimp	30 m	45%
pink shrimp	50-70 m	58%
anomuran crabs	10 m	40%
pea crabs	30 m	32%
Cancer I crabs	10-30 m	75%
Tanner crabs	50 m	48%
Dungeness crab	10-30 m	58%
red king crab	10 m	35% and 90 m, 30%

1/ The catch rate for the 30 m stratum was more than 40% of the sum of catch rates for all strata combined.

Ichthyoplankton

The shelf off Kodiak was found to be a spawning and nursery area for many species of fish. Eggs and larvae of a number of the more than 60 taxa identified were found in every season (Tables 41 and 42). No area was found to lack young stages of fish. Among the species found there were those of present or potential commercial value, and others of value as forage for other fish, birds and mammals. The entire water column was used by ichthyoplankton and the neuston (surface) layer was particularly important to a number of species.

A species-by-species account of the geographical and seasonal distribution of the more abundant taxa collected during sampling at the grid stations will be presented first. Because they contain several species of importance in our samples, the families Hexagrammidae, Cottidae, Bathymasteridae and Pleuronectidae are discussed in general before discussions of individual species. Otherwise the most precise taxonomical category that we identified is discussed. Introductory comments about each species contain information from Hart (1973), Macy et al. (MS 1978) and Trumble (1973) and other sources noted in the individual accounts. Egg and larval distributions will be discussed as influenced by bathymetric and hydrographic features of the area. The effect of time of day of sampling at individual stations will be discussed in light of the results of the diel series which will be presented in detail in the following section. Figures 122 to 187 portray the geographic distribution of taxa with five or more occurrences in bongo or neuston net tows on a cruise. Figures 188 to 203 show the length distribution by cruise and gear for larvae of several of the more abundant species.

Distribution and Discussion of Selected Taxa

<u>Mallotus</u> <u>villosus</u> - Capelin (Figures 122-125, 189)

Capelin are distributed in the boreal and arctic portions of the Atlantic and Pacific oceans. They are harvested in the Atlantic, and show potential for harvest off Alaska, although their use at present is quite limited. Adults move from deeper water shoreward in spring and spawn nearshore and intertidally at various times of year, depending on the locality. Spawning occurs in May and June in Bristol Bay, and in September and October off British Columbia. They spawn demersal eggs which are buried to some extent, either by the parents or wave action. Spawning takes place in water of 10.0°-12.5°C. Eggs hatch in about 2-3 weeks. Larvae have been reported around Kodiak Island in September.

Capelin larvae were identified in neuston tows from all but the summer cruise. In summer small larvae that could only be identified as osmerids were encountered; many of these may have been capelin larvae. Since capelin seem to spawn primarily in summer near Kodiak in order to follow their seasonal cycle of larval occurrences, they will be discussed starting with the fall cruises, then winter, and then spring. In both fall cruises larvae occurred in neuston and bongo tows. In collections from both fall cruises the larvae were larger (mean length) in neuston tows than in bongo tows (1977: 41.8 mm in neuston, 21.8 mm in bongo; 1978: 35.7 mm in neuston, 21.7 mm in bongo). They were more widespread, and seemed to be more abundant in bongo than in neuston collections. In both years they were concentrated in the northeast part of the study area over North Albatross Bank, although they were found over much of the rest of the area. They appeared more abundant and widespread in fall 1978 than in fall 1977. In winter they were again most abundant in bongo tows in which they occurred in much the same area as in fall, although they were not quite as widespread. Winter mean lengths were 40.1 mm in the neuston net and 31.3 mm in the bongo net. By spring the larvae were taken in more than five tows only in the neuston net and occurred at only a few scattered stations near the southern part of the study area. They averaged 40.8 mm long in spring. Apparently they are no longer available to our sampling gear after they reach about 55 mm. In all cruises far more were taken in the neuston net at night than in the daytime, which accounts for some of the apparent pattern in their geographic distribution, as shown by neuston catches.

Leuroglossus schmidti (= *Bathylagus schmidti*) - Northern smoothtongue (Figures 126-129)

Northern smoothtongue are a widely distributed bathypelagic smelt-like fish found throughout the North Pacific Ocean and Bering Sea. Little is known about their life history, although larvae and juveniles have been found in the stomachs of a number of pelagic fish species, and their larvae have been collected in the Bering Sea in July, September, and January.

Northern smoothtongue eggs and larvae were taken in bongo catches. The eggs occurred well offshore near the edge of the shelf in all but the summer cruise and they were most widely distributed in fall 1978, although fewer offshore stations were sampled in fall 1977. In winter 1979 the eggs occurred in lower numbers, and at fewer stations than in fall 1978 and were taken at only a few stations in spring. They were taken in substantial numbers during the only diel series that was located in water deeper than 200 m (fall 1978, Diel 7), were generally more abundant in the net sampling the 40-193 m stratum and were not found in the neuston catches. Larvae were found during all of the cruises and were mainly at the offshore stations in water deeper than 200 m. However, in the summer and fall cruises they were also found over the nearshore area of Portlock Bank. Presumably these larvae were carried into this region in water from that part of the Alaska Stream that moves toward Shelikof Strait.

Protomyctophum thompsoni - Bigeye lanternfish (Figure 132)

As an adult this species is bathypelagic throughout the North Pacific from Mexico to Japan.

Larvae of bigeye lanternfish were taken in bongo tows during the two fall cruises when they were found in low abundance mainly at stations near the edge of the shelf. They were probably in offshore Alaska Stream water that spilled up onto the shelf. That they were caught more frequently in the bongo net than the neuston net indicates a preference for subsurface waters.

Stenobrachius leucopsarus - Northern lampfish (Figures 130-131)

This species is mesopelagic throughout the North Pacific Ocean from Mexico to Japan. Larvae of this species have been the most abundant taken in several surveys although little is known about it in the Gulf of Alaska and LeBrasseur (MS 1970) took no larvae near Kodiak. Spawning was reported to occur in December through March off Oregon.

Northern lampfish larvae were taken in bongo tows on all but the first fall cruise. They never were very abundant, but occurred at scattered stations throughout the study area. Their distribution was not limited to nearslope waters as was the case with other mesopelagic species, rather they occurred all across the shelf to the stations nearest shore in some areas. Little seasonal difference in abundance or distribution is evident, although more seemed to be present in the summer cruise. In summer more were taken at stations in slope waters (average 18.0/10 m^2) than in midshelf or nearshore waters (average 5.1/10 m^2).

Theragra chalcogramma - Walleye pollock (Figures 133-135, 188)

Pollock occur from California to Japan and are apparently the most abundant finfish of the shelf off Kodiak. They are the object of an extremely large fishery by several nations in the Bering Sea and in the Gulf of Alaska. They spawn pelagic eggs in winter and early spring in various parts of their range. In the Kodiak area, the largest concentrations of eggs have been reported from the channel extension of Shelikof Strait near the Trinity Islands.

Eggs of walleye pollock were taken in neuston and/or bongo tows during all the cruises. Eggs were concentrated toward the southern end of Kodiak Island with areas of abundance in the Kiliuda Trough-Horsehead Basin area in fall and spring and, in summer, also near Shelikof Strait. They were also taken at scattered stations throughout the study area and in several of the diel series, notably in spring (Diel 4) when enough were caught to characterize their vertical distribution. At each station of this series generally at least half of the eggs in the water column were in the neustonic layer and the other two depth strata sampled (0-66 m and 66-121 m) generally had about equal numbers of eggs. The water column was hydrographically homogeneous at this station. Larvae were taken in bongo tows in spring, summer and fall. In spring the larvae were in much the same area as the eggs at that time--in the southern half of the study area, whereas in summer the largest area of occurrence of pollock larvae was off the northeast portion of Kodiak Island. Another area of concentration was near the southern end of Shelikof Strait. In fall only five larvae were taken in 1977, none in 1978.

In spring the larvae were 2-8 mm (mean 4.3 mm) long and in summer they were 5-37 mm (mean 19.1). In summer larvae larger than 21 mm were taken only at night, indicating some net avoidance during daytime. The catch rates did not seem to vary consistently with day and night sampling, although too few larvae were taken for detailed analysis.

Macrouridae - Grenadiers (Figure 136)

Several species of these deepwater gadoids are found in the North Pacific. Since they occur in deep waters, their biology is poorly known; however, they lay pelagic eggs and have distinctive larvae.

Eggs of grenadiers were taken in the bongo net on the summer and fall (1978) cruises. On both cruises they were taken only at offshore stations in water deeper than 100 m and the areas of occurrence were quite similar on both cruises. Their absence in the first fall cruise (1977) may have been due to the paucity of stations occupied in the offshore area where those eggs were taken in 1978. A few grenadier larvae were taken in bongo tows in the winter, spring and summer cruises.

Sebastes spp. - Rockfish (Figure 137)

This speciose genus occurs in northern waters of both the Atlantic and Pacific oceans and includes about 18 species that occur in the Kodiak area. The most important commercial species in the Kodiak area, *S. alutus*, Pacific ocean perch, occurs near the shelf-slope break, and migrates along it from the Unimak area in summer to the north and northeast Gulf of Alaska in fall. Rockfish give birth to free swimming prolarvae, during the first six months of the year, after embryonic development in the female. The larvae of most species from the Kodiak area cannot be distinguished from each other at present.

In summer rockfish larvae were taken in both the bongo and neuston nets in more than five instances and a few were also taken in fall and winter. In summer they were found in low abundance and scattered throughout the study area, mainly offshore. Bongo net catches of larvae in summer were taken over much of the survey area and show a complex pattern of distribution from stations nearest the mainland north of Kodiak Island to nearshore stations at the easternmost part of Kodiak Island. They were more frequently caught in bongo and neuston tows at slope stations, where they were several times more abundant than in midshelf or nearshore stations. Possibly some of the irregularities in distribution are due to the presence of several species that we were unable to identify in these samples. In both neuston and bongo catches rockfish larvae appeared more abundant during night than during daytime, both in percent of possible occurrences and in numbers/10 m^2. These larvae were taken at both of the diel series conducted during the summer cruise (Diel 5 and 6) and at both stations they were generally most abundant in the 0-28 m stratum although a few were taken in the neustonic layer or deeper than 71 m. No diel differences in vertical distribution were noted.

Hexagrammidae - Greenlings

This family is represented in Kodiak waters by three genera. All species have a commercial potential, although only *Ophiodon elongatus* and *Pleurogrammus monopterygius* are presently harvested in quantity. Most species are demersal in rocky nearshore habitats, but *P. monopterygius* is mainly pelagic and ranges considerable distances offshore. All species spawn demersal eggs in nests and the larvae of all but O. elongatus are highly neustonic. Although species of Hexagrammos larvae are difficult to distinguish and most literature reports them at the generic level, they comprise a substantial part of the ichthyoplankton of the Kodiak area and as many as possible were identified to species using published descriptions, and new information from reared larvae and the specimens collected off Kodiak.

Hexagrammos decagrammus - Kelp greenling (Figures 141-145, 190)

This greenling occuring from California to the Aleutian Islands, is reported to spawn in October and November and young are present in late spring.

Kelp greenling larvae were taken in neuston and bongo tows in all five cruises. Seasonally the larvae first appeared in fall and in both years their distribution was centered near Middle Albatross Bank. In fall 1977 maximum abundances occurred over Kiliuda Trough, but larvae occurred all across the shelf from the nearshore stations to the stations over the slope. Lengths in neuston catches averaged 9.6 mm in fall 1977 and 10.0 mm in fall 1978. In winter larvae were much more widely distributed in a complex pattern of abundance. They averaged 10.7 mm long in neuston catches in winter. In spring their distribution was quite similar in extent and complexity to that seen in winter and they averaged 11.8 mm long in neuston catches. In both seasons an area of concentration over Middle Albatross Bank was evident. Bongo catches in winter and spring occurred in areas of high abundance in the neuston net. By summer although the abundance of larvae had decreased, their area of distribution remained large. In summer they ranged up to 56 mm long in neuston catches at night, but only 29 mm long in daytime catches. The overall mean length was 19.7 mm in neuston catches in summer. In the diel series nearly all larvae were taken in the neustonic layer, although a few were taken deeper mostly during the daytime.

Hexagrammos lagocephalus - Rock greenling (Figures 140 and 191)

There is some confusion concerning the taxonomy of this greenling, which occurs from California to Japan. Quast (1960) synonymized H. superciliosus with H. lagocephalus, but Harris and Hart (MS 1977) reported two forms of rock greenling in bays of Kodiak Island which they grouped under H. lagocephalus. We found larvae only of the eastern form, according to Gorbunova's (1962) descriptions which were called H. lagocephalus; however, if there are, in fact, two species in this complex, the larvae we have would be H. superciliosus.

Rock greenling larvae were taken in the neuston net during the two fall cruises. They were widely distributed, and had similar abundances in both years. In both years they occurred near shore of and over North Albatross Bank. Larvae also occurred over Middle Albatross Bank. They were taken all across the shelf, to the most offshore stations, although they were most abundant at midshelf stations. In fall 1977 the mean length was 11.2 mm and in fall 1978 it was 11.7 mm.

Hexagrammos octogrammus - Masked greenling (Figures 138-139, 192)

This greenling has been reported in the North Pacific from British Columbia to the Okhotsk Sea.

Masked greenling larvae were taken in neuston tows in all but the spring cruise. In the fall cruises they were widespread in the study area, in low abundance and no nearshore-offshore pattern was evident in either year. In both years they were taken over Middle Albatross Bank, and they occurred in several areas in fall 1978 that were not sampled in fall 1977 but the distributions in the two years were dissimilar. In 1977 they were found over North Albatross Bank and over Horsehead Basin, areas where they were absent in 1978. Catches in winter 1979 were fewer and the larvae were lower in abundance than in fall, although they were found mainly near areas where they had occurred in the previous fall. In fall 1977 they averaged 11.4 mm, in fall 1978, 13.4 mm and in winter 1979, 24.1 mm in neuston catches.

Hexagrammos stelleri - Whitespotted greenling (Figures 146-150, 193)

This greenling occurs from northern California to the northwest Pacific Ocean and is reported to spawn in April.

Whitespotted greenling larvae were taken in neuston and bongo tows on all five cruises. The bongo catches were quite small and widely scattered, and cannot be used to determine details of distribution. Neuston catches in fall throughout the study area indicated larvae were generally more abundant nearshore and south of Kodiak Island, although they occurred to the edge of the shelf. In winter, although abundances were generally lower than in fall, three areas of concentration were seen - Stevenson Trough, near Horsehead Basin, and near Shelikof Strait, and the larvae were mainly further offshore than they had been in fall. In spring larvae were present in much the same areas as they had been in winter, and in about equal abundance but by summer only a few larvae were taken at scattered stations near the edge of the shelf and over Kiliuda Trough. The larvae averaged 10.1 mm in length in fall 1977, 11.9 mm in fall 1978, 19.3 mm in winter 1979, and 23.0 mm in spring 1978.

Ophiodon elongatus - Lingcod (Figure 151)

Lingcod are the largest of the greenlings and occur from Baja California to the Aleutian Islands. About 5 million pounds of lingcod are landed annually in Canada alone. They are mainly demersal and predatory on smaller fish and spawn in December through March nearshore in areas of reduced salinity.

Lingcod larvae were taken in summer at several stations in the neuston net. They were in low abundance, and no pattern of distribution in the study area can be discerned.

Pleurogrammus monopterygius - Atka mackeral (Figures 152-155, 194)

This species retains, as adults, the pelagic habitat of juveniles of other members of the family. They range from California to the northwest

Pacific and the adults are fished by several nations. Pleurogrammus azonus, sometimes considered a synonym, occurs off Japan. During most of the year they are found along the slope but migrate to nearshore spawning grounds in June-August and spawn demersal eggs (on rocky bottoms in areas of high current) which hatch in about 40-45 days in fall.

Atka mackeral larvae were present in all cruises except that in summer and they were more abundant at midshelf and slope stations than at nearshore stations. Their occurrences in this study will be discussed starting with the two fall cruises, then the winter, then the spring cruise. In fall of both years the neuston tows showed a similar pattern of distribution with a concentration of larvae over Middle Albatross Bank and Kiliuda Trough, and an indication of a smaller area of concentration near the inshore end of Stevenson Trough. In fall 1978 larvae were also found along the shelf edge in most of the study area. Bongo catches in fall coincided with areas where neuston catches were large. In fall of both 1977 and 1978 larvae averaged 10.4 mm long in neuston catches. In winter 1979 neuston catches of Atka mackeral were widely distributed with areas of abundance near Horsehead Basin and Stevenson Trough and over the middle of the shelf in most of the study area; lengths averaged 14.3 mm. Areas of bongo catches were mainly in waters over troughs. In spring 1978 areas of abundance in neuston and bongo catches were over Stevenson Trough and Middle Albatross Bank as well as at other scattered stations extending all across the shelf; lengths averaged 17.6 mm in neuston catches.

In two of the diel series taken in fall (Diels 1 and 7) Atka mackeral larvae were abundant and taken primarily in the neustonic layer. Although a few were also found in deeper water down to 45 m no marked diel differences were observed.

Anoplopoma fimbria - Sablefish (Figure 156)

Sablefish are harvested by several nations throughout their range along the Pacific rim from Mexico to Japan, and occur near bottom at depths of 200-400 m off Kodiak. They move inshore somewhat in spring and summer. They spawn pelagic eggs in winter, and the larvae and juveniles remain pelagic until fall when they descend to the bottom.

Sablefish larvae were taken at several stations in the neuston net during the summer cruise. Always in low abundance and irregularly distributed in the study area, they occurred primarily at several stations at the eastern (offshore) end of the station pattern and averaged 19.1 mm in length.

Cottidae - Sculpins

The sculpins are a large, circumpolar group of fishes distributed in both marine and fresh waters. Members of this family are found throughout the northeast Pacific Ocean with over 39 species inhabiting waters in the Gulf of Alaska (Howe and Richardson, MS 1978). Sculpins are frequently bottom dwellers and exhibit a wide variety of forms. Most species are found in shallow water and may be abundant intertidally (Hart, 1973), although some species occur in deep water.

Eggs of most sculpins are adhesive and demersal (Breder and Rosen, 1966). Many species are benthic as adults and juveniles, and planktonic as larvae (Howe and Richardson, MS 1978). Although larvae were taken frequently in our sampling, little information is known about the family. Sculpins have received little study because, presently, they lack commercial importance.

Hemilepidotus spp. - Irish lords (Figures 157-161, 195)

Larvae of the genus *Hemilepidotus*, which is endemic to the northeast Pacific Ocean, were taken frequently in our plankton surveys off Kodiak Island. Six species are recognized, four of which may occur in the Gulf of Alaska (Peden, 1978). *Hemilepidotus hemilepidotus* and *H. jordani* have been reported in the Kodiak area while *H. spinosus* and *H. zapus* may also occur there. Larval identification to species (<18 mm) is difficult based on the available literature (Richardson and Washington, in press).

Larvae of Irish lords were taken in the bongo net in all but the summer cruise; they occurred in the neuston net in all the cruises. They had the highest mean density of any taxon during the two fall cruises and the winter cruise. Larvae were caught at more than 50 stations on each of these three cruises and occurred throughout the study area with no definitive pattern of distribution evident. Larvae were most abundant in fall and least abundant in summer, reflecting their late summer spawning and prolonged larval phase. The mean lengths of larvae in neuston catches reflect this same pattern; 5.6 mm, fall 1977; 6.6 mm, fall 1978; 8.3 mm, winter; 10.7 mm, spring; and 22.1 mm, summer. Night neuston catches were greater than day catches in all cruises, a result borne out by catches during the diel series when they were more abundant in the neuston at night and more abundant in the next deeper stratum during daytime. This complicates the analysis of geographic distribution of these larvae based on neuston catches.

Hemilepidotus jordani - Yellow Irish lord (Figure 163)

Yellow Irish lord reach sizes to 410 mm and range from southeast Alaska through the Bering Sea to southern Kamchatka (Peden, 1978). Juveniles and adults are usually found in subtidal depths but may be taken on suitable bottoms to 110 m.

Little information is available on the spawning and development of *H. jordani* except that spawning occurs in August throughout Asian waters (Peden, 1978). The larvae are difficult to distinguish from those of other members of the genus; characters used by Gorbunova (1964) are not sufficient to recognize the species at sizes smaller than about 20 mm (Richardson and Washington, in press).

Yellow Irish lord larvae were identified only in the neuston samples of the summer cruise. They may have been present in additional samples from the summer cruise and in samples from other cruises but were too small to identify beyond the generic level. They were at low abundance and scattered throughout the study area; no pattern of distribution was observed.

Hemilepidotus hemilepidotus - Red Irish lord (Figure 162)

Red Irish lord range from Monterey Bay, California to the Bering Sea (Howe and Richardson, MS 1978). They reach approximately 510 mm, and are found in shallow waters, intertidal to 48 m (Howe and Richardson, MS 1978), and according to Peden (1978) may live in tide pools and rocky habitats as juveniles and adults. In British Columbia the red Irish lords lay pink egg masses in shallow waters during March (Hart, 1973) and the larvae hatch at 5-6 mm.

Red Irish lord larvae were identified only in the summer cruise. They may have been present in additional samples from the summer cruise and in samples from other cruises but were too small and not well enough developed to identify beyond the generic level. In the summer cruise they were taken in low abundance at stations scattered throughout the study area; however, there did seem to be a regular pattern of occurrence in waters over Kiliuda Trough. Larvae ranged from 16-22 mm long (mean = 19.3 mm). More were taken in the neuston at night (43.0/1000 m^3) than in daytime (15.7/1000 m^3) but the size of larvae did not vary with time of day.

Bathymasteridae - Ronquils

Ronquils are a small family of three genera, with no present commercial value, that are distributed in the North Pacific Ocean. Four species in two genera are reported to occur in the Gulf of Alaska near Kodiak Island; *Bathymaster caeruleofasciatus*, *B. leurolepis*, *B. signatus*, and *Ronquilus jordani*. Size as well as habitat varies among the species. Ronquils range in size from 170-300 mm. *Bathymaster leurolepis* is commonly taken inshore in tide pools to a maximum depth of 9 m (McPhail, 1965); others are commonly taken offshore in deeper water.

Eggs are probably demersal and spawned in masses (Breder and Rosen, 1966), and larvae are planktonic. Information on the taxonomy and early life history is limited; at present only *R. jordani* larvae are easily separable while all others are grouped in the genus *Bathymaster*.

Bathymaster spp. - searchers (Figures 164-166)

Members of the genus *Bathymaster* were the most abundant group of ronquils from plankton surveys off Kodiak Island. *Bathymaster* is the most speciose genus in the family with four species, three of which are reported to occur in the Kodiak area. Little information is available on the early development of any of the species. *Bathymaster signatus* young have been taken commonly in surface waters of Saanich Inlet, British Columbia during April through June and gravid *B. leurolepis* females have been taken off Attu Island, Alaska during May.

Searcher larvae occurred in samples from the spring, summer, fall (1978) and winter cruises. They were present in the neuston net in all four cruises and in the bongo net during the spring and summer cruises. In summer larvae were quite widespread, occurring at nearly every station. From the bongo catches they appeared most concentrated over the middle of the shelf and neuston catches indicated areas of apparent abundance over Kiliuda and Stevenson

Troughs. By fall the abundance and area of distribution were considerably reduced, and larvae occurred mainly offshore and over Middle Albatross Bank. In winter a few larvae were found over Stevenson Trough and off North Albatross Bank. At the diel series during summer (Diels 5 and 6) they were taken primarily at the surface and in the 0-28 m stratum. During daytime they seemed to move from the neustonic layer to the next deeper stratum.

Stichaeidae - Pricklebacks (Figure 167)

Pricklebacks are a large, circumboreal family of fishes inhabiting bottom waters. At least 27 species have been recorded from Alaska waters (Quast and Hall, 1972) and approximately 13 species have been taken near Kodiak Island. They include species of widely varying size none of which are presently taken commercially.

Although some stichaeids have been studied, little is known about the taxonomy and early life history of most species and those species studied have adhesive demersal eggs which are usually spawned in shallow coastal waters; parental care is common with females guarding and aerating the eggs (Breder and Rosen, 1966). The larvae are planktonic and were taken frequently during our cruises. As larvae, few members of this family can be identified to species.

Larvae of unidentified pricklebacks caught in bongo tows in spring and summer were widely distributed. In spring an area of abundance was observed near Horsehead Basin and South Albatross Bank and larvae occurred at scattered locations elsewhere in the study area also. In summer they were less abundant and widely scattered throughout the study area in water shallower than 200 m.

Lyconectes aleutensis - Dwarf wrymouth (Figures 168-169, 196)

The dwarf wrymouth is an elongate fish taken from Northern California to the Bering Sea which normally reaches a size of at least 27 cm and ranges in depth to 350 m. Eggs are demersal and were taken at 28 m in July off the San Juan Islands, Washington. Young larvae (6-28 mm) have been taken in May in Saanich Inlet, B.C.

Dwarf wrymouth larvae occurred in samples from the spring, summer and winter cruises. They were taken mainly in the neuston net, but in winter, two small larvae (13.9 and 15.0 mm) were taken in the bongo net. In spring larvae were concentrated mainly near the southern end of Kodiak Island and around the Trinity Islands. Although they were caught more frequently nearshore larger catches were made offshore. In summer they were more widespread and caught more frequently offshore than in spring. They seemed to be concentrated in waters over Kiliuda and Stevenson Troughs. They were taken in bongo tows in summer in areas where they appeared abundant based on neuston catches.

The mean length of the larvae in the neuston catches in spring was 16.4 mm (range 12-25 mm) and in summer it was 26.0 mm (range 12-34 mm). Size of larvae did not vary with day or night sampling. In summer, when the larger larvae were present, they were more frequently caught in neuston tows at night than in daytime. During one of the diel series from spring (Diel 4) they were primarily in the neustonic layer, and were considerably more abundant there at night than during daytime.

Ammodytes hexapterus - Pacific sand lance (Figures 170-172, 197)

Members of the genus Ammodytes occur in the northern waters of the Atlantic and Pacific oceans. They are fished in Japan and Europe, but not in the northeast Pacific presently. They are important forage for a variety of larger fish, including halibut and salmon. The specific taxonomy of the genus is unsettled but apparently only one species occurs in the North Pacific, ranging there from California to Japan. These are slender fish that occur mainly nearshore over sandy bottoms. They bury in the sand at times, and in winter lay demersal eggs in the sand that hatch in about 33 days at 6.2°C. The larvae are found in spring and summer. They are taken in plankton nets to a fairly large size (about 50 mm).

Pacific sand lance larvae were found in the winter, spring, and summer cruises. In winter they occurred only in the bongo net, whereas in spring and summer they occurred in both the neuston and bongo nets. In winter a few larvae (mean length 5.5 mm), were taken in bongo tows at widely scattered stations. They were so sparsely distributed that no pattern of occurrence could be discerned. Larvae were more widespread and abundant in the bongo catches in spring when they occurred throughout the study area, but were most concentrated nearshore off the southern end of Kodiak Island and over the nearshore end of Stevenson Trough; larvae averaged 8.1 mm. Catches in spring in the neuston net were made in these areas of high abundance. In summer, larvae were not as widespread or abundant as in spring; fewer and smaller (34.9 mm) larvae were taken in daytime neuston tows than night tows (45.3 mm). They were patchily distributed, but showed areas of concentration over Kiliuda and Stevenson Troughs. In the diel series in spring, where the larvae were about 10 mm long, they occurred primarily below the surface with about half of the larvae overall in the 43-85 m stratum. In the diel series in summer, the larvae were 45 mm long and nearly all were taken at night at the surface.

Pleuronectidae - Righteye Flounders

The family includes small to large fishes commonly called flounders, soles, halibuts or turbot, a number of which are of considerable economic importance. Approximately 15 species of these flounders are present in the Kodiak Island area (Quast and Hall, 1972) and eggs or larvae of 13 of these species were captured in our plankton surveys.

Atheresthes stomias - Arrowtooth flounder (Figure 173)

Arrowtooth flounder (or turbot) range from California to the northern Bering Sea and the Asiatic coast. They are moderately sized fishes habitating waters down to 730-900 m and reaching 84 cm in length. In the Kodiak area, arrowtooth flounder are exploited commercially primarily by the Japanese and are considered moderately abundant. The annual mean catch of arrowtooth flounder by Japanese trawlers in this area from 1969-1974 was 297 metric tons (Ronholt, et al., MS 1978). Webber and Sample (MS 1976) summarized their life history.

Little is known of the early life history of this species. Spawning reportedly occurs in the winter, at least in the Bering Sea. Eggs are large, 2.5-3.5 mm in diameter and apparently are bathypelagic. Fecundity is probably high, as the closely related A. evermanni is reported to produce from 130,000 to 500,000 eggs. Individuals must transform at a fairly large size, as individuals as large as 38.5 mm have been captured in surface waters.

Arrowtooth flounder larvae were captured in bongo nets in the winter at seven stations, six of which were in slope waters. The overall mean catch was 8.2/10 m^2 and the mean length was 7.6 mm (range 7-8 mm). In spring, larvae were captured in bongo nets at seven locations over the slope and at one station north of the Trinity Islands. The mean catch was 7.5/10 m^2 of sea surface and mean length of larvae was 6.6 mm (range 5-10 mm).

Glyptocephalus zachirus - Rex sole (Figures 174-175, 198)

Rex sole range from southern California to the Bering Sea. These are relatively small fishes, reaching about 59 cm. They apparently are most abundant in water deeper than about 366 m. Relatively little is documented on the life history of this species but spawning of planktonic eggs that are 1.85-2.10 mm in diameter occurs in the spring.

Rex sole eggs and larvae were captured only during the summer cruise. Eggs were distributed primarily over slope waters from Stevenson Trough to west of South Albatross Bank and were captured in the neuston net at 29 locations and averaged 46.9/1000 m^3. Eggs were captured in the bongo net at 23 stations and averaged 13.9/10 m^2 (9.1/1000 m^3). There was little apparent difference in the distribution of rex sole eggs in bongo catches as opposed to neuston catches.

Rex sole larvae were captured only in bongo nets at 27 stations, generally at stations inshore of those where eggs were captured. The mean catch was 10.3/10 m^2 of sea surface and larvae ranged from 6-20 mm in length (mean 11.8 mm) as shown in Figure 198. There was no apparent difference in day and night catches of larvae (9.3/10 m^2 in day; 10.1/10 m^2 at night). The mean catch of larvae at offshore stations was 13.4/10 m^2.

Hippoglossoides elassodon - Flathead sole (Figures 176-178, 199)

Flathead sole range from northern California to the Bering Sea, west to the Kurile Islands, Okhotsk Sea and to Japan and reach about 48 cm in length. Flathead sole spawn pelagic eggs 2.75-3.75 mm in diameter in the spring at depths of 50-150 m.

Eggs of flathead sole were captured in neuston and bongo tows in spring and summer. In spring, neuston catches of eggs were primarily in Kiliuda

Trough and Chiniak Trough. They were found at only seven stations and the mean catch was 41.5/1000 m^3; whereas, bongo catches of flathead sole eggs ccurred at nine stations primarily in Kiliuda Trough and over South Albatross Bank and the mean catch was 44.9/10 m^2 (45.3/1000 m^3). In summer, flathead sole eggs were found in neuston tows at 17 stations, with a mean catch of 59.3/1000 m^3, and in bongo nets at 25 stations, principally over banks and troughs, with a mean catch of 14.5/10 m^2 or 16.7/1000 m^3.

Flathead sole larvae were taken only in the summer and then at 41 stations. The mean catch was 10.7/10 m^2 and the mean size of larvae was 10.8 mm (range 4-24 mm) as shown in Figure 199. Catches of larvae in day tows were similar to those in night tows (11.0/10 m^2 in day, 8.9/10 m^2 at night). Catches of larvae over troughs were 5.6/10 m^2 and 13.1/10 m^2 over banks. Catches were similar at midshelf and slope stations (7.4/10 m^2 at midshelf; 11.4/10 m^2 at slope stations).

Hippoglossus stenolepis - Pacific halibut

Pacific halibut range from California northward to the Bering Sea, westward to the Gulf of Anadyr and south to Hokkaido, Japan. These are large flatfishes (females reaching 267 cm in length and 216 kg in weight; males may reach 140 cm and 56 kg) and are the object of an intensive set-line fishery by the United States and Canadian fisherman.

Halibut tend to move from deep water along the edge of the continental shelf to shallower banks in the summer and return to deep water in the winter, partially associated with spawning which occurs in the winter at depths of 275-412 m. Females may produce from 100,000 up to 2 to 3 million planktonic eggs which are about 2.9-3.6 mm in diameter. The larvae hatch after about 15 days, and are about 8 mm in length. The length of larval life may extend up to 6 months after which they transform at about 30 mm and begin their demersal existence. Considerable numbers, mainly juveniles, are captured incidentally by commercial fishing vessels, primarily Japanese and USSR trawlers.

Only three halibut larvae were captured in bongo nets: two in spring - one nearshore at Station G71A (17.8 mm) and one off the slope at Station G51A (14.4 mm); and a single halibut larva (26.6 mm) was captured in summer at Station G18A in Stevenson Trough. That few halibut larvae were captured may be due to the time of sampling. Thompson and Van Cleve (1936) found 16.2-20.8 mm halibut larvae over the shelf at the southwest end of Kodiak Island in May and June (i.e., between the times of our spring and summer cruises). Newly hatched larvae were generally found by Thompson and Van Cleve outside the edge of the Continental slope at depths greater than 425 m; later larvae apparently move to near surface waters with growth and are carried inshore by currents (Skud, 1977).

Isopsetta isolepis - Butter sole (Figures 179-180, 200)

Butter sole range from Southern California to the Bering Sea (Quast and Hall, 1972). These are relatively small fishes, the males reaching 39 cm and the females 46 cm and are usually found in shallow water but have been recorded from the 274-366 m zone. Butter sole spawn planktonic eggs in the spring that range from 0.94-1.10 mm in diameter; newly hatched larvae are about 3.0 mm and transform at about 18-23 mm.

Only late stage eggs of butter sole were identified. Butter sole eggs and larvae were captured primarily during the summer. Catches of eggs in the neuston sampler were small (83.2/1000 m^3) and the distributions patchy. Catches in the bongo net were even lower (36.0/1000 m^3 or 17.9/10 m^2) and were primarily over Middle Albatross Bank where 7 of the 11 positive stations occurred.

Butter sole larvae were captured in bongo nets at 16 stations primarily over Middle and North Albatross Banks and the overall mean catch was 13.0/10 m^2 and lengths ranged from 3-13 mm (mean 7.2 mm). Catches were too sparse to compare day-night, bank-trough, or midshelf-slope abundances.

Lepidopsetta _bilineata_ - Rock sole (Figures 181 and 201)

Rock sole range from Southern California to the Bering Sea and south to the Sea of Japan. Three subspecies are recognized: _L. bilineata bilineata_ (Ayres), ranging from California to British Columbia; _L. bilineata mochigarei_ Snyder which occurs from the northwestern Pacific south to Korea, and a northern form, _L. bilineata peracuata_ (Cope) ranging from the Gulf of Alaska to the Bering Sea and the northern Okhotsk Sea (Alton and Sample, MS 1976). These are moderately sized fishes, males reaching 53 cm and females 60 cm, and are found mostly in shallow water (37-55 m) off British Columbia but may be found as deep as 366 m. Alton and Sample (MS 1976) summarized the life history of the rock sole. Rock sole spawn demersal adhesive eggs (about 0.92 mm in diameter) in the winter and spring (females 35 cm in length produce about 400,000 eggs, and at 46 cm about 1,300,000 eggs) which, depending on water temperatures (between 6.5° and 8.0°C), hatch in 9 to 18 days and the planktonic larvae, about 5 mm long at hatching, transform at about 20 mm.

Rock sole larvae were captured in bongo nets in both the spring and summer. In spring, catches were made at 29 stations primarily over Portlock Bank and Stevenson Trough and over the area from Middle Albatross Bank to North Albatross Bank. Larvae ranged from 2-6 mm in length (mean 4.2 mm) as shown in Figure 201, and the mean catch was 16.4/10 m^2. Catches in day tows averaged 24.0/10 m^2 as opposed to 9.4/10 m^2 at night, and catches averaged 12.4/10 m^2 over banks and 21.0/10 m^2 over troughs; nearshore stations averaged 21.1, midshelf stations 11.6, and slope stations 13.0/10 m^2.

In summer rock sole larvae were distributed in nearshore and midshelf waters, primarily from North Albatross Bank to South Albatross Bank and occurred at 23 stations, averaging 9.1/10 m^2. Sizes of larvae (Figure 201) ranged from 3-20 mm and averaged 11.8 mm. Catches made during day and night hauls were similar (8.8/10 m^2 in day; 9.5/10 m^2 at night) as were catches over banks (7.7/10 m^2) and troughs (8.0/10 m^2). Nearshore catches averaged 11.7/10 m^2 whereas catches over midshelf stations averaged 7.4/10 m^2.

Limanda aspera - Yellowfin sole (Figure 182)

Yellowfin sole are found from British Columbia to the Bering Sea, Asia, Japan and west to Korea. They range to 45 cm in length and occur to depths of 360 m, although in the Gulf of Alaska they are generally confined to shelf waters of 100 m or less. The center of abundance of yellowfin sole is the eastern Bering Sea and they are relatively scarce in the Gulf of Alaska. Yellowfin sole spawn pelagic eggs, about 0.68-0.90 mm in diameter, in summer (females may produce from 1.3 million, in 25-30 cm fish, to 3.3 million eggs in 40-45 cm fish) that at 13°C, hatch in about 4 days. The newly hatched planktonic larvae range from 2.25-2.80 mm in length and transform to a demersal existance at about 17 mm.

Yellowfin sole eggs were captured in neuston and bongo nets only in summer and, although most eggs were captured in neuston nets, both kinds of gear showed similar distributional patterns. Eggs were captured in neuston nets at 17 stations (mean catch 2276.8/1000 m^3), but most were captured at 8 nearshore stations (mean catch 4387.0/1000 m^3). A similar pattern of distribution and apparent abundance was reflected in bongo tows in which the mean catch at 15 positive stations was 49.9/10 m^2 (73.0/1000 m^3) and most eggs were captured at 7 nearshore stations (mean catch of 86.9/10 m^2 or 118.9/1000 m^3).

No yellowfin sole larvae were captured, possibly due to lack of sampling in late summer and early fall.

Microstomus pacificus - Dover sole (Figures 183-184, 202)

Dover sole occur from northern Baja California to the Bering Sea from the surface to depths of over 1,000 m and reach 71 cm in length. Spawning occurs from November to February off California, but during summer off Kodiak (females 42.5 cm in length produce 52,000 planktonic eggs, and at 57.5 cm, 226,000 planktonic eggs that are 2.05-2.57 mm in diameter). The pelagic stage is prolonged over several months and the larvae may reach 100 mm before transformation.

Dover sole eggs and larvae were captured in both neuston and bongo nets in summer. Eggs were primarily associated with midshelf and slope waters and most Dover sole eggs were captured in neuston samples where they occurred at 38 stations (mean catch 244.8/1000 m^3; 0.6/10 m^2). Bongo catches of Dover sole eggs were made at 31 stations (mean catch 35.5/10 m^2) and most were captured at 18 stations over the slope (mean catch 45.6/10 m^2). At one of the diel series from summer (Diel 6) well over half of the eggs were in the neustonic layer. Although a few larvae were captured in the neuston net, they were most abundant in bongo samples and in the 18 positive bongo hauls the mean catch was 12.7/10 m^2. Larvae ranged in length from 5-10 mm and averaged 7.5 mm (Figure 202). Most catches were over the Kiliuda Trough-South Albatross Bank area, although they were also captured at six slope stations (mean catch 13.9/10 m^2). Day and night catches were similar (12.5 versus 12.9/10 m^2). Data are inadequate to examine bank-trough relationships.

Psettichthys melanostictus - Sand sole (Figures 185 and 203)

Sand sole are distributed from southern California to the Bering Sea. They are a shallow water species (<183 m) which reaches 63 cm in length. Sand sole spawn in winter in Puget Sound and in summer off British Columbia and Kodiak Island. The pelagic eggs are about 1.0 mm in diameter and hatch in 5-7 days at 7^{o}-9^{o}C at which time the larvae are about 2-8 mm long. Metamorphosis occurs at about 27 mm.

Only late stage eggs of sand sole were identified to species. A total of four eggs was captured in the neuston net at nearshore and midshelf stations in summer. Sand sole larvae were captured in bongo nets in the summer and were widely distributed from Portlock Bank to South Albatross Bank and from nearshore waters to slope waters. The overall mean catch was 18.4/10 m^2; and larvae averaged 5.5 mm in length (Figure 203) with a range of 3-11 mm. Mean catches during daylight hours were 22.5/10 m^2 as opposed to 8.4/10 m^2 at night. Bank and trough catches were comparable (mean catch of 24.9/10 m^2 vs. 15.1/10 m^2) and catches at nearshore stations and midshelf stations were similar (mean catch of 23.9/10 m^2 vs. 27.7/10 m^2).

Other Flatfishes

Although slender sole, *Lyopsetta exilis*, have not been reported near Kodiak Island in the literature (Quast and Hall, 1972), adults of this species have been captured near Kodiak Island during NWAFC resource assessment cruises (RV *Miller Freeman*, cruise 79-1, March-April 1979). A total of two slender sole eggs (no larvae) was captured in bongo nets at two stations over Kiliuda Trough during the summer cruise.

Eggs and larvae of the starry flounder, *Platichthys stellatus*, were captured in limited numbers in bongo and neuston nets during the spring and summer cruises. In spring, eight eggs (no larvae) were captured at five locations, primarily over Kiliuda Trough. In summer, seven eggs were captured at two locations in Chiniak Trough and two larvae were captured near Shelikof Strait (station G31A).

A total of two eggs of Alaska plaice, *Pleuronectes quadrituberculatus*, was captured in neuston nets during spring, one over South Albatross Bank and the other over Kiliuda Trough.

Unidentified flatfish eggs were captured in neuston and bongo nets during the spring and summer cruises. The majority were early and middle stage eggs, about 1.0 mm in diameter, and are most likely of four possible species: starry flounder, sand sole, English sole (i.e., *Parophrys vetulus*) or butter sole. In the spring, the distribution of these eggs, as reflected by catches in both kinds of gear, was essentially the same (Figure 186). They were found nearshore and midshelf primarily from Portlock Bank westward to Middle Albatross Bank, although relatively isolated catches were made over South Albatross Bank and west of the Trinity Islands. These eggs were captured in neuston gear at 15 stations (mean 119.5/1000 m^3; 0.2/10 m^2) and no differences were noted in apparent abundance over banks or troughs (mean catch of 81.5/1000 m^3 over banks; 98.2 over troughs). Catches of pleuronectid eggs in bongo nets (Figure 186) occurred at 21 stations (mean 26.4/10 m^2; 50.3/1000 m^3) and were similar over banks (34.2/10 m^2) and troughs (36.3/10 m^2) but different at nearshore stations (mean 9.4/10 m^2) as opposed to midshelf stations (mean 29.4/10 m^2.

In summer (Figure 187), catches of unidentified pleuronectid eggs were made at nearshore and midshelf stations, as in spring, but they were found primarily from North Albatross Bank southwestward to South Albatross Bank and west of Trinity Islands. They were captured in neuston nets at 20 stations (mean 411.8/1000 m^3; 0.6/10 m^2), and were most abundant nearshore (mean 861.6/1000 m^3). In bongo nets, these eggs were captured at 31 stations (mean 123.7/1000 m^3; 68.6/10 m^2), and catches in the nearshore region were twice those at midshelf (mean 114.9/10 m^2 as opposed to 56.6/10 m^2).

Summary of Seasonal and Geographical Ichthyoplankton Distributions (Table 43, Figure 204)

The major occurrences of pelagic young stages of fish in the Kodiak Island shelf area based only on the five cruises we conducted are summarized by season, by distance from shore and by geographic region. Relative and absolute abundances of the various taxa, and details of seasonal and geographic distribution probably vary from year to year.

Fall - In fall all species of hexagrammids showed their initial seasonal presence in the neuston and it was the period of maximum abundance for all but *Hexagrammos decagrammus*. It was also the initial period and the period of maximum abundance for the larvae of *Hemilepidotus* spp., which was the most abundant taxon in the neuston at this season. In subsurface waters larvae of the ubiquitous mesopelagic species (*Leuroglossus schmidti*, *Stenobrachius leucopsarus*, and *Protomyctophum thompsoni*) were present. Several of the species found in the neuston were also found below the surface, and *Hemilepidotus* spp. larvae were again the most abundant of the taxa encountered, followed by *Mallotus villosus* larvae. Two taxa whose maximum abundances occurred earlier in the year were still present in lower concentrations in fall (*Theragra chalcogramma* and *Sebastes* spp.).

Winter - In winter only three species had their initial seasonal appearances and all were found in subsurface waters (*Ammodytes hexapterus*, *Atheresthes stomias* - as eggs and larvae, and *Glyptocephalus zachirus* - as eggs). Most of the larvae found in winter were larger stages of species found initially in fall and most were at lower abundances in winter than in fall (although *Mallotus villosus* and *Hexagrammos decagrammus* were more abundant in the neuston in winter than in fall).

Spring - Several more taxa were found in spring than in winter. In the neuston *Bathymaster* spp. and *Lyconectes aleutensis* made their initial seasonal appearance. *Ammodytes hexapterus* was in the neuston in spring whereas it had been only in subsurface waters in winter. Several hexagrammids were still present in the neuston and *Hexagrammos decagrammus* reached its seasonal maximum abundance in spring, attaining the highest density among the taxa taken. In subsurface waters, Gadus macrocephalus, Theragra chalcogramma, several cottids and stichaeids, Bathymaster spp. and several flatfishes as eggs or larvae (Hippoglossoides elassodon, Isopsetta isolepis, Microstomus pacificus, Platichthys stellatus - all as eggs, and Lepidopsetta bilineata and Hippoglossus stenolepis as larvae) made their first seasonal appearance.

Summer - More taxa of fish eggs and larvae were found in summer than in any other season. The neuston was dominated by small osmerid larvae and Bathymaster spp. larvae and large Ammodytes hexapterus larvae were also taken in abundance. Otherwise the neustonic layer held a diverse, but sparse population of larval fishes. In subsurface waters, the population was even more diverse with several taxa present that were not found during any other season. Eggs (Glyptocephalus zachirus, Limanda aspera and Microstomus pacificus) and larvae of several species of flatfishes (particularly Hippoglossoides elassodon, Glyptocephalus zachirus, Isopsetta isolepis, Microstomus pacificus and Psettichthys melanostictus) were quite abundant and only present in summer. Several mesopelagic fishes were also only present in summer (Bathylagus milleri, Stenobrachius nannochir, and Protomyctophum crockeri). Larvae of several species such as Theragra chalcogramma were larger in summer than in spring.

Nearshore - The fish eggs and larvae found nearshore generally were of species that spawned in this area including both species with demersal and pelagic eggs. In fall, larvae of Mallotus villosus and eggs of Theragra chalcogramma were taken. In winter no species was concentrated in the nearshore area. In spring, pelagic eggs of Theragra chalcogramma and pleuronectids were found along with larvae of Lepidopsetta bilineata and Ammodytes hexapterus, which are both resultants of demersal eggs. In summer, pleuronectid eggs and eggs identified as Isopsetta isolepis and Limanda aspera were present.

Midshelf - Waters of the midshelf area contained mainly larvae of hexagrammids in fall and winter and pleuronectids in spring and summer. Later stages of some species (Mallotus villosus, Isopsetta isolepis, and Lepidopsetta bilineata) initially found inshore were subsequently found in midshelf waters indicating some offshore movement during development. Three taxa, all with demersal eggs (Hexagrammos octogrammus, H. lagocephalus, and Bathymaster spp.) were caught in abundance only in the midshelf area although all three occurred elsewhere also. Hippoglossoides elassodon eggs and larvae and larvae of Psettichthys melanostictus were caught primarily in this area. Glyptocephalus zachirus larvae were found mainly om the midshelf area although its eggs were found most often in slope waters. Briefly then, the midshelf area appears to be used by a few species primarily during all their planktonic young stages, and by other species during their larval or late larval stages with earlier stages occurring elsewhere.

Slope - Early stages of bathypelagic and pleuronectid fishes were found primarily in the slope waters sampled. Eggs of Leuroglossus schmidti and macrourids were found in abundance only in the slope area. Among the pleuronectids, Atheresthes stomias larvae and Microstomus pacificus eggs and larvae were mainly in slope waters. As mentioned above, Glyptocephalus zachirus eggs were in slope waters, but the larvae were mostly in the midshelf area. Larvae of two myctophids (Stenobrachius leucopsarus and Protomyctophum thompsoni) occurred here but also closer to shore where hydrography indicated that offshore waters extended onto the shelf. Sebastes spp. larvae were abundant in slope waters in summer.

Ubiquitous - Larvae of several generally abundant species occurred equally throughout the area sampled. Some larvae (Hexagrammos decagrammus, H. stelleri, and Hemilepidotus spp.) were also present during all seasons, some (Anoplopoma fimbria, Ophiodon elongatus, Ammodytes hexapterus) were found only during summer, while others (Theragra chalcogramma and Lyconectes aleutensis) were found during spring and summer. Pleurogrammos monopterygius was found in all seasons but summer. The larvae of all but two species (Theragra chalcogramma and Anoplopoma fimbria) found ubiquitously originated from demersal eggs, while no identified eggs were ubiquitously distributed. Apparently two different spawning patterns lead to the observed ubiquitous distribution patterns of larvae: spawning of demersal eggs at widely dispersed sites and spawning of pelagic eggs that disperse widely in the water column during development.

Diel Migration and Depth Distribution

The diel-vertical distribution of fish eggs and larvae was investigated at one or more locations during the first four cruises. Generally, planktonic fish eggs are spawned at some depth below the surface and rise toward the surface during development. The young larvae hatch at the surface or somewhere below the surface, and generally undergo vertical-diel migrations that increase in extent with their development. Although this is the generally observed pattern, individual species follow it to varying extents. The actual vertical patterns of the eggs and larvae of fish off Kodiak were virtually unknown. If either of these components of the ecosystem move from the surface to depth, such movement could be a mechanism for transporting surface contaminants to greater depths. We also wished to define which taxa were primarily surface dwellers (neustonic) as opposed to those forms which dwell primarily below the surface as the former might well be more vulnerable to surface pollutants.

It was anticipated that the species composition of shelf communities would differ from the composition found in slope or oceanic waters. Initially we chose locations over the shelf for diel studies, one in Kiliuda Trough and one over South Albatross Bank. Specific locations of the series were changed as experience was gained, and in the summer and fall 1978 cruises, they were moved to near the shelf break over South Albatross Bank to sample deeper waters.

A summary of the catches of fish eggs and larvae during the seven diel-vertical distribution series is presented in Table 44. Information obtained on fish eggs and larvae from the diel series will be presented in three ways. Initially the catches from each of the seven series will be discussed separately noting abundances, diel migrations, depth distributions, relative sizes and hydrography. Following this, seasonal comparisons of abundant taxa taken during the diel series will be made and series within a cruise and from other cruises during the same season will be used to characterize seasonal patterns. Finally, diel and vertical distributional patterns of fish eggs and larvae will be summarized.

The vertical distribution of planktonic organisms in the water column is influenced by a number of factors, physical and biological. Among the physical factors, light intensity and its changes with time of day and weather are quite important. The hydrographic structure of the water column (e.g. thermocline intensity and depth) is also important. Biological factors include diel migration associated with feeding and predator avoidance. In addition the "apparent" vertical distribution as revealed by discrete depth sampling with plankton nets may result partially from variable net avoidance at different times of day. Also patchiness and the ability during sampling to maintain position relative to the drifting plankton community affect results. As in all plankton studies chance also plays a part in the catches obtained. With meroplanktonic stages of fishes still other factors such as spawning and/or hatching site and depth and changes in behavior with growth influence depth distribution. In the following discussions we mention the factors that seem most probable in producing the distribution we observed; however, other factors may also have been important.

Results of Each Diel Series (Tables 44-75, Figures 205-230)

Diel 1 (4MF77, D33A-L) (Tables 45-47, Figures 205-207, 225) - The most abundant group of larvae, *Hemilepidotus* spp., was present in every station of the series. Also abundant were two hexagrammids, *Pleurogrammus monopterygius* and *Hexagrammos decagrammus*. *Hemilepidotus* spp. had the most day-night variation in apparent abundance with large catches at the surface during the night and large catches in the upper net (0-26 m) during the day. Larvae of *Pleurogrammus monopterygius* were also more abundant at the surface during the night until just after sunrise. Largest numbers of *Hexagrammos decagrammus* larvae were taken prior to and just after sunrise.

Depth distribution differed between the hexagrammids and *Hemilepidotus* spp. Larvae of both *Hexagrammos decagrammus* and *Pleurogrammus monopterygius* appeared to be at the surface, with only a few larvae taken in the upper net, and only an occasional larva found below 26 m. Larvae of *Hemilepidotus* spp., however, were present throughout the water column sampled (0-45 m), primarily in the upper net by day and in surface waters at night. Although found in small numbers, *Hemilepidotus* spp. were consistently taken in the lower net (26-45 m).

No differences in size were observed between the various depth ranges for larvae of *Hemilepidotus* spp. Mean length for larvae taken at the surface was 6.2 mm (range 4-8 mm). The mean length for larvae taken between 0-26 m was 6.9 mm (range 4-8 mm), and those larvae taken from 26-45 m had a mean length of 6.5 mm (range 4-7 mm). The smallest larvae were taken at the surface during the day (5.3 mm) and the largest larvae were taken between 0-26 m during the day (7.0 mm).

Mean lengths for larvae of Hexagrammos decagrammus were the same in waters between 0-26 m and for those larvae taken at the surface. In surface waters mean length of Hexagrammos decagrammus larvae was 10.3 mm (range 8-12 mm), and between 0-26 m the mean length was 11.0 mm (range 9-14 mm). No size differences were observed with time of day. Only two larvae were taken below 26 m thereby preventing any discussion of relative size.

Larvae of Pleurogrammus monopterygius were similar in size based on mean length in waters between 0-26 m and for those taken at the surface. The mean length of larvae taken at the surface was 10.4 mm (range 9-12 mm), and the mean length of larvae taken between 0-26 m was 10.9 mm (range 9-12 mm). Only one larva (10.7 mm) was taken below 26 m.

Salinity values ranged from 31.4 to 32.2°/oo in surface waters, increased with depth to 32.4-33.5°/oo, and decreased to 32.9-32.5°/oo in deep water. Water temperatures decreased with depth from 6.5°C at the surface to 5.8°C in midwater, to 5.3°C near bottom.

Diel 2 (4MF77, D35A-L) (Table 48, Figures 208 and 225) - The only group with abundant larvae during this series was Hemilepidotus spp. Almost without exception, largest catches occurred during neuston hauls at night. Hemilepidotus spp. larvae were present in the entire water column (0-101 m) and similar to the previous diel series, they were abundant at the surface during the night and abundant in the upper net (0-42 m) only during the day.

No differences were observed in mean length of Hemilepidotus spp. larvae for various depths or time of day. Larvae taken at the surface had a mean length of 6.3 mm (range 4-7 mm). Larvae taken between 0-42 m had a 6.5 mm mean length (range 4-8 mm), and those larvae found below 42 m had a mean length of 6.3 mm (range 4-8 mm).

Temperature and salinity values were the same as those reported for Diel 1.

Diel 3 (4DI78, D45A-L) (Tables 49-51, Figures 209-211, 226) - Only three groups of larvae occurred in sufficient numbers during this series to examine their diel-vertical distribution. Most abundant were larvae of Hexagrammos decagrammus and, although fewer in numbers, larvae of Hemilepidotus spp. and Ammodytes hexapterus were caught consistently during the series. Both Hexagrammos decagrammus and Hemilepidotus spp. larvae showed considerable day-night variation in apparent abundance; they were present in large numbers during the night in surface waters. Hemilepidotus spp. larvae were not present at all in surface waters during the day. Ammodytes hexapterus larvae did not exhibit any diel differences in abundance during this series.

All three groups of larvae showed different depth distribution during the series. Larvae of Hemilepidotus spp., as in previous series, were abundant only at night in surface waters and were present in the upper net (0-43 m) during the day. No Hemilepidotus spp. larvae were taken below 43 m in this series. Hexagrammos decagrammus larvae were present at the surface during the entire 24-hour period, although in greater numbers at night. Hexagrammos decagrammus larvae were also taken in the upper net (0-43 m) and they were occasionally found below 43 m. Ammodytes hexapterus larvae were not caught in the neuston net; they were taken between 0-43 m, but were found below 43 m in greatest numbers.

No differences were observed in mean length with time of day or depth for larvae of Hexagrammos decagrammus. Mean length for neustonic larvae was 11.5 mm (range 9-17 mm), and mean length for the larvae taken between 0-43 m was 11.0 mm (range 9-14 mm).

Nearly all of the Hemilepidotus spp. larvae were taken at the surface, but mean lengths were similar to those for larvae taken between 0-43 m. Mean length of the larvae found in surface waters was 12.2 mm (range 7-17 mm), and mean length of larvae taken in deeper waters (0-43 m) was 11.0 mm (range 7-13 mm).

The small, recently hatched, larvae of Ammodytes hexapterus did not show any differences in mean length between catches during day or night or at different depths. Larvae taken between 0-43 m had a mean length of 10.2 mm (range 5-13 mm) and those larvae found between 43-85 m had a mean length of 9.8 mm (range 5-13 mm).

Salinity in surface waters was approximately 32.5°/oo as was the average value of salinity in the depth stratum sampled by the upper net. Salinity ranged from 32.2 to 32.6°/oo at depths of 0-43 m. In the waters sampled by the lower net, salinity values increased only slightly from 32.6 to 32.7°/oo. The average water temperature in the stratum sampled by the upper net was 4.4°C, ranging from 4.3°-4.7°C. The average water temperature increased in the stratum sampled by the lower net to 4.7°C ranging from 4.4°-5.1°C. In summary then, both salinity and temperature values were fairly constant in water sampled by the upper net, and both values increased with depth in the waters sampled by the lower net.

Diel 4 (4DI78, D63A-L), (Tables 52-58, Figures 212-215, 227) - Hexagrammos decagrammus larvae were the most abundant group in the series, but larvae of Hemilepidotus spp., Ammodytes hexapterus, Lyconectes aleutensis, and Lepidopsetta bilineata as well as eggs and larvae of Theragra chalcogramma were consistently present. Only larvae of Hexagrammos decagrammus, Hemilepidotus spp., and Lyconectes aleutensis showed day-night variation in apparent abundance - Hexagrammos decagrammus larvae were present in larger numbers during night stations; Hemilepidotus spp. larvae were present at the surface only at night; and, Lyconectes aleutensis larvae occurred only at the surface during the night through the dawn period.

Theragra chalcogramma eggs were distributed throughout the water column at all depths (0-121 m) sampled, while the larvae were found mostly in the upper net (0-66 m). Lepidopsetta bilineata larvae also occurred primarily in the upper net with only a few larvae present in the lower net (66-121 m) at night. Larvae of Ammodytes hexapterus were consistently between 0-66 m during the entire series; however, some were taken below 66 m at night.

Larvae of Hexagrammos decagrammus occurred almost exclusively in the neuston net and had an overall mean length of 11.2 mm (range 9-18 mm); the majority of these larvae were taken at night and then had a mean length of 11.2 mm (range 8-18).

Larvae of both Hemilepidotus spp. and Lyconectes aleutensis were taken only at night in surface waters; their mean lengths were 10.4 mm (range 6-16 mm) and 16.7 mm (range 13-23 mm), respectively.

Theragra chalcogramma larvae were newly hatched and showed no variation in mean length for various depths. Mean length for Theragra chalcogramma larvae taken between 0-66 m was 4.1 mm (range 3-5 mm), and the mean length for those larvae taken between 66-121 m was 4.2 mm (range 2-4 mm). Lepidopsetta bilineata larvae were also newly hatched and showed no difference in size with depth. The mean length of larvae found between 0-66 m was 4.2 mm (range 3-5 mm) and those larvae taken between 66-121 m had a mean length of 3.9 mm (range 3-4 mm).

Young larvae of Ammodytes hexapterus taken at night between 0-66 m were similar in size to those larvae taken during the day at the same depth - the overall mean length was 9.9 mm (range 6-13 mm) while the mean length at night only was 9.7 mm (range 6-12 mm).

During this series salinity values were fairly constant in waters sampled by the upper net (0-66 m), ranging from 32.2-32.4°/oo, and averaging 32.3°/oo. Salinity was more consistent in waters sampled by the lower net with an average value of 32.5°/oo. The most variation in water temperature occurred in the upper 25 m, ranging from 3.9°-4.4°C and averaging between 4.0°-4.1°C. As with salinity, water temperature was constant in the depths sampled by the lower net, averaging 4.0°C from 66 to 121 m.

Diel 5 (2MF78, D01A-L) Tables 59-65, Figures 216-218, 228) - The total larval catch during this series was extremely low. Sebastes spp., Bathymaster spp., and Ronquilus jordani larvae were taken in sufficient numbers to examine their vertical-diel distribution while catches for four pleuronectid larvae (Psettichthys melanostictus, Isopsetta isolepis, Lepidopsetta bilineata, and Hippoglossoides elassodon) were low, but may provide some information on depth distribution. Larvae of Hemilepidotus spp. and Ammodytes hexapterus were taken only at night in surface waters accounting for overall low catches. Day-night differences are difficult to evaluate based on the low numbers observed, but some migration appears to occur with larvae of Bathymaster spp. They were more abundant at the surface during the night while during the day most of them were present in the upper net (0-27 m). Sebastes spp. larvae were also present at the surface during night stations and were also consistently found in the upper net at all times. Ronquilus jordani larvae were present in the upper layer also but a few larvae were taken at the lower layer below 27 m. Unlike the closely related Bathymaster spp., they do not appear to migrate at night to surface waters. The pleuronectid larvae all appeared to stay within the upper and middle layers between 0-71 m.

Ammodytes hexapterus larvae were taken only in four hauls during this series and three of those were neuston hauls taken at night or during sunrise. Howevewr, the numbers of these larvae in only two neuston hauls (D01G, 188.2/100 m^3 and D01H, 21.2/100 m^3 - the only two night stations) were the largest for fish larvae taken during this series. Evidently during the summer these larvae were at the surface at night but were not available to our sampling during the day.

The overall mean length of Ammodytes hexapterus larvae taken at the surface was 45.4 mm (range 26-56 mm), and the mean length of those larvae taken only at night in surface waters was similar, 45.9 mm (range 32-56 mm). Hemilepidotus spp. larvae which were taken only in surface waters at night had a mean length of 25.5 mm (range 18-29 mm).

Newly hatched larvae of Isopsetta isolepis and Psettichthys melanostictus were taken between 0-27 m with mean lengths of 4.6 mm (range 3-6 mm) and 6.5 mm (range 3-9 mm) respectively. Almost all larvae of Hippoglossoides elassodon were taken between 0-27 m and had a mean length of 11.8 mm (range 5-19 mm). Lepidopsetta bilineata larvae which were also taken between 0-27 m had a mean length of 14.5 mm (range 8-19 mm) and were larger than the other pleuronectids taken in this series.

Salinity values in surface to upper net waters varied from 32.0-32.2°/oo, becoming slightly higher with increasing depth. Salinity increased to 32.5°/oo for the water depth sampled by the middle net and averaged about the same for waters in the lower net. Water temperatures for the upper net were over a wide range, from 6.3°-8.5°C and averaged between 7.5°-8.3°C. Water temperatures continued to decrease with depth for the middle net, ranging from 8.4°-6.0°C and averaging between 7.6°-6.3°C. Temperature values in waters sampled by the lower net decreased to an average of 6.0°-5.7°C, ranging from 6.1° to 5.1°C.

Diel 6 (2MF78, D69A-L) (Tables 66-68, Figures 219-221, 229) - Catches of three groups, Bathymaster spp. larvae, Sebastes spp. larvae, and Microstomus pacificus eggs were sufficient to give indications of depth distribution. Hexagrammos decagrammus larvae occurred in all surface hauls at night, but numbers were too low to determine changes in abundance with time. Only larvae of Bathymaster spp. showed any diel migration; high numbers of larvae caught were caught at the surface during the night, encompassing both dawn and dusk. During the daylight hours Bathymaster spp. larvae were taken in the upper (0-28 m) as well as the middle (28-71 m) net and a few larvae were also taken below 71 m. Larvae of Sebastes spp. were taken in all nets during the series, but most were taken in the upper net (0-28 m). Microstomus pacificus eggs were present throughout the water column with largest catches in the surface and upper net.

Hexagrammos decagrammus larvae were taken at the surface where larvae taken at night were longer than those larvae taken during the day. The mean length of larvae taken at the surface during the day was 22.0 mm (range 16-30 mm) while the mean length of larvae during the night was 30.8 mm (range 12-49 mm).

In waters sampled by the upper net, salinity values increased slightly with depth (range: from 32.0-32.4^{o}/oo, average 32.3^{o}/oo). In waters sampled by the middle net, salinity values continued to increase from 31.9-32.6^{o}/oo, averaging from 32.4-32.5^{o}/oo. Salinity values in waters sampled by the lower net remained in the same range from 32.4-32.6^{o}/oo.

The temperature range in depths sampled by the upper net decreased with depth from 8.5^{o}-8.3^{o}C to 8.3^{o}-7.3^{o}C, averaging from 7.4^{o} to 8.3^{o}C. In the middle depth interval, a strong thermocline was present with water temperature values decreasing sharply with depth. At the shallow end of this interval they were 7.2^{o}-8.4^{o}C and at the deep end they were 5.4^{o}-5.8^{o}C. Water temperatures in the depth interval of the lower net averaged 5.6^{o}C.

Diel 7 (1WE78, D01A-G) (Tables 69-75, Figures 222-224, 230) - *Pleurogrammus monopterygius* larvae were the most abundant group in this series. Also present in sufficient numbers to investigate diel-vertical distribution were *Hemilepidotus* spp. larvae and *Leuroglossus schmidti* eggs and larvae; however, *Hexagrammos decagrammus*, *H. octogrammus*, and *H. lagocephalus* larvae were also taken in some hauls. Both *Pleurogrammus monopterygius* and *Hemilepidotus* spp. larvae displayed some degree of diel migration with more larvae caught at the surface during the night. *Pleurogrammus monopterygius* larvae were caught mainly in the surface and upper nets (0-40 m). *Hemilepidotus* spp. larvae were at the surface at night and in the upper net during the day. *Hexagrammos* larvae of the various species were present in near surface waters throughout the series. *Leuroglossus schmidti* eggs were not taken at the surface but were present in all other nets; most occurred in the middle net (40-192 m) as did most of the larvae.

The overall mean length of *Pleurogrammus monopterygius* larvae taken in surface waters was 11.4 mm (range 9-14 mm) and those caught only at night (11.5 mm) were similar in size to those taken during the day (10.7 mm). Smaller 7.7 mm (range 6-11 mm) larvae were taken between 0-40 m.

Newly hatched *Hemilepidotus* spp. larvae taken in surface waters at night were similar in size to those taken in waters between 0-40 m. The larvae had an overall mean length of 6.9 mm (range 5-8 mm), and a mean length of 7.3 mm (range 5-8 mm) at night. Larvae taken between 0-40 m had a mean length of 5.5 mm (range 5-6 mm).

Temperature and salinity ranges were small during Diel 7. Salinity in waters sampled by the upper net was consistent over a small range, from 32.6-32.7^{o}/oo. In waters sampled by the middle net, salinity increased slightly, ranging from 32.7-33.8^{o}/oo in the deeper water. In the upper 40 m water temperature averaged about 6.6^{o}C. Water temperature decreased steadily with depth in the middle sampling interval (40-193 m) and the average temperature was between 5.2^{o}-6.7^{o}C with a range of 5.1^{o}-6.2^{o}C. Temperature decreased with depth in the lower sampling interval (193-368 m) averaging between 5.1^{o}-4.0^{o}C.

Review of Diel-Vertical Depth Distribution of Abundant Taxa - (Table 76)

Hemilepidotus spp. - These larvae were taken at all seven diel series but were abundant only during the five series taken in fall and spring. They were consistently taken in large numbers at night in the neuston net. During the day, most were found in the upper water column between 0-40 m (mean depth range among series for upper net).

Fall 1977 and 1978 - During Diels 1 and 2 in fall 1977, Hemilepidotus spp. were the only larvae not only present but relatively abundant in both series. Although sampling was over different net depth ranges for the two series, the larvae showed similar patterns of diel migration and depth distribution. Catches were consistently higher at the surface during night than during day, and catches were greater in the upper net (average depth 35 m) during day than during night. During Diel 2, the larvae were taken in much deeper water (0-101 m) during all hours. Mean lengths of larvae during the two series were similar for the various net depths. In both series, those taken in surface waters were mostly small with a combined mean length of 6.3 mm (range 4-7 mm).

Catches of Hemilepidotus spp. larvae in fall 1977 and 1978 can be compared even though net depths varied among the series. The largest catches during fall 1978 were taken at night in the surface net; the data are inconsistent during the day without markedly higher concentrations of larvae in the upper net. Larvae were taken at greater depths during Diel 2 (42-101 m). Catches during Diel 7 in fall 1978 also confirmed their presence in deep water as they were found in over half the hauls taken in the lower net (193-368 m). Mean lengths in surface waters were similar during Diels 1 and 2 (combined mean 6.3 mm) and Diel 7 (6.9 mm) and the mean lengths of larvae taken in waters between approximately 0-40 m were also similar during Diel 1 (6.9 mm), Diel 2 (6.3 mm) and Diel 7 (5.7 mm).

Spring 1978 - Hemilepidotus spp. larvae had similar diel-vertical distributions during both series; they were present during the night in large numbers at the surface (165.8 and 102.7 larvae/100 m^3), and when taken during the day they were in the upper net (mean depth range 0-55 m). None were taken at the surface during the day in either series. The mean lengths were similar during Diel 3 (12.2 mm) and Diel 4 (10.5 mm). Larvae, however, were much larger in the spring (combined mean 11.4 mm) than during the fall (combined mean 6.3 mm).

Summer 1978 - Only a few larvae were taken during either diel series. They were taken mostly at the surface during the night and were larger in the summer (mean 25.5 mm) than in the spring (combined mean 11.4 mm).

Hexagrammos decagrammus - These larvae were taken during diel series in all seasons but were only abundant during spring and fall. They were frequently taken in the neuston net with largest catches occurring at night.

Fall 1977 and 1978 - Larvae (mean 10.4 mm) were taken during the night at the surface during Diel 1. Catches during Diels 2 and 7 were minimal.

Spring 1978 - Hexagrammos decagrammus larvae were at the surface during both diel series and highest catches were during sunset and through the night (e.g., Diel 3: 207.4 larvae per tow/100 m^3). They had similar mean lengths during both series; during Diel 3 the mean length of larvae at the surface during the night was 11.5 mm and during Diel 4 the mean length was 11.2 mm. Larvae were only slightly larger in spring with a range of 9-17 mm compared to a range of 8-13 mm in the fall.

Summer 1978 - Only a few larvae were taken during the two series and they were larger during summer (mean 26.4 mm) than in spring (combined mean 11.4 mm). The larvae continued to be taken only at night in surface waters but none were taken during the day in the neuston net. Apparently their ability to avoid the net during day was greater during the summer when the larvae were larger.

Pleurogrammus monopterygius - These larvae were mostly taken during diel series in the fall. They were found most often in surface waters but did not appear to be restricted to the upper 1 m since some were also found in the 0-30 m stratum.

Fall 1977 and 1978 - During Diel 1 (1977) and 7 (1978), larvae of Pleurogrammus monopterygius were taken in sufficient numbers for comparison. They were taken during both diel series mainly in surface waters with higher concentrations taken during the night. Lengths of those below surface waters (0-30 m) were similar during Diel 1 (mean 10.9 mm) and Diel 7 (mean 7.7 mm). Larvae taken at the surface were also similar in length during Diel 1 (mean 10.4 mm) and Diel 7 (mean 11.4 mm).

Ammodytes hexapterus - These larvae were taken during diel series in spring and summer. They were more widely distributed in spring and occurred mainly in waters between 40-70 m.

Spring 1978 - Ammodytes hexapterus larvae did not appear to undergo diel migrations in spring; they remained in the upper layer, probably between 43-66 m. Mean lengths were approximately the same for all depths sampled during the spring (combined mean 10.0 mm).

Summer 1978 - Larvae of Ammodytes hexapterus had quite different diel-vertical distribution patterns during the summer than those observed in the spring. In the spring (Diels 3 and 4) they were taken below the surface at all hours with a combined mean length of 10.0 mm. During the summer (Diel 5), most of them were taken in surface waters at night with a mean length of 45.4 mm.

Our data indicate that larger Ammodytes hexapterus larvae may undergo some diel migration while smaller ones do not. During spring the larvae were not taken at the surface day or night but were taken between the average depths of 0-100 m during all hours. In summer they were taken at the surface mostly at night with only one during the day. Low catches during the day may have been due to either net avoidance or possibly the larvae were located below our maximum sampling depth of 136 m. In summer, when the larvae were larger than in spring (mean length 45.4 and 10.0 mm, respectively), they were probably more successful in avoiding the net during the day but it also appears some vertical migration was involved.

Sebastes spp. - The larvae were abundant only during summer diel series.

Summer 1978 - Sebastes spp. larvae were most concentrated in the upper layer (0-28 m, 0-27 m) during both diel series. During Diel 6 some were taken in both the middle net and lower net whereas during Diel 5 they were almost exclusively between 0-27 m. No diel migrations were apparent in either diel series.

Bathymaster spp. - The larvae were taken in large numbers only during the two diel series in summer.

Summer 1978 - Although numbers were low during Diel 5, the larvae demonstrated a diel migration to the surface at night. Highest catches at the surface were during night, and during the day consistently high catches were found in the upper net (0-28 m). More were caught in Diel 6, and the diel migration could be seen more clearly. The larvae stayed in the upper and to a lesser extent middle layers all the time, and at night some migrated to surface waters.

Lepidopsetta bilineata - These larvae were taken in low numbers during diel series in both spring and summer. They had similar diel-vertical distribution patterns during summer and spring. Larger in the summer (mean 14.5 mm) than in the spring (mean 4.2 mm), Lepidopsetta bilineata larvae were taken during both seasons at depths of 0-45 m (mean depth range among series).

Other Taxa - Some limited information can be ascertained for depth distribution of larvae of Theragra chalcogramma and Leuroglossus schmidti but no information on diel migration. Theragra chalcogramma larvae were obviously not neustonic but were found mostly above 50 m; they may migrate within the 0-50 m depth interval but no evidence of migration to the surface was seen. All larvae taken during the diel series were newly hatched during the spring with a mean length of about 4.1 mm. Leuroglossus schmidti larvae were found at deeper stations in the deeper net, mostly at depths between 40-192 m, but not in the surface waters.

Three pleuronectids, Hippoglossoides elassodon, Psettichthys melanostictus, and Isopsetta isolepis appeared to be concentrated at depths of 0-30 m but they may also be in deeper waters than we sampled (136 m).

Summary of Diel Migration and Vertical Patterns

Many groups of fish larvae and eggs were taken during the seven diel series (Table 44); 17 have been discussed in detail. Although difficult to categorize, four patterns of diel-vertical distribution were observed.

Pattern I--Marked diel-vertical migration (larvae of Hemilepidotus spp. and Bathymaster spp.). Species with this pattern concentrated in shallow water (<50 m) during daylight, and occasionally occurred in deeper water. At night, these species concentrated in the surface layer, with large numbers of larvae migrating to the neustonic layer. Occasionally larvae with this pattern were entirely absent from the surface during the day (i.e., zero catch) especially *Hemilepidotus* spp. larvae which apparently became increasingly successful at net avoidance as they became larger.

Pattern II--Neustonic (strictly neustonic regardless of time of day with only a few individuals occurring below the surface; larvae of *Lyconectes aleutensis*, *Hexagrammos* spp. and *Pleurogrammus monopterygius*). For species with this pattern, surface catches were much larger during the night apparently because of net avoidance during daytime, especially when the larvae were larger. Larvae of *Lyconectes aleutensis* taken during the spring had a mean length of 16.7 mm and were probably large enough to avoid the net during daylight. Of the hexagrammids, larvae of *Pleurogrammus monopterygius*, besides being concentrated in the neuston, were also taken at depths to 45 m.

Pattern III--Upper mixed layer, summer (larvae of *Sebastes* spp. and *Ronquilus jordani*). Although occasionally taken at the surface as well as in deeper water, most of these larvae were consistently taken in large numbers from the surface to about 28 m with no differences between day and night catches.

Pattern IV--Homogeneous with time and depth (planktonic eggs of *Theragra chalcogramma*, *Leuroglossus schmidti* and *Microstomus pacificus*). *Theragra chalcogramma* eggs were taken throughout the water column (0-121 m). *Leuroglossus schmidti* eggs were taken over deeper water; they were not taken at the surface but were in all other depths to greater than 192 m. *Microstomus pacificus* eggs were taken at all depths but were more abundant from the surface to 28 m.

SUMMARY

1. From fall 1977 to winter 1979, five cruises were conducted to the continental shelf off Kodiak Island to characterize the seasonal, geographical and vertical distribution of zooplankton of the area with emphasis on euphausiids, decapod larvae and ichthyoplankton.

2. Hdrography of the area during the study showed the annual cycle of cooling and warming and freshening from runoff with associated seasonal changes in stratification. The influence of the Alaska Stream was seen over the slope and nearer shore in the troughs and between Kenai Peninsula and Afognak Island. This was borne out by the occurrence of oceanic euphausiids (*Euphausia pacifica* and *Thysanoessa longipes*) and young mesopelagic fishes (Myctophidae, *Leuroglossus schmidti*) in these regions.

3. Total plankton volumes were highest in summer in all regions of the Kodiak Island shelf area. Of these regions in summer, midshelf plankton volumes were higher than volumes recorded at slope and nearshore stations. No apparent differences in plankton volumes were observed between the bank and trough regions of the shelf.

4. Copepods dominated the invertebrate zooplankton and plankton volumes by season were directly proportional to copepod abundance. Chaetognaths were uniformly abundant throughout much of the year with mean densities consistently greatest at slope stations. Cnidaria were most numerous at nearshore and midshelf stations in summer and fall. Amphipoda were caught in substantial numbers in the shelf area throughout the year with greatest abundance found in summer and fall.

5. Subadult euphausiids were found in high concentrations nearshore during summer. *Thysanoessa inermis* was the most abundant adult euphausiid of the Kodiak Island shelf area throughout the year with greatest abundance recorded in winter and fall.

6. Among taxa which include important meroplanktonic species: Cirripedia (barnacle) nauplii and cyprids were found in high concentrations nearshore in summer and to a lesser extent in spring; Echinodermata larvae were found in greatest abundance nearshore in fall but were also found in substantial numbers across the shelf and over the slope in summer; and, Mollusca larvae were found throughout the year with the highest concentrations recorded midshelf in spring and nearshore in summer.

7. Decapod larvae were more abundant in the bays than offshore, more abundant in Kiliuda Bay than in the other three studied, and less abundant in the southernmost offshore subarea than in the other offshore subareas. They were more abundant during summer than in other seasons, although protracted seasonal larval release was indicated by the presence of early larval stages from late winter through summer.

8. Larvae of decapods of current economic value were less abundant than those of other decapods; pea crabs and *Cancer* I were the most frequently encountered taxa among the decapod larvae.

9. Diel-vertical distribution studies of decapod larvae indicated that larvae of most species occurred nearer surface in daytime than at night, and most occurred at the shallowest depths sampled (10-30 m).

10. Eggs and/or larvae of about 60 taxa of fish were collected and while the egg and larval descriptions of many remain inadequate it was possible to identify to species almost half of these.

11. Fish use the study area as a spawning and nursery ground year round but more animals belonging to more taxa were found in summer than in other seasons. In fall and winter larvae of *Hemilepidotus* spp. and *Mallotus villosus* dominated bongo net catches, in spring larvae of *Ammodytes hexapterus* and *Theragra chalcogramma* and in summer *Bathymaster* spp. and *Sebastes* spp.

12. The eggs and larvae of fish that spawned in the nearshore area were found there, but no species was concentrated there in winter. The midshelf area was used by some species during all their planktonic stages, and by others during later stages, only with spawning and early development occurring elsewhere. Egg and larval stages of bathypelagic fishes as well as of some pleuronectids and larvae of *Sebastes* spp. were found in the slope area. Larvae of several species occurred abundantly throughout the study area; these were mainly of fish with demersal eggs.

13. Throughout the year the waters over Kiliuda Trough held relatively high concentrations of eggs and larvae of several species of fish (fall - eggs of *Theragra chalcogramma*, larvae of *Hexagrammos decagrammus* and *Pleurogrammus monopterygius*; spring - eggs of *Hippoglossoides elassodon* and larvae of *Mallotus villosus*, *Theragra chalcogramma*, Stichaeidae, and *Lyconectes aleutensis*; summer - larvae of *Hemilepidotus* spp.).

14. Several species of fish have extended neustonic prejuvenile stages. The neuston was dominated by *Hemilepidotus* spp. and several hexagrammids (led by *Hexagrammos decagrammus*) throughout the year with *Bathymaster* spp. in abundance in summer.

15. Four basic patterns of distribution were observed during diel-vertical distribution studies of ichthyoplankton - marked diel migration (larvae of *Hemilepidotus* spp. and *Bathymaster* spp.), neustonic (larvae of *Hexagrammos* spp., *Pleurogrammus monopterygius*, and *Lyconectes aleutensis*), upper mixed layer (larvae of *Sebastes* spp. and *Ronquilus jordani*), and homogeneous with time and depth (planktonic eggs of *Theragra chalcogramma*, *Leuroglossus schmidti*, and *Microstomus pacificus*).

16. This study covered only a portion of the geographic range of spawning or occurrence of the species studied and therefore it is not possible to determine the relative significance of the Kodiak area to their population dynamics and overall life histories.

ACKNOWLEDGMENTS

We thank a number of people at NWAFC for assistance in this study: Beverly Vinter for identifying most of the fish larvae; Kenneth Waldron for serving as chief scientist on three OCSEAP cruises and for other assistance; Jay Clark for maintaining data files and associated ADP work; Jim Ingraham for computer programming; Bernie Goiney and Donald Fisk for assisting in a number of ways; Evan Haynes (Auke Bay Biological Laboratory) for advising on larval decapod identification; Gale Hudkins (Kodiak Facility) for assisting in sorting and larval identification of decapod larvae; and Langdon Quetin (formerly NWAFC) for analyzing some of the invertebrate data. Bruce Gibbs deserves special thanks for computer programming and establishing the data management system. James Peacock and staff provided excellent graphics. Ethel Zweifel did the replication work.

We thank the following present or past members of the Juneau Project Office, OCSEAP: Dr. Jawed Hameedi for guidance and encouragement; Donald Day for help in administrative matters; JoAnn Hilton, for assistance in dealing with the bureaucracy; and George LaPiene, for help in logistics problems.

Dr. James Schumacher, Pacific Marine Environmental Laboratory, NOAA, Seattle, allowed use of unpublished data, arranged for processing of CTD tapes, and rendered other assistance.

Dr. Felix Favorite, NWAFC, was one of the original principal investigators and through his help in initiating, planning and directing this work, the present report is possible. We thank him for all his efforts in behalf of this work.

LITERATURE CITED

ALTON, M.S., AND T.M. SAMPLE.

MS 1976. Rock sole (Family Pleuronectidae). In: Pereyra, W.T., J.E. Reeves, and R.G. Bakkala, editors, Demersal fish and shellfish resources of the eastern Bering Sea in the baseline year 1975, Vol. I, pp. 461-474. Unpubl. manuscr., Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

ARON, W.

MS 1960. The distribution of animals in the eastern North Pacific and its relationship to physical and chemical conditions. Dep. Oceanogr., Univ. Wash., Seattle, Tech. Rep. 63, 65 p. + 156 p. appendix.

1962. The distribution of animals in the eastern North Pacific and its relationship to physical and chemical conditions. J. Fish. Res. Board Can. 19:271-314.

BANNER, A.H.

1950. A taxonomic study of the Mysidacea and the Euphausiacea (Crustacea) of the Northeastern Pacific. III. Euphausiacea. Trans. Roy. Can. Inst. 28:1-63.

BARR, L.

1970. Alaska's fishery resources - The shrimps. U.S. Fish. Wildl. Serv., Fish. Leaflet 631, 10 p.

BERKELEY, A.

1930. The post-embryonic development of the common pandalids of British Columbia. Contrib. Can. Biol. 6:79-163.

BOWMAN, THOMAS E.

1960. The pelagic amphipod genus Parathemisto (Hyperiidea: Hyperiidae) in the North Pacific and adjacent Arctic Ocean. Proceedings of the U.S. Natl. Mus. Smithsonian Inst., Vol. 112, No. 3439:343-392.

BREDER, C.M., AND D.E. ROSEN.

1966. Modes of reproduction in fishes. T.F.H. Publications, P.O. Box 33, Jersey City, N.J., 941 p.

BRIGHT, D.B.

1967. Life histories of the king crab, Paralithodes camtschatica, and the "Tanner" crab, Chionoecetes bairdi, in Cook Inlet, Alaska. Ph.D. thesis, Univ. Southern Calif., 265 p.

BRINTON, E.

1962. The distribution of Pacific euphausiids. Bull. Scripps Inst. Oceanogr. 8:51-270.

BRODSKII, K.A.

1940. Veslonogie rachki Calanoida Dal'nevostochnykh morei SSSR i Polyarnogo basseina (Calanoida of the Far Eastern Seas and polar basin of the USSR). Akad. Nauk SSSR, Zool. Inst., Opred. po Faune SSSR 35, 442 p. In Russian. (Transl. by Israel Program Sci. Transl., 1967, 440 p., avail. Natl. Tech. Inf. Serv., Springfield, VA., as TT-67-51200.)

CLARKE, M.R.

1969. A new midwater trawl for sampling discrete depth horizons. J. Mar. Biol. Ass. U.K. 49:945-960.

DAMKAER, D.M., AND D.B. DEY

MS 1977. Initial zooplankton investigations in Prince William Sound, Gulf of Alaska, and Lower Cook Inlet. Ann. Rep. OCSEAP RU425, Vol. X:137-274, Unpubl. Manuscr., OCSEAP, Natl. Ocean. Atmos. Admin., Boulder, CO 80303.

DAVIDSON, G.

1869. Report of assistant George Davidson relative to the resources and coast features of Alaska Territory. U.S. Coast Survey Rept. 1867. App. 188, U.S. Gov. Print. Off., Wash. D.C., p. 205.

DODIMEAD, A.J., F. FAVORITE, AND T. HIRANO.

1963. Salmon of the North Pacific Ocean - Part II, Review of oceanography of the Subarctic Pacific Region. Int. N. Pac. Fish. Comm. Bull. 13, 195 p.

DUNN, J.R., AND N.A. NAPLIN.

MS 1974. Fish eggs and larvae collected from waters adjacent to Kodiak Island, Alaska, during April and May 1972. MARMAP Rep. 12. Unpubl. manuscr., 61 p. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

DUNN, J.R., A.W. KENDALL, JR., R.W. WOLOTIRA, L. QUETIN, AND J.H. BOWERMAN, JR.

MS 1979. Seasonal composition and food web relationships of marine organisms in the nearshore zone. Ann. Rep. OCSEAP RU551. Unpubl. Manuscr., 75 p. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

FAVORITE, F., W.J. INGRAHAM, JR., AND D.M. FISK.

MS 1975. Environmental conditions near Portlock and Albatross Banks (Gulf of Alaska), May 1972. Unpubl. manuscr., 45 p. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

FAVORITE, F., A.J. DODIMEAD, AND K. NASU.

1976. Oceanography of the Subarctic Pacific Region. Int. North Pac. Fish. Comm., Bull. 33, 187 p.

FAVORITE, F., AND W.J. INGRAHAM, JR.

1977. On flow in the Northwestern Gulf of Alaska, May 1972. J. Oceanogr. Soc. Japan 33:67-81.

FACULTY OF FISHERIES, HOKKAIDO UNIVERSITY.

1979. Data record of oceanographic observations exploratory fishing No. 22. Fac. Fish., Hokkaido Univ., Hakodate, Hokkaido, Japan, 272 p.

GORBUNOVA, N.N.

1962. Razmnozhenie i razvitie ryb semeistva terpugovykh (Hexagrammidae) (Spawning and development of greenlings (Family Hexagrammidae)). Akad Nauk SSSR, Tr. Inst. Okeanol 59:118-182. In Russian. (Transl. by Israel Program Sci. Transl., 1970, p. 121-185, in T.S. Rass (editor), Greenlings: taxonomy, biology, interoceanic transplantation, avail. Natl. Tech. Inf. Serv., Springfield, VA., as TT-69-55097.)

1964. Razmnozhenie i razvitie polucheshuinykh bychkov (Cottidae, Pisces) (Breeding and development of hemilepidotine sculpins (Cottidae, Pisces)). Akad. Nauk SSSR, Tr. Inst. Okeanol. Tom 73. In Russian. (Transl. by Israel Program Sci. Transl., 1966, p. 249-266 in T.S. Rass (editor), Fishes of the Pacific and Indian Oceans, avail. Natl. Tech. Inf. Serv., Springfield, VA., as TT-65-50120.)

GOSHO, M.E.

1977. The food and feeding habits of juvenile pink salmon in the estuaries of Kodiak Island, Alaska. M.S. thesis, Univ. Washington, Seattle, 87 p.

GULLAND, J.A.

1970. The fish resources of the ocean. Food Agric. Organ., U.N., FAO Fish. Tech. Pap. 97, 425 p.

HARDY, A.

1970. The open sea: Its natural history, Part I: The world of plankton. Houghton Mifflin Co., Boston, Mass., 335 p.

HARRIS, C.K., AND A.C. HARTT.

MS 1977. Assessment of pelagic and nearshore fish in three bays on the east and south coasts of Kodiak Island, Alaska. Final Rep. OCSEAP RU485. Unpubl. Manuscr., 190 p. Fish. Res. Inst. Univ. Wash., Seattle, WA.

HART, J.L.

1973. Pacific fishes of Canada. Fish. Res. Board Can., Bull. 180, 740 p.

HILSINGER, J.R.

1975. Aspects of the reproductive biology of female snow crabs, Chionoecetes bairdi, from Prince William Sound, Alaska. M.S. thesis, Univ. Alaska, 88 p.

HOOPES, D.T.

1973. Alaska fishery resources: The Dungeness Crab. Natl. Mar. Fish. Serv., Fishery Facts 6, 14 p.

HOWE, K., AND S.L. RICHARDSON.

MS 1978. Taxonomic review and meristic variation in marine sculpins (Osteichthys: Cottidae) of the northeast Pacific Ocean. Final Rep., NOAA NMFS contract No. 03-78-MO2-120, 1 January 1978 to 30 September 1978. Unpubl. Manuscr., 142 p. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

INGRAHAM, W.M., JR.

1979. The anomalous surface salinity minima area across the northern Gulf of Alaska and its relation to fisheries. Mar. Fish. Rev., May-June, 1979: 8-19.

INGRAHAM, W.J., JR. AND J.R. HASTINGS.

1974. Seabed drifters used to study bottom currents off Kodiak Island. Mar. Fish. Rev., 36(8):39-41.

INGRAHAM, W.J., JR., A. BAKUN, AND F. FAVORITE.

MS 1976. Physical oceanography of the Gulf of Alaska. Final Rep. OCSEAP RU357. Unpubl. Manuscr., 132 p. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112.

ITO, K.

1967. Ecological studies on the edible crab, Chionoecetes opilio (O. Fabricius) in the Japan Sea. I. When do female crabs first spawn and how do they advance into the following reproductive stage. Bull. Jap. Sea. Reg. Fish. Res. Lab., 17:67-84. In Japanese. (Transl. by Fish. Res. Board Can., Transl. Ser. No. 1103).

IVANOV, B.G.

1969. The biology and distribution of the northern shrimp (Pandalus borealis Kr.) in the Bering Sea and Gulf of Alaska. Food Agric. Organ. U.N., FAO Fish. Rep. 57:800-810.

KRAMER, D.E., M.J. KALIN, E.G. STEVENS, J.R. THRAILKILL, AND J.R. ZWEIFEL.

1972. Collecting and processing data on fish eggs and larvae in the California current region. U.S. Dep. Commer., NOAA Tech. Rep. NMFS Circ. 370, 38 p.

LASKER, R.

1966. Feeding, growth, respiration, and carbon utilization of a euphausiid crustacean. J. Fish. Res. Board Can. 23:1291-1317.

LeBRASSEUR, R.J.

1959. Sagitta lyra, a geological indicator species in the subarctic waters of the eastern Pacific Ocean. J. Fish. Res. Board Can. 16:795-805 p.

MS 1965a. Biomass atlas of net zooplankton in the northeastern Pacific Ocean, 1956-1964. Fish. Res. Board Can. Manuscr. Rep. Ser. (Oceanogr. and Limnol.) 201, 294 p.

MS 1965b. Seasonal and annual variations of net zooplankton at Ocean Station P, 1956-1964. Fish. Res. Board Can., Manuscr. Rep. Ser. (Oceanogr. Limmol.) 202, 153 p.

MS 1970. Larval fish species collected in zooplankton samples from the northeastern Pacific Ocean 1956-1959. Fish. Res. Board Can. Tech. Rep. 175, 47 p.

LEE, RICHARD F.

1975. Fate of petroleum hydrocarbons in marine zooplankton. Proc. 1975 Conference on Prevention and Control of Oil Pollution, March 25-27, 1975, San Francisco, Calif., p. 549-553. Am. Petroleum Inst., Washington, D.C.

LISOVENKO, L.A.

1964. Raspedelenie lichnok tikhookeanskogo morskogo okunia Sebastodes alutus Gilbert v zalive Aliaska (Distribution of the larvae of rockfish (Sebastodes alutus G.) in the Gulf of Alaska. Tr. Vses. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 53 (Izv. Tikhookean. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 52:223-231). In Russian. (Transl. by Israel Program Sci. Transl., 1968, p. 217-225, in P.A. Moiseev (editor), Soviet fisheries investigations in the northeast Pacific, Part 3, avail. Natl. Tech. Inf. Serv., Springfield, VA., as TT-67-51205.)

MACY, P.T., J.M. WALL, N.D. LAMPSAKIS, AND J.E. MASON

MS 1978. Resources of non-salmonid pelagic fishes of the Gulf of Alaska and eastern Bering Sea. Part 1. Introduction, general fish resources and fisheries, review of literature on non-salmonid pelagic fishes. 355 p. Unpubl. manuscr., Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112.

MALINS, D.C. (editor).

1977. Effects of petroleum on arctic and subarctic marine environments and organisms. Volume 2. Biological effects. Academic Press, Inc., New York, 500 p.

MAZMANIDI, N.D., AND T.R. BAZHASHVILI.

1975. Effects of dissolved petroleum products on the embryonic development of the Black Sea flounder. Vopr. Ikhtiol. Tom 15. In Russian. (In J. Ichthyol. 15:811-816.)

McALLISTER, C.D.

1961. Zooplankton studies at Ocean Weather Station "P" in the Northeast Pacific Ocean. J. Fish. Res. Board Can. 18:1-29.

McEWEN, G.F., T.G. THOMPSON, AND R. VAN CLEVE.

1930. Hydrographic sections and calculated currents in the Gulf of Alaska, 1927 to 1928. Rept. of Int. Fish. Comm., 4:5-36.

McMULLEN, J.C., AND H.T. YOSHIHARA.

1969. Fate of unfertilized eggs in king crabs, Paralithodes camtschatica (Tilesius). Alaska Dept. Fish. Game, Informational Leaflet 127, 14 p.

McPHAIL, J.D.

1965. A new ronquil, Bathymaster leurolepis, from the Aleutian Islands. J. Fish. Res. Board Can. 22:1293-1296.

MILNE, A.A.

1959. The centric systematic area sample treated as a random sample. Biometrics 15:270-297.

MIRONOV, O.G.

1969. The development of some Black Sea fishes in sea water polluted by petroleum products. Vopr. Ikhtiol. Tom 9. In Russian. (In Probl. Ichythyol. 9:919-922.)

MOORE, S.

1973. Towards a model of the effects of oil on marine organisms; background papers for a workshop on inputs, fates and effects of petroleum in the marine environment. Ocean Affairs Board, Natl. Acad. Sci., Vol. II: 635-653.

MOORE, S.F., R.L. DWYER, AND A.M. KATZ.

1973. A preliminary assessment of the environmental vulnerability of Machias Bay, Maine, to oil supertankers. Mass. Inst. Technol., Rep. MITSG 73-6, 162 p.

NATIONAL OCEAN SURVEY.

1976. Tide tables 1977, west coast of North and South America including the Hawaiian Islands. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Ocean Survey, Rockville, Md., 220 p.
1977. Tide tables 1978, west coast of North and South America including the Hawaiian Islands. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Ocean Survey, Rockville, Md., 222 p.
1978. Tide tables 1979, west coast of North and South America including the Hawaiian Islands. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Ocean Survey, Rockville, Md., 230 p.

NORTH PACIFIC COMMITTEE.

1960. Oceanic observations of the Pacific 1955: The NORPAC Atlas. Univ. Calif. Press and Univ. Tokyo Press, 532 p.

PARSONS, T.R. AND R.J. LeBRASSEUR.

1970. The availability of food to different trophic levels in the marine food chain. In J.H. Steele (editor), Marine food chains, p. 325-343, Univ. of Calif. Press, Berkeley.

PEDEN, A.E.

1978. A systematic revision of the hemilepidotine fishes (Cottidae). Syesis 11:11-49.

PONOMAREVA, L.A.

1963. Evfauziidy severnoi poloviny Tikhogo okeana, ikh rasprostranenie i ekologiya massovykh vidov (Euphausiids of the North Pacific, their distribution and ecology). Izd. Akad. Nauk SSSR, Moscow, 142 p. In Russian. (Transl. by Israel Program Sci. Transl., 1966, 154 p., avail. Natl. Tech. Inf. Serv., Springfield, VA., as TT-65-50098.)

POOLE, R.L.

1966. A description of laboratory-reared zoeae of Cancer magister (Dana), and megalopae taken under natural conditions (Decapoda, Brachyura). Crustaceana 11:83-97.

POWELL, G.C., AND R.E. REYNOLDS.

1965. Movement of tagged king crabs, Paralithodes camtschatica (Tilesius), in the Kodiak Island-Lower Cook Inlet region of Alaska, 1954-1963. Alaska Dept. Fish. Game, Informational Leaflet 55, 10 p.

QUAST, J.C.

1960. The fishes of the family Hexagrammidae: their classification, variation, and osteology. Ph.D. thesis, Univ. Calif., Los Angeles, 380 p.

QUAST, J.C., AND E.L. HALL.

1972. List of fishes of Alaska and adjacent waters with a guide to some of their literature. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-658, 47 p.

RICHARDSON, S.L., AND B.B. WASHINGTON.

In press. Guide to identification of some sculpin (Family Cottidae) larvae from marine and brackish waters off Oregon and adjacent areas. U.S. Dep. Commer., NOAA Tech. Rep. NMFS Circ. 430.

ROGERS, D.E., D.J. RABIN, B.J. ROGERS, K. J. GARRISON, AND M. E. WANGERIN.

MS 1979a. Seasonal composition and food web relationships of marine organisms in the nearshore zone of Kodiak Island--including ichthyoplankton, meroplankton (shellfish), zooplankton, and fish. Ann. Rep. OCSEAP RU553. Unpubl. manuscr. 121 p. Fish. Res. Inst., Univ. Wash., Seattle.

MS 1979b. Seasonal composition and food web relationships of marine organisms in the nearshore zone of Kodiak Island--including ichthyoplankton, meroplankton (shellfish), zooplankton, and fish. Annual Rep. OCSEAP RU553. Unpubl. manuscr., 291 p. Fish Res. Inst., Univ. Wash., Seattle.

RONHOLT, L.L., H.H. SHIPPEN, AND E.S. BROWN.

MS 1978. Demersal fish and shellfish resources of the Gulf of Alaska from Cape Spencer to Unimak Pass 1948-1976 (A historical review), Vols. 1-4, Unpubl. manuscr. 955 p. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E., Seattle WA 98112.

ROYER, T.C.

MS 1977. Circulation and water masses in the Gulf of Alaska. Ann. Rep. OCSEAP RU289, Vol. X: 292-323. Unpubl. Manuscr., OCSEAP, Natl. Ocean. Atmos. Admin., Boulder, CO 80303.

ROYER, T.C., D.V. HANSEN, AND D.J. PASHINSKI.

1979. Coastal flow in the northern Gulf of Alaska as observed by dynamic topography and satellite-tracked drogued drift buoys. J. Phys. Oceanogr. 9:785-801.

SAMEOTO, D.D., AND L.O. JAROSZYNSKI.

1969. Otter surface sampler: a new neuston net. J. Fish. Res. Board Can., 25:2240-2244.

SATO, S.

1958. Studies on larval development and fishery biology of king crab, Paralithodes camtschatica (Tilesius). Bull. Hokkaido Reg. Fish. Res. Lab. 17:29 and 35-37. In Japanese. (Transl. by Natl. Mar. Fish. Serv., Auke Bay, Alaska.)

SCHUMACHER, J.D., R. SILLCOX, D. DREVES, AND R.D. MUENCH.

1978. Winter circulation and hydrography over the continental shelf of the Northwest Gulf of Alaska. U.S. Dep. Commer., NOAA Tech. Rep. ERL 404-PMEL31, 16 p.

SCHUMACHER, J.D., R.K. REED, M. GRIGSBY, D. DREVES.

1979. Circulation and hydrography near Kodiak Island, September to November, 1977. U.S. Dep. Commer., NOAA Tech. Memo ERL-PMEL 13, 49 p.

SCHUMACHER, J.D., AND R.K. REED.

MS 1979. Coastal flow in the northwest Gulf of Alaska: The Kenai Current. Unpubl. manuscr., 32 p. Pacific Mar. Environ. Lab., Environ. Res. Lab., NOAA, 3711 - 15th Ave. N.E., Seattle, WA 98105.

SCIENCE APPLICATIONS, INC.

MS 1979a. Environmental assessment of the Alaskan continental shelf. Kodiak Interim Synthesis Report. Unpubl. manuscr., 215 p. Science Applications, Inc., Boulder, CO 80302.

MS 1979b. Circulation in the Kodiak lease area. Unpubl. manuscr., 83 p. Science Applications, Inc., Boulder, CO 80302.

SHEARD, K.

1947. Plankton of the Australian-Antarctic quadrant. I. Netplankton volume determination. Brit. Aus. New Zeal. Antarctic Res. Exped. Reports, Ser. 6:1-20.

SHIH, C.-T., A.J.G. FIGUEIRA, AND E.H. GRAINGER.

1971. A synopsis of Canadian marine zooplankton. Fish. Res. Board Can., Bull. 176, 264 p.

SKUD, B.E.

1977. Drift, migration, and intermingling of Pacific halibut stocks. Int. Pac. Halibut Comm., Sci. Rep. 63, 42 p.

SMITH, P.E., AND S.L. RICHARDSON.

1977. Standard techniques for pelagic fish egg and larva surveys. Food Agric. Organ. U.N. FAO Fish. Tech. Pap. 175, 100 p.

STRUHSAKER, J.W., M.B. ELDRIDGE, AND T. ECHEVERRIA.

1974. Effects of benzene (a water-soluble component of crude oil) on eggs and larvae of Pacific herring and northern anchovy. In F.J. Vernberg and W.B. Vernberg (editors), 253-284. Pollution and physiology of marine organisms. Academic Press, Inc., New York.

SUND, PAUL N.

1959. The distribution of Chaetognatha in the Gulf of Alaska in 1954 and 1956. J. Fish. Res. Board Can. 16:351-361.

THOMPSON, W.F., AND R. VAN CLEVE.

1936. Life history of the Pacific halibut. (2) Distribution and early life history. Int. Fish. Comm. Rep. 9, 184 p.

THRELKELD, S.T.

MS 1973. The occurrence and distribution of five species of Monstrillidae (Copepoda: Monstrilloida) from near Kodiak, Alaska. MARMAP Survey I Rep. 7. Unpubl. manuscr., 23 p. Northwest and Alaska Fisheries Center, Natl, Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.
1977. The distribution of five species of Monstrillidae (Copepoda: Monstrilloida) near Kodiak Island, Alaska. Crustaceana 32:225-228.

TRASK, T.

1970. A description of laboratory-reared larvae of Cancer productus Randall (Decapoda, Brachyura) and a comparison to larvae of Cancer magister Dana. Crustaceana 18:133-146.

TRUMBLE, R.J.

1973. Distribution, relative abundance, and general biology of selected underutilized fishery resources of the eastern North Pacific Ocean. M.S. thesis, Univ. Washington, Seattle, 178 p.

WEBBER, R.A., AND T.W. SAMPLE.

MS 1976. Arrowtooth flounder (Family Pleuronectidae). In Pereyra, W.T., J.E. Reeves, and R.G. Bakkala (editors), Demersal fish and shellfish resources of the eastern Bering Sea in the baseline year 1975. Vol. I, pp. 523-529. Unpubl. manuscr., Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., 2725 Montlake Blvd. E., Seattle, WA 98112.

WEIBE, P.H., S. BOYD, AND J.L. COX.

1975. Relationships between zooplankton displacement volume, wet weight, dry weight, and carbon. Fish. Bull. U.S. 73:777-786.

WOLFE, D.A. (editor).

1977. Fate and effects of petroleum hydrocarbons in marine ecosystems and organisms. Pergamon Press, New York, N.Y., 478 p.

Table 1. --Summary of previous plankton sampling surveys relevant to the Kodiak Island shelf area.

Authors	Agency1/	Years of Sampling	Months Sampled	General Area of Survey	Number Stations Near Kodiak	Sampling Gear and Type of Tow	Kinds of Data Reported
Thompson and VanCleve (1936)	IPHC	1926-34	Jan-Jun	Gulf of Alaska	ca 104	1-and 2-meter nets, Petersen young fish trawls. Oblique tows, (30^{o}).	Distribution and abundance of Pacific halibut, _Hippoglossus stenolepis_, eggs and larvae.
North Pacific Committee (1960)	NORPAC	1955	Jun -Oct	North Pacific Ocean	10	Clarke-Bumpus nets, oblique tow.	Station data; list of dominant zooplankton taxa; depth of haul: displacement volume.
LeBrasseur (MS 1965)	FRBC	1956-64	Jan-Dec	Gulf of Alaska	114	NORPAC-vertical.	Weight of zooplankton and certain invertebrate taxa. For 1963-64, numbers of certain species of copepods and other taxa reported.
LeBrasseur (MS 1970)	FRBC	1956-59	Jan-Aug	Gulf of Alaska	19	NORPAC; IKMT; vertical and horizontal.	Identification of fish larvae by station.
Faculty Fisheries, Hokkaido Univ. (1960)	FFHU	1953-77	May-Aug	North Pacific Ocean	7	Various: Ring net, NORPAC,neuston, vertical and horizontal.	Station data: variable other data on ichthyo-, and zooplankton.
Aron (MS 1960; 1962)	UW	1957	Jul	North Pacific Ocean	5	3- and 6-foot IKMT, oblique tows.	Station data, plankton volume, dominant zooplankton, species composition of adult, juvenile and larval fishes by station.
Lisovenko (1964)	VNIRO	1963	Apr-Jul	Gulf of Alaska; Kodiak Island	50	80 cm conical, oblique (?) tows.	Distribution of rockfish, _Sebastes_ sp., larvae.
Dunn and Naplin (MS 1974)	NWAFC	1972	Apr-May	East side of Kodiak Island	67	60 cm Bongo, oblique tow.	Distribution and abundance of fish eggs and larvae; station and haul data.
Threlkeld (MS 1973; 1977)	NWAFC	1972	Apr-May	East side of Kodiak Island	67	60 cm Bongo, oblique tow.	Distribution of monstrillid copepods.
Damkaer and Dey (MS 1977)	PMEL	1975-76	Oct-Nov 75; Apr-Aug 76	Gulf of Alaska, Prince William Sound and Lower Cook Inlet	10	Vertical ring net. Oblique Bongo net.	Distribution, composition, and abundance of zooplankton taxa.
Cosho (1977)	UW	1971	Jun-Aug	Alitak and Kiliuda Bays, Kodiak Island	61	30 cm ring; horizontal tow.	Abundance and size composition of major zooplankton groups.
Harris and Hartt (MS 1977)	UW	1976	May-Sep	Ugak, Kaiugnak and Alitak Bays, Kodiak Island	ca 170	Tow nets; herring trawl; beach seine trynet and Trammel net.	Distribution, abundance, age and food habits of adult and juvenile fishes.
Dunn et al., (MS 1979)	NWAFC	1977-78	Oct-Nov 77 Mar-Apr 78	East side of Kodiak Island	150	Bongo nets; neuston nets, Tucker trawls.	Distribution and abundance of ichthyoplankton, decapod larvae, euphausiids, and other zooplankton taxa.
Rogers et al. (MS 1979a)	UW	1978	Mar-Aug, and Nov (11 cruises)	Kalsin-Chiniak, Kiliuda, Kaiugnak, Kodiak Island	ca 286	Neuston nets, Bongo nets, Tucker trawl, Epi-benthic sled.	Distribution and abundance of ichthyoplankton and euphausiids. Food habits of adult and juvenile fishes.
Rogers et al. (MS 1979b)	UW	1978-79	Mar-Aug, Nov 78, Mar 79 (12 cruises)	As above	ca 350	As above.	As above.

1/ IPHC = International Pacific Halibut Commission; NORPAC = North Pacific Committee; FRBC = Fisheries Research Board of Canada; FFHU = Faculty of Fisheries, Hokkaido University; UW = University of Washington; VNIRO = All-Union Scientific Research Institute of Marine Fisheries and Oceanography; NWAFC = Northwest and Alaska Fisheries Center; PMEL = Pacific Marine Environmental Laboratory.

Table 2. --Number of plankton samples collected and associated measurements made on OCSEAP plankton cruises, October 1977 - March 1979.

			COUNTS									
				Samples by gear type (mesh size in mm)								
Cruise	Vessel	Cruise Dates	Stations Occupied	Neuston 0.505	Bongo 0.505	Bongo 0.333	Tucker 0.505	IKMT	Samples Collected	CTD Casts	XBT Probes	Seabed Drifters Released
4MF77	*Miller Freeman*	31 Oct-14 Nov 1977	61	83	59	58	168	0	369	40	31	400
4DI78	*Discoverer*	28 Mar-20 Apr 1978	89	111	85	85	138	56	475	117	0	800
2MF78	*Miller Freeman*	19 Jun-09 Jul 1978	91	111	89	89	176	40	505	106	0	800
1WE78	*Wecoma*	25 Oct-17 Nov 1978	94	101	98	98	100	0	397	97	0	768
1MF79	*Miller Freeman*	13 Feb-11 Mar 1979	88	89	88	88	74	0	339	88	0	768

Table 3. --OCSEAP plankton cruises of the inshore region of Kodiak Island shelf area. Dates and numbers of samples by gear type.

Cruise No.	Cruise Date	Number of Stations Occupied	Number of Samples by Gear Type (mesh size in mm)					Total No. Samples Collected	No. of Samples Sorted for Decapods
			Neuston 0.505	Bongo 0.505* 0.333 1/	Tucker* 0.505	Tucker 3.0	Sled* 0.505		
I	29 Mar-8 Apr 1978	20	20	16	12	2	2	52	30
II	10-17 Apr 1978	20	22	17	24	4	7	74	48
III	21 Apr-1 May 1978	20	22	17	24	4	7	74	48
IV	3-28 May 1978	26	28	26	24	4	8	90	58
V	31 May-6 Jun 1978	26	28	25	24	4	8	89	57
VI	14-26 Jun 1978	26	27	25	24	4	5	85	54
VII	28 Jun-18 Jul 1978	26	28	25	24	4	4	85	53
VIII	21-29 Jul 1978	26	28	26	24	4	4	86	54
IX	1-9 Aug 1978	26	27	25	24	4	4	84	53
X	15-21 Aug 1978	26	27	23	24	4	4	82	51
XI	4 -13 Nov 1978	26 2/	27	15	24	0	0	66	39
XII	4-16 Mar 1979	25	27	18	24	0	0	69	42
TOTALS		293	311	258	276	38	53	936	587

1/ * Denotes gear types from which decapod larvae samples were analyzed.

2/ Although all stations were occupied and decapod larvae sorted from appropriate samples, data from five stations in Chiniak Bay were absent from computer printouts used for these analyses.

Table 4.--Data sets used in analyses of decapod larvae collected during OCSEAP offshore and inshore plankton cruises.

Analysis	Offshore Cruises		Inshore Cruises		
	Bongo 0.333 mm mesh	Tucker 0.505 mm mesh	Bongo 0.333 mm mesh	Tucker 0.505 mm mesh	Benthic sled 0.505 mm mesh
Incidence of occurrence	X	X	X	X	X
Relative density by area and season	X		X		
Relative density by depth and time of day		X		X	
Time of occurrence by larval stage			X	X	X

Table 5. --Grid station numbers used for comparison of catches in nearshore, midshelf, and slope regions and trough and bank areas.

Cruise [1]	Nearshore Stations	Midshelf Stations	Slope Stations	Trough Stations	Bank Stations
4MF77 31 Oct- 14 Nov 77	G01A, G03A, G04A, G36A, G38A, G41A, G43A, G45A, G50A, G51A, G53A	G06A-12A, G19A-20A, G26A-29A, G34A-35A, G37A, G48A	G13A, G21A-24A G30A-32A	G02A, G05A, G07A-8A, G12A-13A, G16A-17A, G20A-21A, G26A, G30A-31A, G34A, G39A, G42A, G44A	G06A, G10A-G11A, G18A-G19A, G25A, G27A-G29A, G35A, G46A-49A, G52A
4DI78 28 Mar- 20 Apr 78	G01A, G04A, G61A, G64A, G66A, G69A, G71A, G73A, G77A, G80A	G06A-7A, G10A-12A, G22A, G31A-32A, G38A-40A, G46A-47A, G62A, G65A, G68A, G70A, G74A-76A	G25A-29A, G34A-35A, G43A-44A, G50A-52A, S30A-34A	G02A-3A, G05A-6A, G08A, G30A, G32A-33A G38A-39A, G42A, G62A-63A, G65A, G67A G70A, G72A	G07A, G09A-10A G22A, G24A, G31A, G36A-37A, G40A-41A, G45A-47A, G68A, G74A-76A
2MF78 19 Jun- 9 Jul 78	G01A, G03A, G21A-28A	G02A, G12A-G15A, G18A-G20A G52A-G64A	G48A-50A, G65A, G67A, G68A, G73A-79A, G81A-87A	G12A-13A, G17A-18A, G40A, G43A-44A, G47A G58A-61A, G64A, G70A	G02A, G10A, G14A-16A, G19A-20A, G37A-39A, G41A-42A, G45A, G52A-57A, G62A-63A G69A, G71A
1WE78 25 Oct- 17 Nov 78	*	G02A, G12A-13A, G15A, G18A-G20A, G52A-G64A	*	*	G02A, G10A, G15A-16A G19A-20A, G37A-39A, G41A-42A, G45A, G52A-57A, G62A-63A G69A, G71A
1MF79 13 Feb- 11 Mar 79	*	G02A, G12A-G15A, G18A-G20A G52A-G64A	*	G12A-13A, G17A-18A G40A, G43A-44A, G47A, G58A, G60A-61A, G64A, G70A	G02A, G10A, G14A-16A, G19A-20A, G37A-39A, G41A-42A, G45A G52A-57A, G62A-63A, G71A

[1] See Figures 3-7.

Table 6. --Seabed drifter release and recovery locations and dates, number of days out, and estimated direction and distance of drift.

Cruise Number	Date Released	Release Location Latitude N	Release Location Longitude W	Recovery Date	Recovery Location Latitude N	Recovery Location Longitude W	Days Out	Estimated direction and distance of drift: Direction (Mag)	Estimated direction and distance of drift: Distance (km)
4MF 77	5 Nov 77	58°02'	151°38'	Jan 79	Nataliu Bay		422 (min)1/	SW	183
	5 Nov 77	56°53'	153°04'	8 Jan 78	56°50'	153°18'	74	SW	19
	2 Nov 77	57°37'	151°55'	-	57°03'	152°48'	90	SW	89
4DI 78	9 Apr 78	57°07'	153°00'	Jan 79	Nataliu Bay		267 (min)1/	SW	41
	8 Apr 78	57°47'	151°41'	19 May 78	57°25'	152°30'	41	SW	70
	9 Apr 78	57°28'	152°10'	30 Sep 78	57°32'	151°42'	175	NE	32
	29 Mar 78	58°04'	151°45'	-	-	-			
	29 Mar 78	58°04'	151°45'	23 Sep 79	Chiniak Gulley		543	S	57
2MF 78	24 Jun 78	56°55'	153°22'	29 Jan 79	57°08'	153°25'	219	NW	26
	24 Jun 78	57°04'	153°03'	11 Nov 78	Ocean Bay, Sitkalidak Isl.		140	W	11
	26 Jun 78	57°16'	151°17'	18 Sep 78	57°34'	151°51'	84	NW	48
	26 Jun 78	56°59'	152°55'	17 Sep 78	57°08'	152°44'	83	N	22
	24 Jun 78	56°55'	153°22'	17 Nov 78	57°05'	153°26'	146	NW	20
	26 Jun 78	57°16'	151°17'	6 Dec 78	57°38'	151°52'	163	NW	59
	26 Jun 78	57°16'	151°17'	28 Sep 78	57°32'	151°42'	94	NW	43
	22 Jun 78	57°36'	151°48'	21 Sep 78	57°32'	151°40'	91	SE	13
	22 Jun 78	57°36'	151°48'	24 Sep 78	57°25'	151°26'	94	SE	33
	27 Jun 78	57°43'	150°54'	26 Sep 78	57°22'	151°22'	91	S	50
	24 Jun 78	57°12'	152°44'	27 Sep 78	56°52'	153°26'	95	SW	59
	24 Jun 78	57°19'	152°24'	27 Oct 78	57°24'	152°24'	125	NW	9
	24 Jun 78	56°55'	153°22'	15 Sep 78	57°03'	153°25'	83	NW	18
	24 Jun 78	56°55'	153°22'	23 Sep 78	57°03'	153°25'	91	NW	16
	26 Jun 78	57°00'	151°55'	29 Sep 78	57°03'	152°30'	95	W	37
	26 Jun 78	57°16'	151°17'	29 Sep 78	57°38'	151°58'	95	NW	63
	21 Jun 78	58°03'	151°25'	20 Jan 79	57°40'	151°50'	213	S	53
	24 Jun 78	56°55'	153°22'	6 Dec 78	57°05'	153°26'	165	NW	20
	24 Jun 78	56°55'	153°22'	23 Oct 78	57°05'	153°26'	121	NW	20
	27 Jun 78	57°43'	150°54'	-	-	-	-	-	-
	24 Jun 78	57°04'	153°03'	18 Feb 79	Ocean Bay, Sitkalidak Isl.		239	NW	11
	22 Jun 78	57°37'	151°47'	18 Feb 79	57°21'	152°33'	241	SW	57
	21 Jun 78	58°03'	151°25'	11 Feb 79	57°31'	152°17'	235	SW	83
	24 Jun 78	56°55'	153°22'	28 Feb 79	57°10'	153°20'	249	NW	33
	24 Jun 78	56°55'	153°22'	26 Feb 79	57°10'	153°19'	247	NW	33
	24 Jun 78	56°55'	153°22'	24 Feb 79	57°09'	153°21'	245	NW	33
	22 Jun 78	58°18'	150°12'	8 Jan 79	-	-	200	-	-
	30 Jun 78	56°26'	153°44'	11 Apr 79	-	154°32'	285	-	-
1WE 78	28 Oct 78	56°55'	153°22'	17 Mar 79	57° -	153°25'	165	NW	26
	28 Oct 78	57°16'	151°17'	2 Feb 79	Silver Bay, Cape Chiniak		97	WNW	70
	1 Nov 78	57°36'	151°46'	5 Jan 79	57°25'	152°00'	65	S	27
	28 Oct 78	56°55'	153°22'	28 Jan 79	57°07'	153°25'	92	NW	26
1MF 79	15 Feb 79	57°04'	153°04'	29 Mar 79	Ocean Bay, Sitkalidak Isl.		42	W	11
	15 Feb 79	57°04'	153°04'	29 Mar 79	"	"	42	W	11
	18 Feb 79	57°45'	151°28'	25 Mar 79	57°56'	151°57'	35	NW	33
	15 Feb 79	57°04'	153°04'	4 Apr 79	Ocean Bay, Sitkalidak Isl.		48	W	11
	15 Feb 79	57°04'	153°04'	4 Apr 79	"	"	48	W	11
	15 Feb 79	57°04'	153°04'	4 Apr 79	"	"	48	W	11
	15 Feb 79	57°04'	153°04'	4 Apr 79	"	"	48	W	11
	18 Feb 79	57°45'	151°28'	23 Sep 79	"	"	217	NW	44

1/ Minimum number of days from time of release.

Table 7.--Mean settled plankton volumes from bongo net tows on OCSEAP plankton cruises in ml/m^3.

	Winter 1MF79 13 Feb-11 Mar 79	Spring 4DI78 28 Mar-20 Apr 78	Summer 2MF78 19 Jun-9 Jul 78	Fall 4MF77; 1WE78 31 Oct-14 Nov 77; 25 Oct-17 Nov 78
Nearshore Stations	0.15	0.11	0.44	0.12
Albatross and Portlock Bank Stations	0.03	0.18	0.69	0.11
Stevenson, Chiniak and Kiliuda Trough Stations	0.08	0.14	0.82	0.10
Midshelf Stations	0.06	0.16	0.74	0.11
Slope Stations	0.09	0.10	0.62	0.10
All Stations Sampled	0.09	0.13	0.63	0.11

Table 8. --Seasonal distribution and abundance of major invertebrate zooplankton groups from bongo net tows on OCSEAP plankton cruises based on mean number of animals/1000 m^3.

	WINTER (1MF79)				SPRING (4DI78)				SUMMER (2MF78)				(4MF77) FALL (1WE78)			
	NEARSHORE STATIONS	MIDSHELF STATIONS	SLOPE STATIONS	ALL STATIONS	NEARSHORE STATIONS	MIDSHELF STATIONS	SLOPE STATIONS	ALL STATIONS	NEARSHORE STATIONS	MIDSHELF STATIONS	SLOPE STATIONS	ALL STATIONS	NEARSHORE STATIONS	MIDSHELF STATIONS	SLOPE STATIONS	ALL STATIONS
COPEPODA	15891.5	16282.1	56222.5	32180.1	157401.8	163662.2	65587.2	123180.1	525803.6	751895.0	369431.3	553691.6	106965.9	87151.4	49346.0	78853.2
ECHINODERMATA LARVAE	37.1	16.6	16.9	20.8	-	-	-	-	403.0	878.5	865.3	778.1	5662.3	1074.3	9.4	1577.5
CHAETOGNATHA	330.4	253.6	6542.8	2784.6	320.4	826.5	1462.8	979.8	432.3	854.5	6175.9	2898.6	887.6	1393.0	5964.9	2888.7
ANNELIDA	-	14.3	40.4	21.9	127.8	179.9	80.5	129.8	774.5	2588.2	1515.9	1796.6	235.8	118.2	119.0	142.1
CNIDARIA	210.8	297.6	1718.0	848.4	421.4	822.3	760.3	717.3	6638.1	6961.3	1238.7	4607.6	5684.0	4063.9	1508.7	3365.8
HYDROZOA SIPHONOPHORA	-	0.5	79.8	32.1	-	5.0	16.9	8.8	75.7	-	-	30.3	-	22.2	17.4	15.8
CTENOPHORA	-	-	-	-	-	-	6.2	2.5	-	-	-	-	65.1	21.9	-	31.6
GASTROPODA LARVAE	11.3	22.2	23.5	20.6	656.1	1528.1	58.5	765.9	1574.9	292.0	260.1	535.8	258.7	206.6	293.1	251.6
PTEROPODA	74.2	293.8	937.6	507.4	4770.2	2328.5	519.7	2093.3	549.1	546.2	231.1	420.7	1022.8	1186.1	1611.6	1369.3
CLADOCERA	-	-	-	-	-	47.3	-	18.9	87.8	279.3	-	129.3	207.1	58.7	-	64.9
OSTRACODA	296.2	361.6	3475.6	1594.1	93.4	541.6	1535.8	849.6	-	-	1734.4	693.8	63.5	70.3	1141.5	418.2
CIRRIPEDIA NAUPLII	13.9	-	2.9	4.0	68638.2	16828.5	865.1	20805.1	103453.0	18197.6	84.4	28003.4	84.0	238.3	-	120.0
CIRRIPEDIA CYPRIDS	20.6	4.0	-	5.7	696.7	272.3	38.7	263.7	2036.5	2948.4	44.2	1764.3	1582.7	1083.6	82.9	840.0
ISOPODA	51.5	58.1	167.3	97.3	-	14.4	17.6	12.8	30.8	-	59.4	29.9	444.0	51.3	141.2	163.2
AMPHIPODA	279.9	205.6	552.2	359.1	569.2	631.4	339.8	502.3	793.1	877.3	3190.4	1785.7	1548.5	1605.0	1136.6	1481.1
MYSIDACEA	30.6	12.2	2.4	12.0	3.9	-	-	0.8	188.8	-	-	75.5	56.8	15.5	5.9	22.3
CUMACEA	34.0	119.1	6.5	57.0	-	59.7	-	23.9	410.0	35.3	-	96.1	-	121.8	-	48.7
THALIACEA	-	-	-	-	-	-	15.6	6.3	-	-	72.0	28.8	-	-	93.2	37.3
LARVACEA	546.7	190.6	290.8	301.9	4801.4	8628.4	865.0	4757.7	8670.7	15911.4	6265.3	10604.7	4064.3	2866.3	1918.1	3201.9

Table 9. --Seasonal distribution and abundance of Euphausiacea from bongo net tows on OCSEAP plankton cruises based on mean number of animals/1000 m^3.

	WINTER (1MF79)				SPRING (4DI78)				SUMMER (2MF78)				FALL (4MF77) (1WE78)			
	NEARSHORE STATIONS	MIDSHELF STATIONS	SLOPE STATIONS	ALL STATIONS	NEARSHORE STATIONS	MIDSHELF STATIONS	SLOPE STATIONS	ALL STATIONS	NEARSHORE STATIONS	MIDSHELF STATIONS	SLOPE STATIONS	ALL STATIONS	NEARSHORE STATIONS	MIDSHELF STATIONS	SLOPE STATIONS	ALL STATIONS
SUBADULTS																
Euphausiacea Larvae	-	0.4	12.3	5.1	1472.5	6922.9	77.0	3094.0	65703.7	92410.0	16003.5	56506.1	2241.7	2464.1	409.2	1911.1
Euphausiacea Juveniles	355.0	273.5	282.3	293.5	13.7	40.6	17.5	29.2	5027.7	14754.1	3523.9	8476.7	2826.6	2521.6	1510.1	2234.1
ADULTS																
Euphausia pacifica	1.6	12.4	102.5	46.3	-	1.1	7.6	3.5	0.7	0.8	67.9	27.6	11.1	32.3	50.1	37.2
Stylocheiron species	-	-	1.1	0.4	-	7.6	-	3.0	-	-	0.5	0.2	-	-	0.8	0.3
Tessarabrachion oculatus	-	-	17.6	7.0	-	-	4.0	1.6	-	-	3.7	1.5	-	-	10.6	3.7
Thysanoessa inermis	4307.1	789.2	413.0	1342.6	82.9	438.1	76.1	222.3	40.3	53.3	202.5	110.4	48.0	436.1	400.6	348.0
T. inspinata	0.8	4.6	26.5	12.6	0.8	-	-	0.3	-	0.7	2.8	1.4	0.8	27.6	23.0	20.7
T. longipes	2.3	3.9	181.8	74.5	-	1.1	323.9	130.0	-	0.4	8.2	3.5	2.3	2.8	34.3	11.0
T. raschii	190.8	26.7	2.2	49.7	-	2.7	-	1.1	3.1	0.2	-	0.7	92.1	14.4	-	24.7
T. spinifera	48.5	27.6	9.8	24.7	2.4	19.8	46.1	26.9	1.1	2.1	1.1	1.5	72.2	74.0	102.9	88.1
TOTAL ADULTS	4551.1	864.4	754.5	1557.8	86.1	470.4	457.7	388.7	45.2	57.5	286.7	146.8	226.5	587.2	790.3	533.7

Table 10.--Weights and lengths of principal species of Euphausiacea from bongo net tows on OCSEAP plankton cruises.

	Winter 1MF79			Spring 4DI78			Summer 2MF78			Fall 4MF77 1WE78		
	Mean Weight (mg)	Mean Length (mm)	Length Range (mm)	Mean Weight (mg)	Mean Length (mm)	Length Range (mm)	Mean Weight (mg)	Mean Length (mm)	Length Range (mm)	Mean Weight (mg)	Mean Length (mm)	Length Range (mm)
Euphausia pacifica	10.3	15.6	12-21	11.6	14.1	12-19	45.9	18.8	12-25	6.8	16.0	10-24
Thysanoessa inermis	3.3	14.5	12-25	25.4	16.9	12-26	36.2	20.6	12-27	4.7	15.2	11-27
Thysanoessa longipes	15.1	15.1	12-28	8.5	16.4	12-26	73.7	20.3	12-29	6.3	13.8	11-25
Thysanoessa raschii	2.8	12.8	12-20	13.7	13.1	12-15	34.4	17.0	14-19	5.5	13.0	12-19
Thysanoessa spinifera	6.4	14.4	12-26	26.8	16.4	11-25	53.6	19.9	12-27	6.0	14.7	10-31

Table 11.--Day and night vertical distributions of Euphausiacea from Tucker trawl tows on OCSEAP plankton cruises.

	DATE	DIEL SERIES [1]	DEPTH INTERVAL (m)	MEAN DENSITY (#/1000m^3) DAY	NIGHT
Euphausiacea larvae	Jun 78	Diel 5	0-27	213,797.5	228,969.4
			27-71	63,285.0	13,947.6
			71-136	2,014.8	3,332.5
	Jul 78	Diel 6	0-28	37,591.6	49,358.9
			28-71	6,893.9	18,559.9
			71-95	1,014.1	8,265.3
Euphausiacea juveniles	Jun 78	Diel 5	0-27	158,214.0	152,600.8
			27-71	67,785.4	8,633.9
			71-136	3,098.0	2,427.4
	Jul 78	Diel 6	0-28	57,954.9	54,505.5
			28-71	13,912.9	20,929.2
			71-95	5,686.3	2,767.7
Thysanoessa inermis (adults)	Apr 78	Diel 3	0-43	1,280.3	1,490.7
			43-85	64.7	1,022.7
	Apr 78	Diel 4	0-66	17.7	353.6
			66-121	29.8	109.2
	Jun 78	Diel 5	0-27	-	493.4
			27-71	22.3	71.7
			71-136	238.5	81.9
Thysanoessa spinifera (adults)	Apr 78	Diel 4	0-66	8.3	84.7
			66-121	19.9	32.6
	Nov 78	Diel 7	0-40	14.3	132.8
			40-193	28.6	8.1
			193-368	19.1	5.5

1/ See Figure 8 for locations of diel series.

Table 12.--Reptantia and Natantia decapod crustacea larvae encountered during OCSEAP inshore and offshore plankton cruises.

Scientific Name and Classification	Common Name	Known Larval Stages	Life Stages Found
Suborder Natantia	shrimps		
Family Pandalidae	pandalid shrimps		
<u>Pandalopsis</u> <u>dispar</u>	sidestripe shrimp		
<u>Pandalus</u> <u>borealis</u>[1] △	pink shrimp	1-6	1,2,3,4,5,6, & J [2]
<u>Pandalus</u> <u>goniurus</u>	humpy shrimp	1-6	1,2,3,4,5,6, & J
<u>Pandalus</u> <u>hypsinotus</u>	coonstripe shrimp	1-6	1
<u>Pandalus</u> <u>playtceros</u>	spot shrimp	1-4	4
<u>Pandalus</u> <u>montagui</u> <u>tridens</u>	--	1-6	1,2,3
<u>Pandalus</u> <u>stenolepis</u>	--	1-6	1,2,3,4,5,6
Family Hippolytidae △	hippolytid shrimps	1-7	1,2,3,4,5,6,7
Family Crangonidae △	crangonid shrimps	1-7	1,2,3,4,5,6,7
Family Pasiphaeidae	pasiphaeid shrimps		
<u>Pasiphaea</u> sp.	--	--	J
Suborder Reptantia	crabs		
Tribe Anomura △	anomuran crabs		
Family Lithodidae	lithodid crabs		
<u>Paralithodes</u> <u>camtschatica</u> △	red king crabs	1-4,G	1,2,3,4, & G
Family Paguridae	hermit crabs	1-4,G	1,2,3,4, & G
Tribe Brachyura	brachyuran crabs		
Family Majidae	spider crabs		
<u>Chionoecetes</u> <u>bairdi</u> △	Tanner crab	1-2,M	1,2, & M
<u>Hyas</u> spp.	--	1-2,M	1,2, & M
<u>Oregonia</u> spp.	--	1-2,M	1,2, & M
Majidae I	--	--	1,2
Family Cancridae	cancer crabs		
<u>Cancer</u> <u>magister</u> △	Dungeness Crab	1-5,M	1,2,3
<u>Cancer</u> I	cancer crab	--	1,2,3,4,5, & M
Family Atelecyclidae	hair crabs		
<u>Telemessus</u> <u>cheiragonus</u>	helmet crab	1-5,M	1,2,3,4,5, & M
Family Pinnotheridae △	pea crabs		
Pinnotheridae I	--	--	1,2,3,4,5, & M

1/ △ Taxa of principal interest discussed in report
2/ J=Juvenile, G=Glaucothe, M=Megalops

Table 13.--Rank order by frequency of occurrence (percent of plankton samples examined for decapod larvae) of Natantia and Reptantia larval taxa in inshore and offshore OCSEAP plankton cruises. Bongo net data.

		Percent of samples examined containing designated taxons					
		Regions Combined	Inshore Region				Offshore Region
Rank	Taxon		Izhut	Chiniak	Kiliuda	Kaiugnak	
1	Hippolytid shrimps Hippolytidae	41.5	87.1	68.3	85.4	60.3	19.8
2.	Anomuran crabs 1/ Anomura	38.7	77.7	42.9	78.1	68.3	20.1
3.	Cancer crabs 2/ _Cancer_ I	21.0	45.1	20.6	29.6	33.3	13.5
4.	Pea crabs Pinnotheridae	19.2	37.9	25.4	52.8	36.5	6.6
5.	Crangonid shrimps Crangonidae	16.9	42.4	17.5	47.2	25.4	4.5
6.	Tanner crab _Chionoecetes bairdi_	14.7	17.0	15.9	18.9	17.5	13.1
7.	Hyas crabs Majidae	11.5	22.8	12.7	30.5	4.8	5.4
8.	Unidentified Brachyuran crabs Brachyura	9.2	19.2	3.2	12.9	9.5	6.7
9.	Pink shrimp _Pandalus borealis_	8.4	27.7	19.0	9.0	14.3	3.3
10.	Dungeness crab _Cancer magister_	7.0	5.4	3.2	33.9	14.3	1.3
11.	Oregonid crabs _Oregonia_ sp.	6.9	27.2	9.5	9.4	9.5	1.8
12.	Red king crab _Paralithodes camtschatica_	5.9	15.6	6.3	14.2	6.3	2.1
13.	_Pandalus stenolepis_	3.9	11.6	1.6	7.3	3.2	1.7
14.	Humpy shrimp _Pandalus goniurus_	2.3	5.8	11.1	6.4	1.6	0.2
15.	Helmet crab _Telemessus cheiragonus_	1.7	2.7	4.8	4.3	3.2	0.7
16.	Side stripe shrimp _Pandalopsis dispar_	0.8	3.6	4.8	--	1.6	0.2
17.	Unidentified Pandalid shrimps Pandalidae	0.8	2.2	--	0.8	--	0.6
18.	_Pandalus montagui tridens_	0.6	2.7	4.8	--	1.6	--
19.	Coonstripe shrimp _Pandalus hypsinotus_	0.2	0.4	--	0.4	--	0.2
20.	Pasiphaeid shrimps _Pasiphaea_ sp.	0.1	--	--	--	--	0.2

1/ Includes members of Paguridae and Lithodidae and several unidentified anomurans.

2/ Excluding Dungeness crab (_Cancer magister_).

Table 14.--Density (numbers/1000 m^3) of hippolytid shrimp larvae, Hippolytidae, by subarea, cruise, and season from the OCSEAP inshore plankton cruises. Bongo net data.

Season	SPRING						SUMMER				FALL	LATE WINTER	Mean Density All Cruises
Cruise	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Subarea													
Izhut Bay	1,125	1,431	3,600	3,053	3,183	2,121	4,826	8,611	13,060	7,623	--	18	4,054
Chiniak Bay	535	4,763	4,462	2,378	1,844	2,410	5,357	6,339	18,352	3,275	1/	54	4,524
Kiliuda Bay	2,641	2,973	2,252	1,523	1,635	4,990	9,568	9,481	9,653	7,736	156	90	4,391
Kaiugnak Bay	1,492	304	3,766	512	236	--	5,906	3,042	2,590	4,523	29	14	1,698
Mean density Bays Combined	1,448	2,368	3,520	1,866	1,724	2,380	5,914	6,868	10,914	5,789	62	44	3,575

1/ - Data not available.

Table 15.--Density (numbers/1000 m^3) of hippolytid shrimp larvae, Hippolytidae, by subarea, cruise, and season from the OCSEAP offshore plankton cruises. Bongo net data.

Season	FALL	SPRING	SUMMER	FALL	WINTER	Mean Density All Cruises
Cruise	4MF77	4DI78	2MF78	1WE78	1MF79	
Subarea						
Portlock	--	203	1,464	108	--	355
Marmot	3	144	1,151	51	--	270
Albatross	--	912	1,380	32	--	465
Sitkinak	--	484	564	7	--	211
Mean Density Per Cruise All Subareas Combined	1	436	1,140	49	--	325

Table 16.--Occurrence of larval stages of hippolytid shrimp larvae, Hippolytidae, by cruise, and season from the OCSEAP inshore plankton cruises. Data from all gear types.

SEASON	SPRING					SUMMER					FALL	LATE WINTER
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
LARVAL STAGE												
1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		-----
2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		-----
3			-----	-----	-----	-----	-----	-----	-----	-----	-----	
4			-----	-----	-----	-----	-----	-----	-----	-----	-----	
5				-----	-----	-----	-----	-----	-----	-----	-----	
6				-----	-----		-----	-----	-----	-----	-----	
juvenile							-----		-----	-----	-----	

Table 17.--Density (numbers/1000 m^3) of crangonid shrimp larvae, Crangonidae, by subarea, cruise, and season from the OCSEAP inshore plankton cruises. Bongo net data.

Season	SPRING					SUMMER					FALL	LATE WINTER	Mean Density All Cruises
Cruise	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Subarea													
Izhut Bay	--	201	218	1,078	1,455	302	686	348	610	--	*1/	*	408
Chiniak Bay	--	--	--	--	--	233	652	--	--	2,545	2/	*	312
Kiliuda Bay	118	126	--	406	465	3,214	5,451	1,687	2,041	2,403	*	*	1,326
Kaiugnak Bay	--	--	--	114	--	--	--	423	607	476	*	*	135
Mean Density Bays Combined	29	82	54	399	480	937	1,697	614	814	1,357	--	--	550

1/ - Not found in bongo net samples but occurred in samples from other gear types.
2/ - Data not available.

Table 18.--Density (numbers/1000 m^3) of crangonid shrimp larvae, Crangonidae, by subarea, cruise, and season from the OCSEAP offshore plankton cruises. Bongo net data.

Season	FALL	SPRING	SUMMER	FALL	WINTER	Mean Density All Cruises
Cruise	4MF77	4DI78	2MF78	1WE78	1MF79	
Subarea						
Portlock	--	11	251	--	--	52
Marmot	--	11	595	--	1	121
Albatross	--	69	521	--	--	178
Sitkinak	--	--	69	8	--	15
Mean Density Per Cruise All Subareas Combined	--	23	359	2	--	77

Table 19.--Occurrence of larval stages of crangonid shrimp larvae, Crangonidae, by cruise, and season from the OCSEAP inshore plankton cruises. Data from all gear types.

SEASON	SPRING						SUMMER				FALL	LATE WINTER
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
LARVAL STAGE												
1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		-----
2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		-----
3			-----	-----	-----	-----	-----	-----	-----	-----	-----	
4				-----	-----	-----	-----	-----	-----	-----	-----	
5				-----	-----	-----	-----	-----	-----	-----	-----	
6					-----	-----	-----	-----	-----	-----	-----	
juvenile							-----		-----	-----	-----	

Table 20.--Density (numbers/1000 m^3) of pink shrimp larvae, *Pandalus borealis*, by subarea, cruise, and season from the OCSEAP inshore plankton cruises. Bongo net data.

Season	SPRING					SUMMER					FALL	LATE WINTER	Mean Density All Cruises
Cruise	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Subarea													
Izhut Bay	32	302	873	60	81	--	--	90	--	--	--	--	120
Chiniak Bay	--	267	1,128	249	--	--	361	--	--	--	1/	--	182
Kiliuda Bay	--	--	566	--	28	--	--	--	--	--	--	--	49
Kaiugnak Bay	639	595	--	229	--	--	--	--	115	--	--	--	131
Mean Density Bays Combined	168	291	642	134	27	--	90	22	29	--	--	--	119

1/ - Data not available

Table 21.--Density (numbers/1000 m^3) of pink shrimp larvae, *Pandalus borealis*, by subarea, cruise, and season from the OCSEAP offshore plankton cruises. Bongo net data.

Season	FALL	SPRING	SUMMER	FALL	WINTER	Mean Density All Cruises
Cruise	4MF77	4DI78	2MF78	1WE78	1MF79	
Subarea						
Portlock	--	--	81	--	--	16
Marmot	--	--	113	--	--	23
Albatross	--	30	--	--	--	6
Sitkinak	--	--	--	--	--	--
Mean Density Per Cruise All Subareas Combined	--	7	48	--	--	11

Table 22.--Occurrence of larval stages of pink shrimp, Pandalus borealis, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.

SEASON	SPRING					SUMMER					FALL	LATE WINTER
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
LARVAL STAGE												
1	---	---	---			---						
2	---	---	---	---								
3			---	---	---							
4				---	---							
5				---	---	---		---	---		---	
6							---		---			
juvenile						---		---	---	---	---	

Table 23.--Density (numbers/1000 m^3) of anomuran crab larvae, Anomura, by subarea, cruise, and season from the OCSEAP inshore plankton cruises. Bongo net data.

Season	SPRING						SUMMER				FALL	LATE WINTER	Mean Density All Cruises
Cruise	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Subarea													
Izhut Bay	3,078	2,405	10,549	7,801	5,017	1,029	3,763	1,186	4,655	575	989	7	3,414
Chiniak Bay	441	750	1,806	933	1,406	2,586	4,315	973	3,347	5,089	1/	8	1,968
Kiliuda Bay	2,062	2,511	4,009	12,061	9,591	10,116	675	955	2,695	4,535	1,294	53	4,213
Kaiugnak Bay	--	718	1,063	5,673	1,612	850	255	2,587	2,158	602	139	30	1,307
Mean Density Bays Combined	1,395	1,595	4,334	6,617	4,407	3,645	2,252	1,425	3,214	2,700	807	25	2,744

1/ - Data not available

Table 24.--Density (numbers/1000 m^3) of anomuran crab larvae, Anomura, by subarea, cruise, and season from the OCSEAP offshore plankton cruises. Bongo net data.

Season	FALL	SPRING	SUMMER	FALL	WINTER	Mean Density All Cruises
Cruise	4MF77	4DI78	2MF78	1WE78	1MF79	
Subarea						
Portlock	7	729	2,867	--	1	729
Marmot	--	421	1,861	12	1	459
Albatross	--	319	4,868	--	3	1,038
Sitkinak	--	164	837	20	--	204
Mean Density Per Cruise All Subareas Combined	1	418	2,608	8	1	605

Table 25.--Occurrence of larval stages of anomuran crab, Anomura, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.

SEASON	SPRING					SUMMER					FALL	LATE WINTER
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Larval Stage												
1	----	----	----	----	----	----	----	----	----		----	----
2	----	----	----	----	----	----	----	----	----	----		
3				----	----	----	----	----	----	----		
4					----	----	----	----	----	----		
glaucothe						----	----	----	----	----	----	

Table 26.--Density (numbers/1000 m^3) of cancer crab larvae, Cancer I, by subarea, cruise, and season from the OCSEAP inshore plankton cruises. Bongo net data.

Season	SPRING				SUMMER						FALL	LATE WINTER	Mean Density All Cruises
Cruise	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Subarea													
Izhut Bay	--	--	--	--	2,826	17,252	67,323	1,552	1,910	277	--	--	7,595
Chiniak Bay	--	--	--	--	--	3,551	1,542	2,032	687	1,018	1/	--	803
Kiliuda Bay	--	--	120	296	952	13,250	5,633	766	402	--	--	--	1,778
Kaiugnak Bay	--	--	--	51	905	1,065	11,751	17,661	7,098	--	--	--	3,221
Mean Density Bays Combined	--	--	30	24	1,171	8,779	21,962	5,503	2,524	324	--	--	3,402

1/ - Data not available

Table 27.--Density (numbers/1000 m^3) of cancer crab larvae, Cancer I, by subarea, cruise, and season from the OCSEAP offshore plankton cruises. Bongo net data.

Season	FALL	SPRING	SUMMER	FALL	WINTER	Mean Density All Cruises
Cruise	4MF77	4DI78	2MF78	1WE78	1MF79	
Subarea						
Portlock	--	--	11,583	--	--	2,317
Marmot	--	--	3,538	--	--	708
Albatross	--	--	7,301	--	253	1,511
Sitkinak	--	--	5,863	3	--	1,173
Mean Density Per Cruise All Subareas Combined	--	--	7,071	1	63	1,427

Table 28.--Occurrence of larval stages of cancer crab, Cancer I, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.

SEASON	SPRING					SUMMER					FALL	LATE WINTER
CRUISE	I	II	III	IV	V	VI	VII	VIII	XI	X	XI	XII
LARVAL STAGE												
1			----	----	----	----	----	----	----	----		
2				----		----	----	----	----	----		
3							----	----	----	----		
4							----	----	----			
5									----	----		
megalops										----	----	

Table 29.--Density (numbers/1000 m^3) of pea crab larvae, Pinnotheridae, by subarea, cruise, and season from the OCSEAP inshore plankton cruises. Bongo net data.

Season	SPRING					SUMMER				FALL	LATE WINTER	Mean Density All Cruises
Cruise	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Subarea													
Izhut Bay	--	--	--	1,622	8,438	4,930	14,179	9,942	1,791	1,365	13	--	3,520
Chiniak Bay	--	--	--	516	958	1,067	2,609	2,918	7,705	2,549	1/	--	1,665
Kiliuda Bay	--	--	--	12,209	32,788	31,073	18,558	12,059	13,567	17,201	38	--	11,458
Kaiugnak Bay	--	--	240	1,195	1,030	488	1,688	1,693	2,017	1,701	27	--	840
Mean Density Bays Combined	--	--	60	3,886	10,803	9,389	9,258	6,653	6,270	5,693	26	--	4,428

1/ - Data not available

Table 30.--Density (numbers/1000 m^3) of pea crab larvae, Pinnotheridae, by subarea, cruise, and season from the OCSEAP offshore plankton cruises. Bongo net data.

Season	FALL	SPRING	SUMMER	FALL	WINTER	Mean Density All Cruises
Cruise	4MF77	4DI78	2MF78	1WE78	1MF79	
Subarea						
Portlock	--	--	2,008	--	--	402
Marmot	--	--	8,042	--	--	1,608
Albatross	--	--	2,977	--	--	595
Sitkinak	--	--	227	--	--	45
Mean Density Per Cruise All Subareas Combined	--	--	3,313	--	--	662

Table 31.--Occurrence of larval stages of pea crabs, Pinnotheridae, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.

SEASON	SPRING					SUMMER					FALL	LATE WINTER
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
LARVAL STAGE												
1			---	---	---	---	---	---	---	---		
2				---	---	---	---	---	---	---		
3							---	---	---	---	---	
4							---	---	---	---	---	
5								---	---	---	---	

Table 32.--Density (numbers/1000 m^3) of Tanner crab larvae, Chionoecetes bairdi, by subarea, cruise, and season from the OCSEAP inshore plankton cruises. Bongo net data.

Season	SPRING					SUMMER					FALL	LATE WINTER	Mean Density All Cruises
Cruise	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Subarea													
Izhut Bay	*[1]	*	--	117	378	41	--	*	*	*	*	--	45
Chiniak Bay	*	*	92	1,065	10,113	326	1,562	*	*	*	[2]	1	1,196
Kiliuda Bay	*	*	--	1,965	1,743	--	--	*	*	*	*	--	309
Kaiugnak Bay	*	*	240	8,300	314	--	--	*	*	*	*	10	738
Mean Density, Bays Combined	--	--	83	2,862	3,137	92	390	--	--	--	--	3	559

1/ - Not found in bongo net samples but occured in samples from other gear types.
2/ - Data not available

Table 33.--Density (numbers/1000 m^3) of Tanner crab larvae, *Chionoecetes bairdi*, by subarea, cruise, and season from the OCSEAP offshore plankton cruises. Bongo net data.

Season	FALL	SPRING	SUMMER	FALL	WINTER	Mean Density All Cruises
Cruise	4MF77	4DI78	2MF78	1WE78	1MF79	
Subarea						
Portlock	--	10	503	--	1	103
Marmot	--	--	251	--	1	50
Albatross	--	--	96	--	1	19
Sitkinak	--	20	1,314	--	5	268
Mean Density Per Cruise All Subareas Combined	--	7	541	--	2	110

Table 34.--Occurrence of larval stages of Tanner crab, Chionoecetes bairdi, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.

SEASON	SPRING					SUMMER					FALL	LATE WINTER
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
LARVAL STAGE												
1	-----		-----	-----	-----	-----	-----					-----
2					-----	-----	-----		-----			
megalops		-----	-----	-----	-----	-----	-----	-----		-----	-----	-----

Table 35.--Density (numbers/1000 m^3) of Dungeness crab larvae, Cancer magister, by subarea, cruise, and season from the OCSEAP inshore plankton cruises. Bongo net data.

Season	SPRING					SUMMER					FALL	LATE WINTER	Mean Density All Cruises
Cruise	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Subarea													
Izhut Bay	--	--	--	129	--	42	464	--	--	*1/	--	--	53
Chiniak Bay	--	--	--	--	--	482	--	--	--	*	--2/	--	44
Kiliuda Bay	--	922	240	871	2,557	1,053	826	624	903	*	--	--	666
Kaiugnak Bay	--	--	--	90	186	670	--	303	--	*	--	6	105
Mean Density Bays Combined	--	230	60	272	686	562	322	232	226	--	--	1	225

1/ - Not found in bongo net samples but occurred in samples from other gear types.
2/ - Data not available.

Table 36.--Density (numbers/1000 m^3) of Dungeness crab larvae, Cancer magister, by subarea, cruise, and season from the OCSEAP offshore plankton cruises. Bongo net data.

Season	FALL	SPRING	SUMMER	FALL	WINTER	Mean Density All Cruises
Cruise	4MF77	4DI78	2MF78	1WE78	1MF79	
Subarea						
Portlock	--	--	--	--	--	--
Marmot	--	--	--	--	--	--
Albatross	--	--	396	--	--	79
Sitkinak	--	--	66	--	--	13
Mean Density Per Cruise All Subareas Combined	--	--	115	--	--	23

Table 37.--Occurrence of larval stages of Dungeness crab, *Cancer magister*, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.

SEASON	SPRING					SUMMER					FALL	LATE WINTER
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
LARVAL STAGE												
1		---	---	---	---	---	---	---	---	---		---
2				---	---	---	---	---		---		
3							---	---	---			
4								---	---			
glaucothe												

Table 38.--Density (numbers/1000 m^3) of red king crab larvae, Paralithodes camtschatica, by subarea, cruise, and season from the OCSEAP inshore plankton cruises. Bongo net data.

Season	SPRING					SUMMER					FALL	LATE WINTER	Mean Density All Cruises
Cruise	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Subarea													
Izhut Bay	--	61	--	--	56	*1/	--	--	--	--	--	5	10
Chiniak Bay	1,017	--	--	249	--	*	--	--	--	--	2/	406	152
Kiliuda Bay	--	103	297	359	73	*	--	--	--	--	--	--	69
Kaiugnak Bay	--	--	361	--	--	*	--	--	--	--	--	17	31
Mean Density Bays Combined	254	41	164	152	32	--	--	--	--	--	--	107	64

1/ - Not found in bongo net samples but occurred in samples from other gear types
2/ - Data not available

Table 39.--Density (numbers/1000 m^3) of red king crab larvae, Paralithodes camtschatica, by subarea, cruise, and season from the OCSEAP offshore plankton cruises. Bongo net data.

Season	FALL	SPRING	SUMMER	FALL	WINTER	Mean Density All Cruises
Cruise	4MF77	4DI78	2MF78	1WE78	1MF79	
Subarea						
Portlock	--	--	--	--	--	--
Marmot	--	--	--	--	--	--
Albatross	--	14	--	--	1	3
Sitkinak	--	--	7	--	--	1
Mean Density Per Cruise All Subareas Combined	--	3	2	--	--	1

Table 40.--Occurrence of larval stages of red king crab, Paralithodes camtschatica, by cruise and season from the OCSEAP inshore plankton cruises. Data from all gear types.

SEASON	SPRING					SUMMER					FALL	LATE WINTER
CRUISE	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
LARVAL STAGE												
1	-----	-----	-----	-----								-----
2	-----	-----	-----	-----	-----	-----						
3	-----	-----	-----	-----	-----	-----						
4	-----		-----	-----	-----	-----						
glaucothe				-----	-----							

Table 41.--Number of occurrences and mean density (number/1000 m^3) of fish eggs and larvae collected in neuston tows during the five OCSEAP plankton cruises.

	4MF77-Fall 1977		4DI78-Spring 1978		2MF78-Summer 1978		1WE78-Fall 1978		1MF79-Winter 1979	
eggs	occur-rences	mean density no./1000^3	occur-rences	mean density no./1000^3	occur-rences	mean density no./1000^3	occur-rences	mean density no./1000^3	occur-rences	mean density no./1000^3
Leuroglossus schmidti							2	19		
Theragra chalcogramma	14	25	23	415	3	14	1	14	1	21
Pleuronectidae			15	119	21	390				
Hippoglossoides elassodon			7	42	17	59				
Isopsetta isolepis			2	25	5	83				
Microstomus pacificus			1	22	38	245				
Platichthys stellatus			1	43	1	52				
Pleuronectes quadrituberculatus			2	18						
Glyptocephalus zachirus					29	47				
Limanda aspera					18	2155				
Psettichthys melanostictus					3	23				
larvae										
Osmeridae					2	2859	24	81	12	32
Mallotus villosus	10	48	6	49						
Bathylagus sp.					1	372				
Myctophidae	1	19	1	14						
Stenobrachius sp.					1	20				
Protomyctophum thompsoni	1	18								
Gadidae					2	92				
Theragra chalcogramma	3	21			3	23				
Sebastes spp.					15	59	1	17	1	15
Hexagrammidae	3	55	5	105			2	16	6	37
Hexagrammos sp.	13	33	8	51	3	73	8	39		
Hexagrammos decagrammus	56	142	75	659	62	66	31	154	74	382
Hexagrammos lagocephalus	40	79					39	88		
Hexagrammos octogrammus	39	37			5	25	39	84	11	21
Hexagrammos stelleri	71	110	33	42	5	59	71	348	29	34
Ophiodon elongatus					7	25				
Pleurogrammus monopterygius	37	413	28	208			36	739	42	348
Anoplopoma fimbria					13	22				
Cottidae			2	26	1	12				
Gymnocanthus sp.			1	36						
Gymnocanthus A			1	14						
Hemilepidotus spp.	60	998	32	581	5	29	52	773	51	409
Hemilepidotus hemilepidotus			2	22	15	37				
Hemilepidotus jordani					5	54				
Icelinus borealis					1	15				
Myoxocephalus sp.					13	50				
Myoxocephalus B.			1	35						
Myoxocephalus G.			1	28						
Cyclopteridae			1	76						
Aptocyclus ventricosus	3	21								
Bathymasteridae	2	28			1	13				
Bathymaster sp.			1	17	44	1946	17	34	5	17
Ronquilus jordani					3	15				
Stichaeidae			2	31	2	85				
Anoplarchus insignis					1	21				
Chirolophis polyacthocephalus			5	92						
Stichaeus punctatus					3	15				
Lyconcetes aleutensis			15	108	30	74				
Pholis sp.					1	16				
Pholis laeta					1	19				
Zapora silenus			2	153						
Ammodytes hexapterus			5	38	20	236				
Glyptocephalus zachirus					2	28				
Hippoglossoides elassodon					2	14				
Lepidopsetta bilineata			1	17	4	18				
Microstomus pacificus					5	20				
Psettichthys melanostictus					2	17				

Table 42.--Total numbers ($\log_{10}$) of eggs and larvae of each taxon of fish estimated from catches in bongo tows during the five OCSEAP plankton cruises.

taxon	4MF77 Fall 1977	4DI78 Spring 1978	2MF78 Summer 1978	1WE78 Fall 1978	1MF79 Winter 1979
eggs					
Bathylagidae					8.85
Leuroglossus schmidti	9.90		9.21	10.91	9.65
Theragra chalcogramma	9.60	12.10	8.54	8.76	9.86
Macrouridae	9.28		10.50	9.73	
Pleuronectidae		10.66	11.00		
Atheresthes stomias					9.47
Glyptocephalus zachirus			10.25		
Hippoglossoides elassodon		10.36	11.31		8.56
Isopsetta isolepis		8.47	9.97		
Limanda aspera			10.53		
Lyopsetta exilis			8.88		
Microstomus pacificus			10.80		
Platichthys stellatus		8.91	8.87		
Psettichthys melanostictus			8.27		
Unidentified	9.18	8.50	9.57	10.77	9.97
larvae					
Clupea harengus pallasi			8.87		
Osmeridae			11.35		
Mallotus villosus	10.34	9.01		11.25	10.67
Bathylagus milleri			8.91		
Bathylagus pacificus		8.98	9.30		9.07
Leuroglossus schmidti	9.49	8.82	9.42	9.38	10.10
Myctophidae			8.22		
Stenobrachius sp.			10.23		
Stenobrachius leucopsarus		9.67	10.12	9.29	9.75
Stenobrachius nannochir			8.62		
Protomyctophum crockeri			8.60		
Protomyctophum thompsoni	9.12		8.58	9.33	9.04
Gadidae			9.30		
Gadus macrocephalus		8.86	8.43		
Theragra chalcogramma	8.92	10.67	9.84		
Macrouridae		8.95	8.58		8.52
Sebastes sp.			11.73	8.97	
Hexagrammos sp.		8.86			8.58
Hexagrammos decagrammus	8.97	9.52	8.57	8.80	9.92
Hexagrammos lagocephalus	8.41				
Hexagrammos octogrammus	8.97			9.06	
Hexagrammos stelleri	9.28	8.12	8.92	9.63	8.94
Pleurogrammus monopterygius	9.36	8.80		10.38	9.63
Cottidae		9.86	10.37	8.23	8.85
Artedius sp.			9.07		
Artedius 1			9.16	8.94	
Artedius 2			8.10		
Clinocottus sp.			8.17		
Dasycottus setiger		8.91	9.10		
Gymnocanthus A		9.93			
Hemilepidotus spp.	11.16	10.06		11.01	10.49
Hemilepidotus hemilepidotus			8.22		
Icelinus borealis	8.29	7.89	9.81		
Malacocottus zonurus 1					8.55
Myoxocephalus sp.		8.34			
Myoxocephalus B.		9.54			
Myoxocephalus G.		9.06			9.07
Radulinus asperellus		9.35			
Triglops sp.		8.37			9.07
Agonidae		9.02	9.57		
Cyclopteridae		9.72	9.61	8.60	
Liparus florae			8.46		
Trichodon trichodon					8.02
Bathymaster sp.		8.97	11.74		
Ronquilus jordani			10.01		
Stichaeidae		9.95	9.54		
Chirolophis polyactocephalus		9.22			
Lumpenella longirostris			8.71		
Lumpenus sagitta		9.45			
Stichaeus punctatus			8.16		
Lyconectes aleutensis		8.85	9.41		8.71
Pholis sp.		9.21	8.46		
Zaprora silenus			9.06		
Ammodytes hexapterus		11.42	8.71		9.18
Pleuronectidae			8.17		
Atheresthes stomias		9.71			9.52
Glyptocephalus zachirus			10.18		
Hippoglossoides elassodon			10.37		
Isopsetta isolepis			10.05		
Lepidopsetta bilineata		10.41	9.98		
Microstomus pacificus			10.10		
Platichthys stellatus			8.93		
Psettichthys melanostictus			10.54		
Hippoglossus stenolepis		8.56	8.51		

Table 43.--Seasons and areas of major occurrences of the most abundant taxa of fish eggs (E) and larvae (L) in the Kodiak Island shelf area based on five OCSEAP plankton cruises, fall 1977-winter 1979.

Table 43.--Seasons and areas of major occurrences of the most abundant taxa of fish eggs (E) and larvae (L) in the Kodiak Island shelf area based on five OCSEAP plankton cruises fall 1977-winter 1979.

	Fall	Winter	Spring	Summer
Nearshore	Mallotus villosus-L Theragra chalcogramma-E		Theragra chalcogramma-E* Lepidopsetta bilineata-L Ammodytes hexapterus-L Pleuronectidae-E	Pleuronectidae-E Isopsetta isolepis-E Limanda aspera-E
Midshelf	Hexagrammos octogrammus-L Hexagrammos lagocephalus-L	Mallotus villosus-L Hexagrammos octogrammus-L	Hippoglossoides elassodon-E	Bathmaster spp.-L* Glyptocephalus zachirus-L Hippoglossoides elassodon-E+L Psettichthys melanostictus-L Isopsetta isolepis-L Lepidopsetta bilineata-L
Slope	Leuroglossus schmidti-E Stenobrachius leucopsarus-L* Protomyctophum thompsoni-L* Macrouridae-E	Leuroglossus schmidti-E Stenobrachius leucopsarus-L* Atheresthes stomias-L	Stenobrachius leucopsarus-L Atheresthes stomias-L	Leuroglossus schmidti-E Stenobrachius leucopsarus-L Macrouridae-E Sebastes spp.-L* Glyptocephalus zachirus-E Microstomus pacificus-E+L
Ubiquitous	Hexagrammos decagrammus-L Hexagrammos stelleri-L Pleurogrammus monopterygius-L Hemilepidotus spp.-L	Hexagrammos decagrammus-L Hexagrammos stelleri-L Pleurogrammus monopterygius-L Hemilepidotus spp.-L	Hexagrammos decagrammus-L Hexagrammos stelleri-L Pleurogrammus monopterygius-L Theragra chalcogramma-L Lyconectes aleutensis-L Hemilepidotus spp.-L	Hexagrammos decagrammus-L Hexagrammos stelleri-L Theragra chalcogramma-L Lyconectes aleutensis-L Anoplopoma fimbria-L Ophiodon elongatus-L Ammodytes hexapterus-L Hemilepidotus spp.-L

* Frequents other geographic regions also.

Table 44.--Abundance of fish larvae and eggs taken during seven diel-vertical distribution series off Kodiak Island, Alaska.

Taxon	Stage[1]	Diel 1 12-13 Nov 4MF77				Diel 2 11-12 Nov 4MF77				Diel 3 14-15 Apr 4DI78				Diel 4 10 Apr 4DI78				Diel 5 28-29 Jun 2MF78				Diel 6 1-2 Jul 2MF78				Diel 7 12-13 Nov 1WE78			
		Neuston		Tucker		Neuston		Tucker		Neuston		Tucker		Neuston		Tucker		Neuston		Tucker		Neuston		Tucker		Neuston		Tucker	
		Hauls	Number	Hauls	Number	Hauls	number	Hauls	Number	Hauls	Number	Hauls	Number	Hauls	Number	Hauls	Number	Hauls	Number	Hauls	Number	Hauls	Number	Hauls	Number	Hauls	Number	Hauls	Number
Clupea harengus pallasi	6																			1	1								
Mallotus villosus	6	3	5	4	6	2	6	13	24	1	1					1	1											1	2
Bathylagus pacificus	6											2	2							3	3			1	2				
Leuroglossus schmidti	1																											26	1279
Leuroglossus schmidti	6							1	1			1	1															18	43
Chauliodus macouni	6																											1	1
Stenobrachius sp.	6																							8	17			3	4
Stenobrachius leucopsarus	6											2	3			4	7			2	2			3	6			4	7
Protomyctophum thompsoni	6			1	2			2	3			1	1											2	2			8	15
Gadidae	6							1	1	1	1																		
Gadus macrocephalus	6															1	1												
Theragra chalcogramma	1			3	3	5	5	11	15			4	129	10	39	23	138												
Theragra chalcogramma	6			1	1			4	5	2	3	6	14	1	1	13	73			1	1			2	3				
Macrouridae	1																											10	49
Macrouridae	6											1	1																
Sebastes sp.	6											1	1					3	11	13	49	2	2	31	297				
Hexagrammidae	6	1	6																										
Hexagrammos sp.	6	1	1																			3	6			1	1		
Hexagrammos decagrammus	6	11	124	6	22	8	24	3	5	12	2470	13	44	12	643	3	6					10	13			4	69	1	2
Hexagrammos lagocephalus	6	4	6			3	4																			4	32		
Hexagrammos octogrammus	6	7	11			3	4	2	2									1	4			1	1			4	29	1	1
Hexagrammos stelleri	6	10	34	1	3	10	29	1	1	5	14			2	2			2	2			2	2			4	15	1	1
Pleurogrammus monopterygius	6	10	60	7	21					1	1			2	2											6	442	9	64
Anoplopoma fimbria	6																					7	8	1	1				
Cottidae	6															17	57			11	13								
Artedius sp.	6																			5	8								
Artedius I	6																			11	24								
Dasycottus setiger	6											1	1			1	1			4	6								
Gymnocanthus sp.	6															1	2												
Gymnocanthus A	6											1	1			4	4												
Hemilepidotus sp.	6	11	105	22	289	10	603	19	13	5	240	8	17	5	94	2	3	3	14			1	1			4	53	18	115
Hemilepidotus hemilepidotus	6									1	14			1	1	1	1	2	9			4	9						
Hemilepidotus jordani	6									1	1							1	1			3	4						
Icelinus borealis	6																			1	1								
Malacocottus zonurus 1	6											1	1	1	1	1	1												
Myoxocephalus B	6															7	11												
Myoxocephalus G	6															1	1												
Radulinus sp.	6															1	1												
Radulinus asperellus	6																			1	1			1	1				
Triglops sp.	6											1	1																
Agonidae	6															1	1												
Agonidae C	6															2	2												
Cyclopteridae	6															1	1	2	2										
Aptocyclus ventricosus	6					1	1																						
Bathymasteridae	6																	1	3										
Bathymaster sp.	6											2	2					5	8	14	43	6	524	26	622	1	1		
Ronquilus jordani	6																			16	46								
Stichaeidae	6											1	1			20	122	1	1	4	4								
Chirolophis polyactocephalus	6									1	1																		
Lumpenella longirostris	6																			1	1								
Lumpenus sagitta	6															10	20												
Stichaeus punctatus	6																	2	4			1	1						
Lyconectes aleutensis	6									3	26	3	4	6	59	4	4	4	11			2	7						
Ammodytes hexapterus	6											20	85	2	2	18	208	3	318	1	1	2	3						
Pleuronectidae	1											1	2			1	1	9	25	15	43								
Atheresthes stomias	6											4	4																
Glyptocephalus zachirus	1																					8	11	11	22				
Glyptocephalus zachirus	6																			10	19			8	19				
Hippoglossoides elassodon	1															11	25	3	4	10	20			1	1				
Hippoglossoides elassodon	6											1	2							16	34			9	13				
Isopsetta isolepis	1															1	2	4	5	6	8								
Isopsetta isolepis	6															1	1	1	1	10	27			7	10				
Lepidopsetta bilineata	6											8	22			14	66			16	26								
Limanda aspera	1																	10	36	9	17								
Microstomus pacificus	1																	1	1	1	1	12	208	21	185				
Microstomus pacificus	6																	2	3	7	7	1	1	8	12				
Platichthys stellatus	1													1	1														
Psettichthys melanostictus	1																	4	6	7	10								
Psettichthys melanostictus	6																			13	43			8	10				
Hippoglossus stenolepis	6											3	4																

[1] Egg = 1 Larva = 6

Table 45.--Catches of *Hemilepidotus* spp. at 2-hr intervals based on number/ 100 m^3 for three selected depths. Stations D33A-L (Diel 1), fall 1977.

	NIGHT						DAY				S[1]	NIGHT
STATION	A	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	0631	0827	1029	1227	1432	1626	1827	2022	2224	0111	0226	0429
Surface net	53.5	8.9	3.4	9.5	62.8	56.5	1.8	1.9	0	1.9	5.0	1.9
Upper net (0-26 m)	2.2	4.5	0.7	2.2	6.1	12.4	103.0	21.3	23.4	6.8	3.7	4.8
Lower net (26-45 m)	1.5	0	2.0	3.6	7.8	1.5	1.1	5.9	0	6.9	9.2	7.4
TOTALS	57.2	13.4	6.1	15.3	76.7	70.3	105.9	29.1	23.4	15.6	17.9	14.1

1/ Station was taken within 30 minutes of sunset.

Table 46.--Catches of *Pleurogrammus monopterygius* larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D33A-L (Diel 1), fall 1977.

	NIGHT						DAY				S[1]	NIGHT
STATION	A	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	0631	0827	1029	1227	1432	1626	1827	2022	2224	0011	0226	0429
Surface net	22.3	23.1	5.1	1.6	20.9	2.6	36.4	7.5	1.9	1.9	0	0
Upper net (0-26 m)	1.4	1.8	1.4	0	0	0.7	6.0	2.8	0	0	0	0
Lower net (26-45 m)	0	0	0.7	0	0	0	0	0	0	0	0	0
TOTALS	23.7	24.9	7.2	1.6	20.9	3.3	42.4	10.3	1.9	1.9	0	0

1/ Station was taken within 30 minutes of sunset.

Table 47.--Catches of Hexagrammos decagrammus larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D33A-L (Diel 1), fall 1977.

	NIGHT						DAY				S[1]/	NIGHT
STATION	A	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	0631	0827	1029	1227	1432	1626	1827	2022	2224	0011	0226	0429
Surface net	13.4	32.0	13.7	4.8	35.6	27.6	47.3	20.6	0	1.9	1.7	27.9
Upper net (0-26 m)	0	0.9	0	0	0	1.5	5.4	5.7	0	0	0	0
Lower net (26-45 m)	0	0	0	0	0	0	0	1.1	0	0	0	0
TOTALS	13.4	32.9	13.7	4.8	35.6	29.1	52.7	27.4	0	1.9	1.7	27.9

1/ Station was taken within 30 minutes of sunset.

Table 48.--Catches of *Hemilepidotus* spp. larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D35A-L (Diel 2), fall 1977.

	NIGHT					R[1]/	DAY				NIGHT	
STATION	A	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	0656	0859	1057	1257	1501	1701	1855	2056	2253	0052	0253	0453
Surface net	0	0	1.9	14.9	61.5	147.4	10.1	5.3	6.6	6.2	851.9	19.8
Upper net (0-42 m)	0	0	2.1	0.8	0.5	7.1	10.2	5.9	2.5	0.6	2.3	2.2
Lower net (42-101 m)	0	2.3	3.4	2.6	2.4	1.0	1.3	0.3	0	0	0.5	0.3
TOTALS	0	2.3	7.4	18.3	64.4	155.5	21.6	11.5	9.1	6.8	854.7	22.3

1/ Station was taken within 30 minutes of sunrise.

Table 49.--Catches of Hemilepidotus spp. larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D45A-L (Diel 3), spring 1978.

	NIGHT		R[1]/	DAY						S[2]/	NIGHT	
STATION	A	B	C	D	E	F	G	H	I	J	K[3]/	L
Time (GMT)	1118	1323	1523	1732	1915	2147	2326	0135	0340	0530	0722	0941
Surface net	43.0	96.5	0	0	0	0	0	0	0	150.0	165.0	25.4
Upper net (0-43 m)	0	0.4	0	1.3	0.7	0	0	0.4	0.7	0.9	0.8	0
Lower net (43-85 m)	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	43.0	96.9	0	1.3	0.7	0	0	0.4	0.7	150.9	165.8	25.4

1/ Station was taken within 30 minutes of sunrise.

2/ Station was taken with 30 minutes of sunset.

3/ Actual depths varied, due to inconsistent wire angles during Tucker trawl sets.

Table 50.--Catches of *Hexagrammos decagrammus* larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D45A-L (Diel 3), spring 1978.

	NIGHT		R1/	DAY						S2/	NIGHT	
STATION	A	B	C	D	E	F	G	H	I	J	K3/	L
Time (GMT)	1118	1323	1523	1732	1915	2147	2326	0135	0340	0530	0722	0941
Surface net	424.6	342.5	100.1	46.8	29.2	14.5	24.3	9.2	10.6	1837.7	1713.1	324.1
Upper net (0-43 m)	0	0	0.8	0.3	0.3	0	2.7	0	1.8	0.3	4.9	0.9
Lower net (43-85 m)	0	0	0	0.4	0	0	1.0	0.5	0	1.1	0.4	0
TOTALS	424.6	342.5	100.9	47.5	29.5	14.5	28.0	9.7	12.4	1839.1	1718.4	325.0

1/ Station was taken within 30 minutes of sunrise.

2/ Station was taken with 30 minutes of sunset.

3/ Actual depths varied, due to inconsistent wire angles during Tucker trawl sets.

Table 51.--Catches of Ammodytes hexapterus larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D45A-L (Diel 3), spring 1978.

	NIGHT		R1/	DAY						S2/	NIGHT	
STATION	A	B	C	D	E	F	G	H	I	J	K3/	L
Time (GMT)	1118	1323	1523	1732	1915	2147	2326	0135	0340	0530	0722	0941
Surface net	0	0	0	0	0	0	0	0	0	0	0	0
Upper net (0-43 m)	1.9	9.0	0.4	2.2	1.7	3.7	6.7	1.1	1.1	0.9	0	0.4
Lower net (43-85 m)	3.1	4.3	1.3	7.9	0	2.5	0	0	1.3	1.6	2.0	0
TOTALS	5.0	13.3	1.7	10.1	1.7	6.2	6.7	1.1	2.4	2.5	2.0	0.4

1/ Station was taken within 30 minutes of sunrise.

2/ Station was taken with 30 minutes of sunset.

3/ Actual depths varied, due to inconsistent wire angles during Tucker trawl sets.

Table 52.--Catches of *Theragra chalcogramma* eggs at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D63A-L (Diel 4), spring 1978.

	DAY			NIGHT					DAY			
STATION	A	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	0000	0206	0400	0602	0754	1006	1157	1404	1604	1800	1955	2212
Surface net	3.0	14.0	1.4	5.1	4.0	1.8	0	0	6.4	5.9	11.0	11.4
Upper net (0-66 m)	1.3	2.2	2.1	0.5	1.7	1.1	1.8	1.5	1.6	2.8	4.6	3.0
Lower net (66-121 m)	4.1	2.2	0.3	0.5	0.8	0.6	0	0.7	1.2	2.6	2.8	2.1
TOTALS	8.4	18.4	3.8	6.1	6.5	3.5	1.8	2.2	9.2	11.3	18.4	16.5

Table 53.--Catches of _Theragra chalcogramma_ larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D63A-L (Diel 4), spring 1978.

	DAY			NIGHT					DAY			
STATION	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
Time (GMT)	0000	0206	0400	0602	0754	1006	1157	1404	1604	1800	1955	2212
Surface net	0	1.4	0	0	0	0	0	0	0	0	0	0
Upper net (0-66 m)	0	0.7	0	0.8	4.8	3.6	0.6	3.4	1.0	1.9	1.9	2.1
Lower net (66-121 m)	0	0	0	0.5	1.5	0	1.1	0	0	0	0	0
TOTALS	0	2.1	0	1.3	6.3	3.6	1.7	3.4	1.0	1.9	1.9	2.1

Table 54.--Catches of *Hexagrammos decagrammus* larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D63A-L (Diel 4), spring 1978.

	DAY			NIGHT					DAY			
STATION	A	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	0000	0206	0400	0602	0754	1006	1157	1404	1604	1800	1955	2212
Surface net	1.5	8.4	146.9	125.8	106.5	428.4	76.2	188.5	54.1	9.9	3.7	18.5
Upper net (0-66 m)	0	0	0	0	0	0	1.2	0	0	0	0.4	0
Lower net (66-121 m)	0	0	0	0	0.3	0	0	0	0	0	0	0
TOTALS	1.5	8.4	146.9	125.8	106.8	428.4	77.4	188.5	54.1	9.9	4.1	18.5

Table 55.--Catches of <u>Ammodytes hexapterus</u> larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D63A-L (Diel 4), spring 1978.

	DAY			NIGHT					DAY			
STATION	A	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	0000	0206	0400	0602	0754	1006	1157	1404	1604	1800	1955	2212
Surface net	0	1.4	0	0	0	0	0	0	1.6	0	0	0
Upper net (0-66 m)	2.1	4.5	0.9	6.6	2.3	7.9	3.6	11.0	3.3	0.9	13.7	3.8
Lower net (0-121 m)	0	0	0.7	1.0	3.1	0.3	0	0.7	0	0	0	0.3
TOTALS	2.1	5.9	1.6	7.6	5.4	8.2	3.6	11.7	4.9	0.9	13.7	4.1

Table 56.--Catches of *Lyconectes aleutensis* larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D63A-L (Diel 4), spring 1978.

	DAY			NIGHT					DAY			
STATION	A	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	0000	0206	0400	0602	0754	1006	1157	1404	1604	1800	1955	2212
Surface net	0	0	0	74.4	12.1	17.9	14.4	7.5	4.7	0	0	0
Upper net (0-66 m)	0	0.2	0	0	0	0.4	0	0	0	0	0	0.3
Lower net (66-121 m)	0	0	0	0	0.3	0	0	0	0	0	0	0
TOTALS	0	0.2	0	74.4	12.4	18.3	14.4	7.5	4.7	0	0	0.3

Table 57.--Catches of *Lepidopsetta bilineata* larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D63A-L (Diel 4), spring 1978.

	DAY			NIGHT					DAY			
STATION	A	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	0000	0206	0400	0602	0754	1006	1157	1404	1604	1800	1955	2212
Surface net	0	0	0	0	0	0	0	0	0	0	0	0
Upper net (0-66 m)	0.3	4.2	0.6	0.5	1.1	1.1	0	1.5	0.3	3.2	2.7	1.5
Lower net (66-121 m)	0	0	0	1.4	0	1.9	0	0.4	0	0	0	0
TOTALS	0.3	4.2	0.6	1.9	1.1	3.0	0	1.9	0.3	3.2	2.7	1.5

Table 58.--Catches of *Hemilepidotus* spp. larvae at 2-hr intervals based on number/100 m^3 for three selected depth intervals. Stations D63A-L (Diel 4), spring 1978.

	DAY			NIGHT					DAY			
STATION	A	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	0000	0206	0400	0602	0754	1006	1157	1404	1604	1800	1955	2212
Surface net	0	0	0	102.7	0	39.4	10.3	20.7	0	0	0	0
Upper net (0-66 m)	0	0	0.6	0	0	0	0	0	0.3	0	0	0
Lower net (66-121 m)	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	0	0	0.6	102.7	0	39.4	10.3	20.7	0.3	0	0	0

Table 59.--Catches of Bathymaster spp. larvae at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-L (Diel 5), summer 1978.

	DAY					S[1]	NIGHT		R[2]	DAY		
STATION	A	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	2059	2300	0100	0302	0501	0705	0902	1104	1302	1504	1701	1902
Surface net	1.7	0	0	0	1.1	1.4	2.4	4.0	0	0	0	0
Upper net (0-27 m)	2.9	2.1	1.7	1.0	2.6	2.1	1.9	4.2	10.6	0	4.4	2.1
Middle net (27-71 m)	0	0	0	1.1	0	0	0.6	0	0	0	0	0.6
Lower net (71-136 m)	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	4.6	2.1	1.7	2.1	3.7	3.5	4.9	8.2	10.6	0	4.4	2.7

1/ Station was taken within 30 minutes of sunset.

2/ Station was taken within 30 minutes of sunrise.

Table 60.--Catches of Ronquilus jordani larvae at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-L (Diel 5), summer 1978.

	DAY					S1/	NIGHT		R2/	DAY		
STATION	A	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	2059	2300	0100	0302	0501	0705	0902	1104	1302	1504	1701	1902
Surface net	0	0	0	0	0	0	0	0	0	0	0	0
Upper net (0-27 m)	2.9	2.1	1.7	1.0	4.3	1.6	4.7	3.1	11.5	0	0.9	0
Middle net (27-71 m)	0	0	0	0.5	0	0	1.2	1.7	0.7	0	0	0
Lower net (71-136 m)	0	0	0	0	0	0	0	0.4	0.4	0	0	0
TOTALS	2.9	2.1	1.7	1.5	4.3	1.6	5.9	5.2	12.6	0	0.9	0

1/ Station was taken within 30 minutes of sunset.

2/ Station was taken within 30 minutes of sunrise.

Table 61.--Catches of Sebastes spp. larvae at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-L (Diel 5), summer 1978.

	DAY					S[1]	NIGHT		R[2]	DAY		
STATION	A	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	2059	2300	0100	0302	0501	0705	0902	1104	1302	1504	1701	1902
Surface net	0	0	0	0	1.1	0	6.0	6.7	0	0	0	0
Upper net (0-27 m)	1.9	6.2	0.8	1.0	3.4	1.6	3.8	9.4	8.6	2.3	5.3	1.1
Middle net (27-71 m)	0	0	0	0	0	0	0	0	0	0	0	0
Lower net (71-136 m)	0	0	0	0	0	0.4	0	0	0	0	0	0
TOTALS	1.9	6.2	0.8	1.0	4.5	2.0	9.8	16.1	8.6	2.3	5.3	1.1

1/ Station was taken within 30 minutes of sunset.

2/ Station was taken within 30 minutes of sunrise.

Table 62.--Catches of *Psettichthys melanostictus* larvae at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-L (Diel 5), summer 1978.

	DAY					S1/	NIGHT		R2/	DAY		
STATION	A	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	2059	2300	0100	0302	0501	0705	0902	1104	1302	1504	1701	1902
Surface net	0	0	0	0	0	0	0	0	0	0	0	0
Upper net (0-27 m)	0	7.2	6.8	0	0	2.1	6.6	0	3.8	0	0	5.3
Middle net (27-71 m)	1.2	0.6	0.6	0	0	0	0.6	0.6	0	0	0.6	0
Lower net (71-136 m)	0	0	0	0	0	0	0	0.4	0	0	0	0
TOTALS	1.2	7.8	7.4	0	0	2.1	7.2	1.0	3.8	0	0.6	5.3

1/ Station was taken within 30 minutes of sunset.

2/ Station was taken within 30 minutes of sunrise.

Table 63.--Catches of Isopsetta isolepis larvae at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-L (Diel 5), summer 1978.

	DAY					S[1]	NIGHT		R[2]	DAY		
STATION	A	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	2059	2300	0100	0302	0501	0705	0902	1104	1302	1504	1701	1902
Surface net	0	0	0	0	0	0	0	0	0	0	1.2	0
Upper net (0-27 m)	4.8	1.0	0	0	0.9	0.5	5.6	0	5.8	0	1.8	2.1
Middle net (27-71 m)	0.6	0	0	0	0	0	1.2	0	0	0	0	0
Lower net (71-136 m)	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	5.4	1.0	0	0	0.9	0.5	6.8	0	5.8	0	3.0	2.1

1/ Station was taken within 30 minutes of sunset.

2/ Station was taken within 30 minutes of sunrise.

Table 64.--Catches of *Lepidopsetta bilineata* larvae at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-L (Diel 5), summer 1978.

	DAY					S[1]	NIGHT		R[2]	DAY		
STATION	A	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	2059	2300	0100	0302	0501	0705	0902	1104	1302	1504	1701	1902
Surface net	0	0	0	0	0	0	0	0	0	0	0	0
Upper net (0-27 m)	0	2.1	1.7	0	0.9	1.1	1.9	1.0	1.0	0	0	3.2
Middle net (27-71 m)	1.8	0.6	1.9	0	0.6	0	0.6	0	0.7	0	0	0
Lower net (71-136 m)	0	0	0	0	0.4	0	0	0	0	0.4	0	0
TOTALS	1.8	2.7	3.6	0	1.9	1.1	2.5	1.0	1.7	0.4	0	3.2

1/ Station was taken within 30 minutes of sunset.

2/ Station was taken within 30 minutes of sunrise.

Table 65.--Catches of *Hippoglossoides elassodon* larvae at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-L (Diel 5), summer 1978.

	DAY					S1/	NIGHT		R2/	DAY		
STATION	A	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	2059	2300	0100	0302	0501	0705	0902	1104	1302	1504	1701	1902
Surface net	0	0	0	0	0	0	0	0	0	0	0	0
Upper net (0-27 m)	1.9	4.1	3.4	0	0.9	0.5	5.6	2.1	1.0	3.4	3.6	1.1
Middle net (27-71 m)	0	0	0	0	0	0.6	0	0.6	0	0	0.6	0
Lower net (71-136 m)	0	0	0	0	0	0	0	0.4	0.4	0	0	0
TOTALS	1.9	4.1	3.4	0	0.9	1.1	5.6	3.1	1.4	3.4	4.2	1.1

1/ Station was taken within 30 minutes of sunset.

2/ Station was taken within 30 minutes of sunrise.

Table 66.--Catches of *Bathymaster* spp. larvae at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D69A-L (Diel 6), summer 1978.

	NIGHT		R[1]	DAY								S[2]
STATION	A[3]	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	0926	1104	1322	1501	1720	1910	2114	2303	0112	0303	0515	1709
Surface net	383.4	165.1	26.9	1.3	0	0	0	0	0	0	1.3	135.1
Upper net (0-28 m)	51.2	35.8	13.5	36.8	28.2	41.6	59.5	16.9	24.9	29.8	25.2	12.0
Middle net (28-71 m)	-	33.7	2.3	8.2	2.2	8.4	5.6	5.0	9.0	2.6	13.7	0.5
Lower net (71-136 m)	13.2	5.6	0	0	0	0	7.1	0	0	0	0	0
TOTALS	447.8	240.2	42.7	46.3	30.4	50.0	72.2	21.9	33.9	32.4	40.2	147.6

1/ Station was taken within 30 minutes of sunrise.

2/ Station was taken within 30 minutes of sunset.

3/ A middle net sample was not taken.

Table 67.--Catches of *Sebastes* spp. larvae at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D69A-L (Diel 6), summer 1978.

	NIGHT		R[1]	DAY								S[2]
STATION	A[3]	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	0926	1104	1322	1501	1720	1910	2114	2303	0112	0303	0515	0709
Surface net	1.4	0	0	0	0	1.5	0	0	0	0	0	0
Upper net (0-28 m)	16.7	17.4	19.8	3.7	16.4	8.8	3.0	3.2	6.4	17.2	25.7	9.2
Middle net (0-28 m)	-	11.6	1.8	0.5	0	6.1	5.1	5.0	6.0	1.6	8.4	15.6
Lower net (71-136 m)	4.4	2.8	1.0	1.4	0	0.9	0	0.6	0.8	0	0.8	0
TOTALS	22.5	31.8	22.6	5.6	16.4	17.3	8.1	8.8	13.2	18.8	34.9	24.8

1/ Station was taken within 30 minutes of sunrise.

2/ Station was taken within 30 minutes of sunset.

3/ A middle net sample was not taken.

Table 68.--Catches of Microstomus pacificus eggs at 2-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D69A-L (Diel 6), summer 1978.

	NIGHT		R1/	DAY								S2/
STATION	A3/	B	C	D	E	F	G	H	I	J	K	L
Time (GMT)	0926	1104	1322	1501	1720	1910	2114	2303	0112	0303	0515	0709
Surface net	44.3	24.3	20.8	17.6	32.5	46.9	12.8	8.4	7.2	16.3	8.0	31.3
Upper net (0-28 m)	15.7	24.2	14.4	34.9	9.1	15.3	12.9	0.8	8.8	2.7	2.6	13.9
Middle net (28-71 m)	-	0.6	0	2.2	0	1.7	1.0	0	1.0	0	1.6	0
Lower net (71-95 m)	0.5	0	0	0	2.1	0	0	0.6	0	0	0	0
TOTALS	60.5	49.1	35.2	54.7	43.7	63.9	26.7	9.8	17.0	19.0	12.2	45.2

1/ Station was taken within 30 minutes of sunrise.

2/ Station was taken within 30 minutes of sunset.

3/ A middle net sample was not taken.

Table 69.--Catches of *Pleurogrammus monopterygius* larvae at 4-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-G (Diel 7), fall 1978.

	DAY		S[1]	NIGHT			DAY
STATION	A	B	C	D	E	F	G
Time (GMT)	1810	2158	0225	0606	1008	1407	1803
Surface net	18.6	40.0	31.3	478.0	68.6	37.4	0
Upper net (0-40 m)	1.1	0	0.5	17.3	0	0	0.4
Middle net (40-193 m)	0	0.5	0	0	0	0	0
Lower net (193-368 m)	0	0	0	0.2	0	0	0
TOTALS	19.7	40.5	31.8	495.5	68.6	37.4	0.4

1/ Station was taken within 30 minutes of sunset.

Table 70.--Catches of *Hemilepidotus* spp. larvae at 4-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-G (Diel 7), fall 1978.

	DAY		S[1]	NIGHT			DAY
STATION	A	B	C	D	E	F	G
Time (GMT)	1810	2158	0225	0606	1008	1407	1803
Surface net	0	0	49.0	1.4	0	22.8	25.3
Upper net (0-40 m)	2.2	0	1.4	0	0.5	0	2.2
Middle net (40-193 m)	0	0.3	0	0.5	0.7	1.4	0.3
Lower net (193-368 m)	0	0	0.2	0.2	0.1	0.5	0
TOTALS	2.2	0.3	50.6	2.1	1.3	24.7	27.8

1/ Station was taken within 30 minutes of sunset.

Table 71.--Catches of *Hexagrammos decagrammus* larvae at 4-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-G (Diel 7), fall 1978.

	DAY		S[1]	NIGHT			DAY
STATION	A[3]	B	C	D	E	F	G
Time (GMT)	1810	2158	0225	0606	1008	1407	1803
Surface net	8.2	29.1	0	54.9	11.0	0	0
Upper net (0-40 m)	0	0	0	0.8	0	0	0
Middle net (40-193 m)	0	0	0	0	0	0	0
Lower net (193-368 m)	0	0	0	0	0	0	0
TOTALS	8.2	29.1	0	55.7	11.0	0	0

1/ Station was taken within 30 minutes of sunset.

Table 72.--Catches of *Hexagrammos lagocephalus* larvae at 4-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-G (Diel 7), fall 1978.

	DAY		S[1]	NIGHT			DAY
STATION	A	B	C	D	E	F	G
Time (GMT)	1810	2158	0225	0606	1008	1407	1803
Surface net	6.7	16.4	0	17.3	5.5	0	0
Upper net (0-40 m)	0	0	0	0	0	0	0
Middle net (40-193 m)	0	0	0	0	0	0	0
Lower net (193-368 m)	0	0	0	0	0	0	0
TOTALS	6.7	16.4	0	17.3	5.5	0	0

1/ Station was taken within 30 minutes of sunset.

Table 73.--Catches of *Hexagrammos octogrammus* larvae at 4-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-G (Diel 7), fall 1978.

	DAY		S[1]	NIGHT			DAY
STATION	A	B	C	D	E	F	G
Time (GMT)	1810	2158	0225	0606	1008	1407	1803
Surface net	0	20.0	0	10.1	2.7	0	0
Upper net (0-40 m)	0	0	0	0.4	0	0	0
Middle net (40-193 m)	0	0	0	0	0	0	0
Lower net (193-368 m)	0	0	0	0	0	0	0
TOTALS	0	20.0	0	10.5	2.7	0	0

1/ Station was taken within 30 minutes of sunset.

Table 74.--Catches of *Leuroglossus schmidti* larvae at 4-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-G (Diel 7), fall 1978.

	DAY		S[1]	NIGHT			DAY
STATION	A	B	C	D	E	F	G
Time (GMT)	1810	2158	0225	0606	1008	1407	1803
Surface net	0	0	0	0	0	0	0
Upper net (0-40 m)	0	0.7	0.6	0	0	0.2	0
Middle net (40-193 m)	0.2	0	0.3	0.4	0.1	0.3	0
Lower net (193-368 m)	0.2	0.6	0	0.7	0	0.1	0.1
TOTALS	0.4	1.3	0.9	1.1	0.1	0.6	0.1

1/ Station was taken within 30 minutes of sunset.

Table 75.--Catches of *Leuroglossus schmidti* eggs at 4-hr intervals based on number/100 m^3 for four selected depth intervals. Stations D01A-G (Diel 7), fall 1978.

	DAY		S[1]/	NIGHT			DAY
STATION	A	B	C	D	E	F	G
Time (GMT)	1810	2158	0225	0606	1008	1407	1803
Surface net	0	0	0	0	0	0	0
Upper net (0-40 m)	0.7	22.1	2.4	0	3.7	1.8	0
Middle net (40-193 m)	13.2	0.9	12.1	8.2	11.8	6.3	5.5
Lower net (193-368 m)	4.9	7.4	3.9	5.7	3.8	2.5	3.1
TOTALS	18.8	30.4	18.4	13.9	19.3	10.6	8.6

1/ Station was taken within 30 minutes of sunset.

Table 76.--Summary of the diel-vertical distribution, abundance, and size of the seven most abundant taxa of fish collected during seven diel-vertical distribution series off Kodiak Island, Alaska.

Taxon	Diel Series Occurrence [1] (number/100 m³) 1 12-13 Nov 1977	2 11-12 Nov 1977	3 14-15 Apr 1978	4 10 Apr 1978	5 28-29 Jun 1978	6 1-2 Jul 1978	7 12-13 Nov 1978	Spring (1978) Mean Length (mm)	Spring Depth (m) of maximum occurrence Day	Spring Night	Summer (1978) Mean Length (mm)	Summer Depth (m) of maximum occurrence Day	Summer Night	Fall (1977 & 1978) Mean Length (mm)	Fall Depth (m) of maximum occurrence Day	Fall Night
Hemilepidotus spp.	13.2	48.0	20.1	8.6	0.8	<0.1	7.4	11.4	0-55	0	25.5	* [2]	0	6.5	0-36	0
Hexagrammos decagrammus	9.7	1.9	207.4	48.7	0	0.7	8.0	11.4	0	0	22.0	*	0	10.4	0	0
Pleurogrammus monopterygius	5.5	0	<0.1	0.2	0	0	50.2							11.0	0	0
Ammodytes hexapterus	0	0	0.7	1.6	18.5	0.2	0	10.0	0-55	0-76	45.5	*	0			
Sebastes spp.	0	0	<0.1	0	1.2	3.4	0					0-28	0-28			
Bathymaster spp.	0	0	<0.1	0	1.0	36.8	<0.1					0-28	0			
Lepidopsetta bilineata	0	0	0.2	0.4	0.3	0	0	4.2	0-66	0-66	14.5	0-28	0-28			

1/ Diel series occurrence was derived by the following equation: $\frac{1}{2}\left[\frac{\text{(mean\#/100 m}^3\text{ in positive neuston tows)}}{\text{total neuston tows in series}} + \frac{\text{(mean\#/100 m}^3\text{ in positive tucker trawl sets)}}{\text{total tucker trawl sets in series}}\right]$

2/* No catch during daytime.

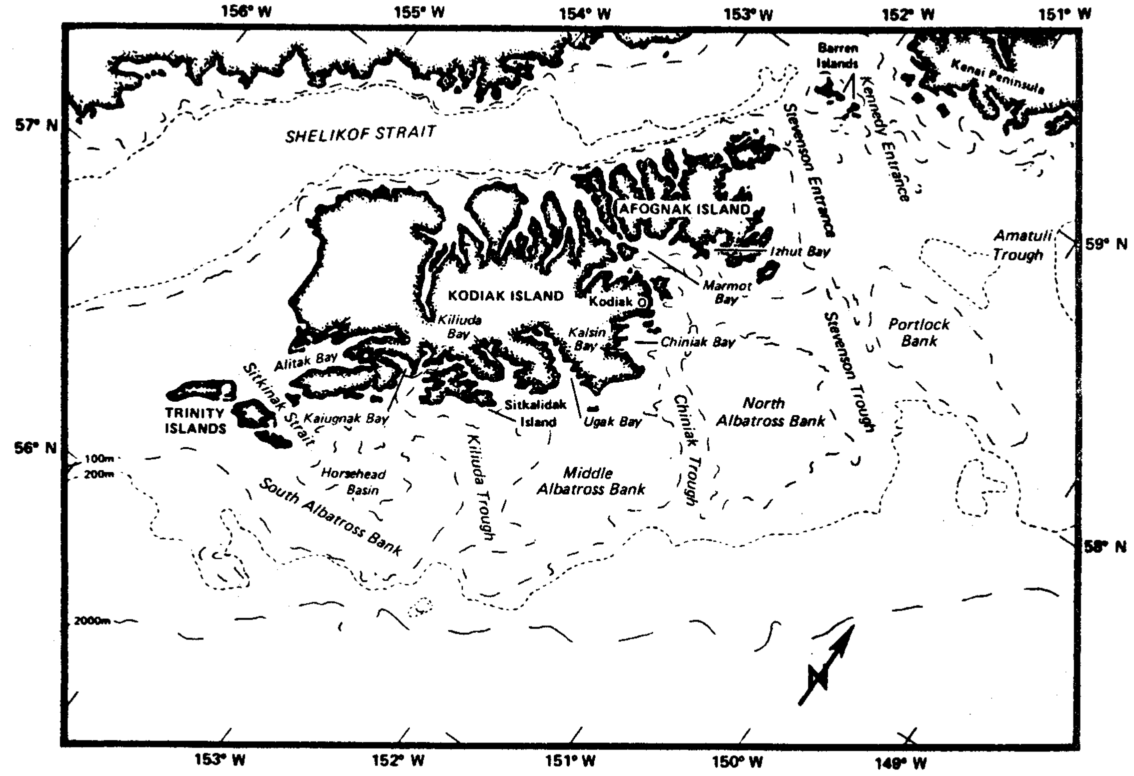


Figure 1.-- Kodiak Island study area depicting general bathymetry and principal bays and inlets (after Science Applications, Inc., MS 1979a).

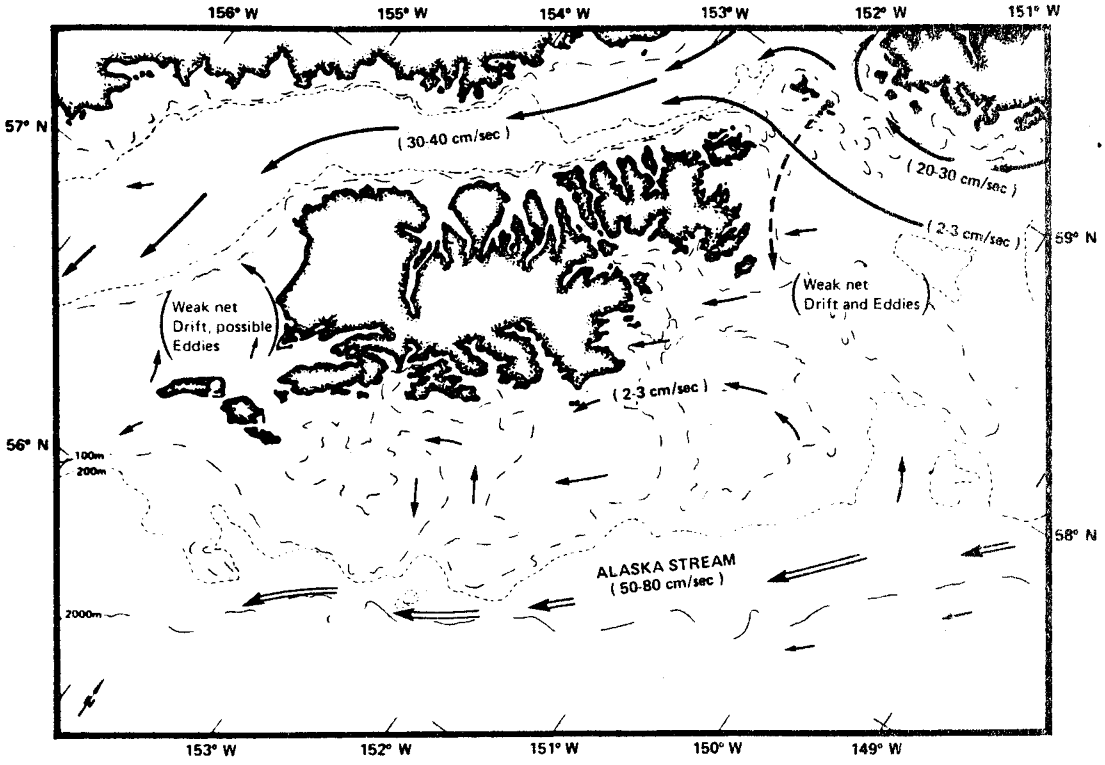
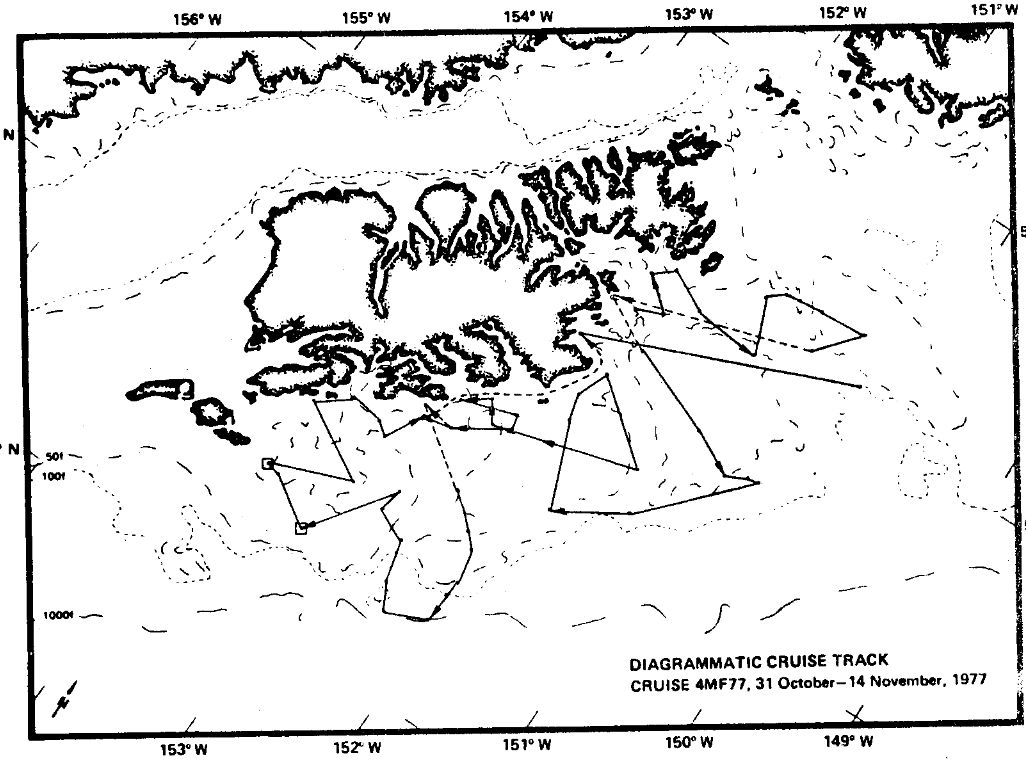


Figure 2.-- Speculative summary of surface currents of the Kodiak Island shelf area (from Science Applications, Inc., MS 1979b).



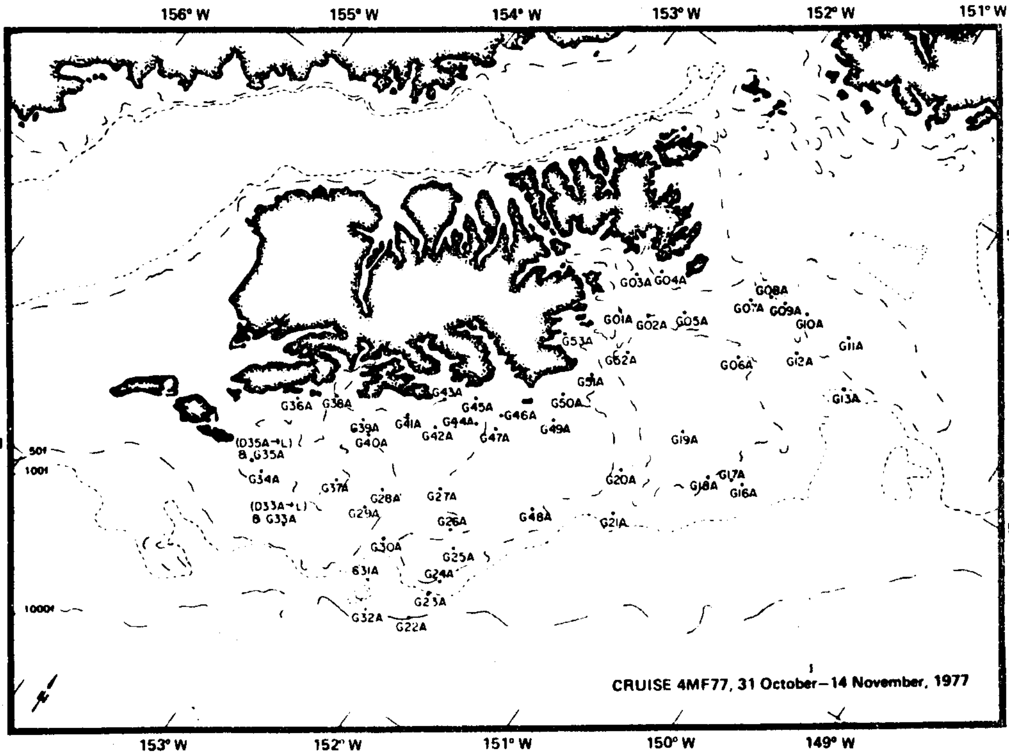


Figure 3.-- Cruise track (top) and station numbers (bottom) for cruise 4MF77, fall 1977.

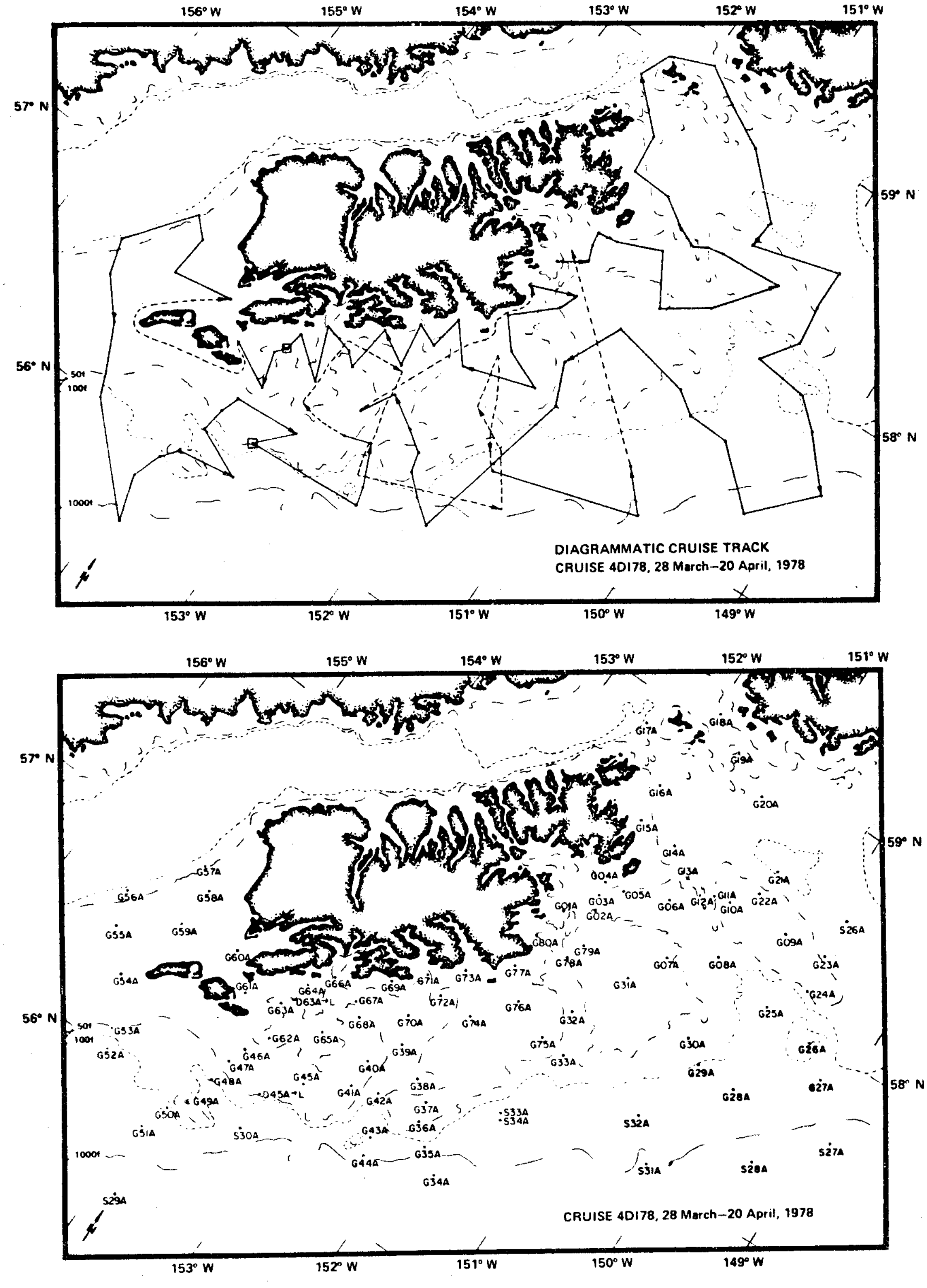
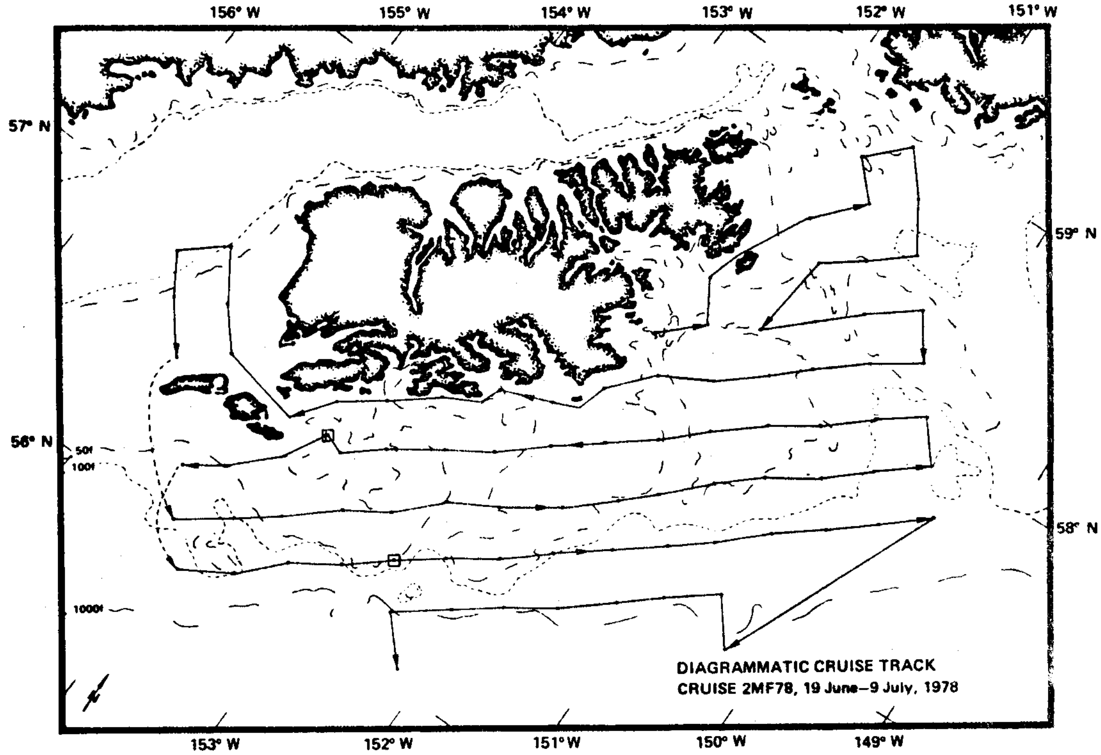


Figure 4.-- Cruise track (top) and station numbers (bottom) for cruise 4DI78, spring 1978.



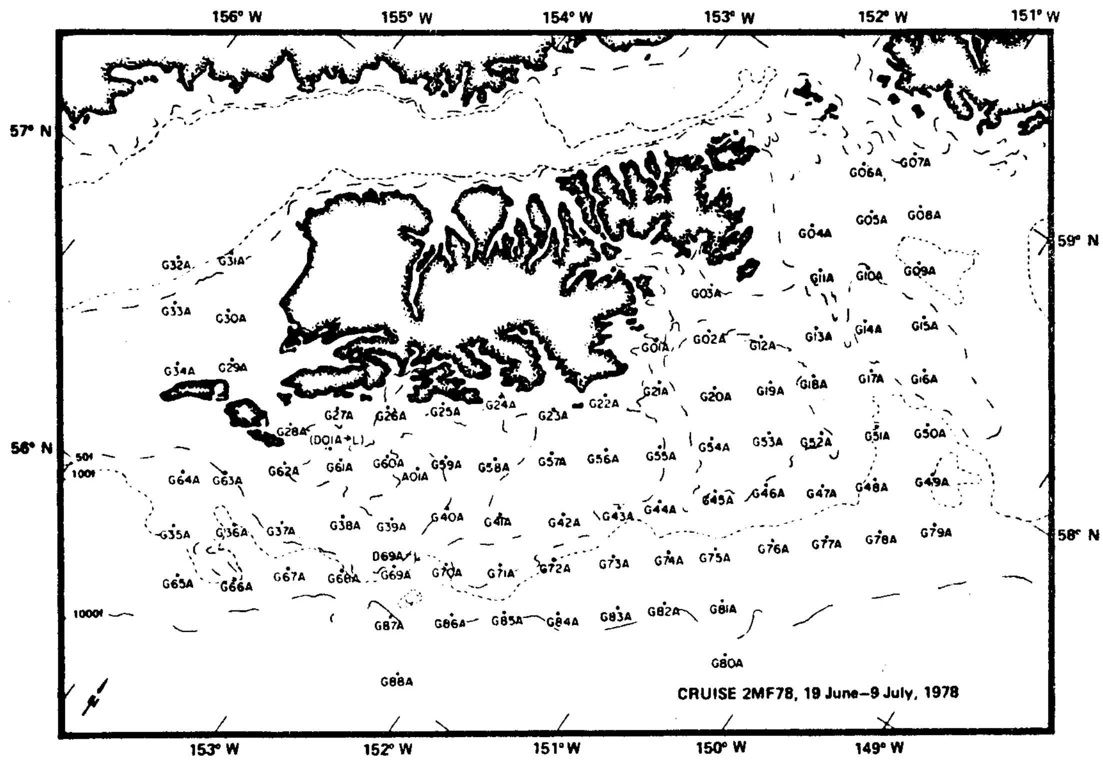
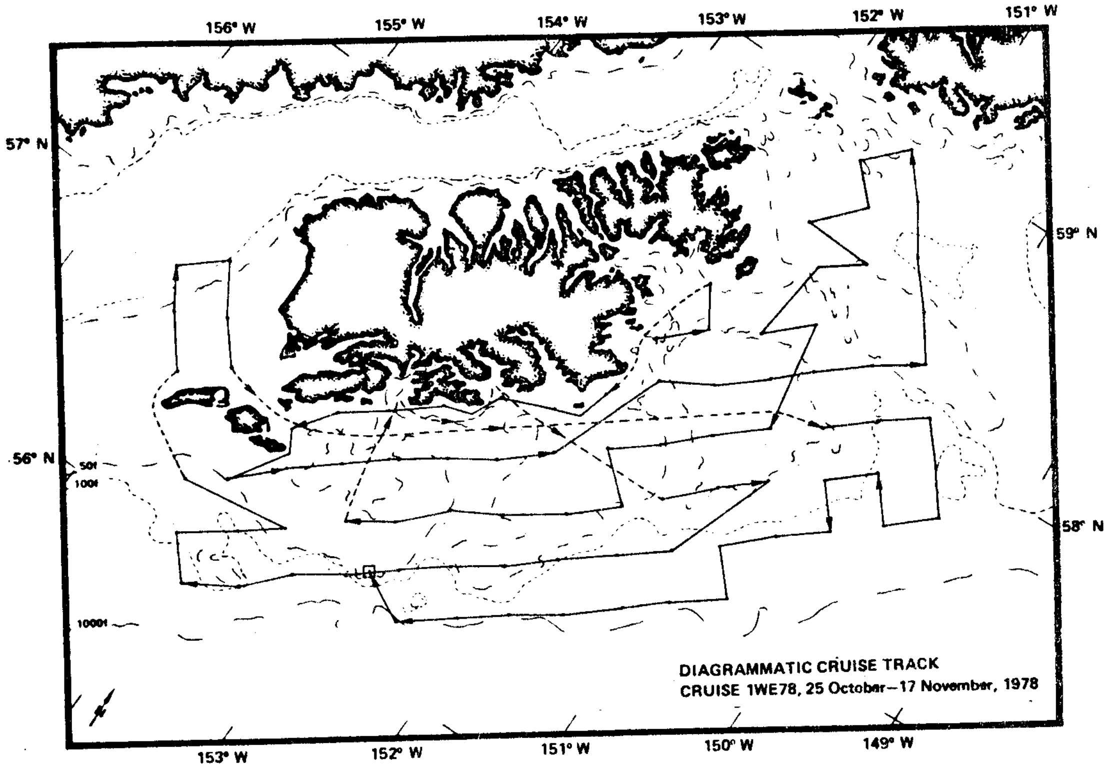


Figure 5.-- Cruise track (top) and station numbers (bottom) for cruise 2MF78, summer 1978.



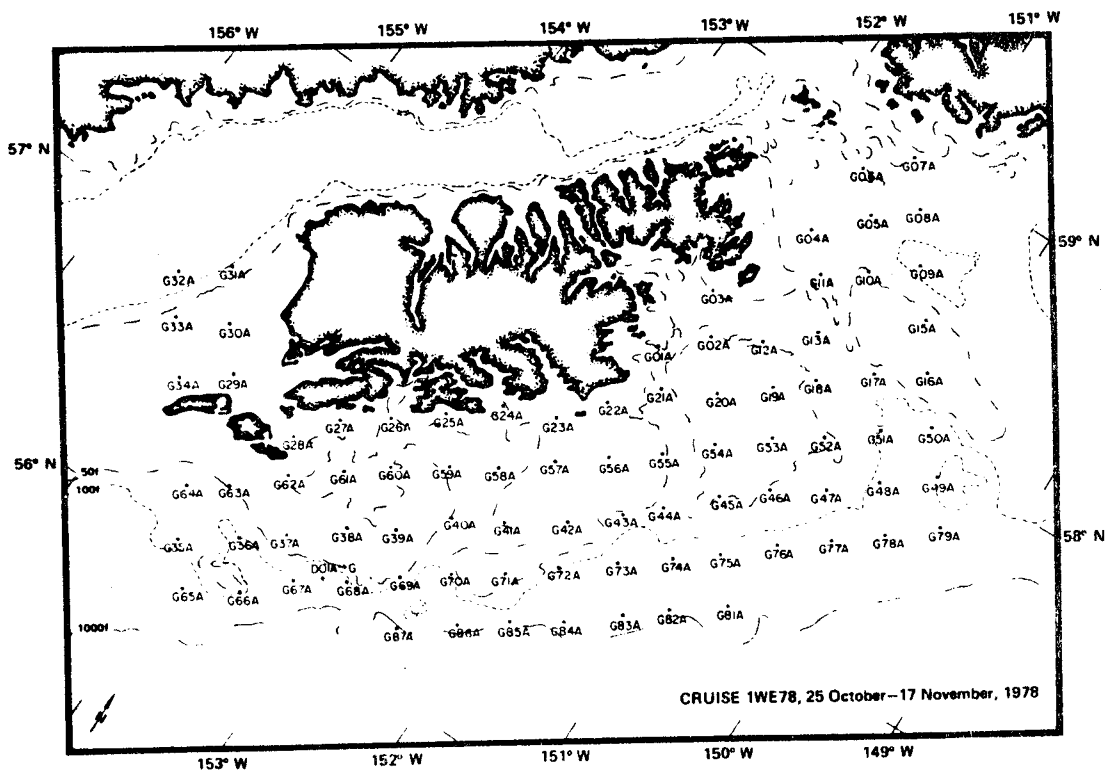


Figure 6.-- Cruise track (top) and station numbers (bottom) for cruise 1WE78, fall 1978.

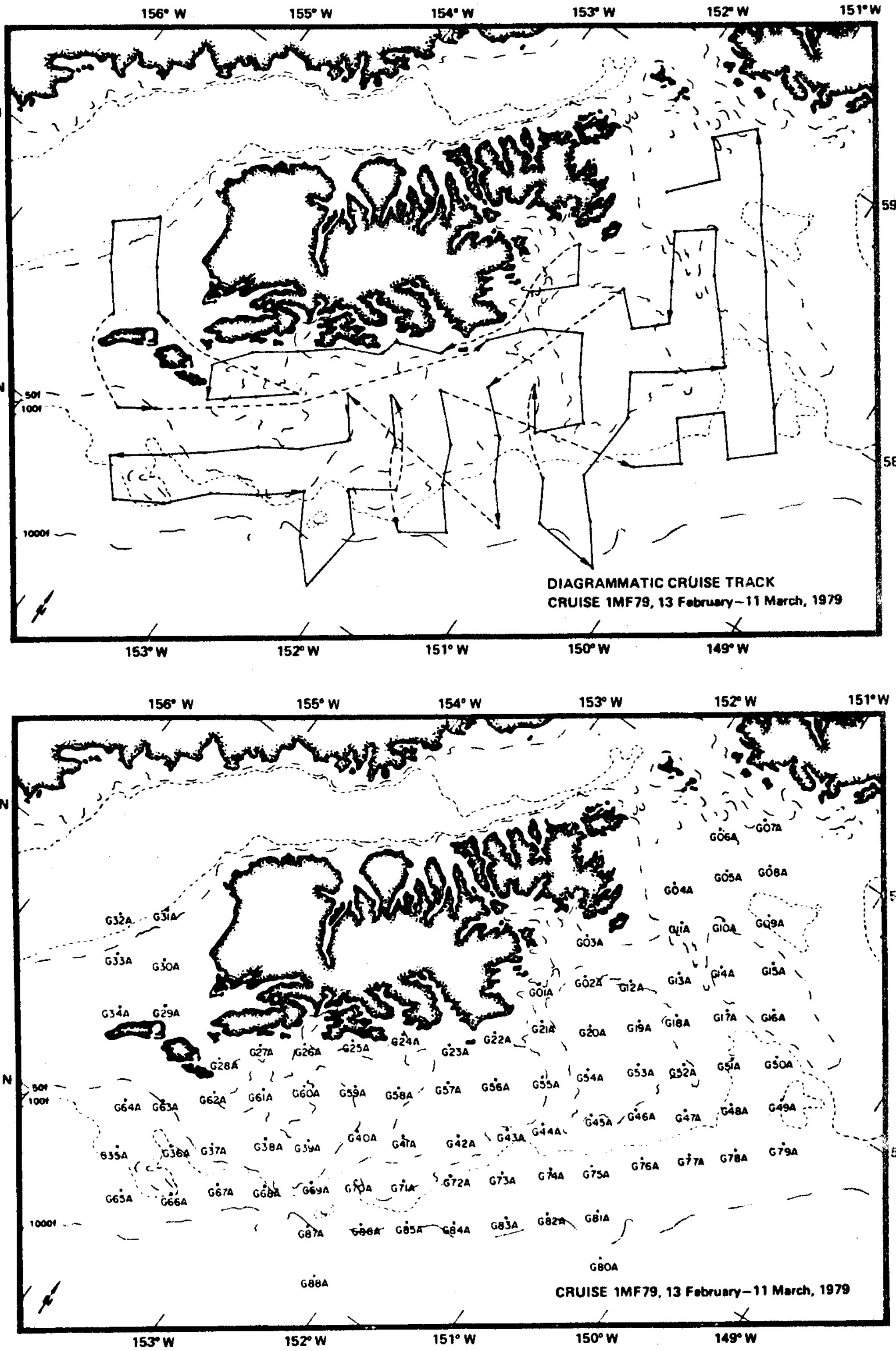


Figure 7.-- Cruise track (top) and station numbers (bottom) for cruise 1MF79, winter 1979.

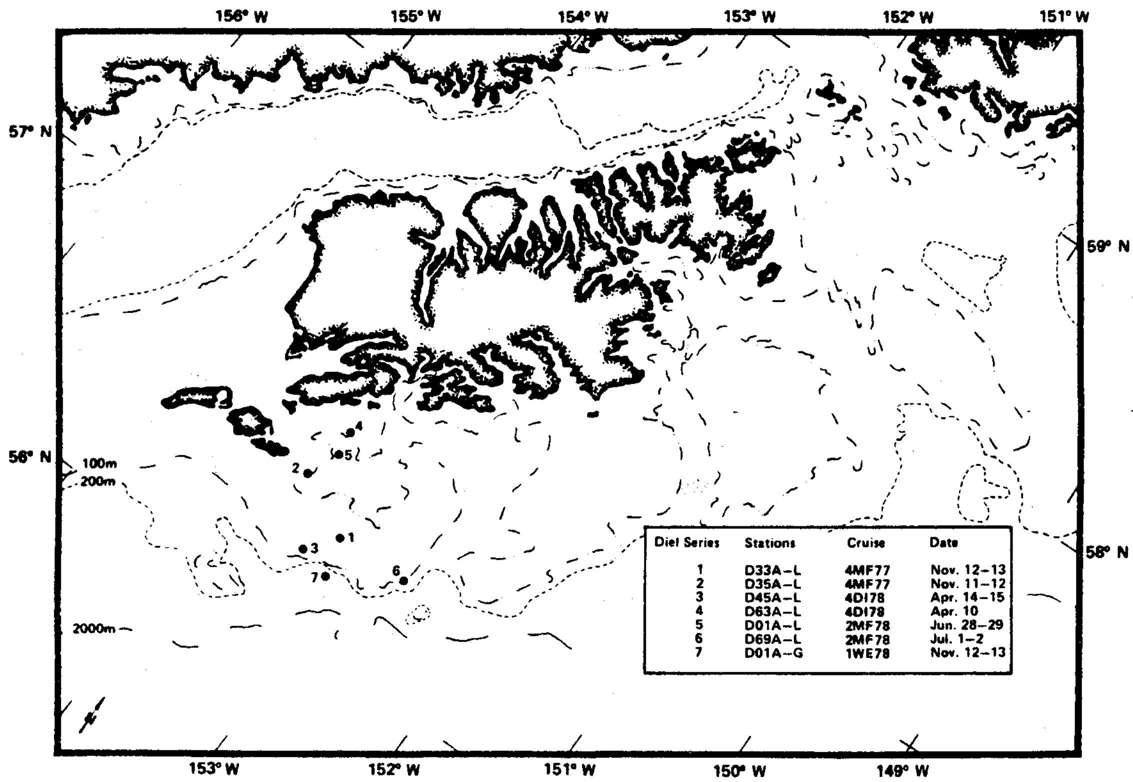


Figure 8.-- Locations of diel sampling series.

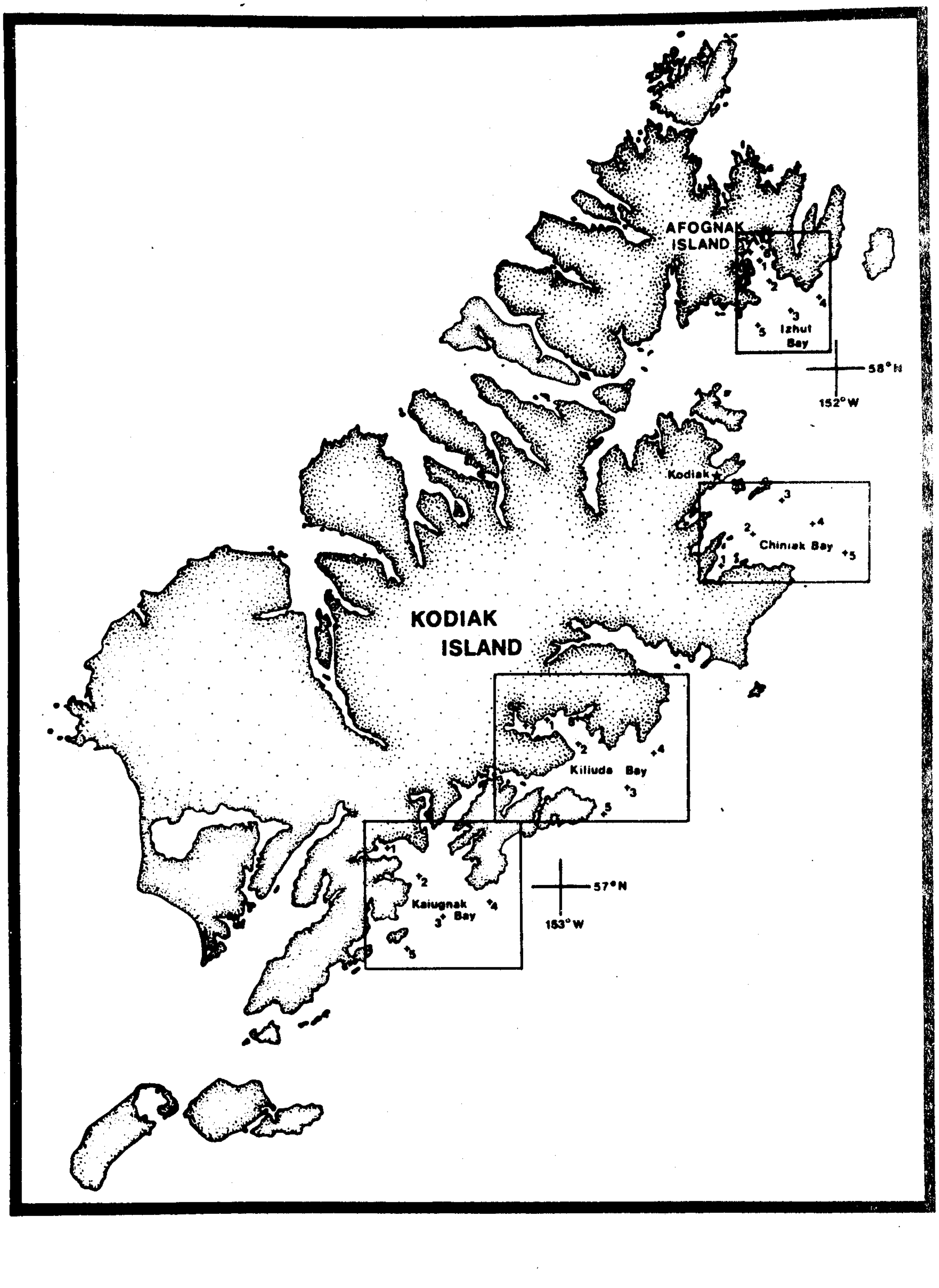


Figure 9.-- Bays and sampling locations of the inshore bay regions of the Kodiak Island study area.

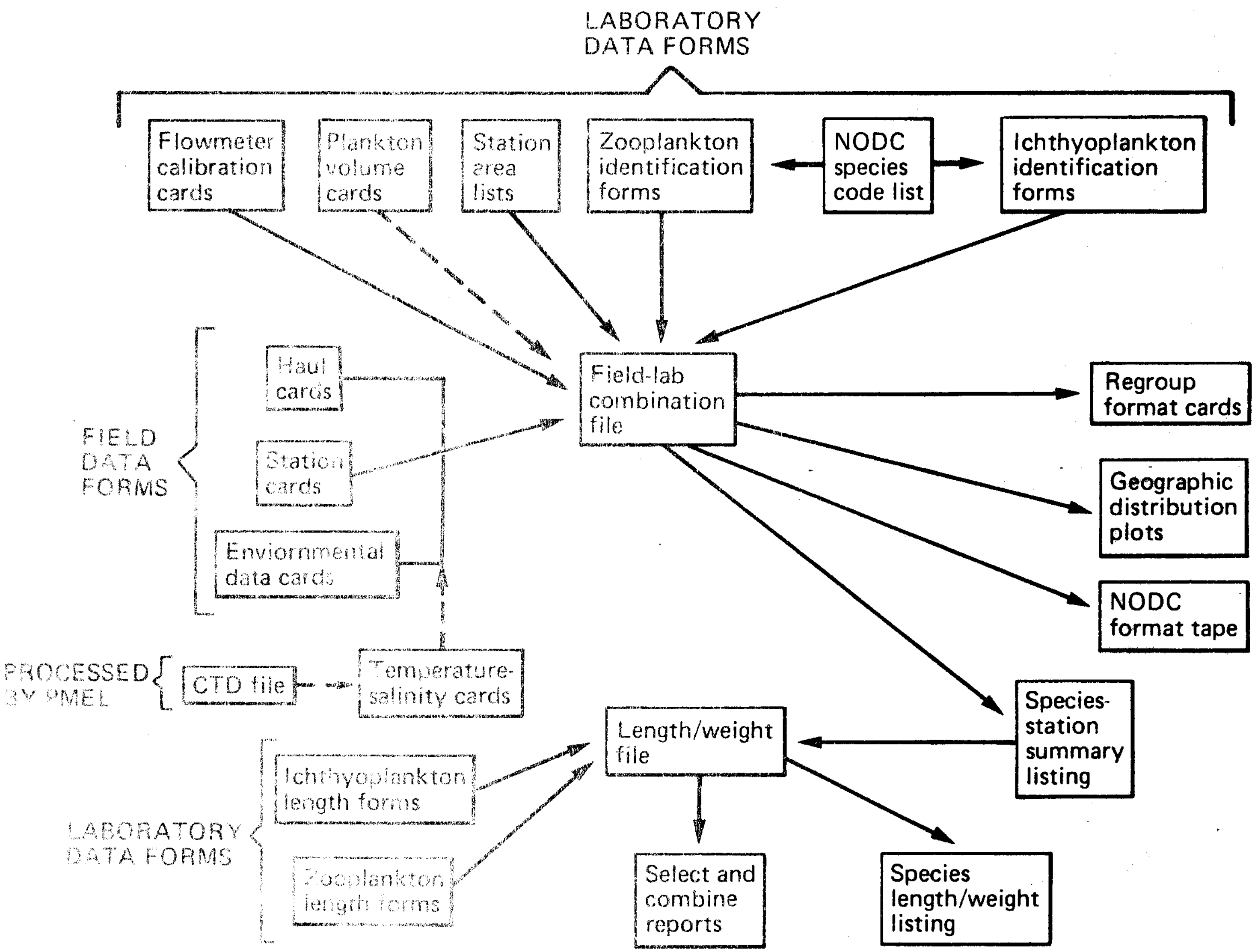


Figure 10.--Diagram of data management system used for reduction and analysis of OCSEAP plankton data.

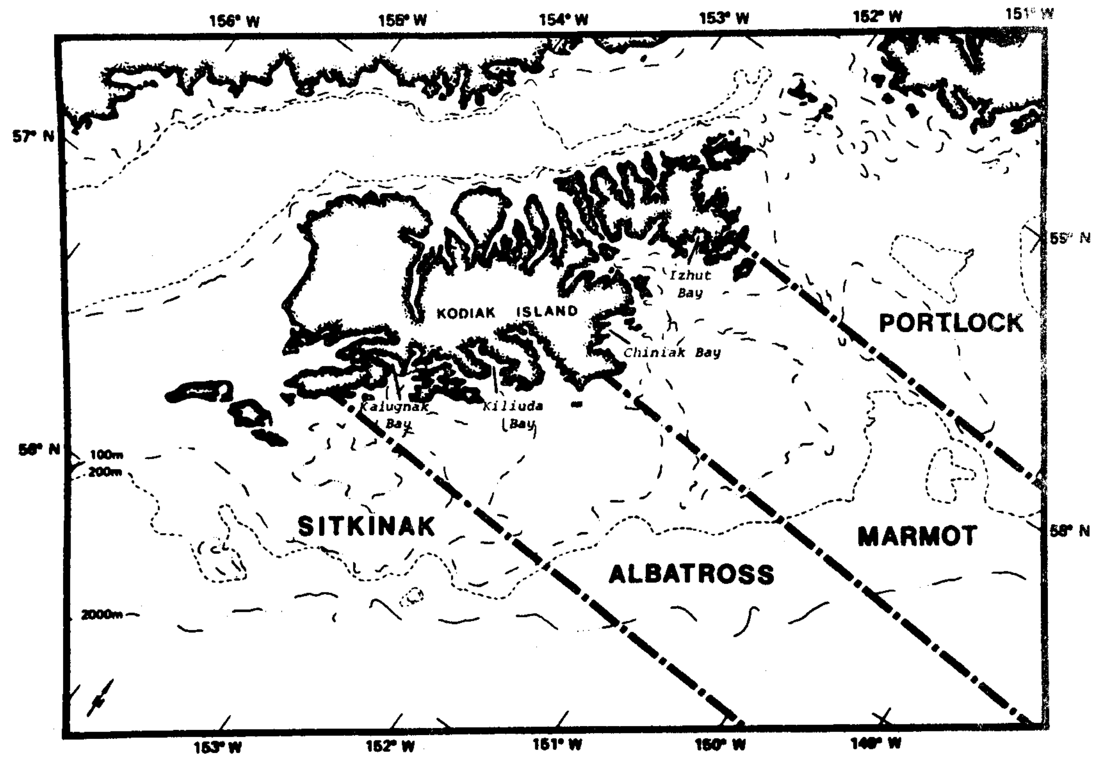


Figure 11.--Offshore region subareas of the Kodiak Island study area identified for the decapod larvae section of this report.

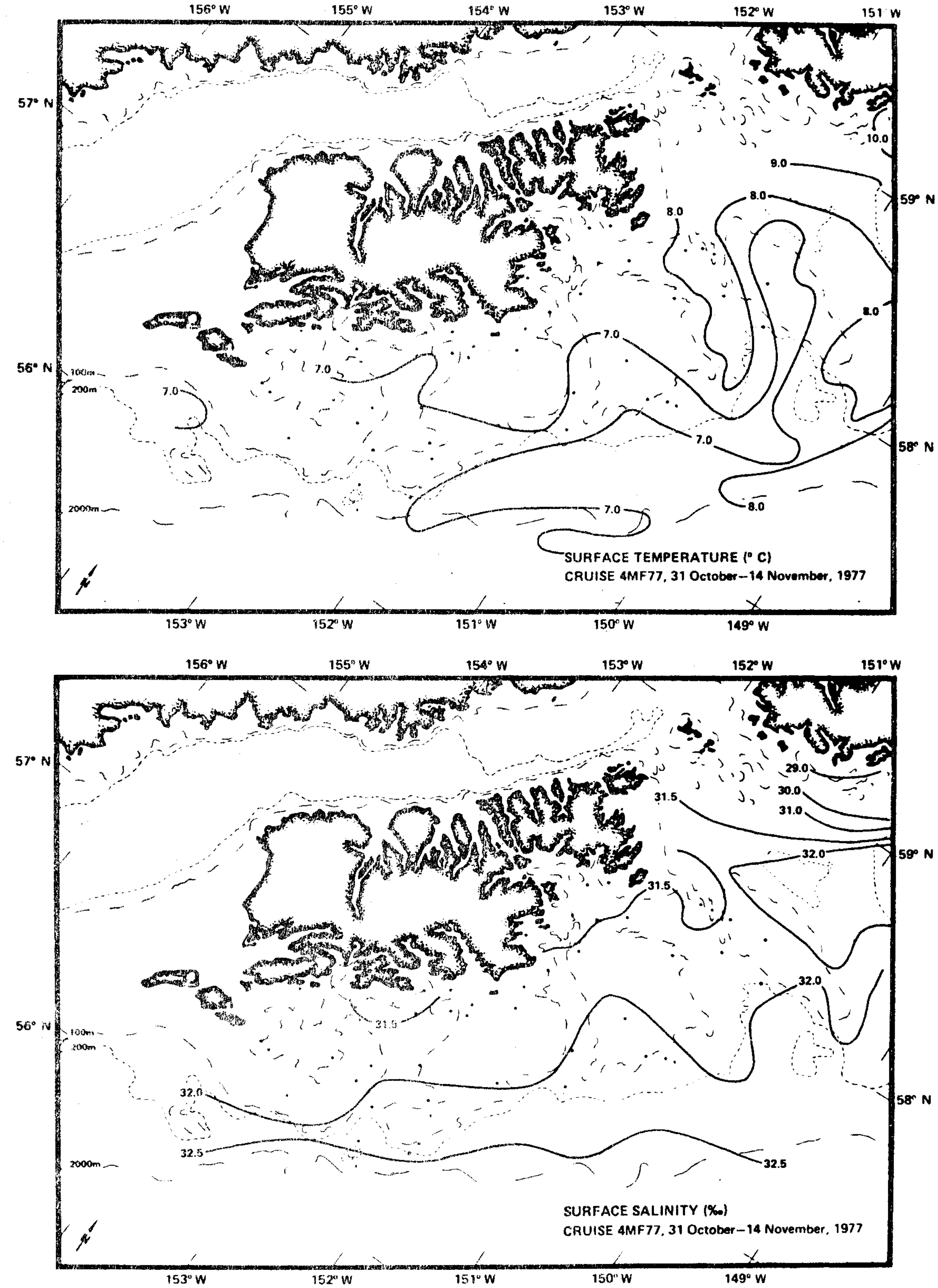


Figure 12.--Surface temperature in ^{o}C (top) and salinity in $^{o}/oo$ (bottom) fall 1977 (Data from Schumacher, et al., 1979).

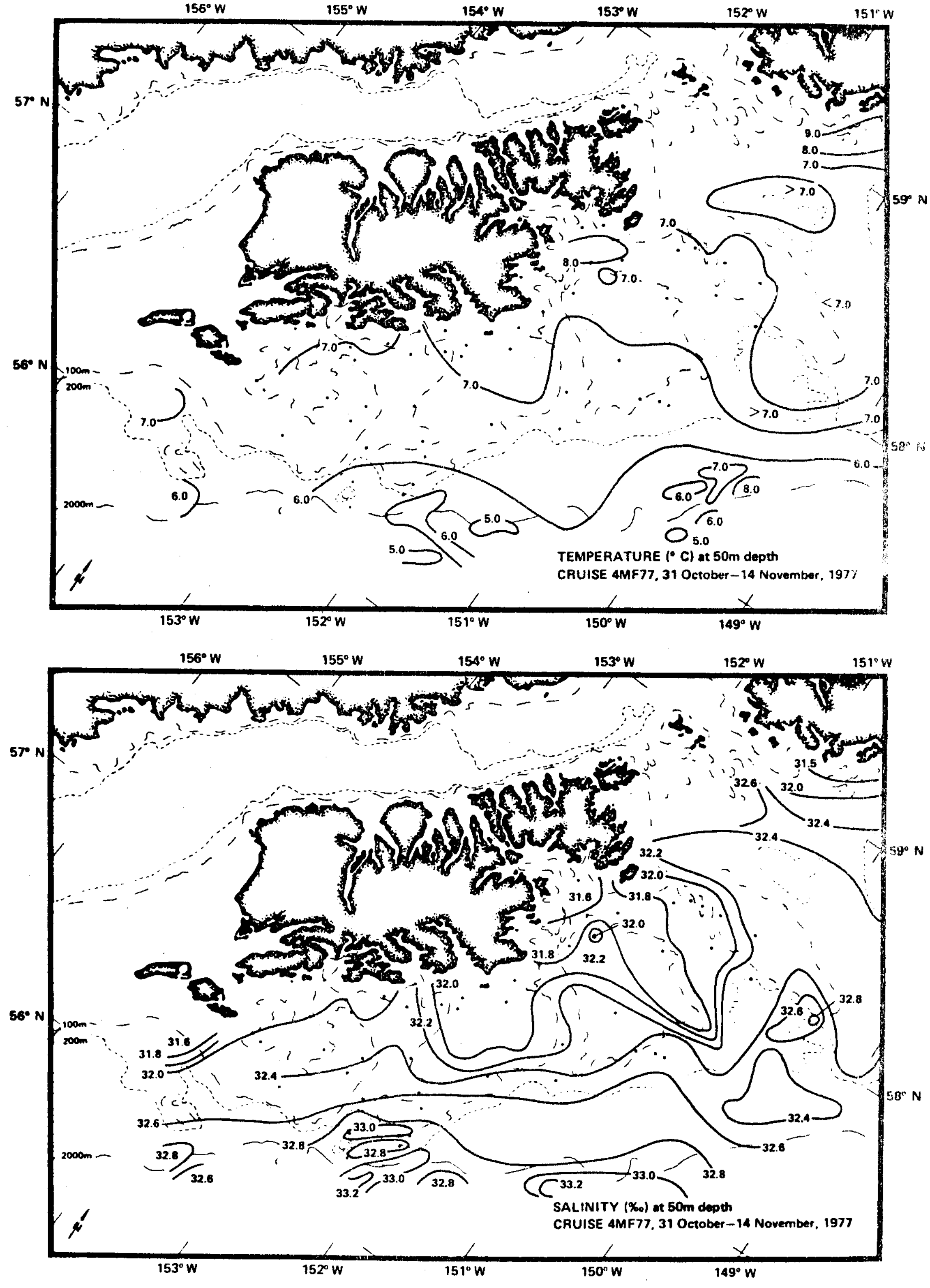


Figure 13.--Temperature in °C (top) and salinity in °/oo (bottom) at 50 m, fall 1977 (Data from Schumacher, et al., 1979).

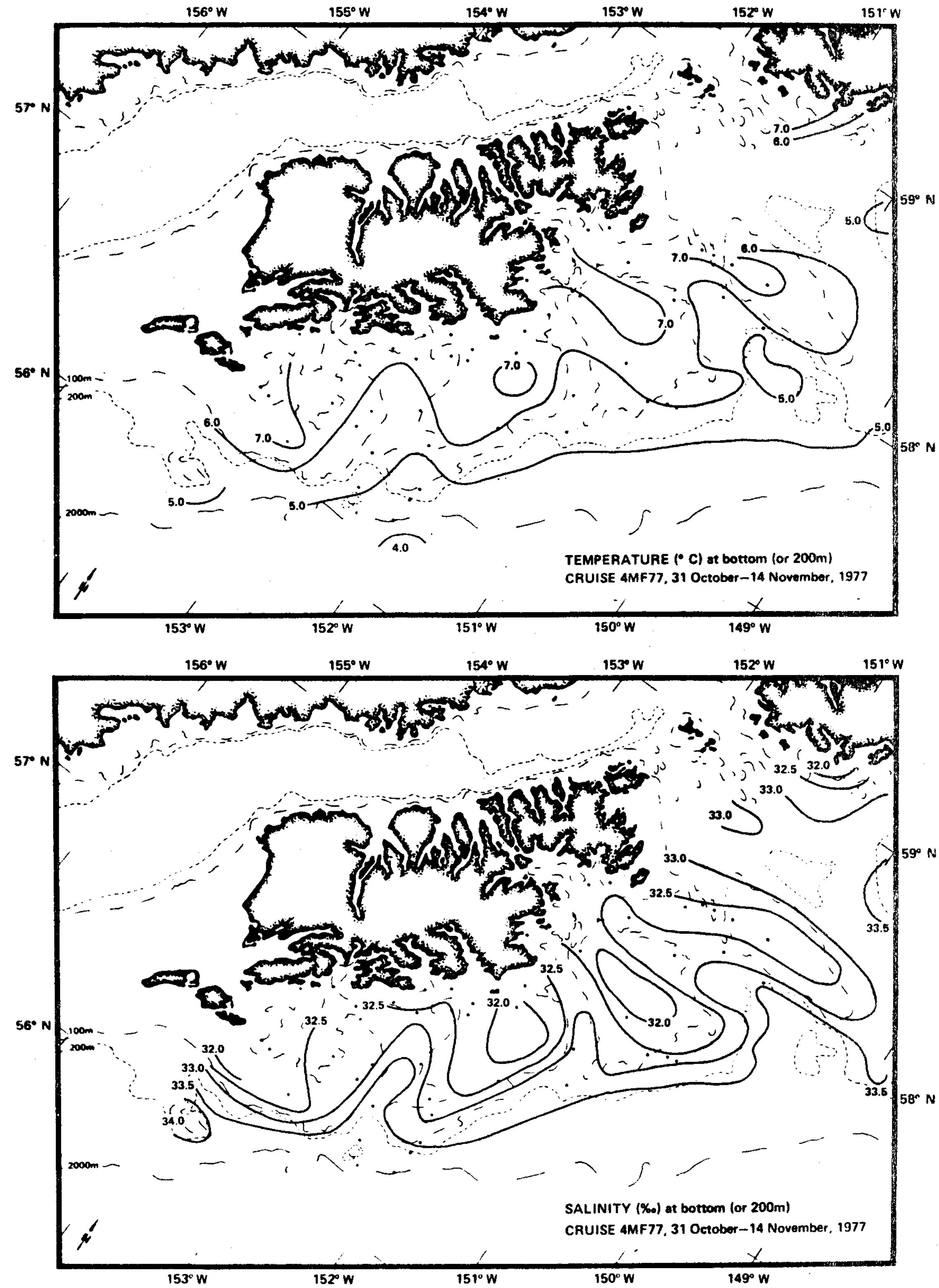


Figure 14.--Temperature in °C (top) and salinity in °/oo (bottom) at bottom (or 200 m), fall 1977 (Data from Schumacher, et al., 1979).

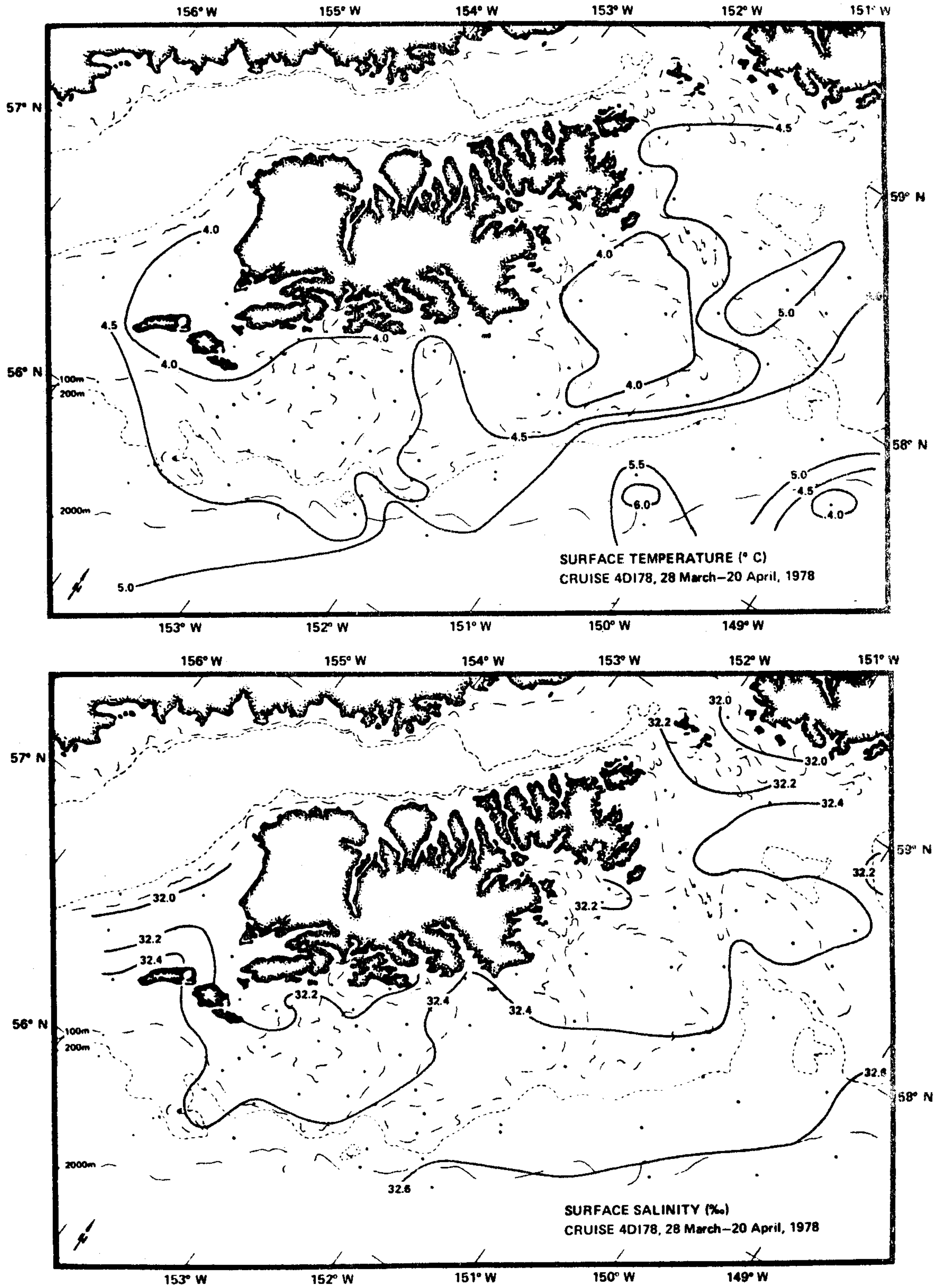


Figure 15.--Surface temperature in ^{o}C (top) and salinity in $^{o}/oo$ (bottom) spring 1978.

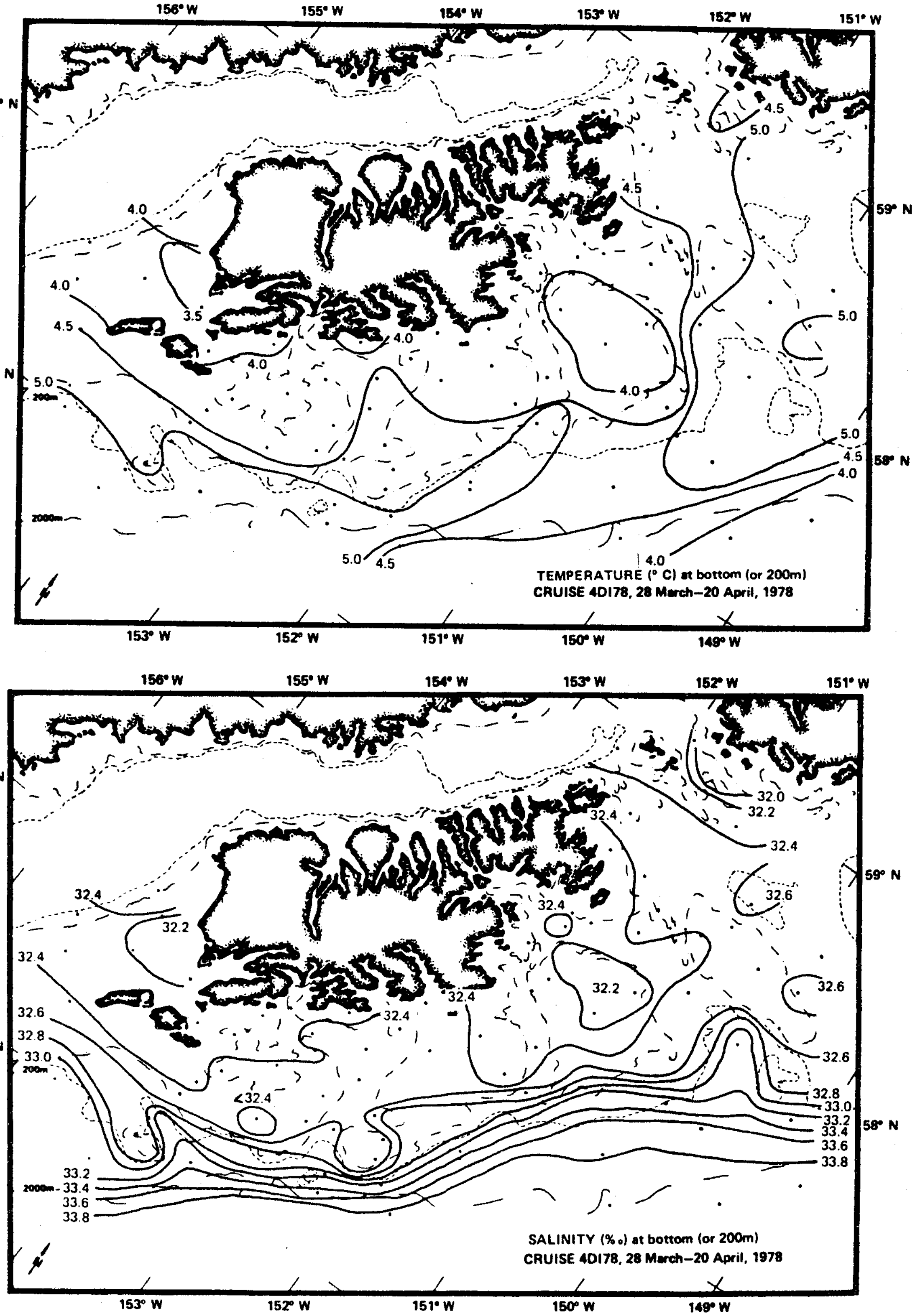


Figure 16.--Temperature in °C (top) and salinity in °/oo (bottom) at bottom (or 200 m), spring 1978.

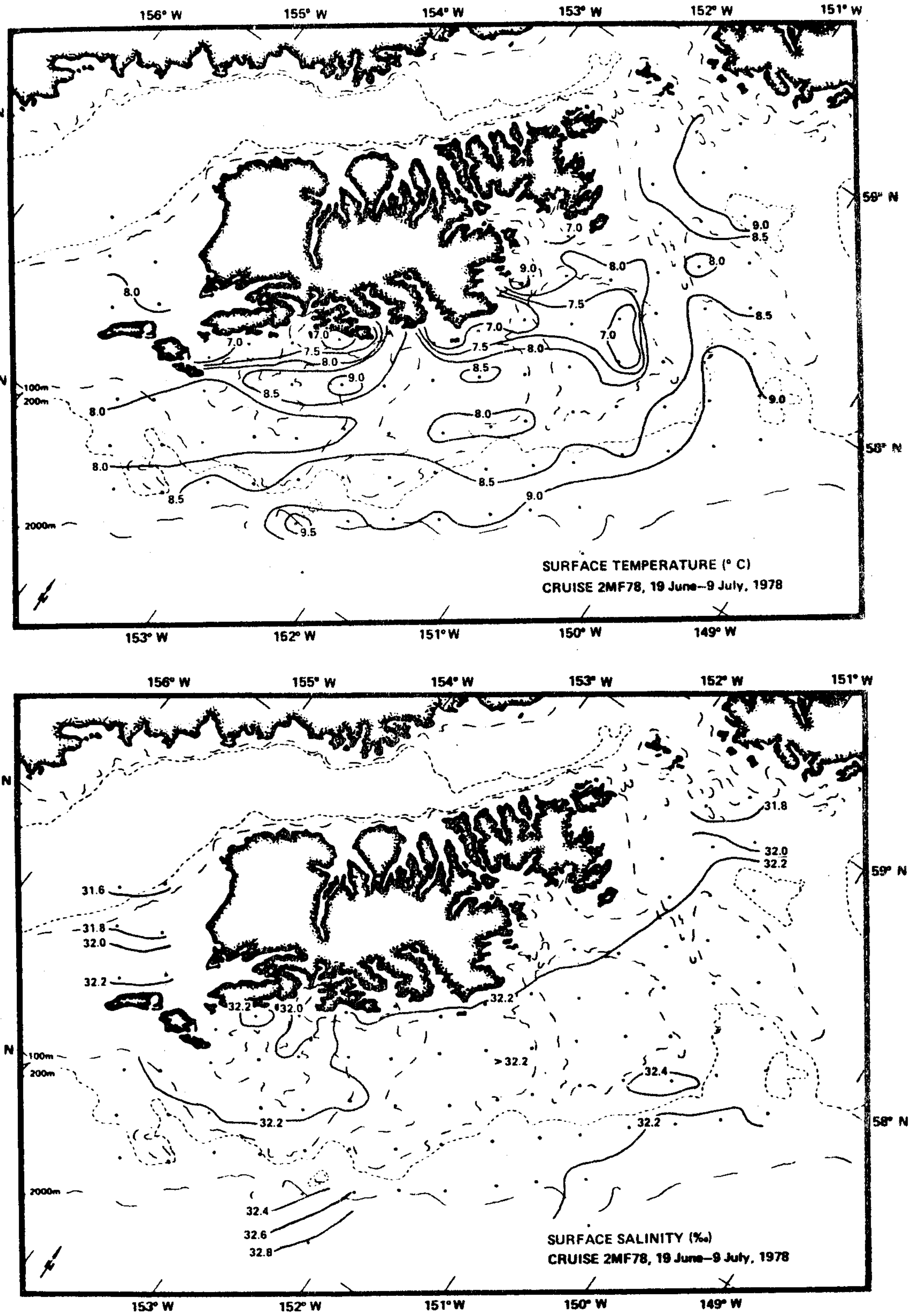


Figure 17.--Surface temperature in °C (top) and salinity in °/oo (bottom) summer 1978.

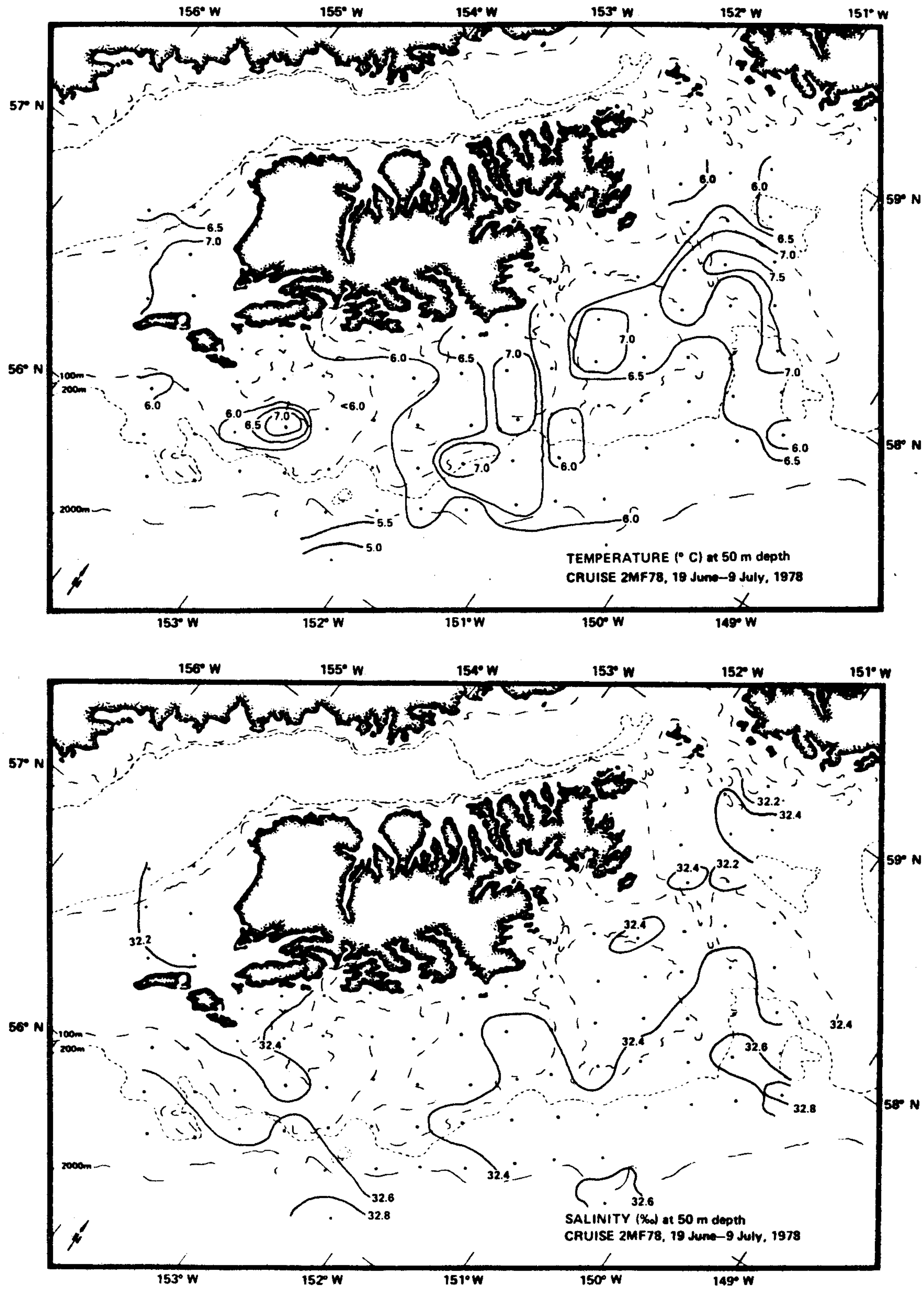


Figure 18.--Temperature in °C (top) and salinity in °/oo (bottom) at 50 m, summer 1978.

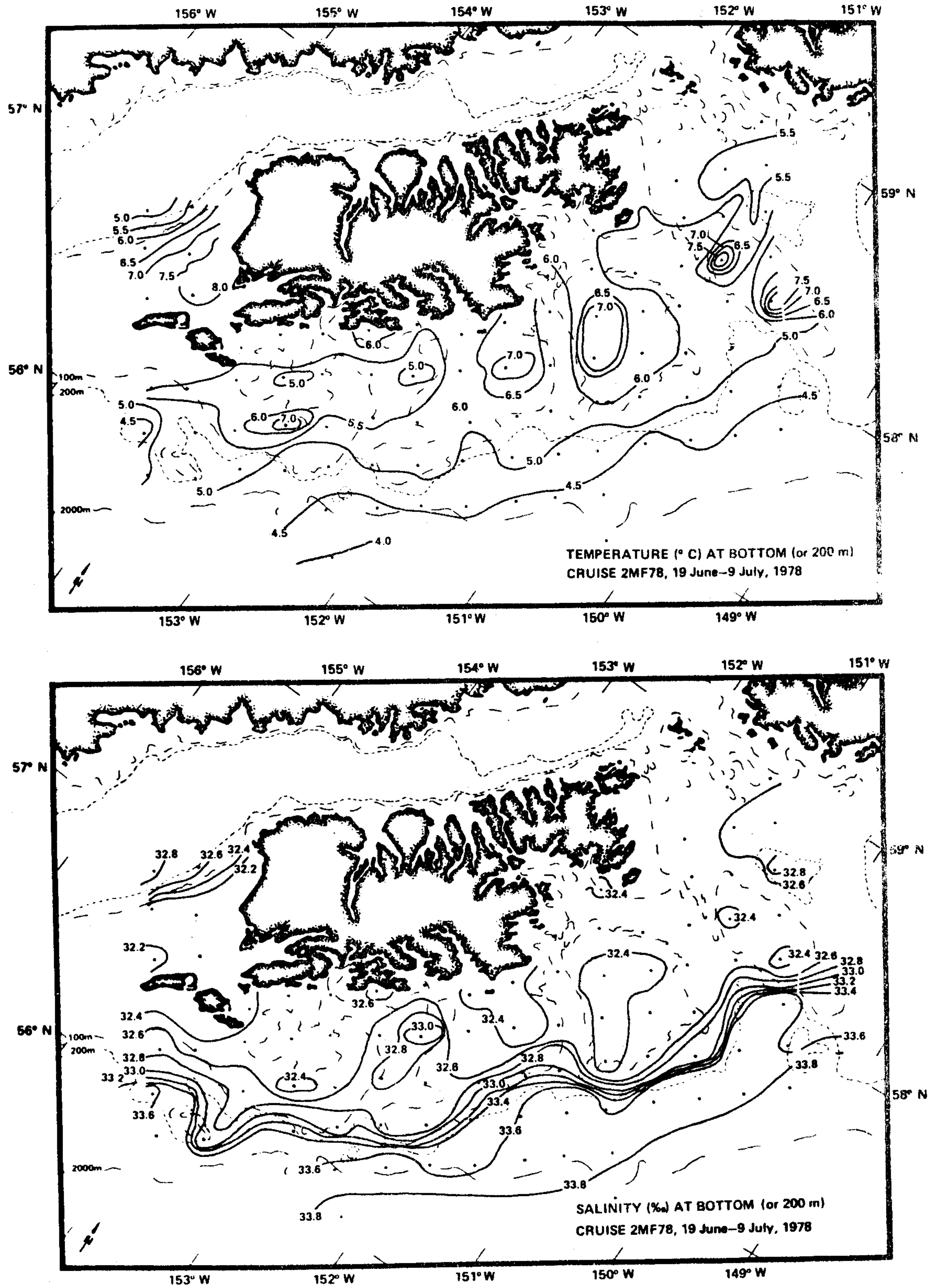
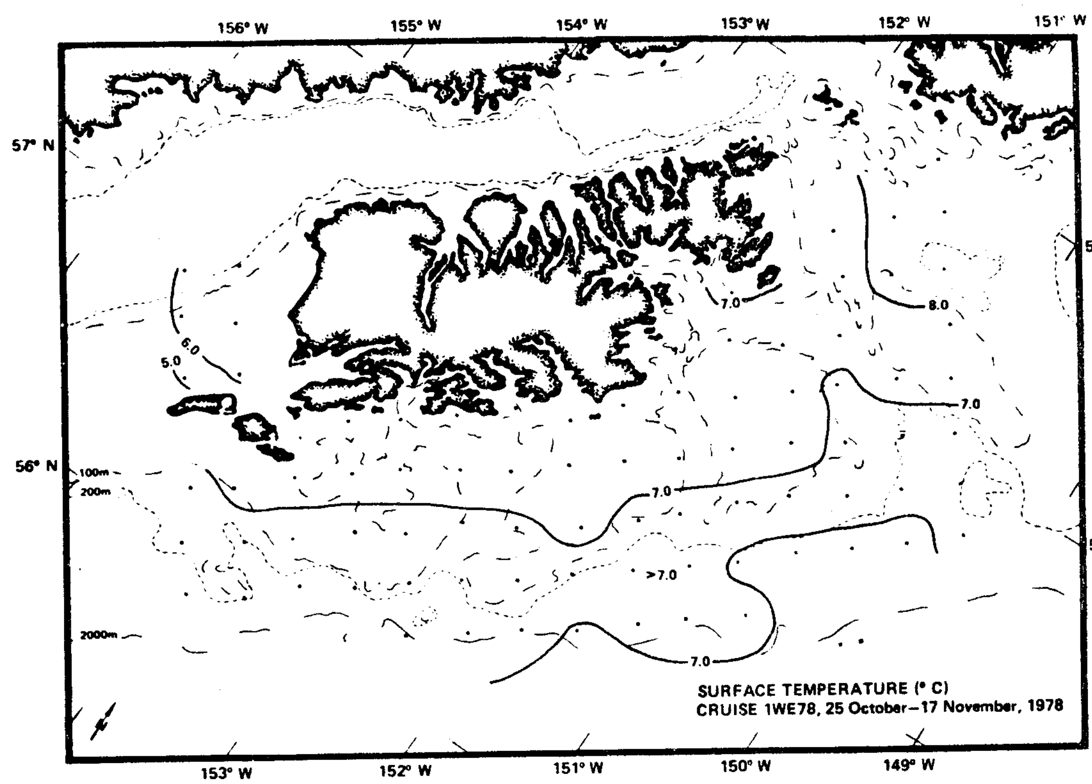


Figure 19.--Temperature in °C (top) and salinity in °/oo (bottom) at bottom (or 200 m), summer 1978.



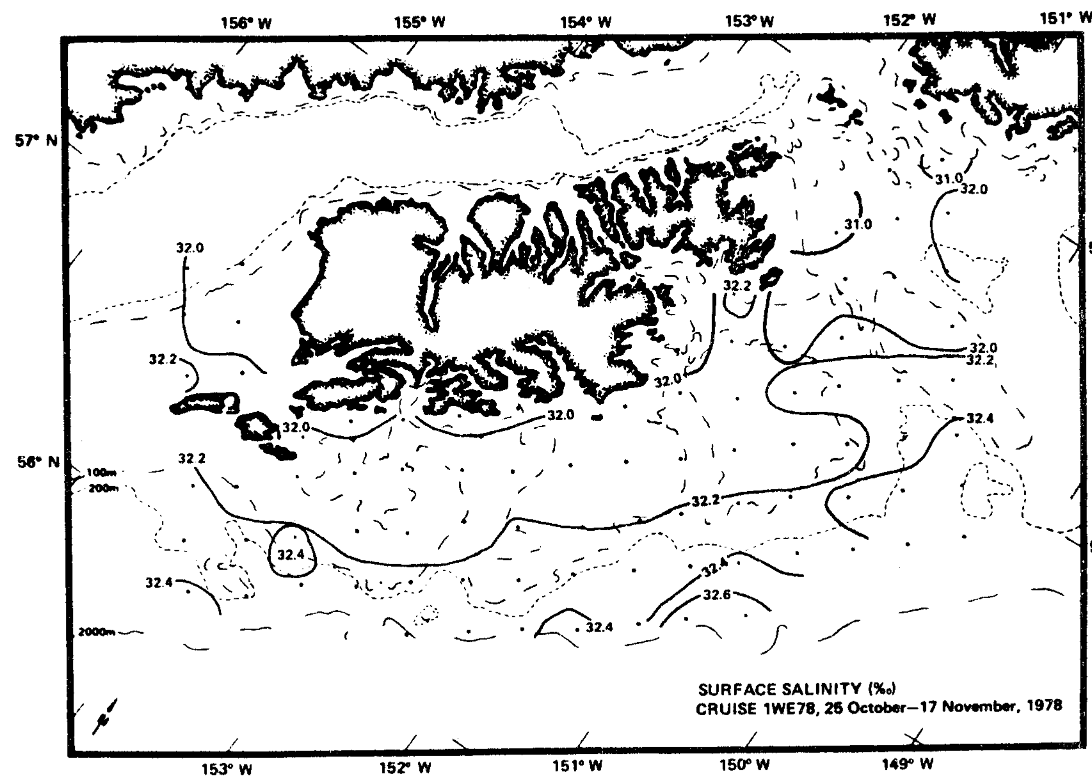


Figure 20.--Surface temperature in °C (top) and salinity in °/oo (bottom) fall 1978.

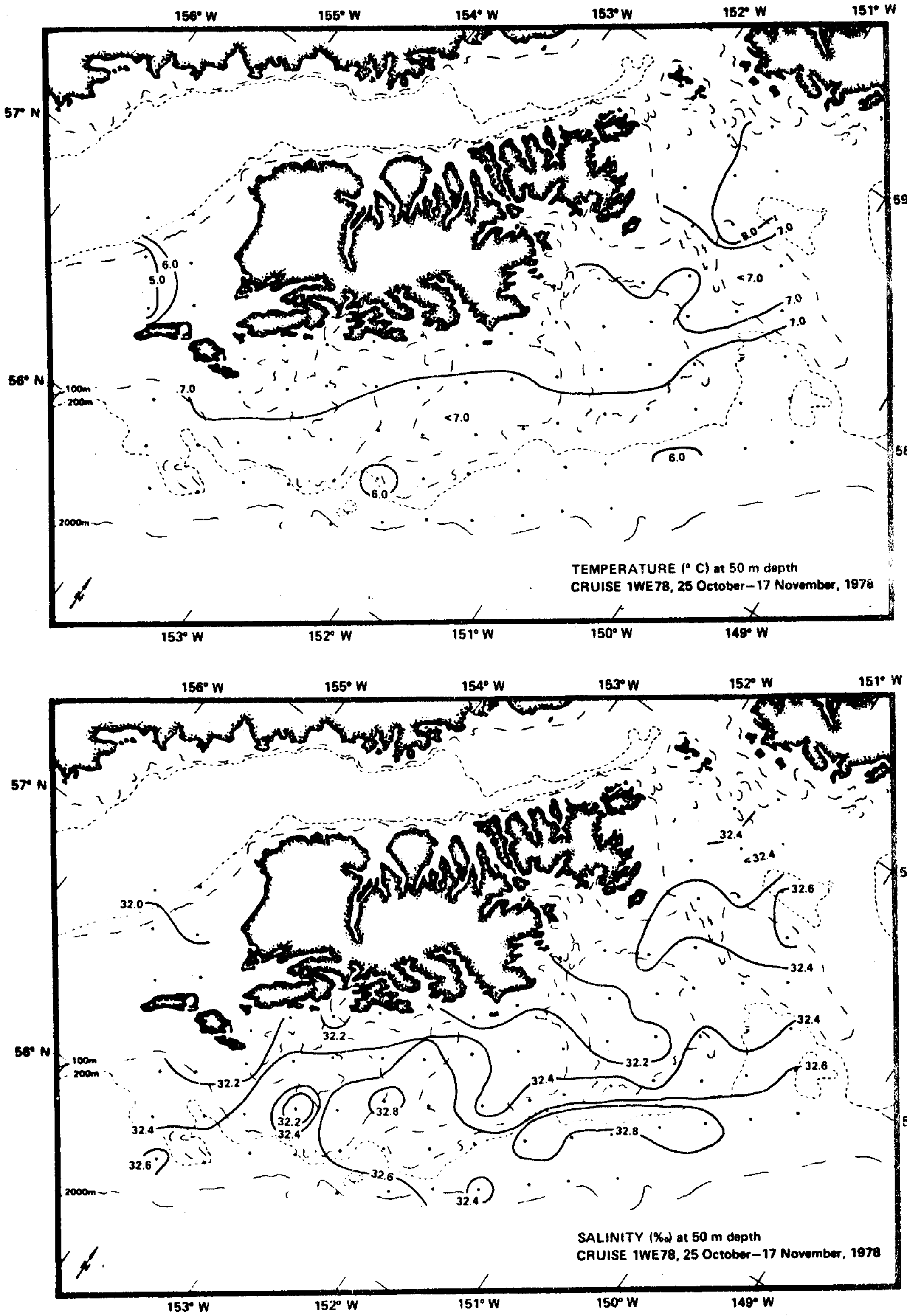
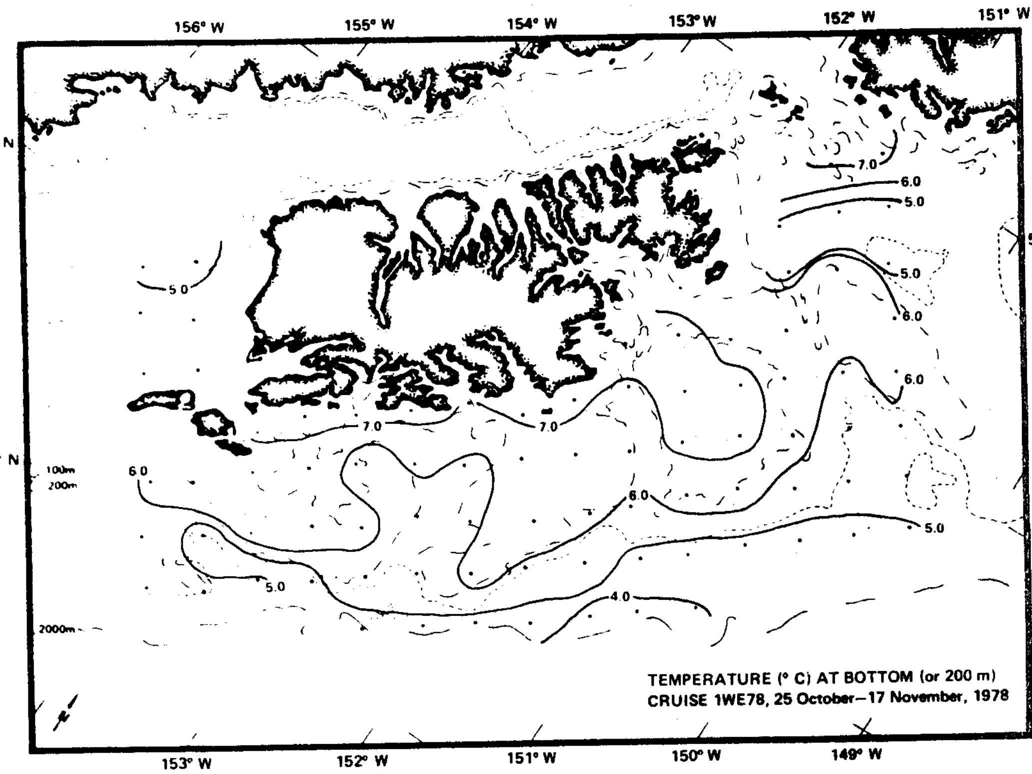


Figure 21.--Temperature in °C (top) and salinity in °/oo (bottom) at 50 m, fall 1978.



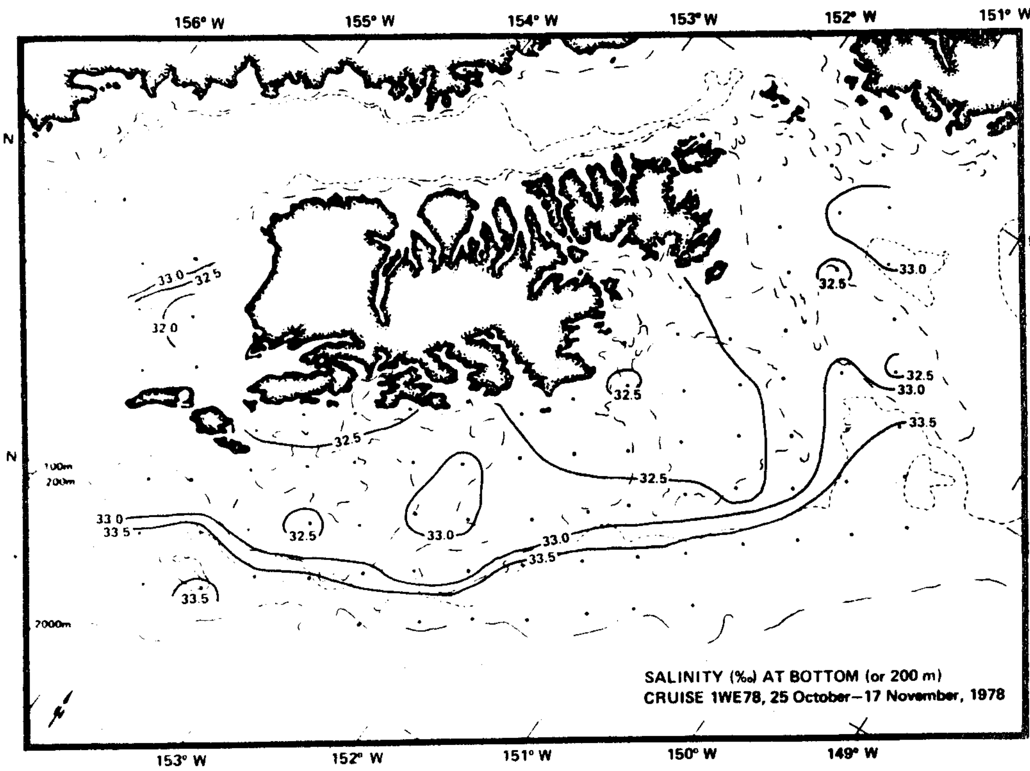


Figure 22.--Temperature in °C (top) and salinity in °/oo (bottom) at bottom (or 200 m), fall 1978.

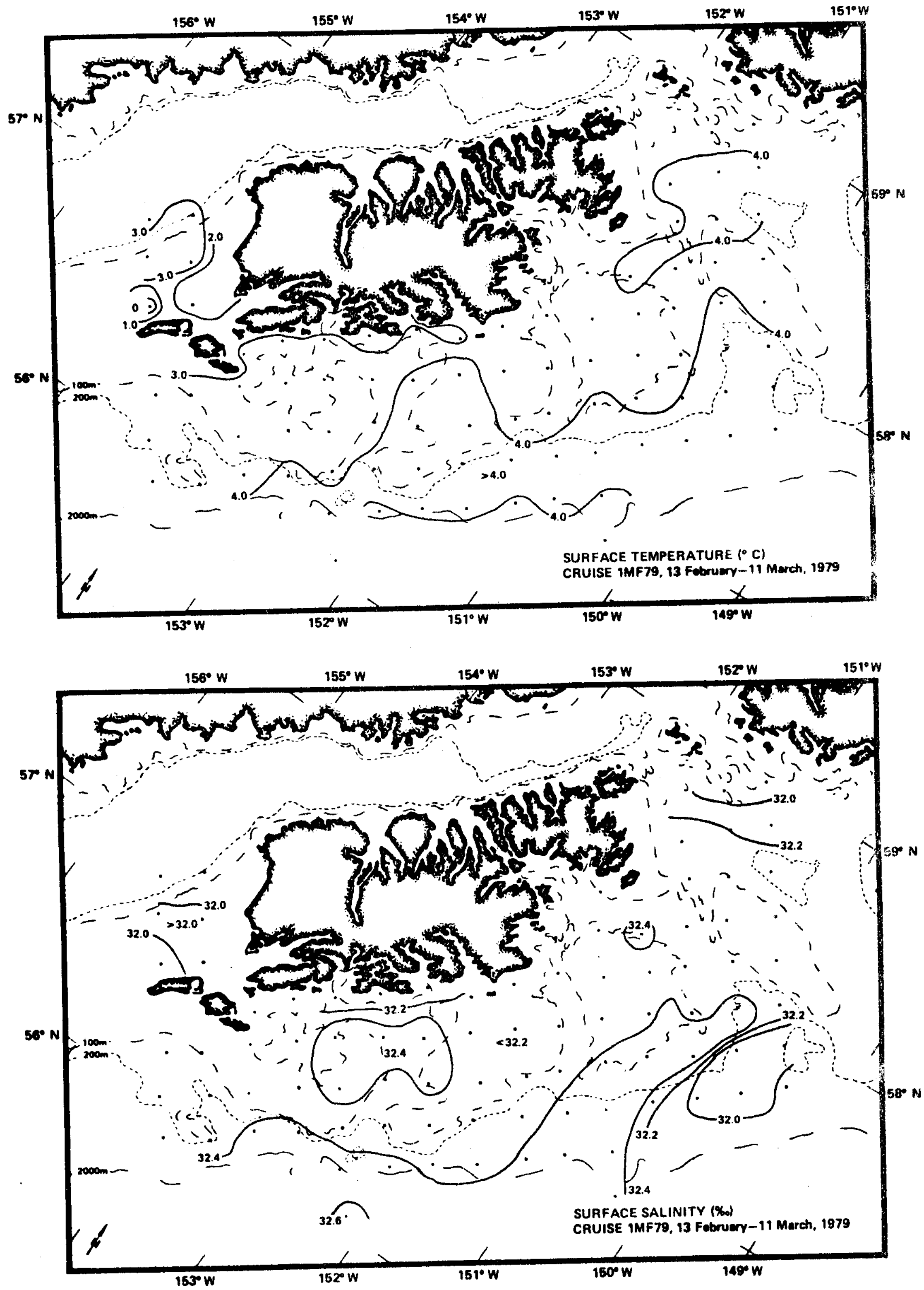


Figure 23.--Surface temperature in °C (top) and salinity in °/oo (bottom) winter 1979.

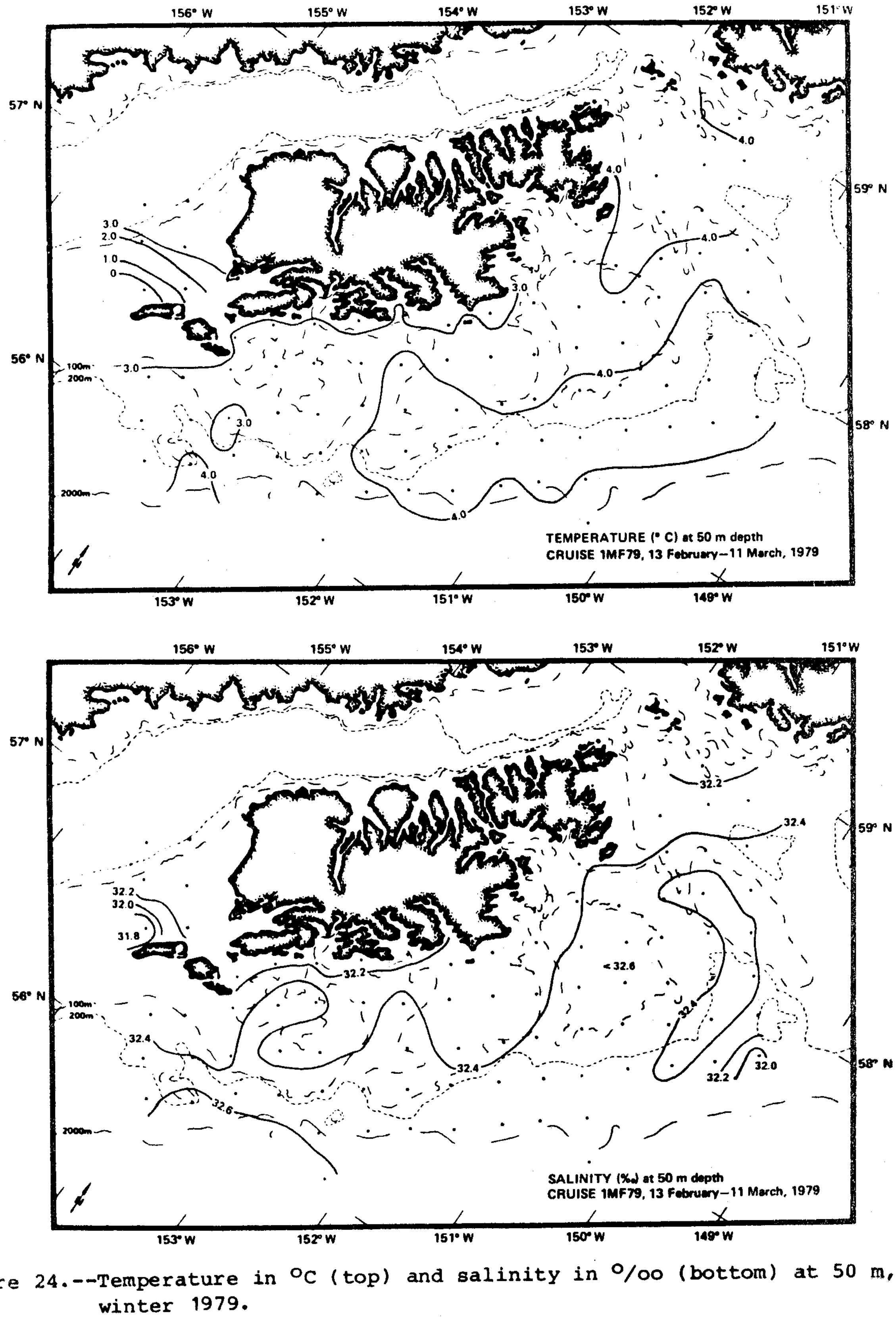


Figure 24.--Temperature in °C (top) and salinity in °/oo (bottom) at 50 m, winter 1979.

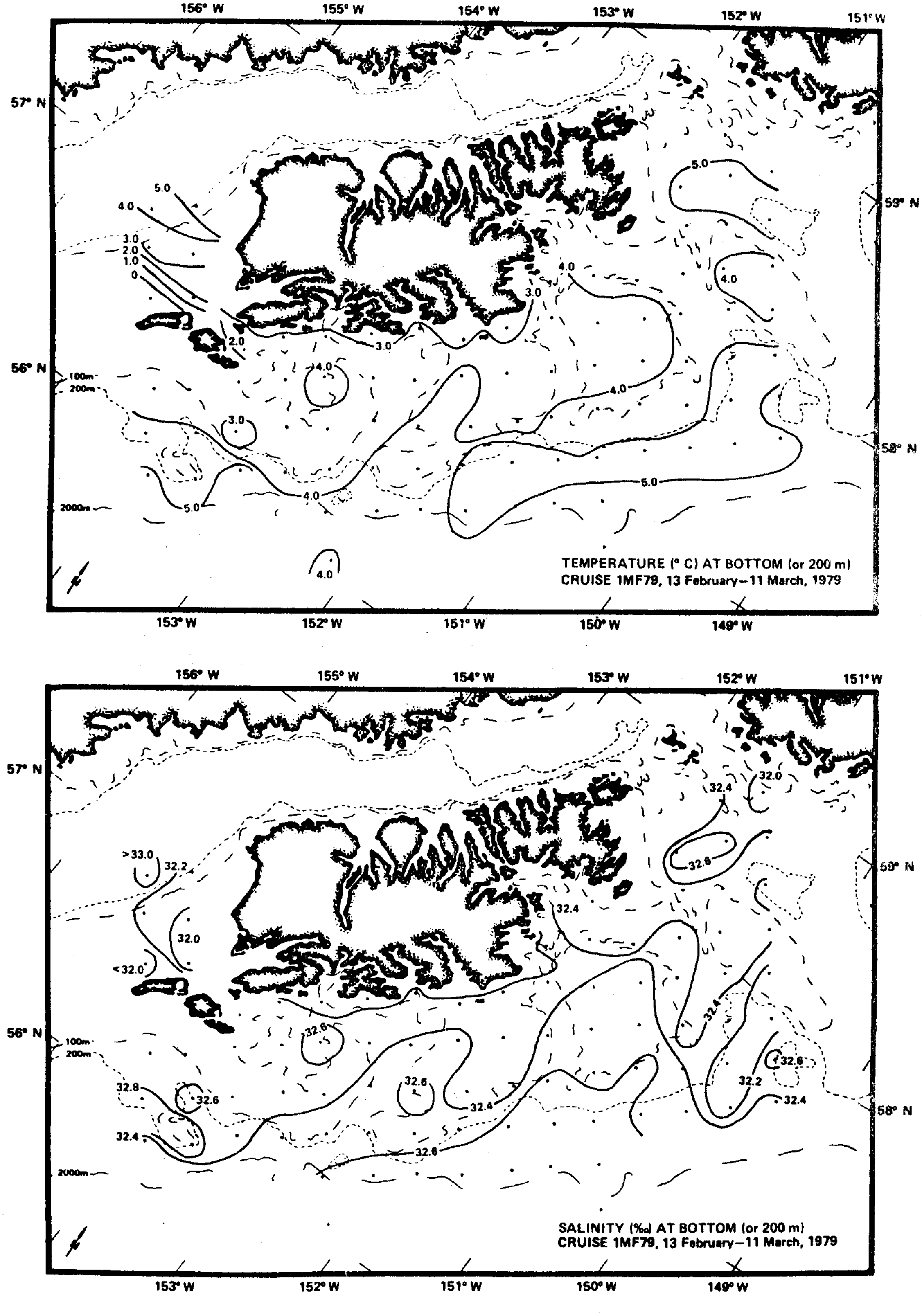


Figure 25.--Temperature in °C (top) and salinity in °/oo (bottom) at bottom (or 200 m), winter 1979.

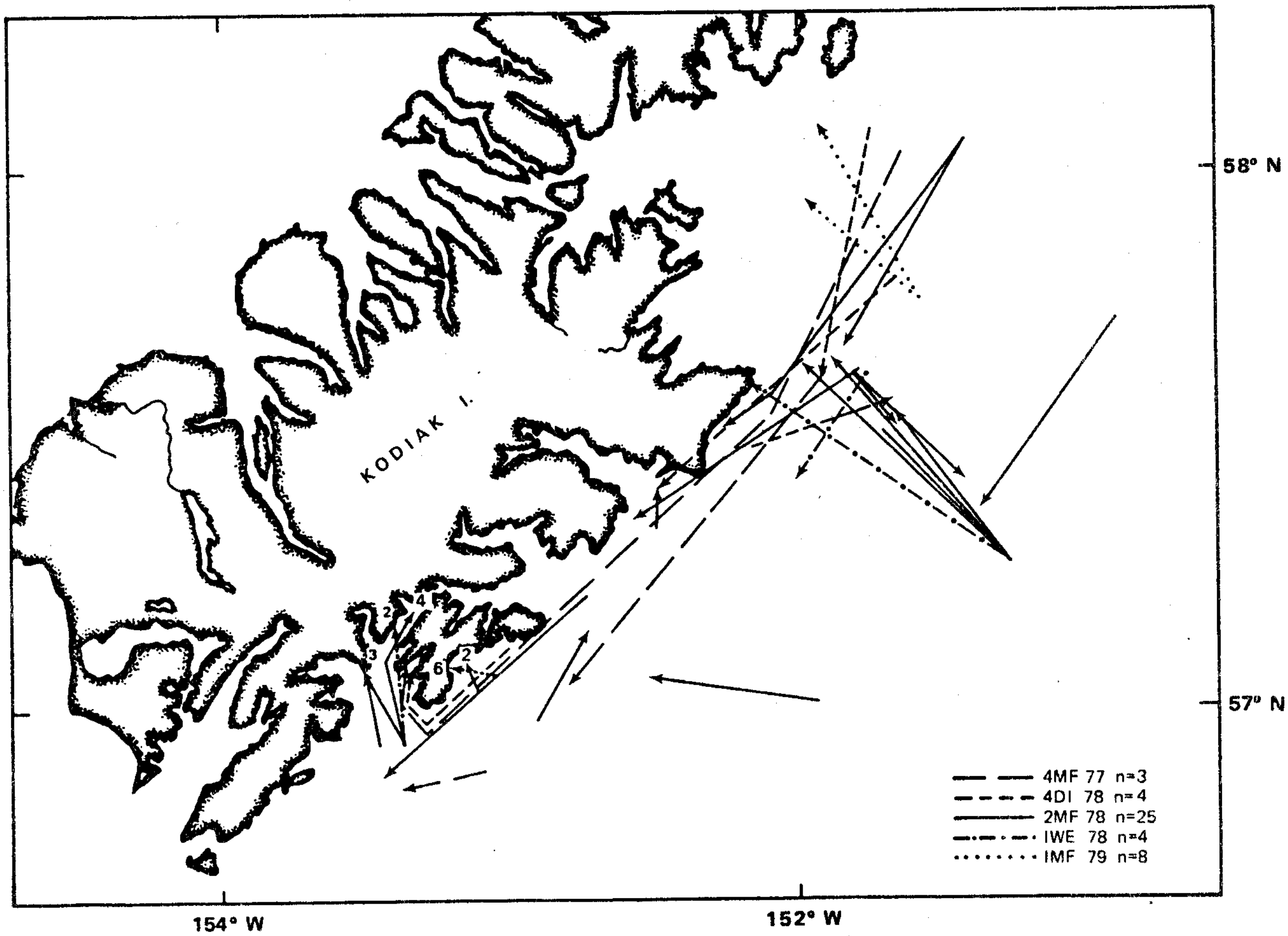


Figure 26.--Release and recovery locations of seabed drifters deployed in the Kodiak Island area during OCSEAP plankton cruises.

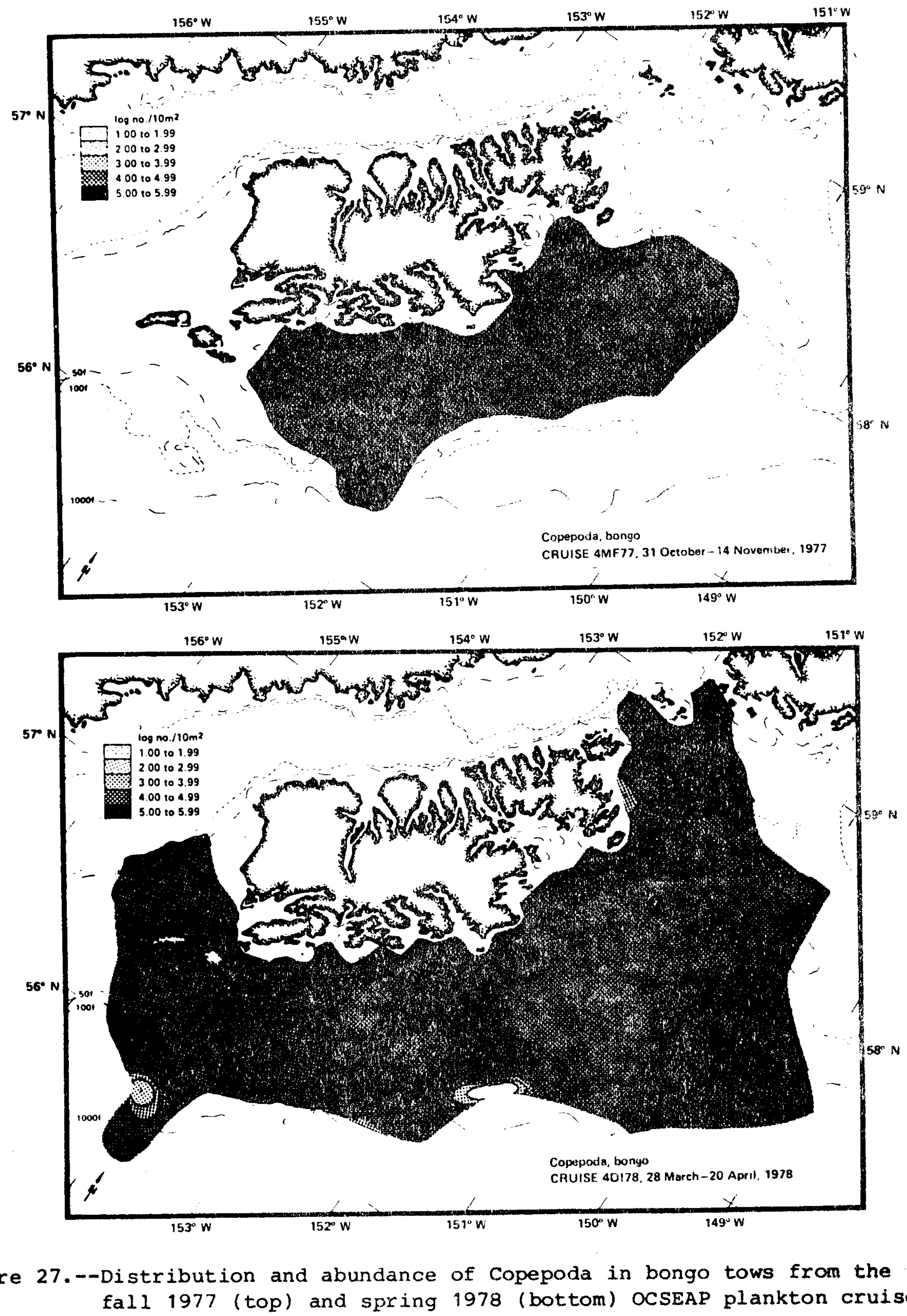
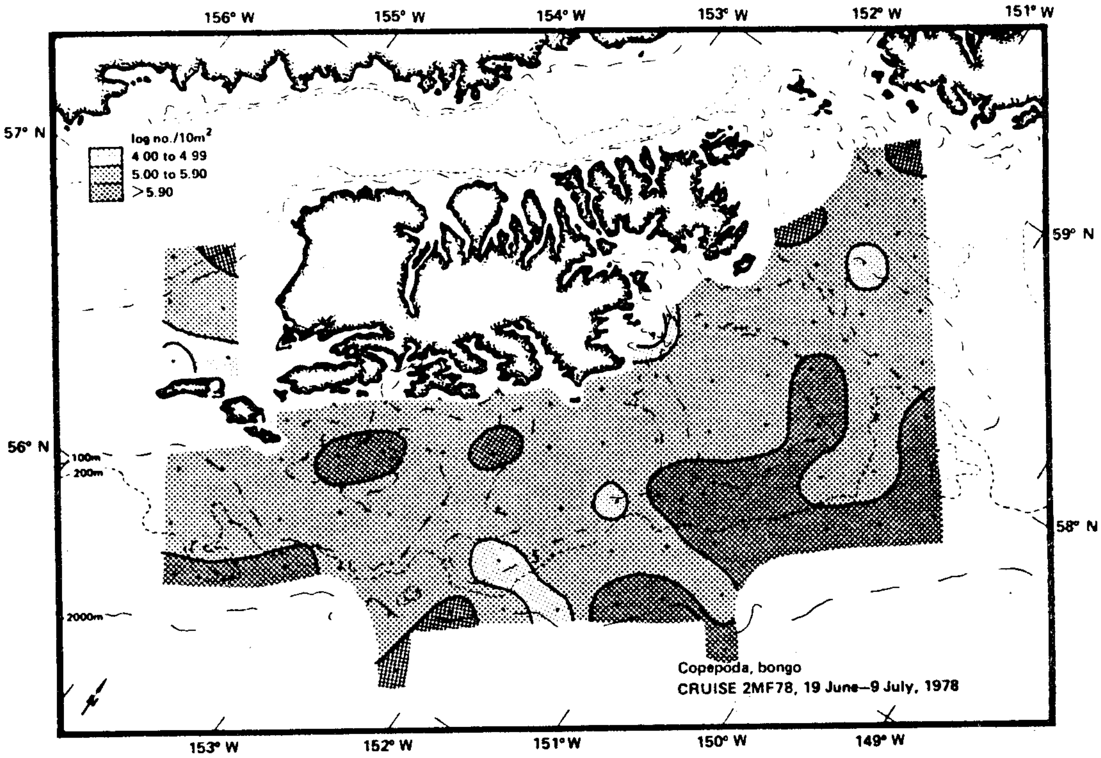


Figure 27.--Distribution and abundance of Copepoda in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.



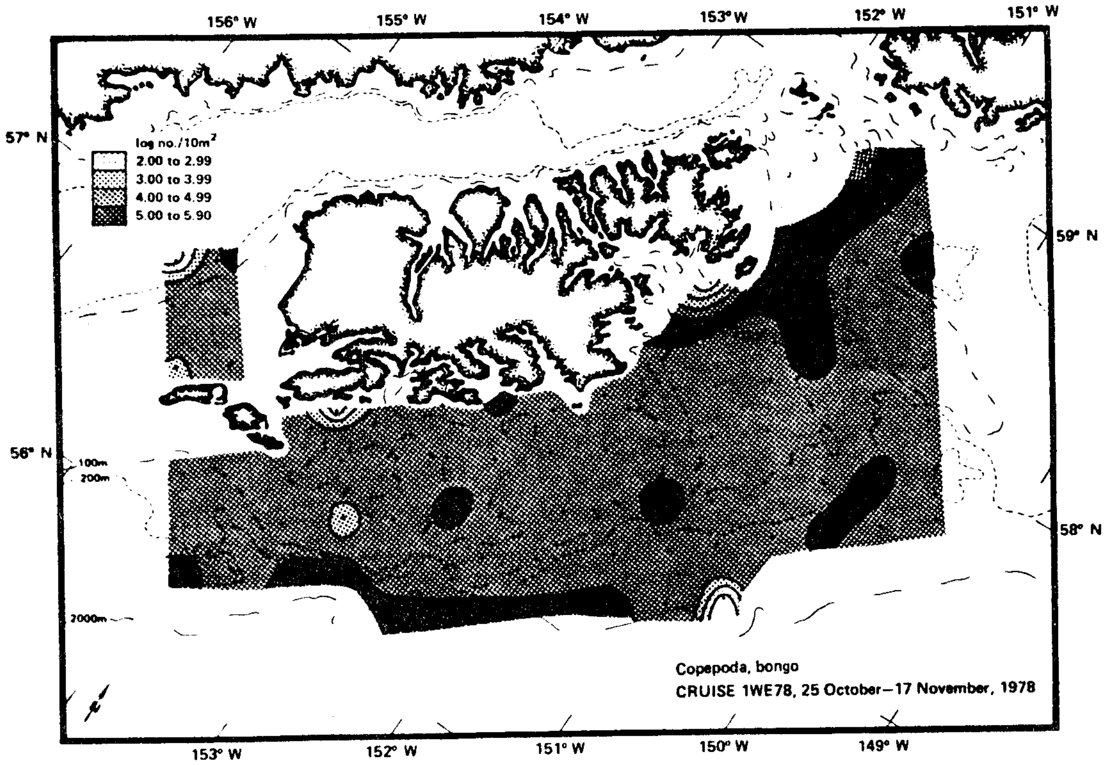


Figure 28.--Distribution and abundance of Copepoda in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

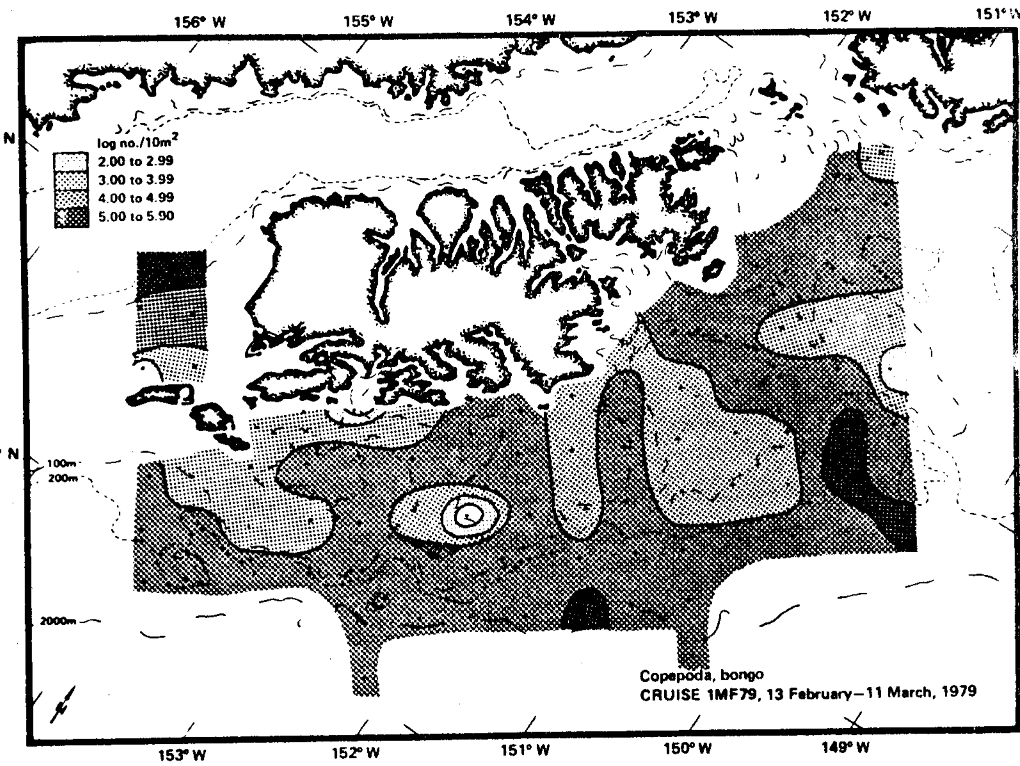
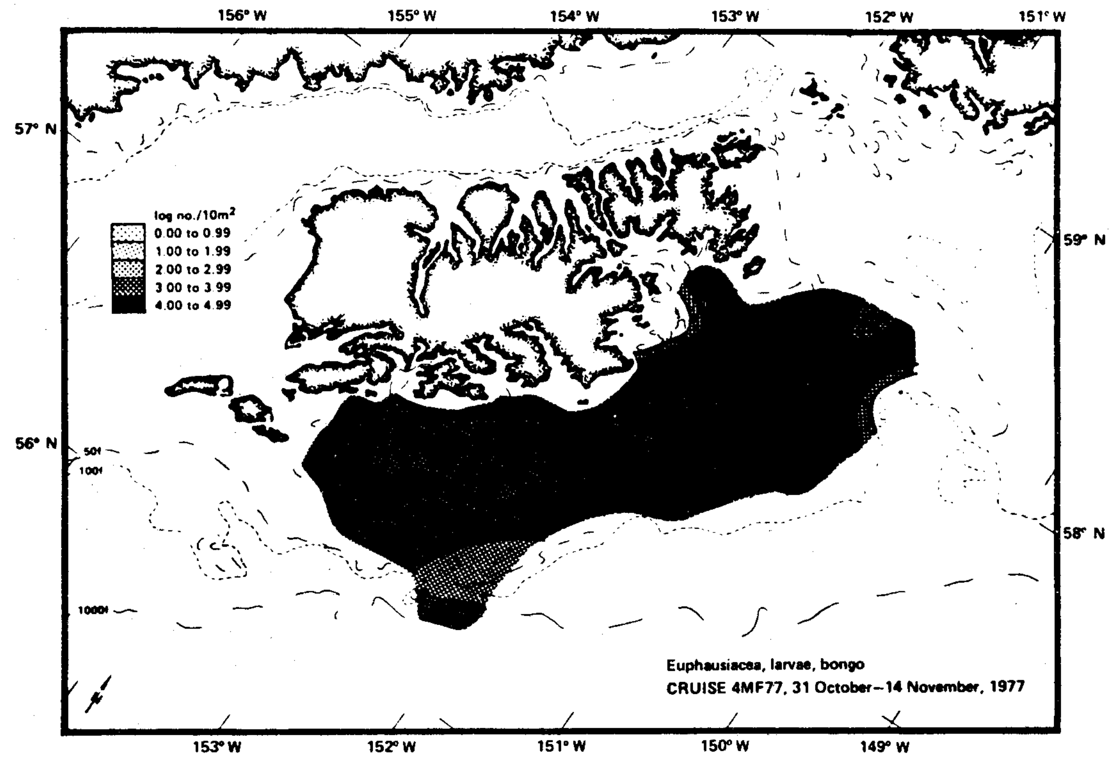


Figure 29.--Distribution and abundance of Copepoda in bongo tows from the winter 1979 OCSEAP plankton cruise.



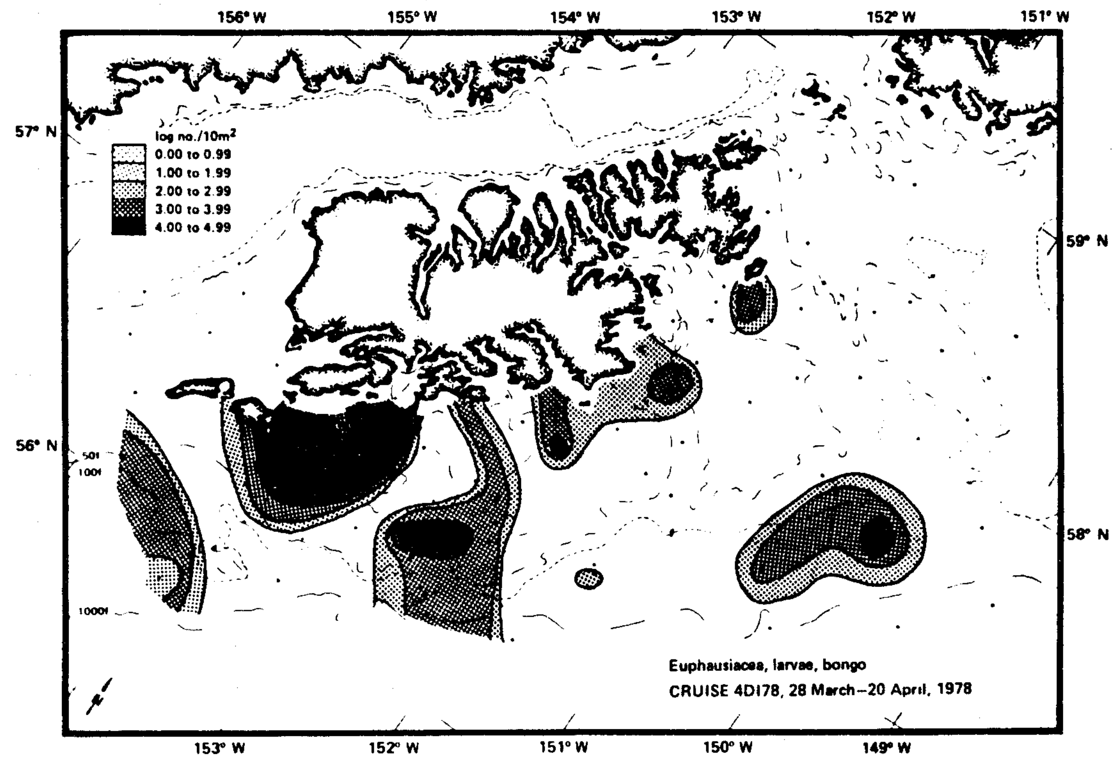


Figure 30.--Distribution and abundance of Euphausiacea larvae in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.

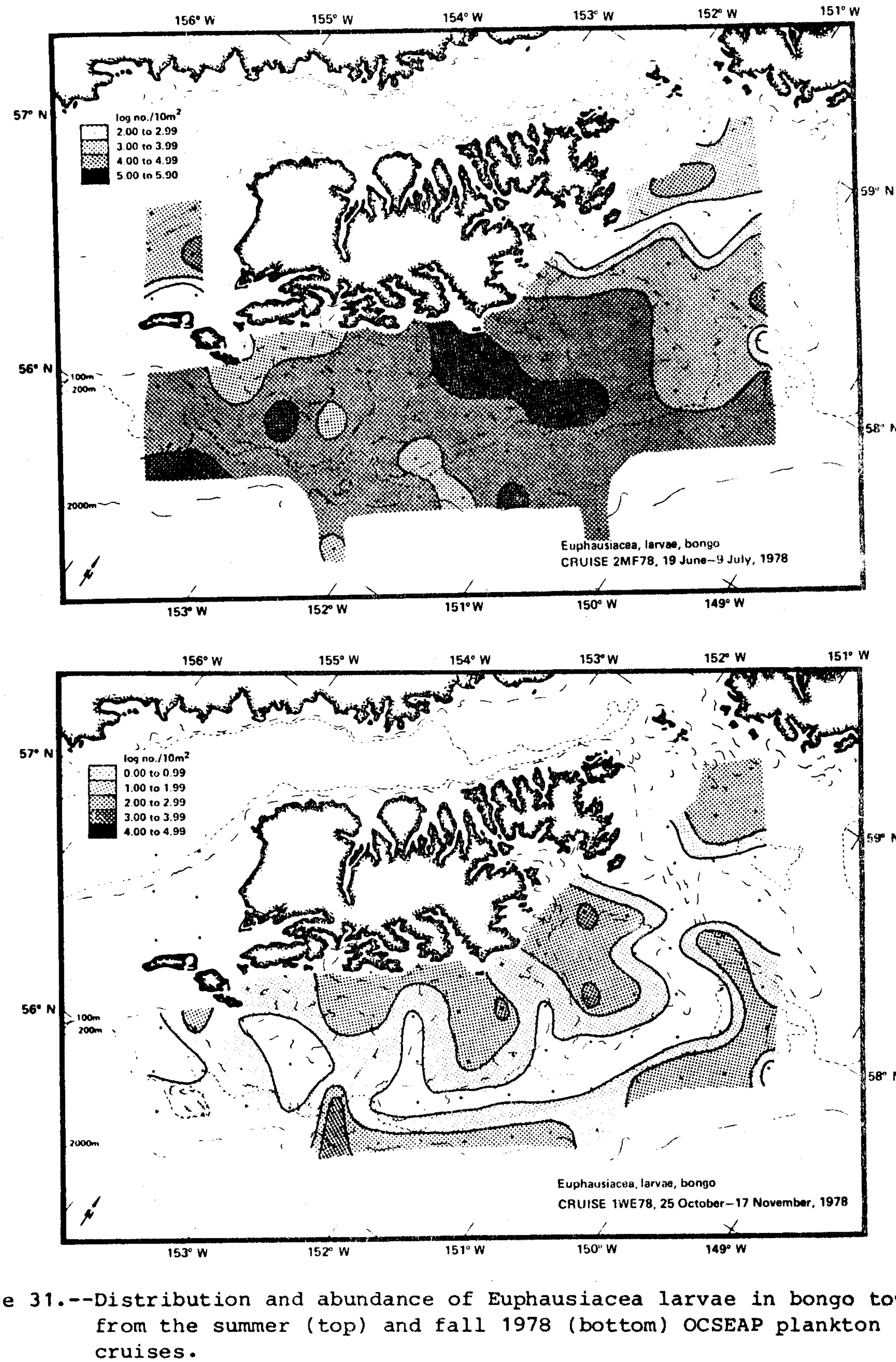


Figure 31.--Distribution and abundance of Euphausiacea larvae in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

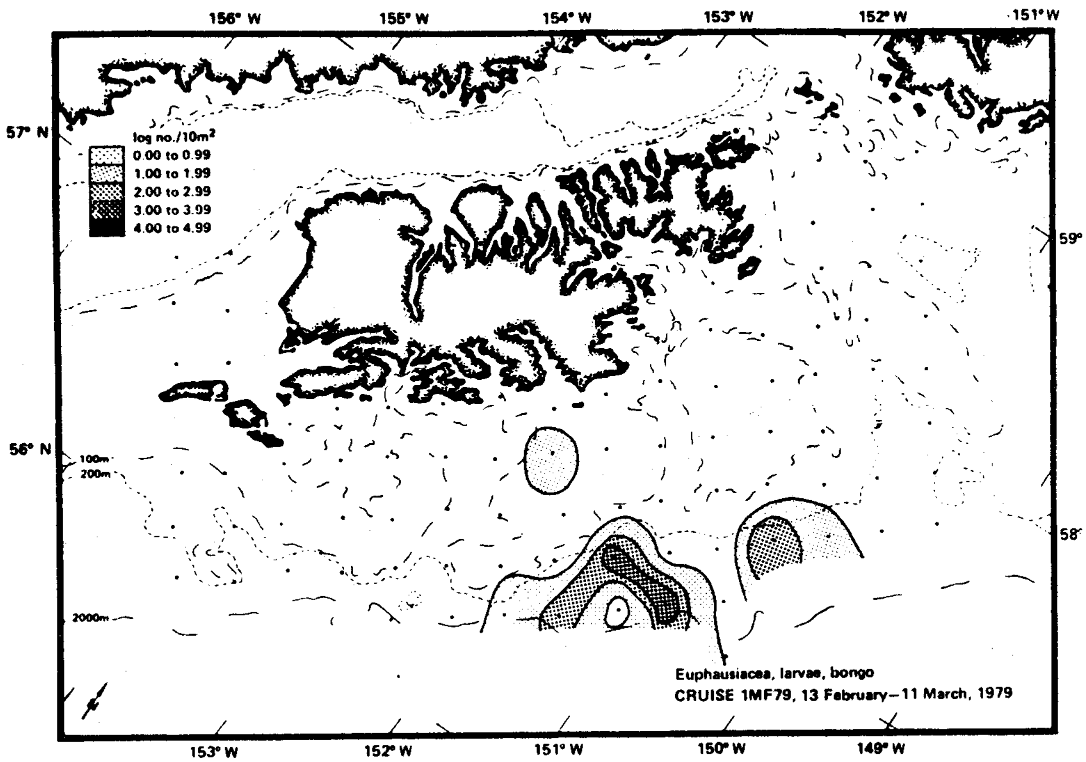
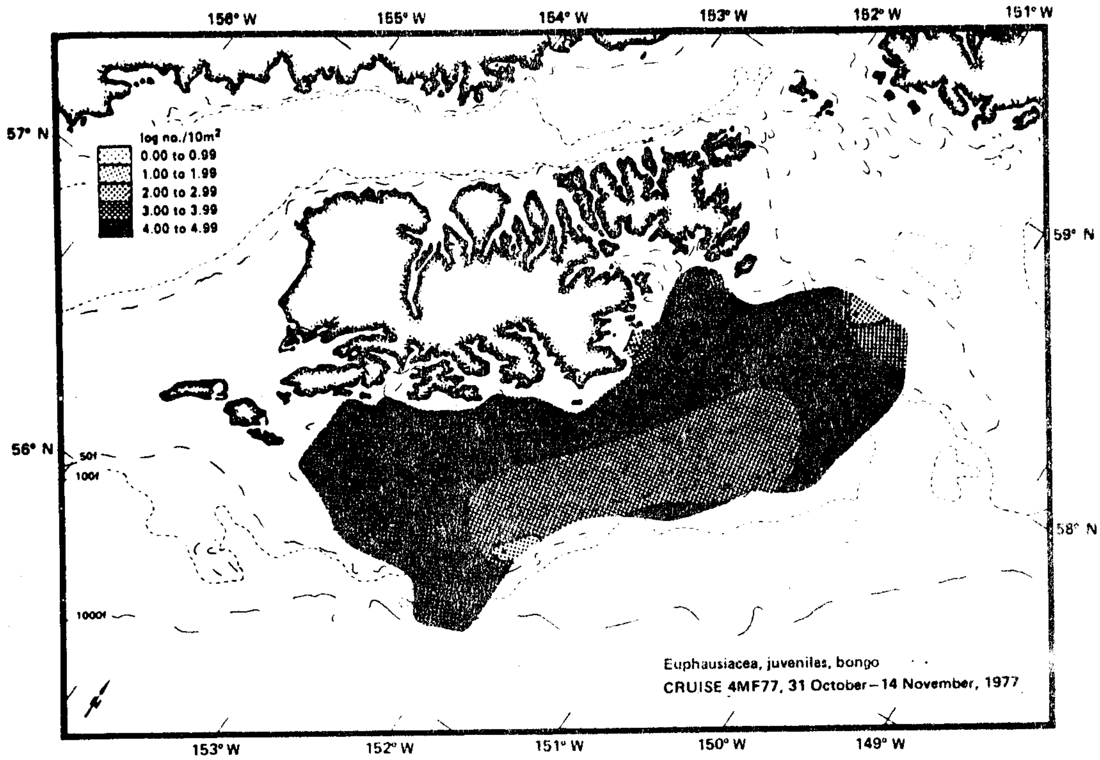


Figure 32.--Distribution and abundance of Euphausiacea larvae in bongo tows from the winter 1979 OCSEAP plankton cruise.



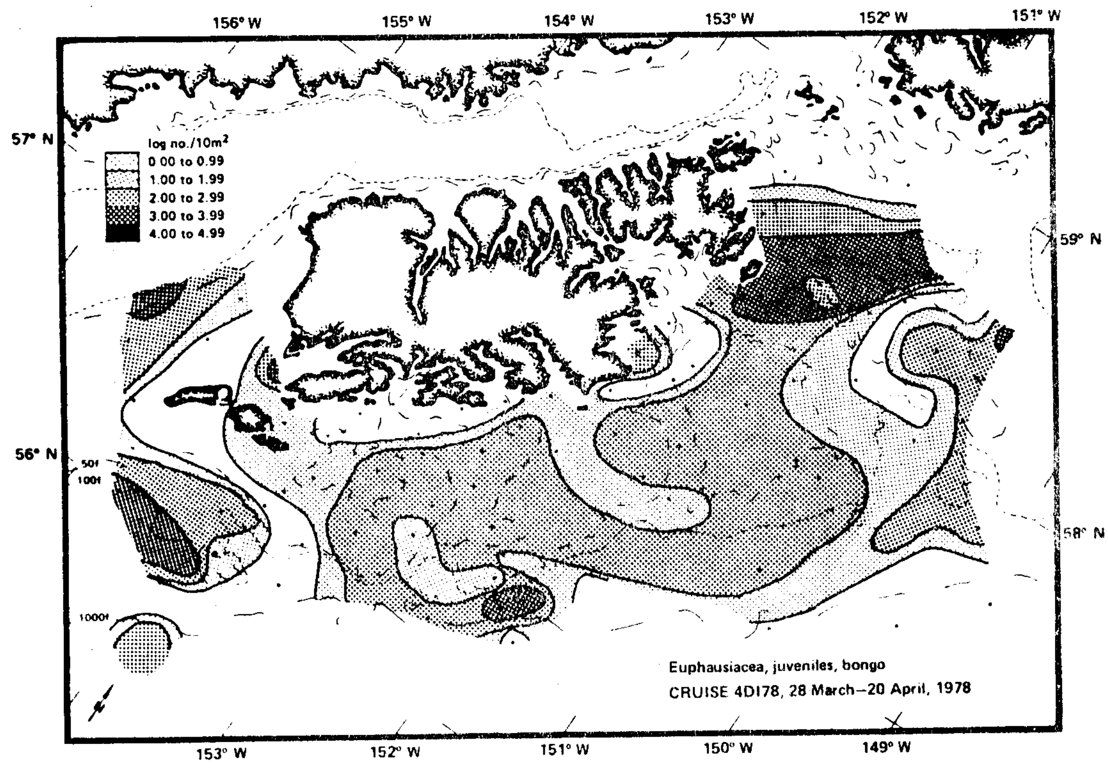
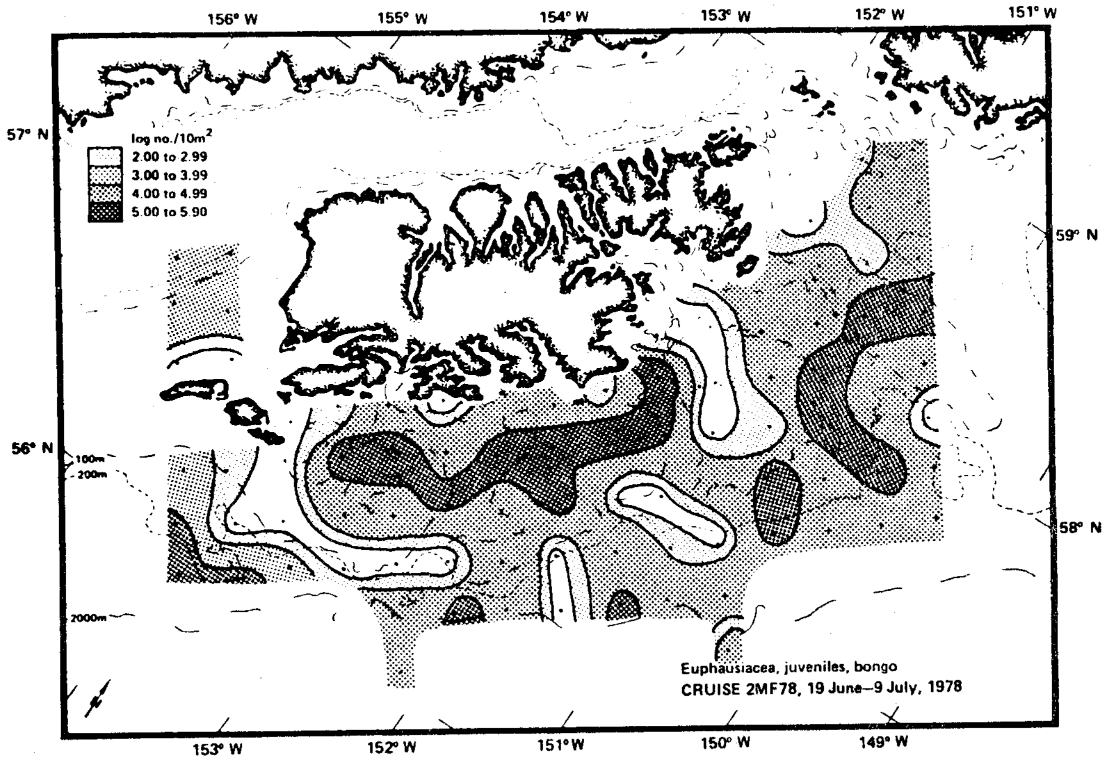


Figure 33.--Distribution and abundance of Euphausiacea juveniles in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.



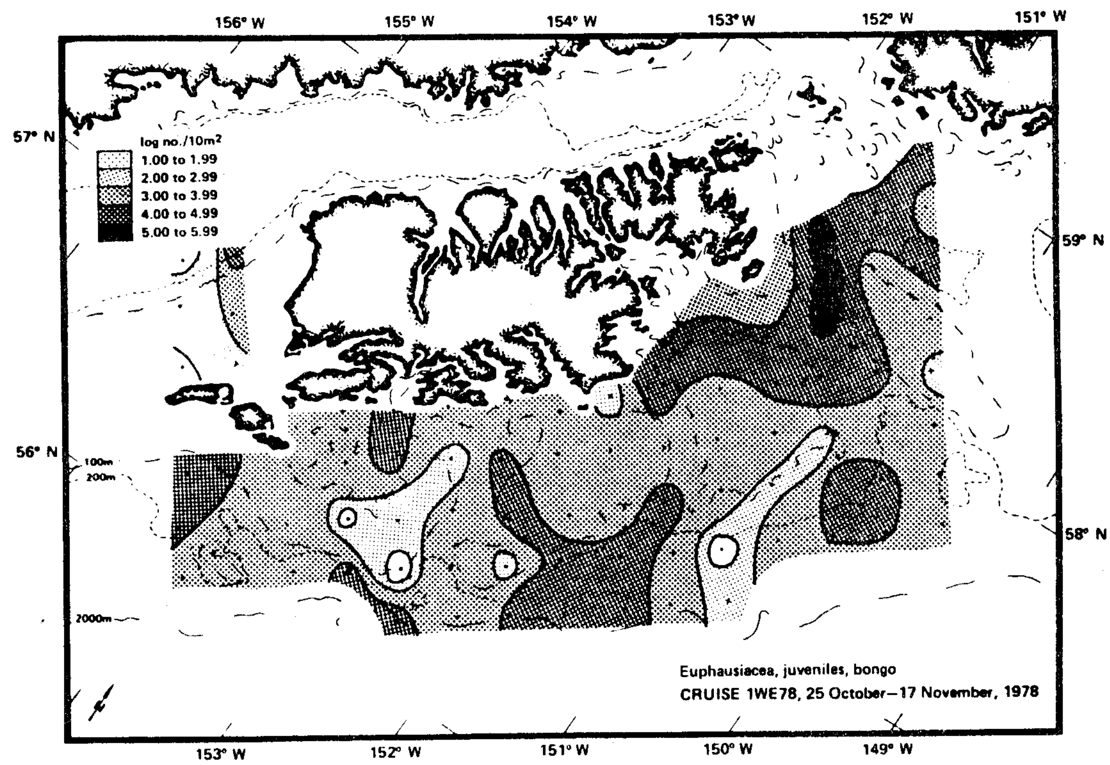


Figure 34.--Distribution and abundance of Euphausiacea juveniles in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

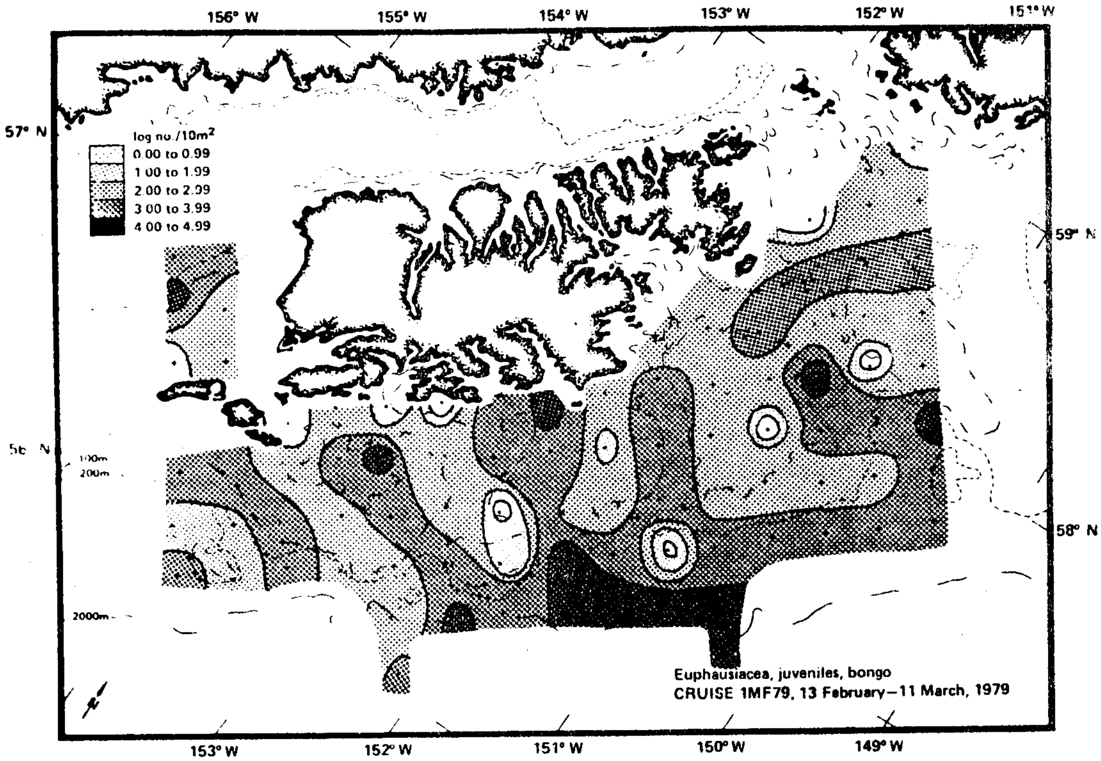


Figure 35.--Distribution and abundance of Euphausiacea juveniles in bongo tows from the winter 1979 OCSEAP plankton cruise.

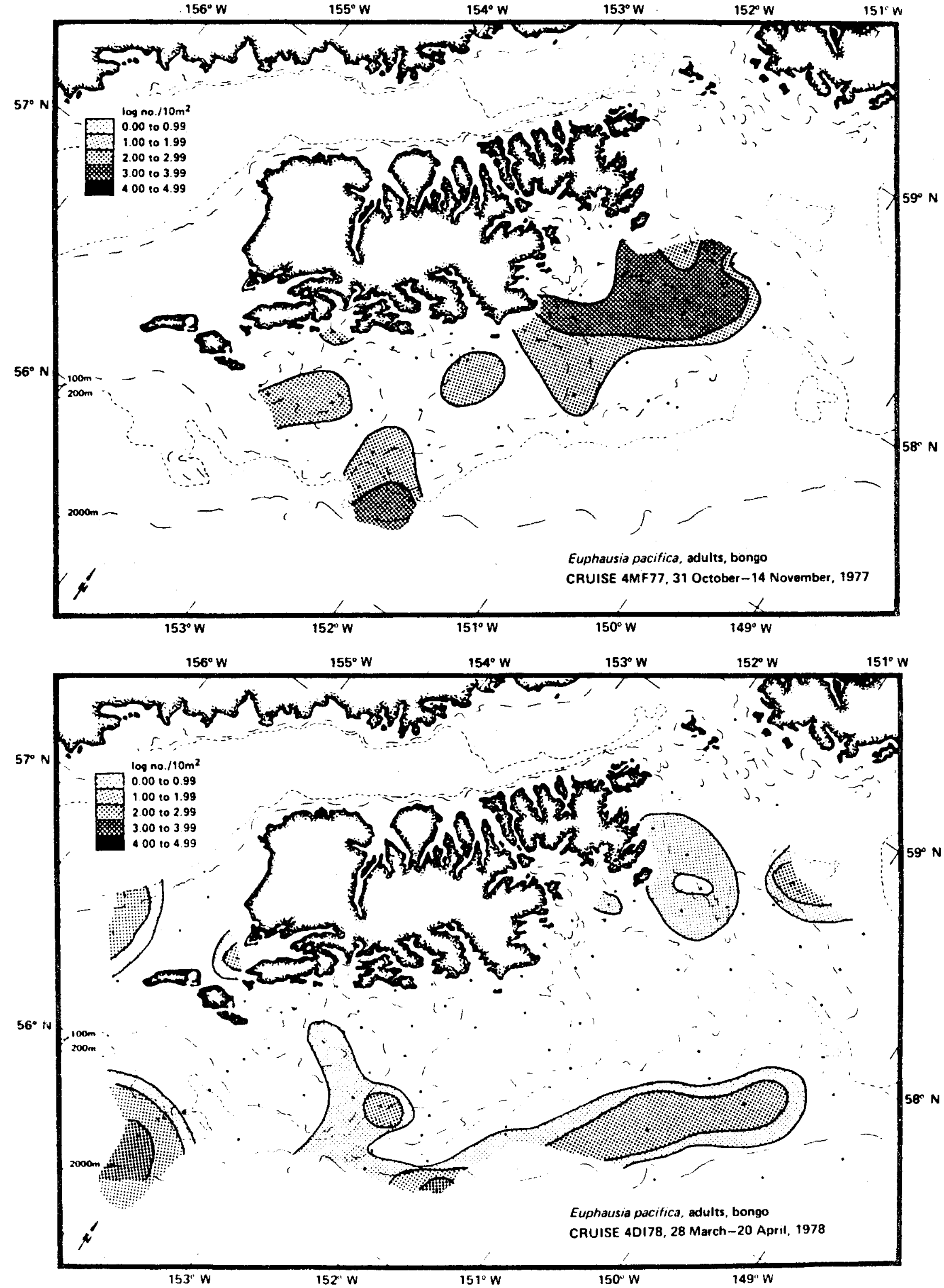
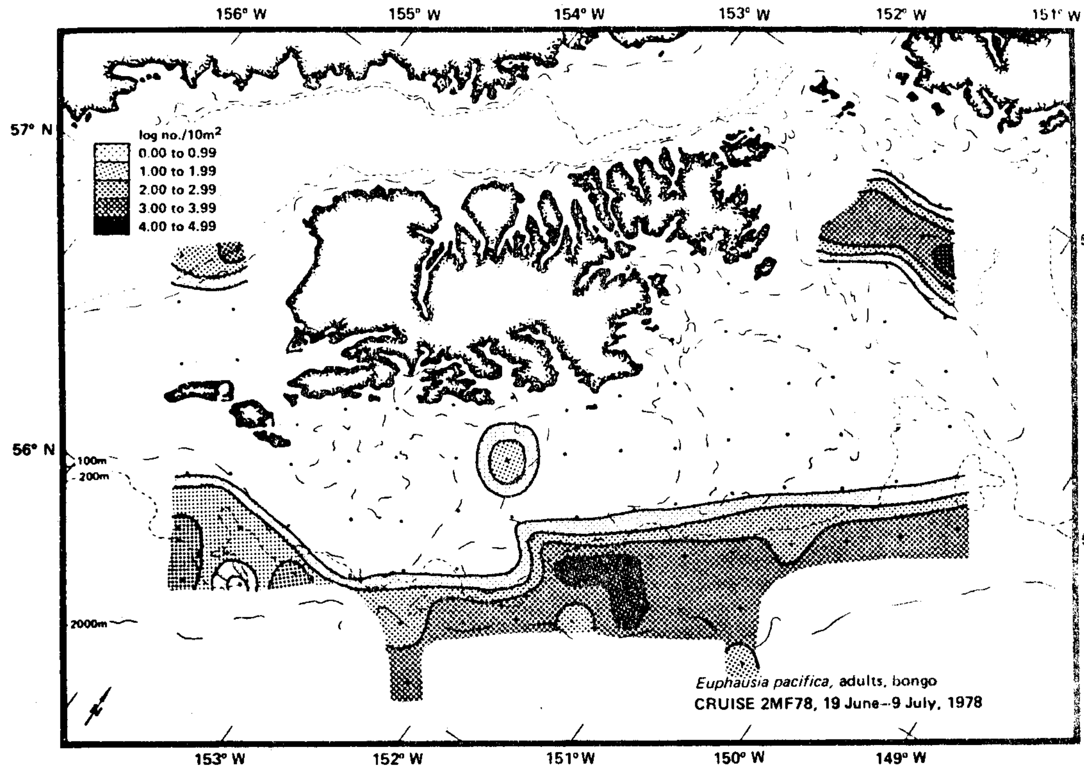


Figure 36.--Distribution and abundance of Euphausia pacifica in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.



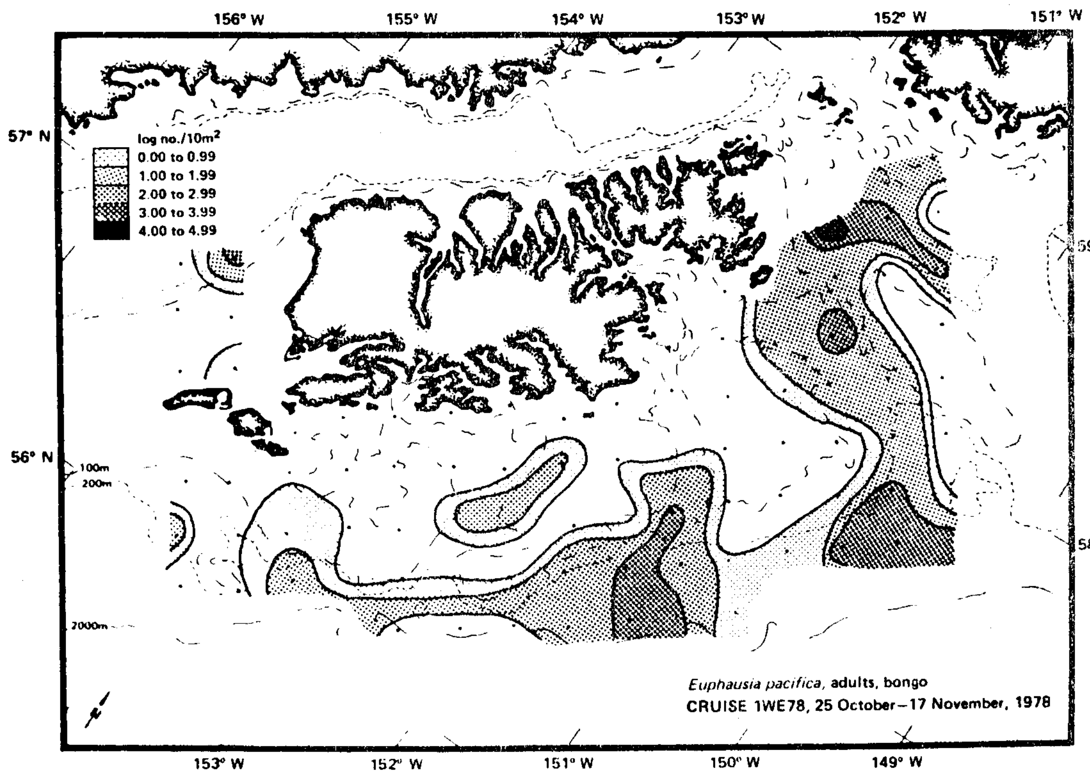


Figure 37.--Distribution and abundance of Euphausia pacifica in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

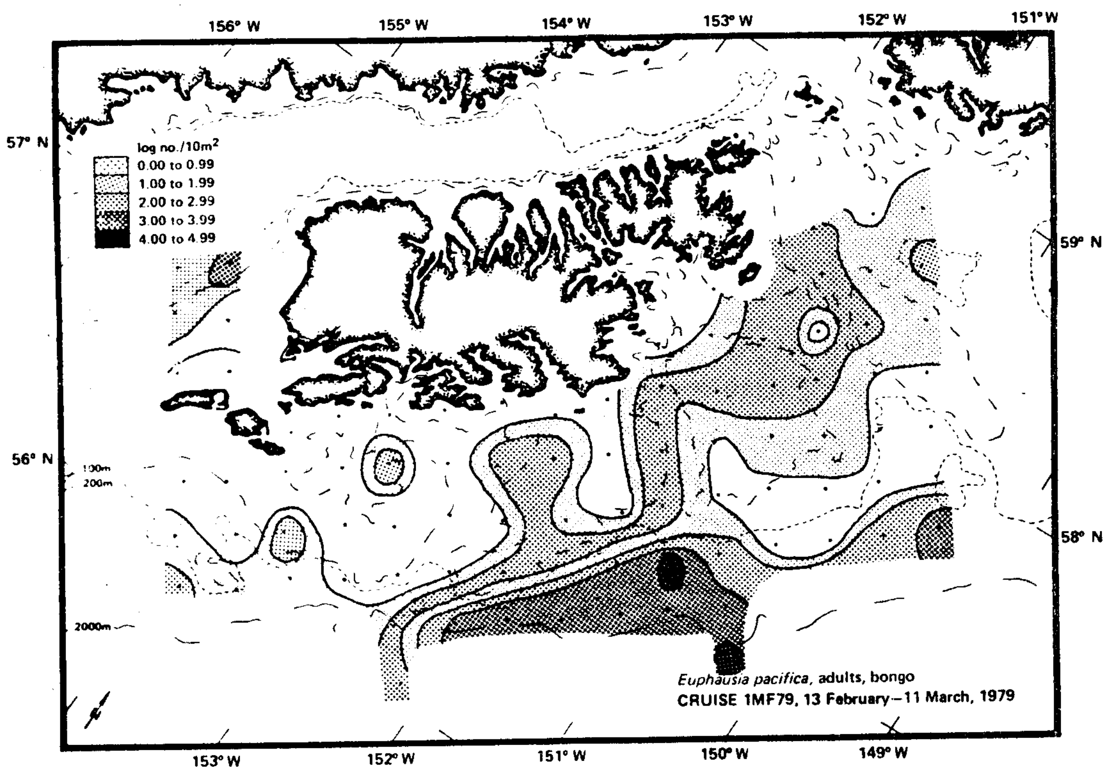


Figure 38.--Distribution and abundance of Euphausia pacifica in bongo tows from the winter 1979 OCSEAP plankton cruise.

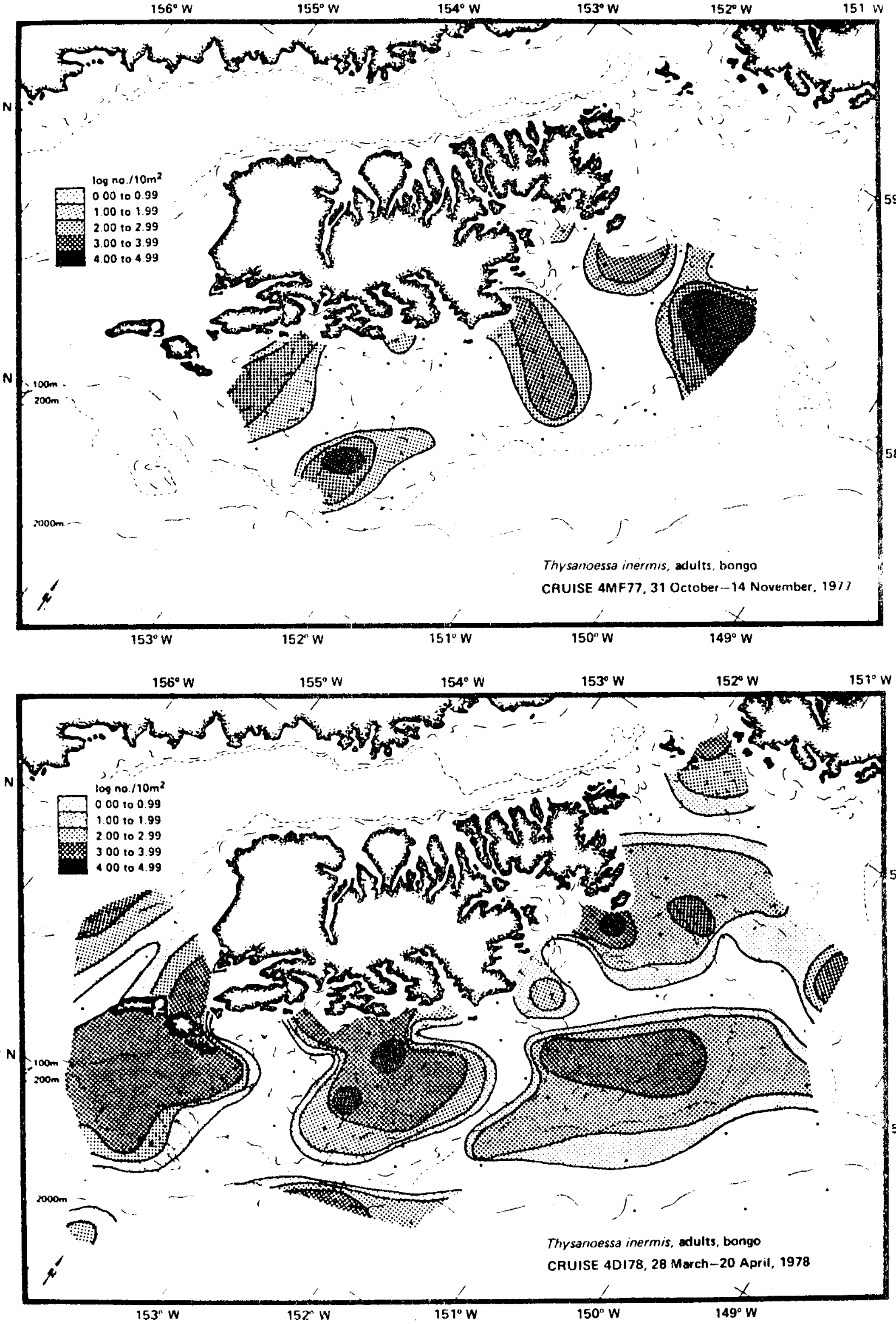
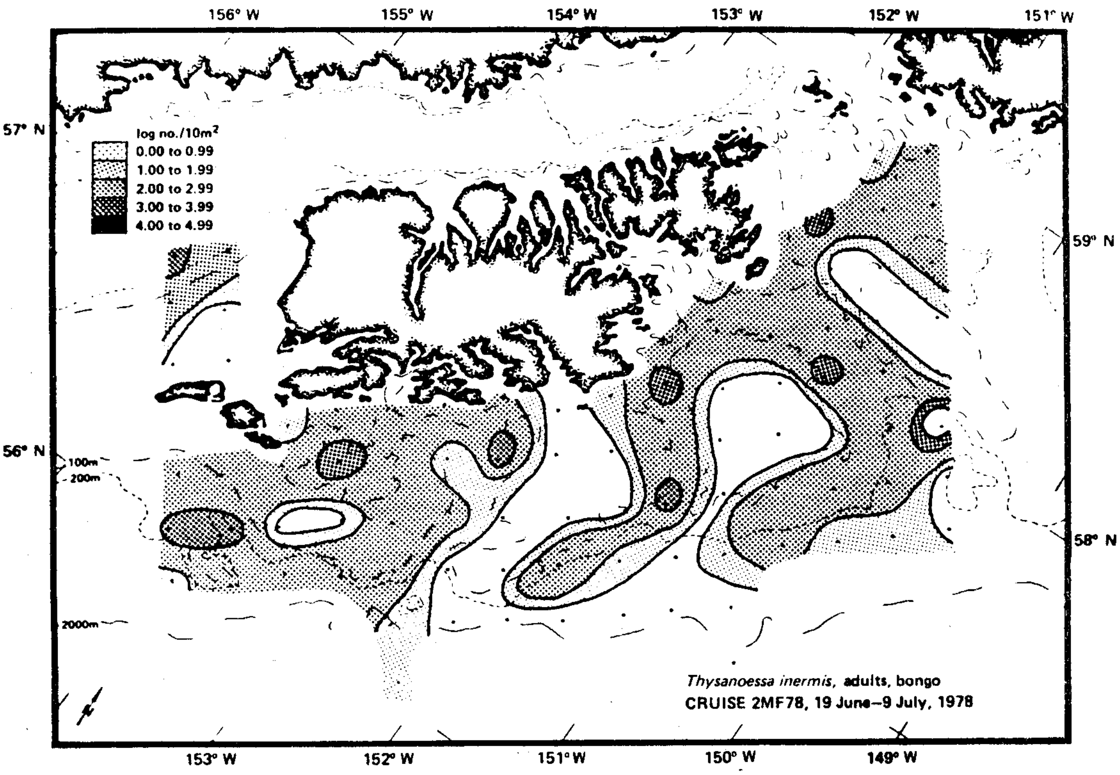


Figure 39.--Distribution and abundance of Thysanoessa inermis in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.



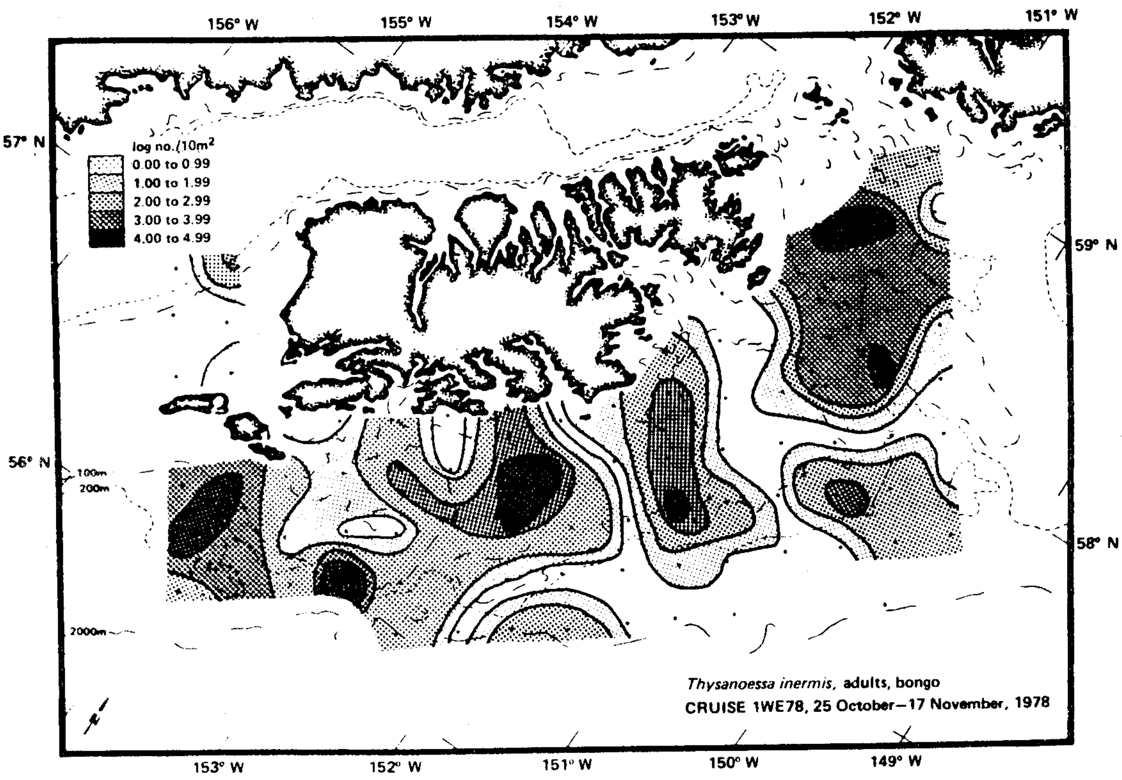


Figure 40.--Distribution and abundance of Thysanoessa inermis in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

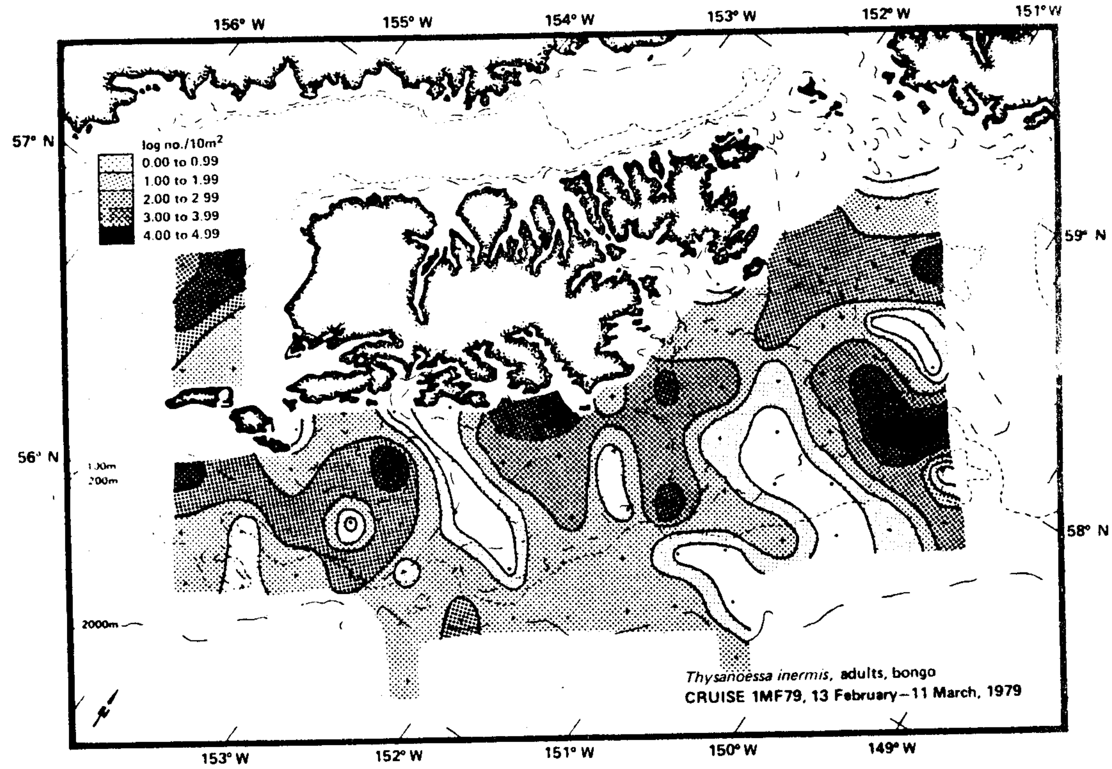
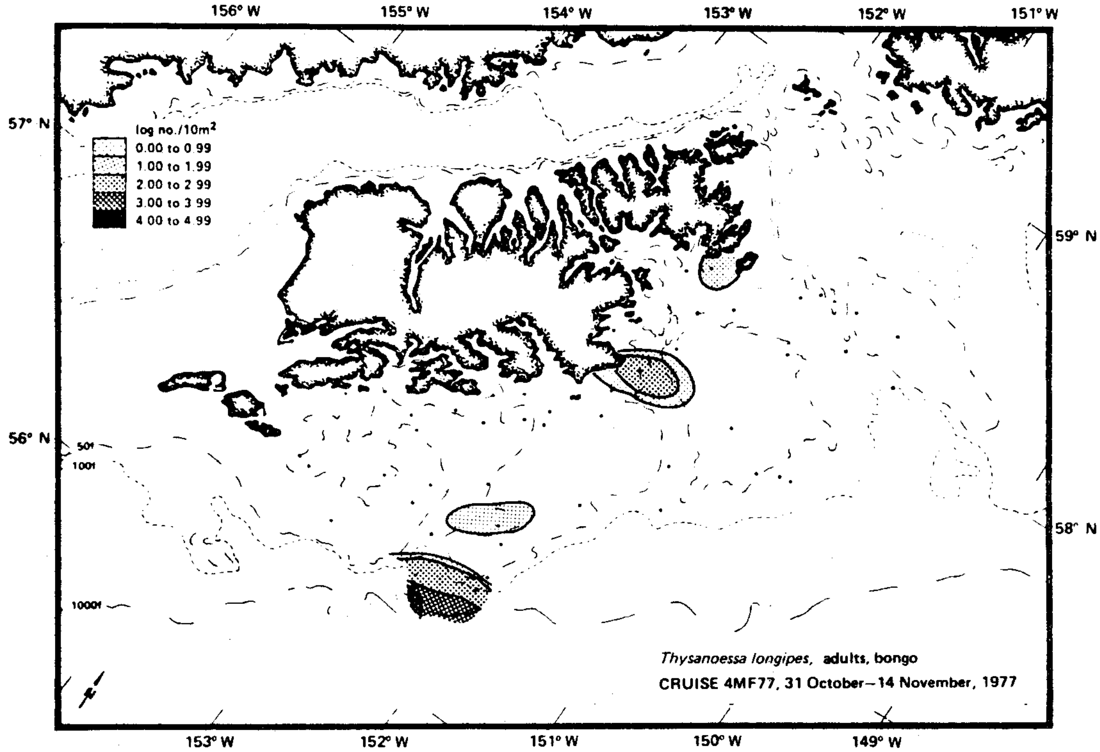


Figure 41.--Distribution and abundance of Thysanoessa inermis in bongo tows from the winter 1979 OCSEAP plankton cruise.



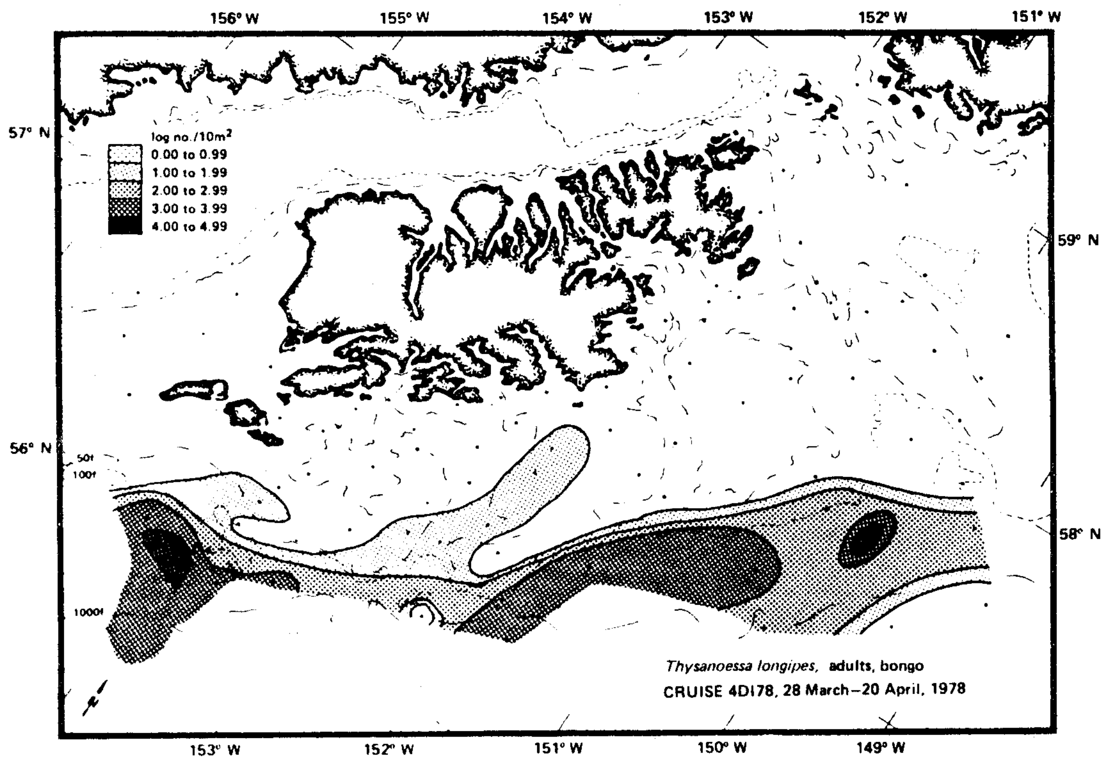


Figure 42.--Distribution and abundance of Thysanoessa longipes in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.

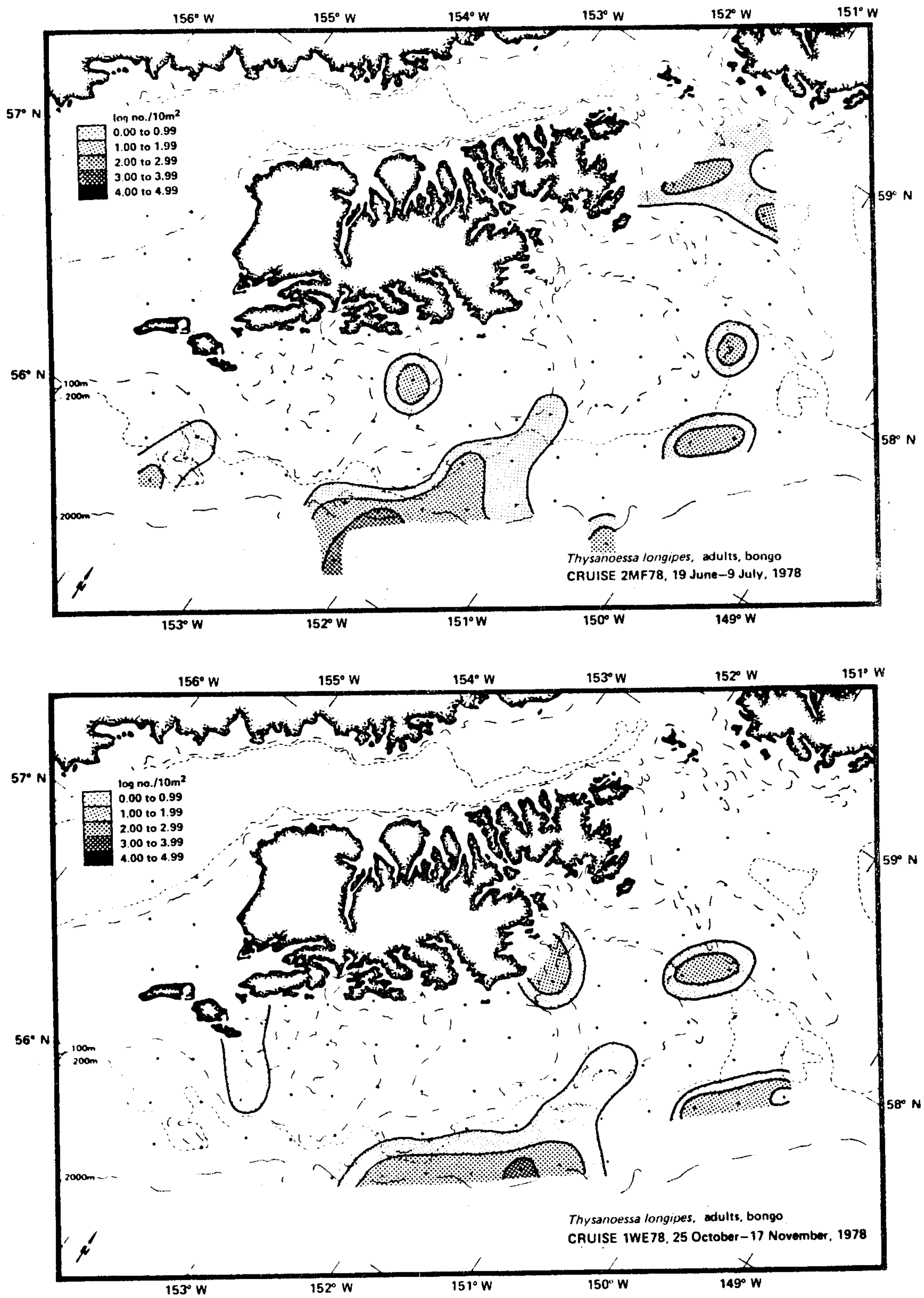


Figure 43.--Distribution and abundance of Thysanoessa longipes in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

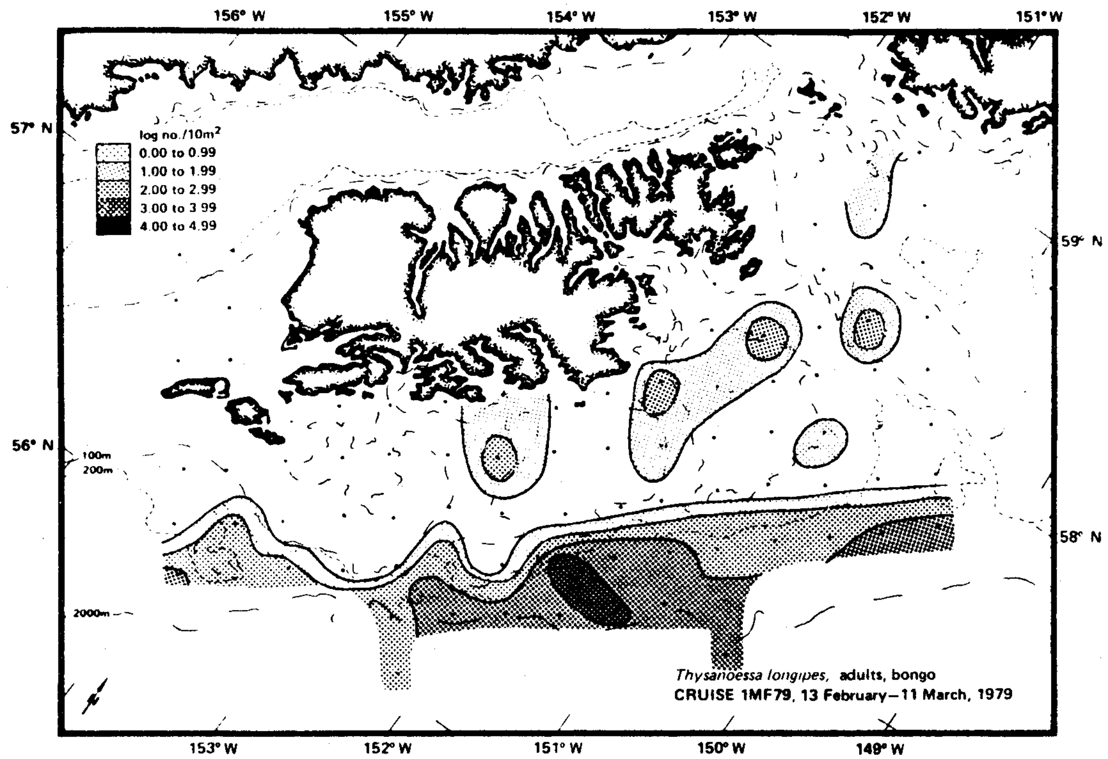


Figure 44.--Distribution and abundance of Thysanoessa longipes in bongo tows from the winter 1979 OCSEAP plankton cruise.

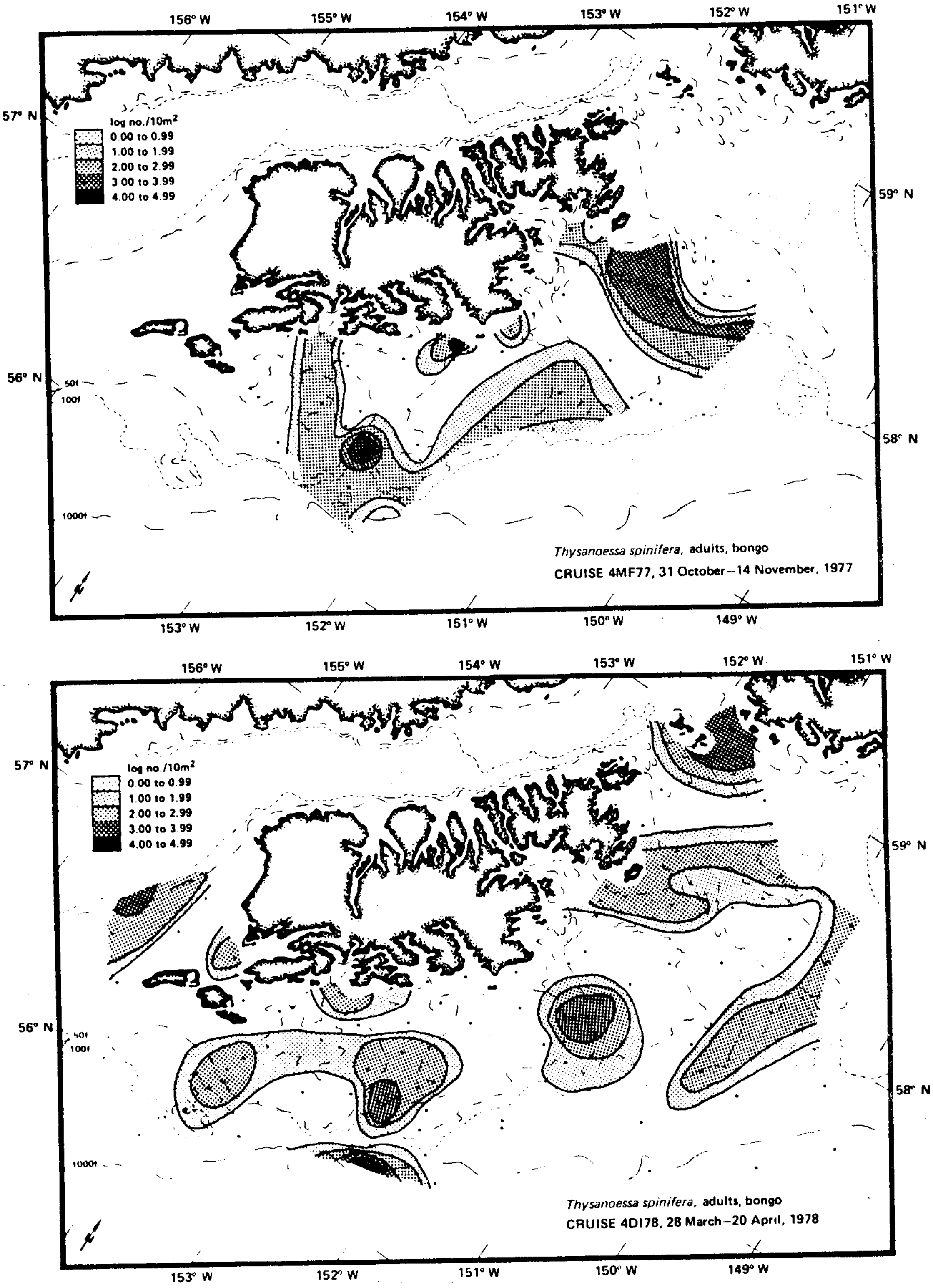
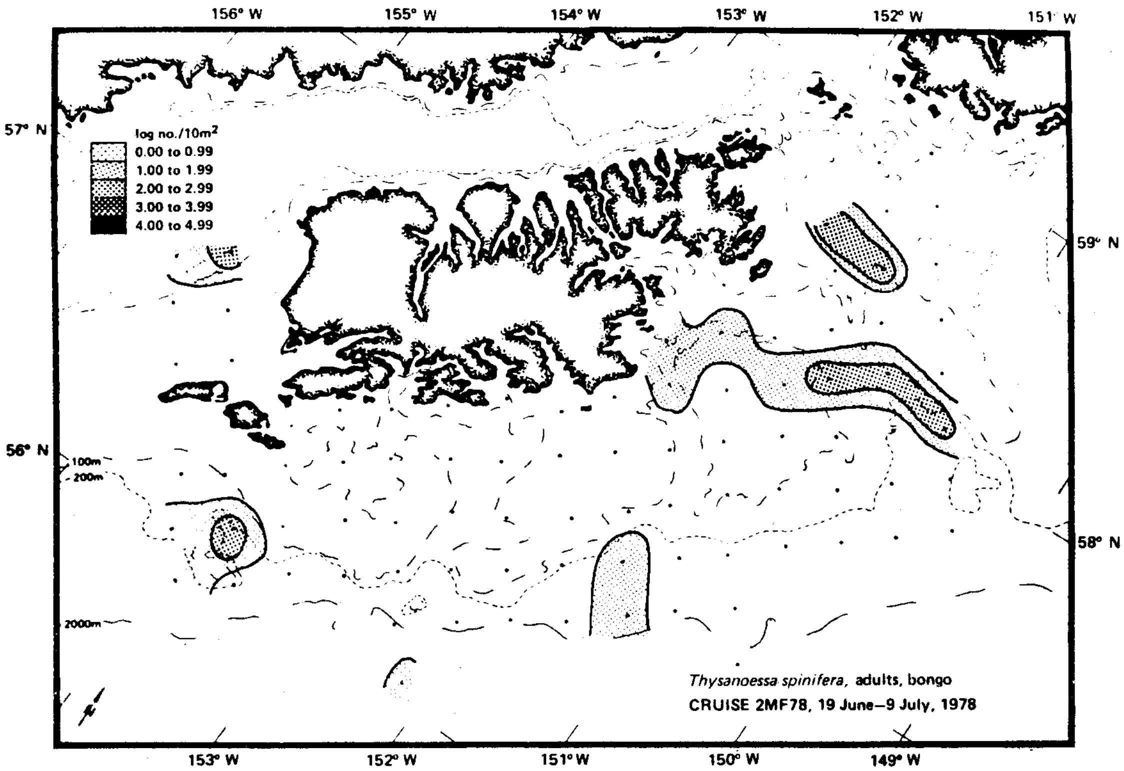


Figure 45.--Distribution and abundance of Thysanoessa spinifera in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.



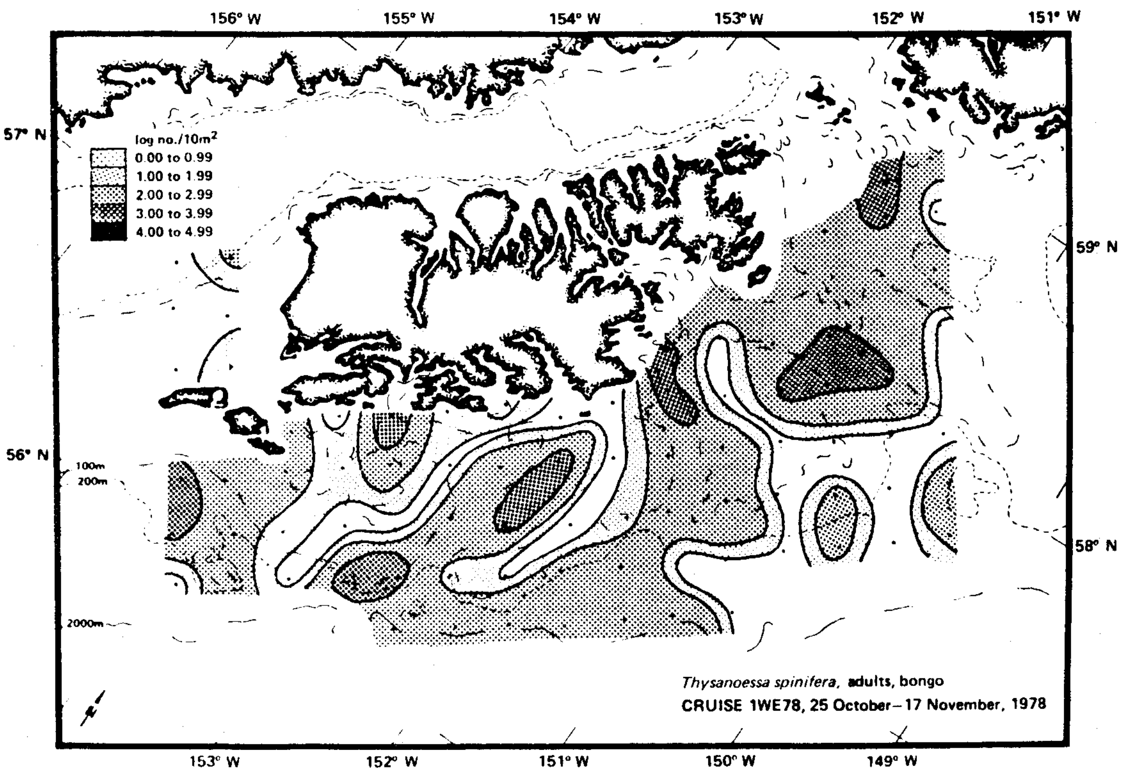


Figure 46.--Distribution and abundance of Thysanoessa spinifera in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

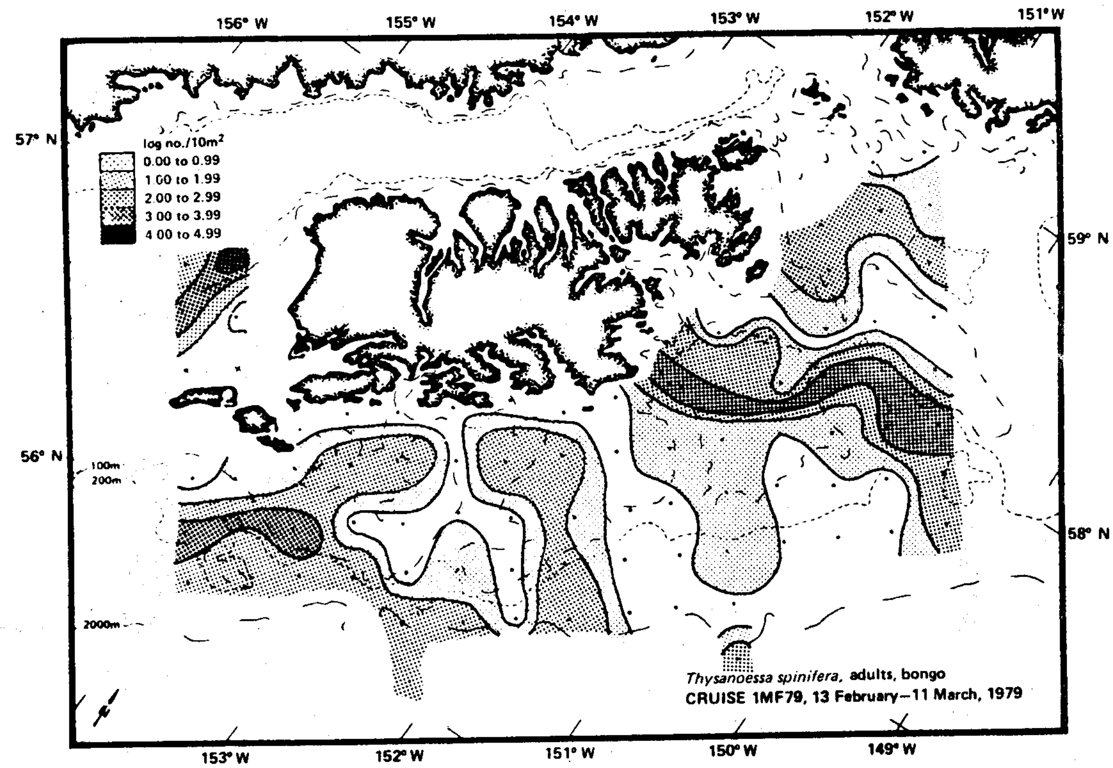


Figure 47.--Distribution and abundance of Thysanoessa spinifera in bongo tows from the winter 1979 OCSEAP plankton cruise.

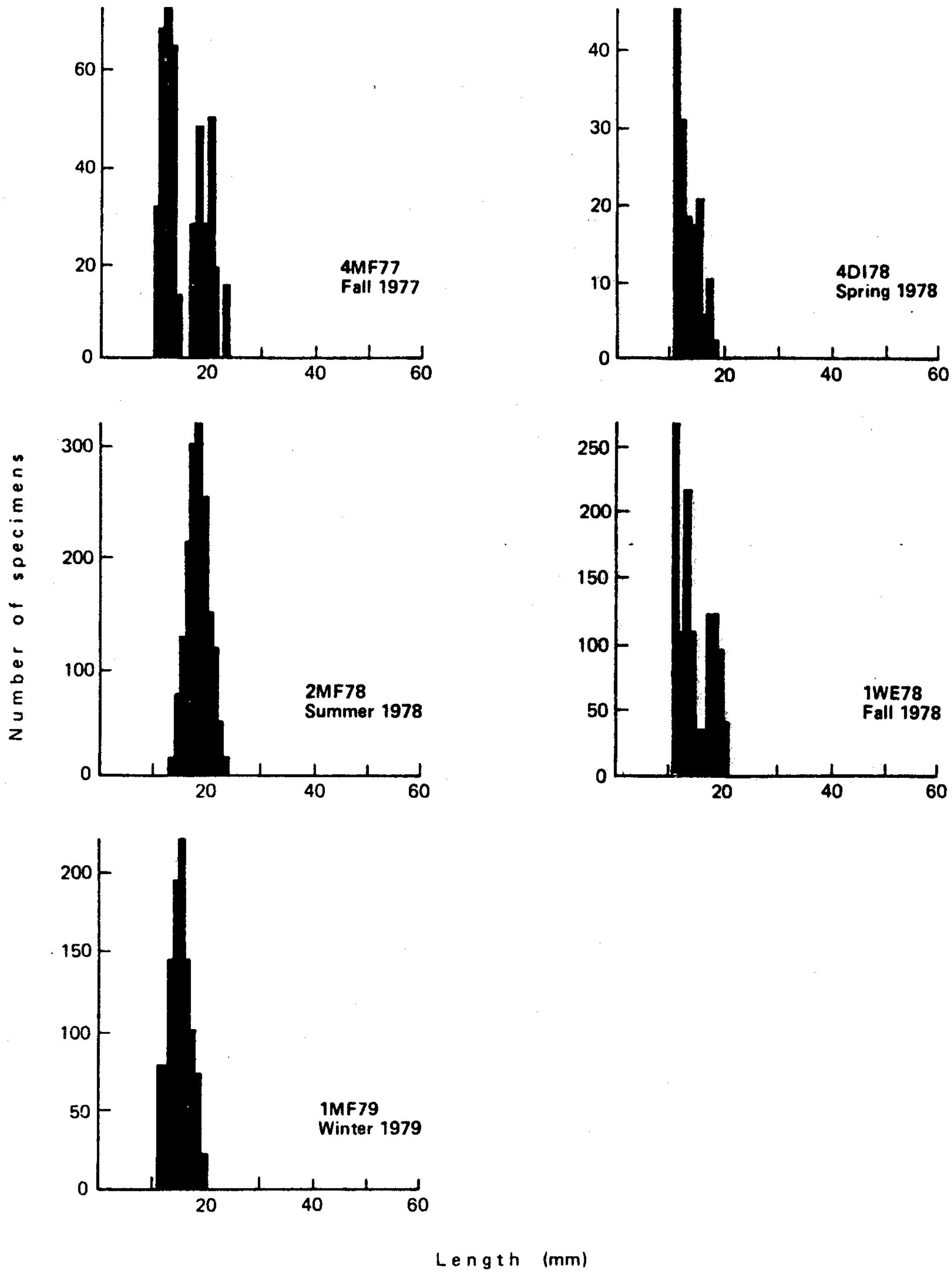


Figure 48.--Lengths of Euphausia pacifica collected in bongo net tows from the five offshore OCSEAP plankton cruises.

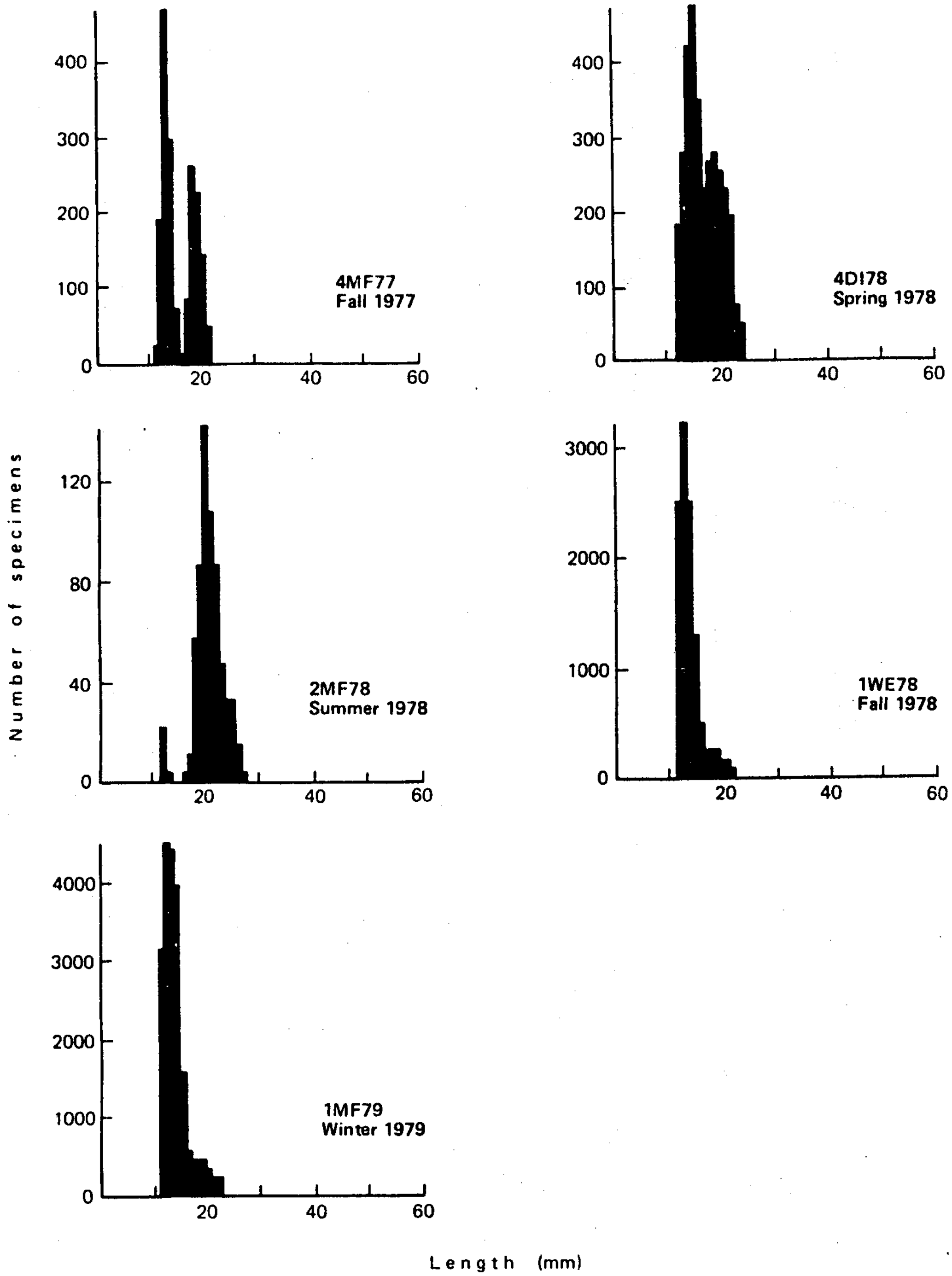


Figure 49.--Lengths of Thysanoessa inermis collected in bongo net tows from the five offshore OCSEAP plankton cruises.

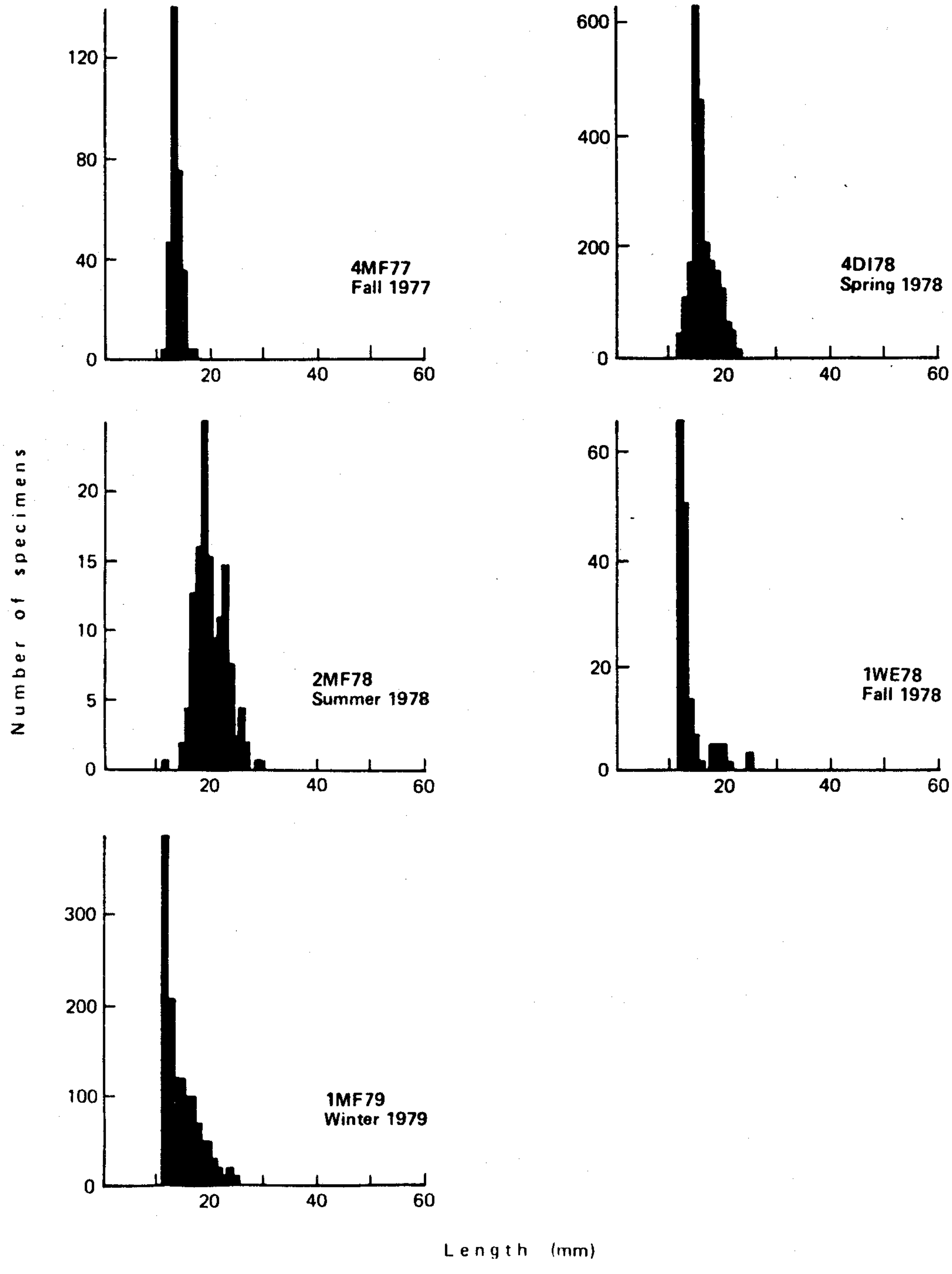


Figure 50.--Lengths of <u>Thysanoessa longipes</u> collected in bongo net tows from the five offshore OCSEAP plankton cruises.

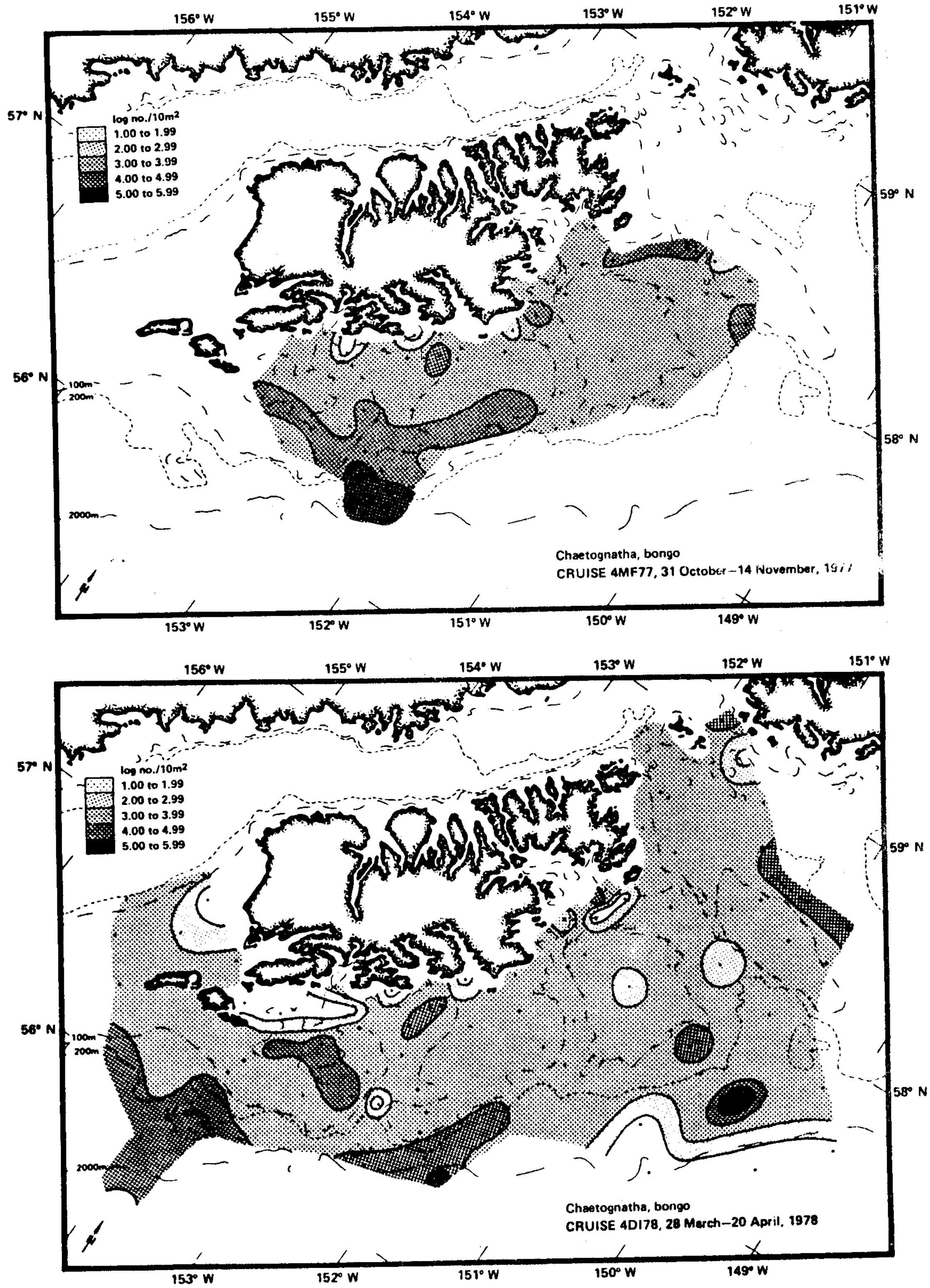
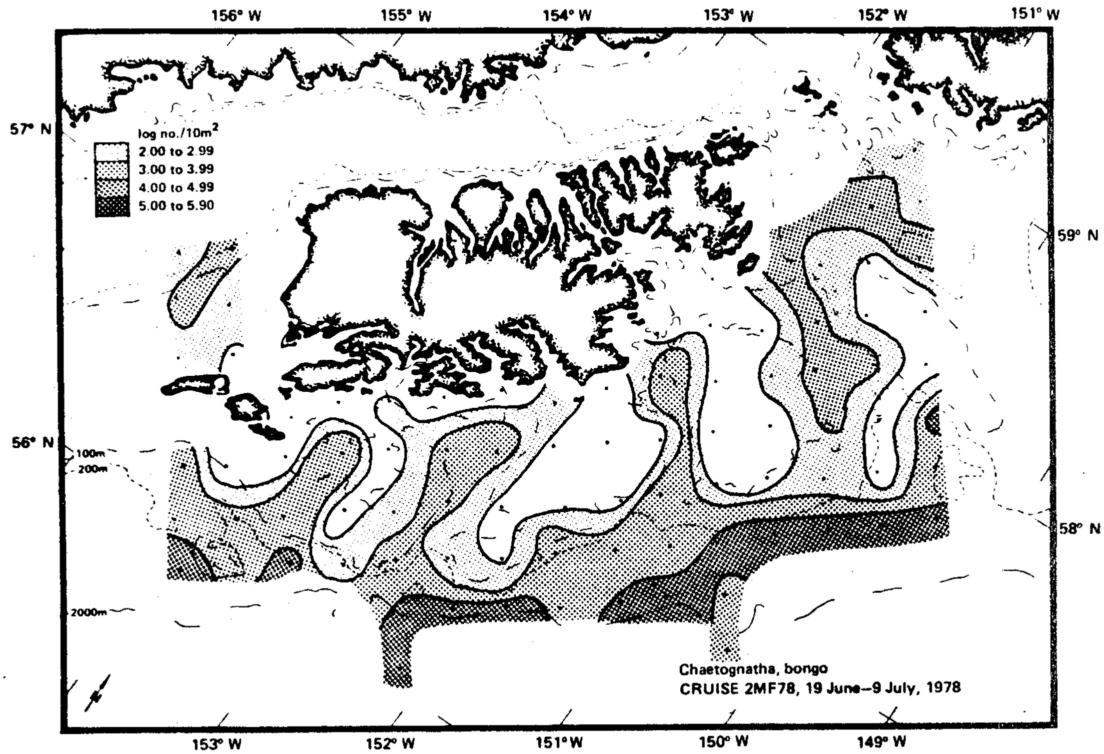


Figure 51.--Distribution and abundance of Chaetognatha in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.



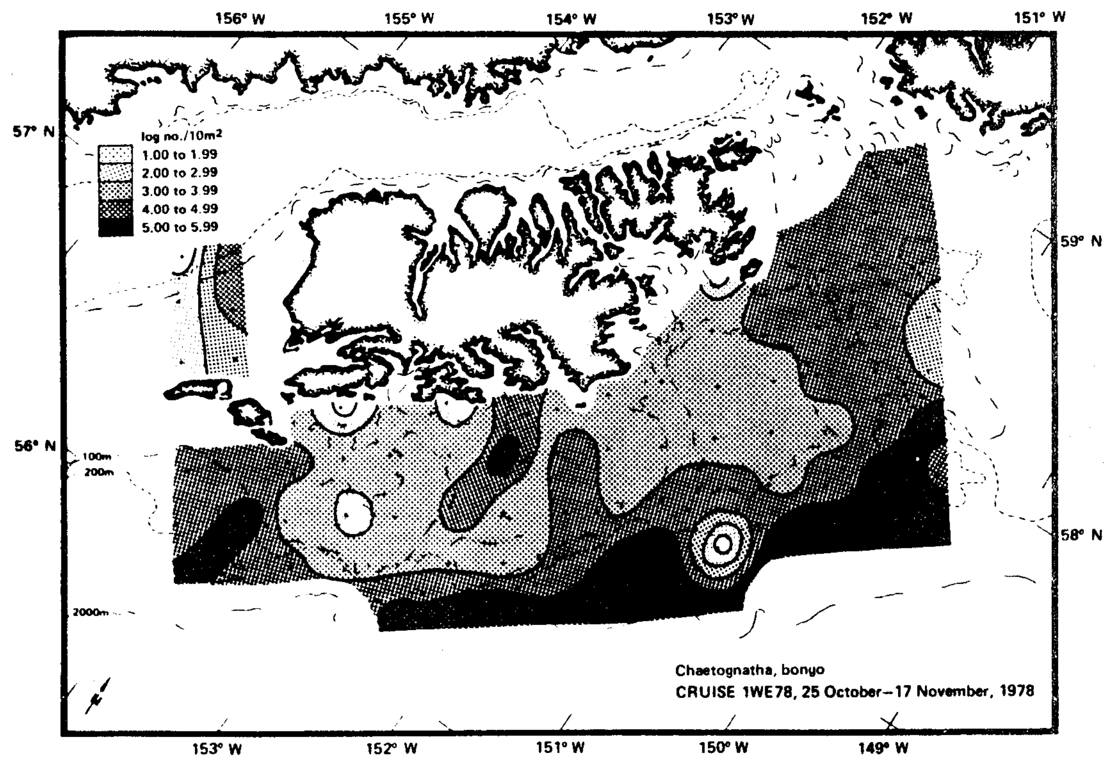


Figure 52.--Distribution and abundance of Chaetognatha in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

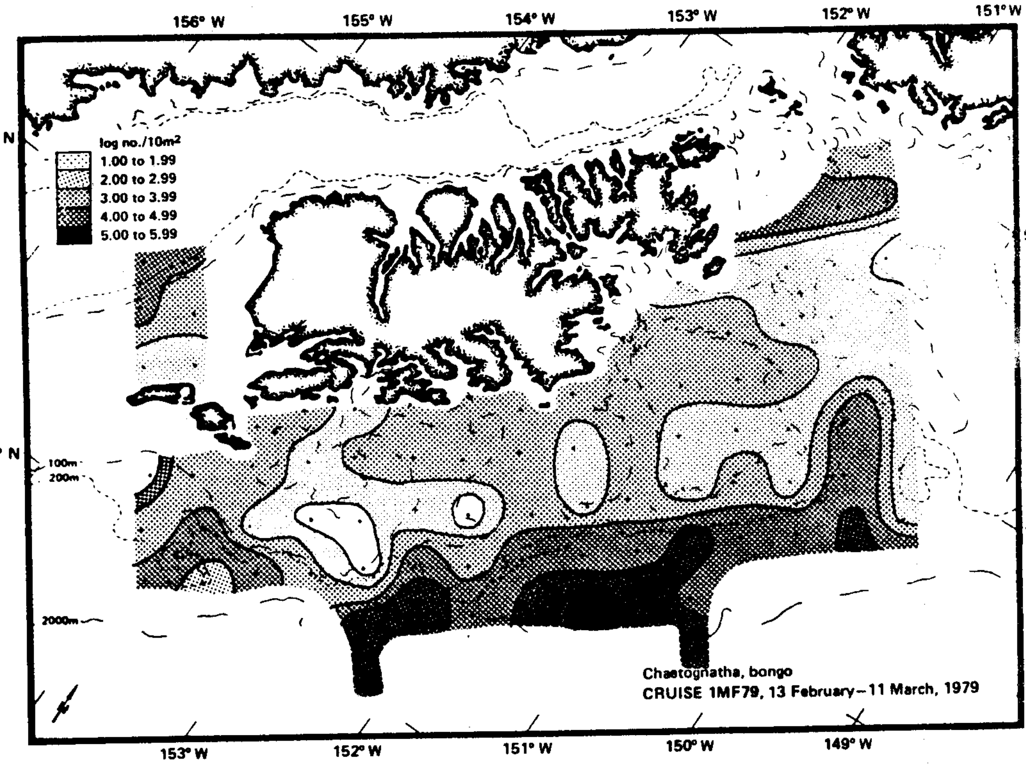


Figure 53.--Distribution and abundance of Chaetognatha in bongo tows from the winter 1979 OCSEAP plankton cruise.

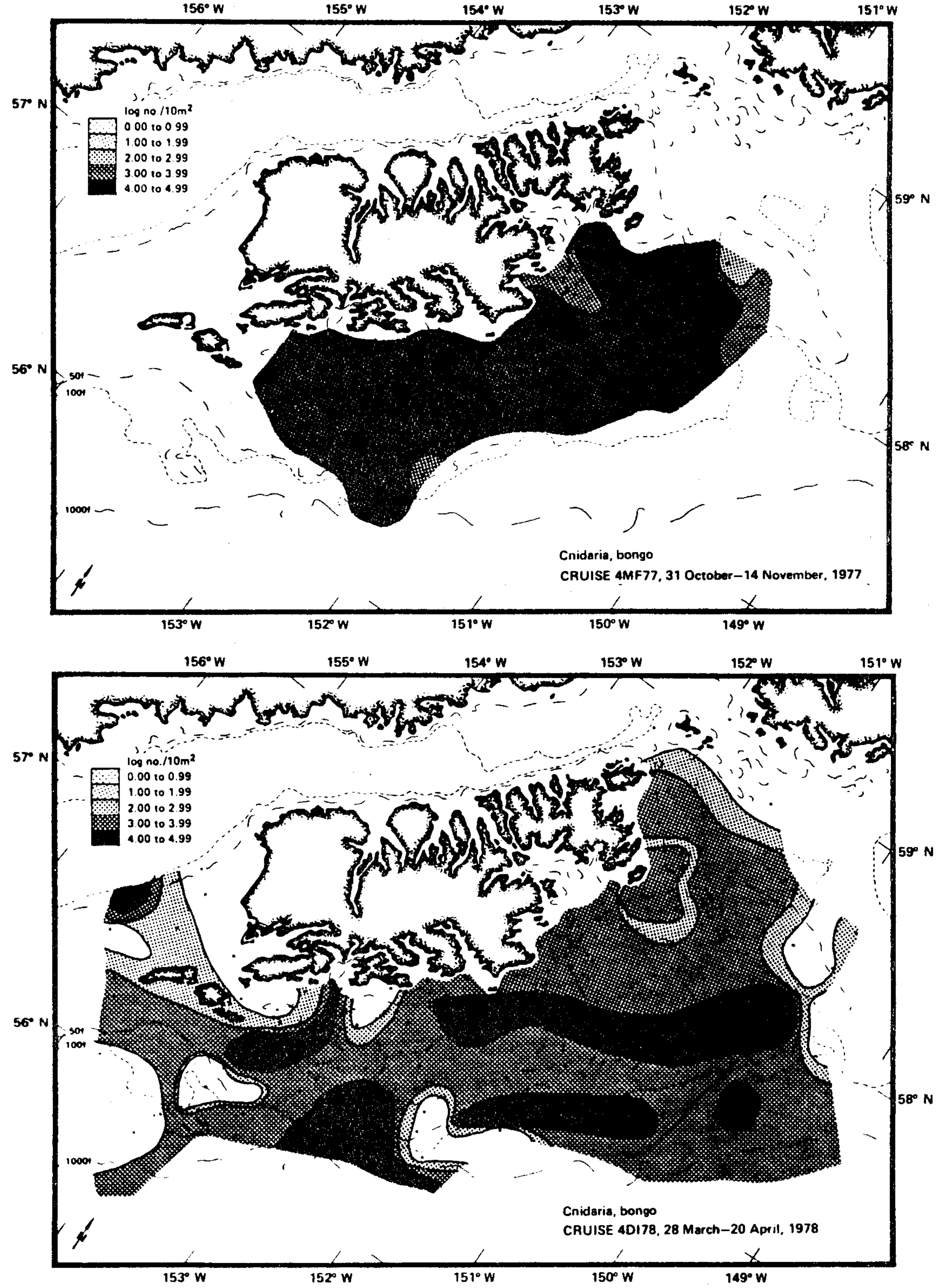


Figure 54.--Distribution and abundance of Cnidaria in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.

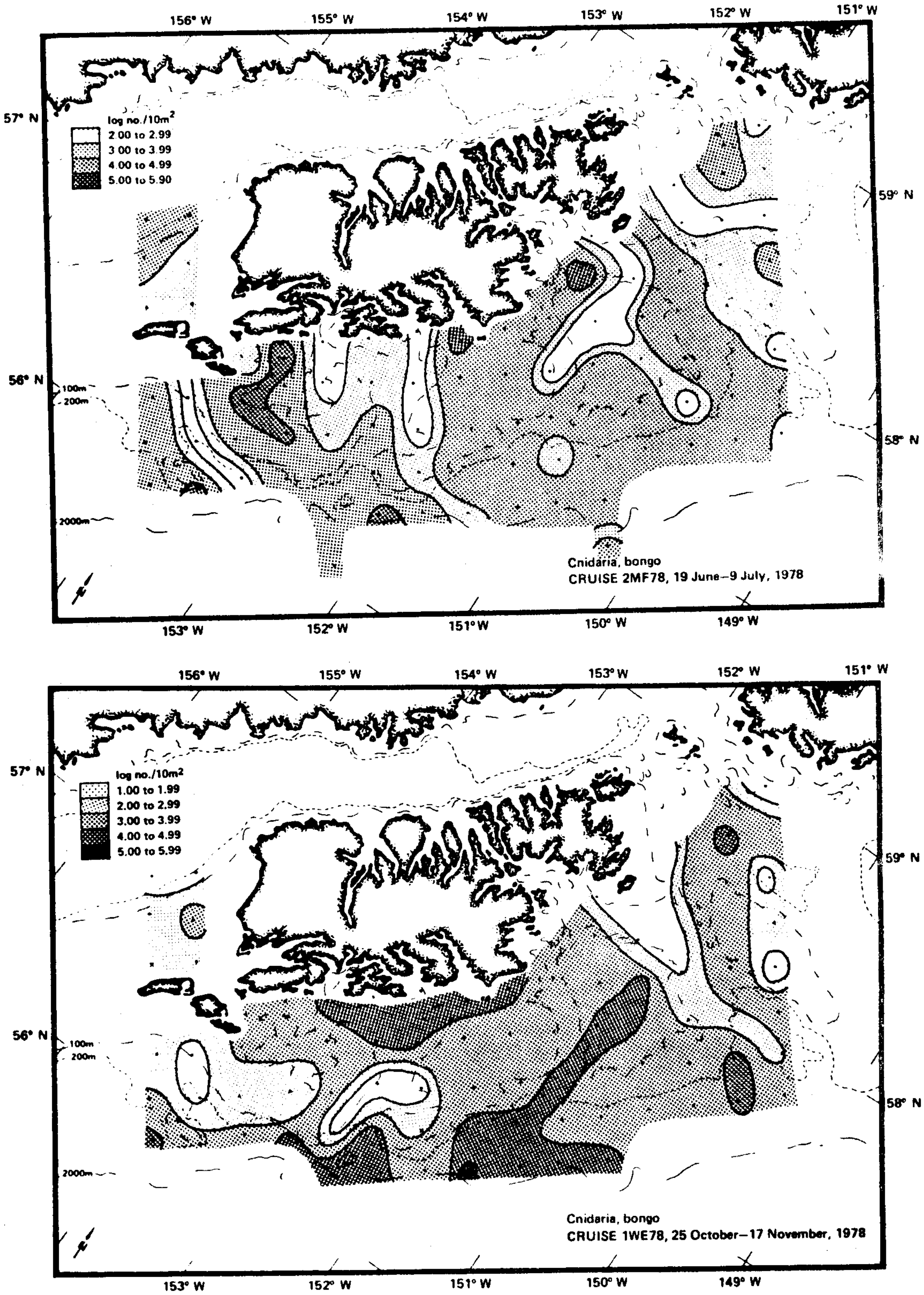


Figure 55.--Distribution and abundance of Cnidaria in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

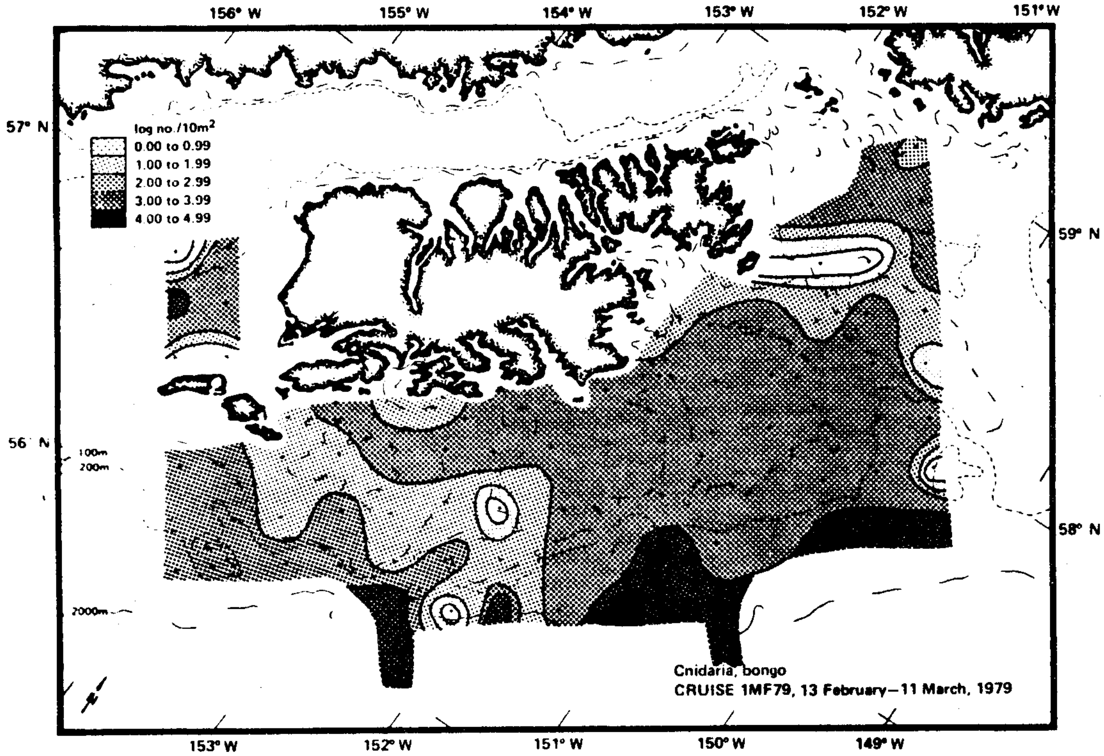


Figure 56.--Distribution and abundance of Cnidaria in bongo tows from the winter 1979 OCSEAP plankton cruise.

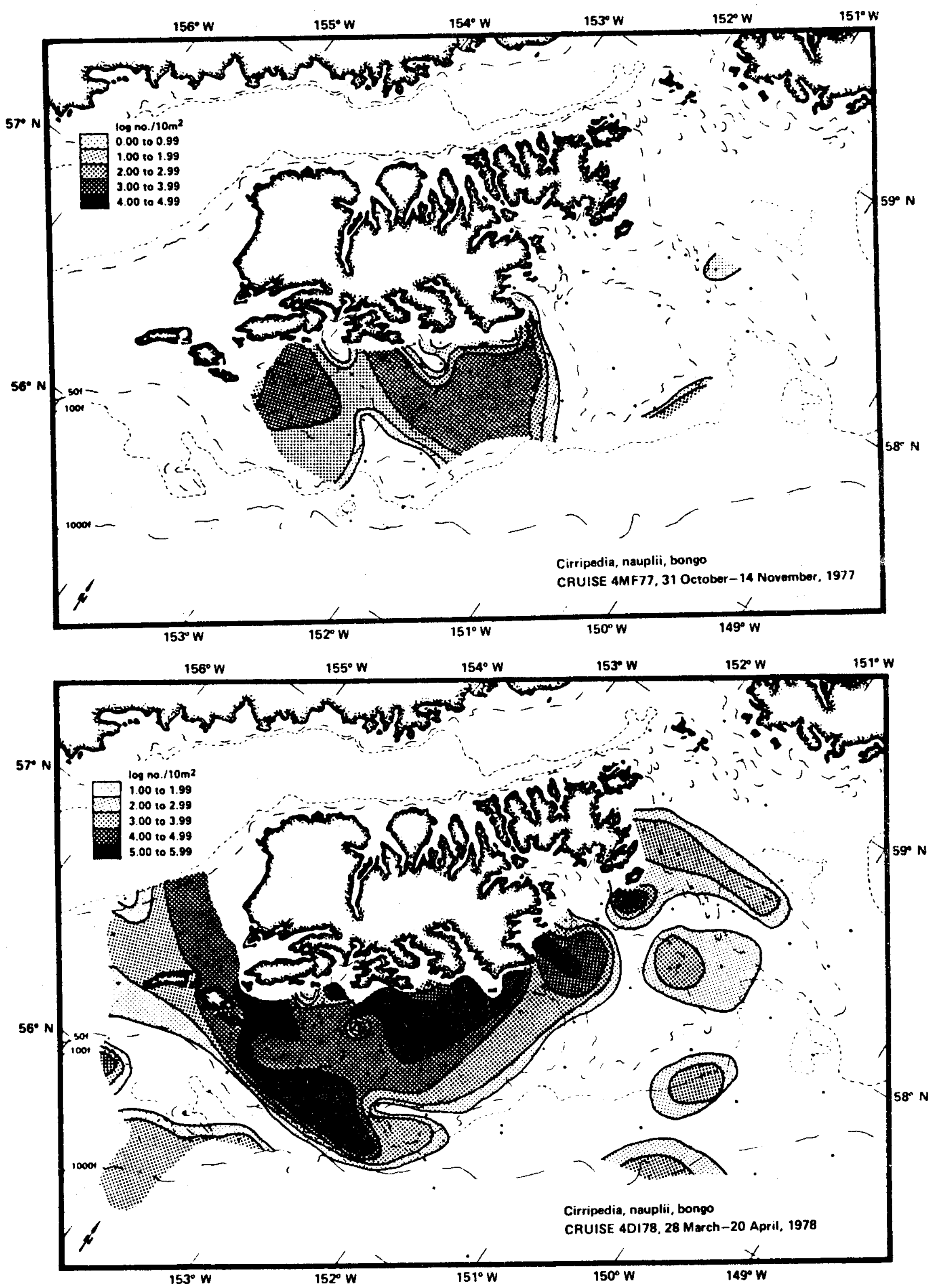


Figure 57.--Distribution and abundance of Cirripedia nauplii in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.

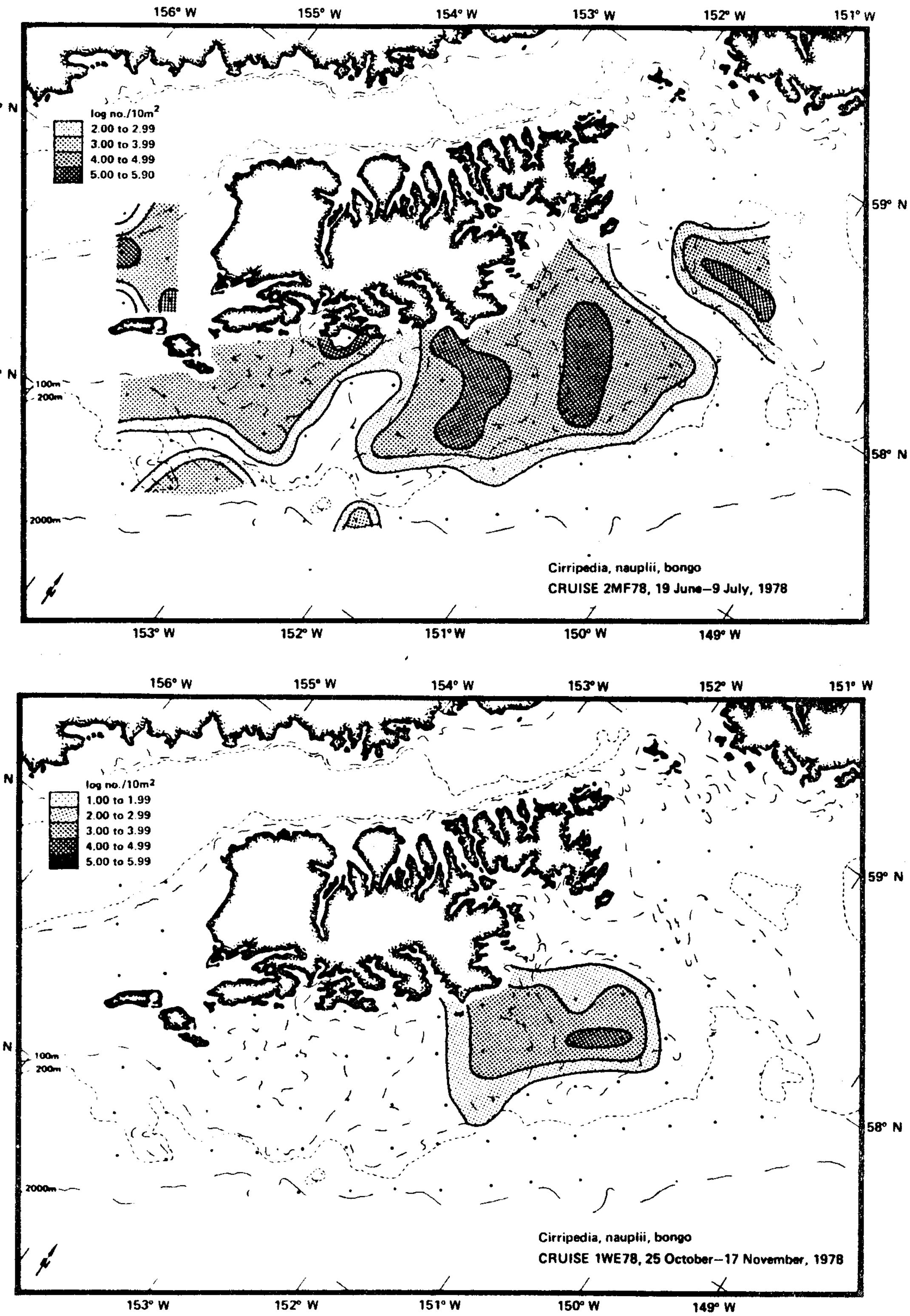


Figure 58.--Distribution and abundance of Cirripedia nauplii in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

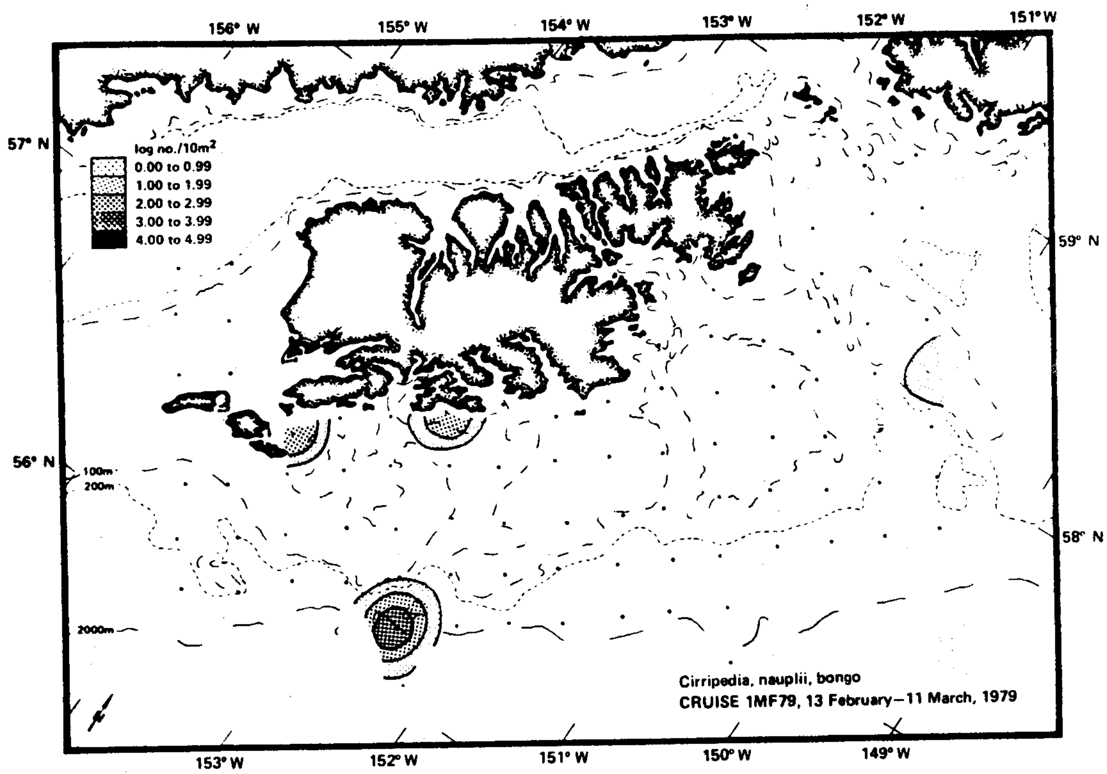


Figure 59.--Distribution and abundance of Cirripedia nauplii in bongo tows from the winter 1979 OCSEAP plankton cruise.

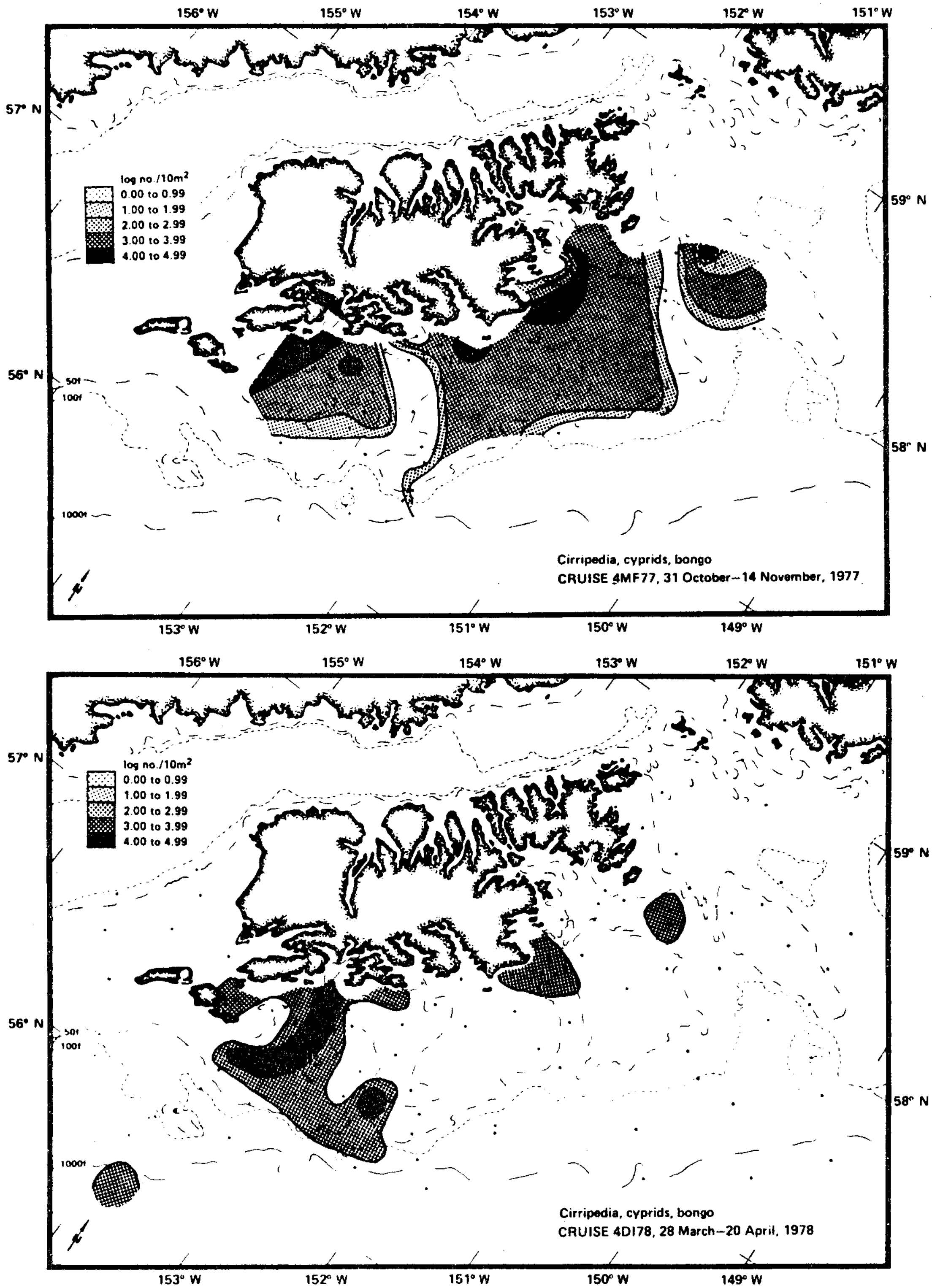


Figure 60.--Distribution and abundance of Cirripedia cyprids in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.

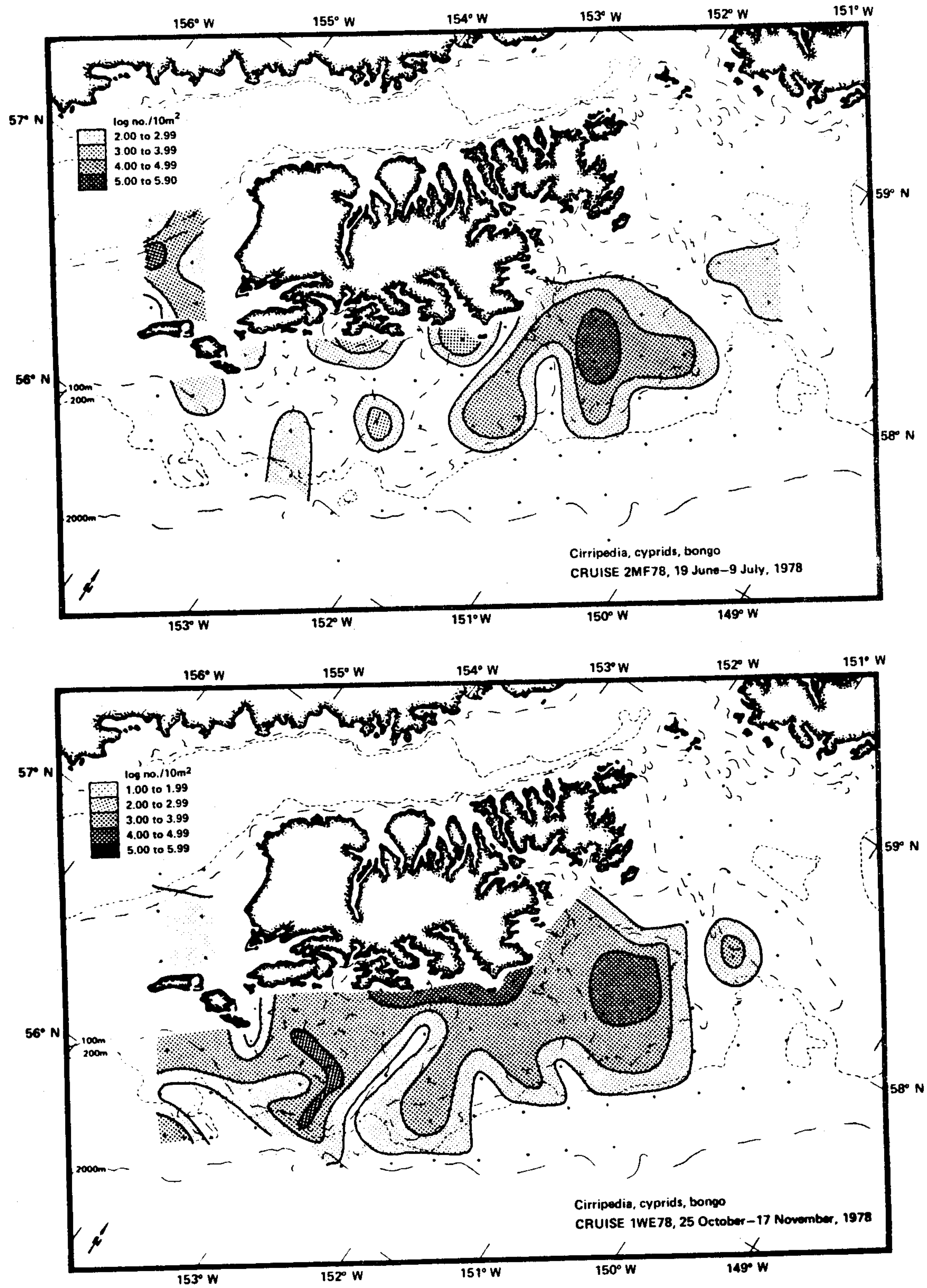


Figure 61.--Distribution and abundance of Cirripedia cyprids in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

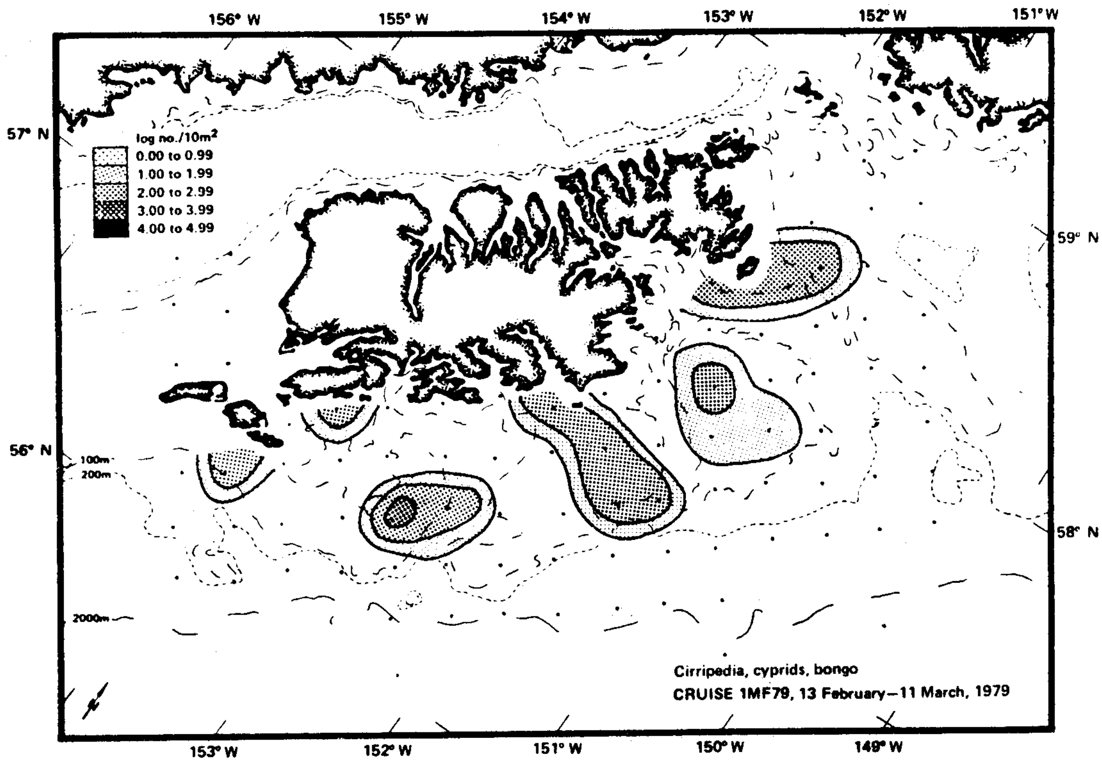
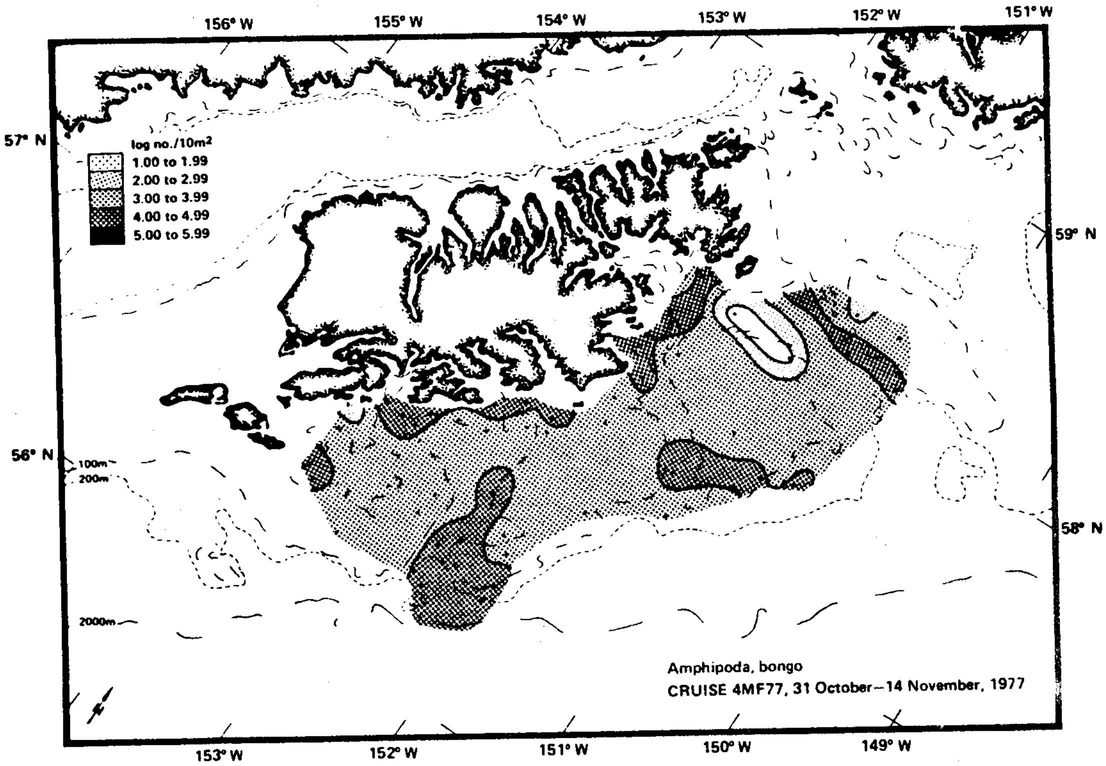


Figure 62.--Distribution and abundance of Cirripedia cyprids in bongo tows from the winter 1979 OCSEAP plankton cruise.



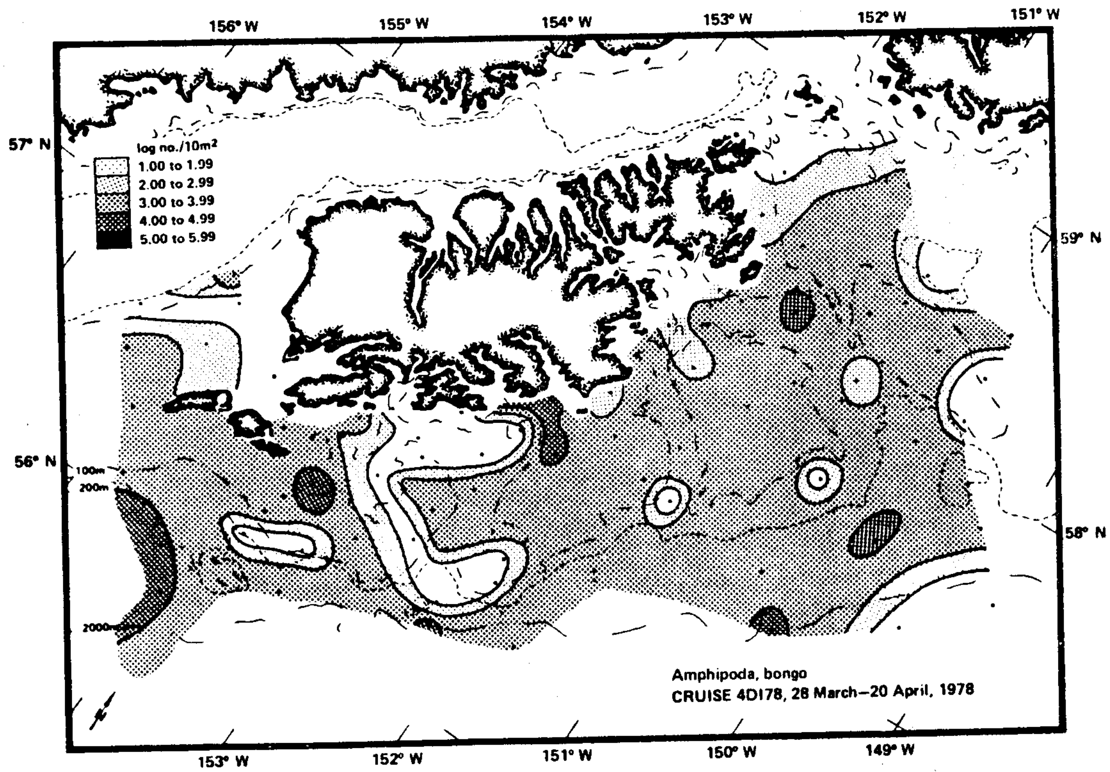


Figure 63.--Distribution and abundance of Amphipoda in bongo tows from the fall 1977 (top) and spring 1978 (bottom) OCSEAP plankton cruises.

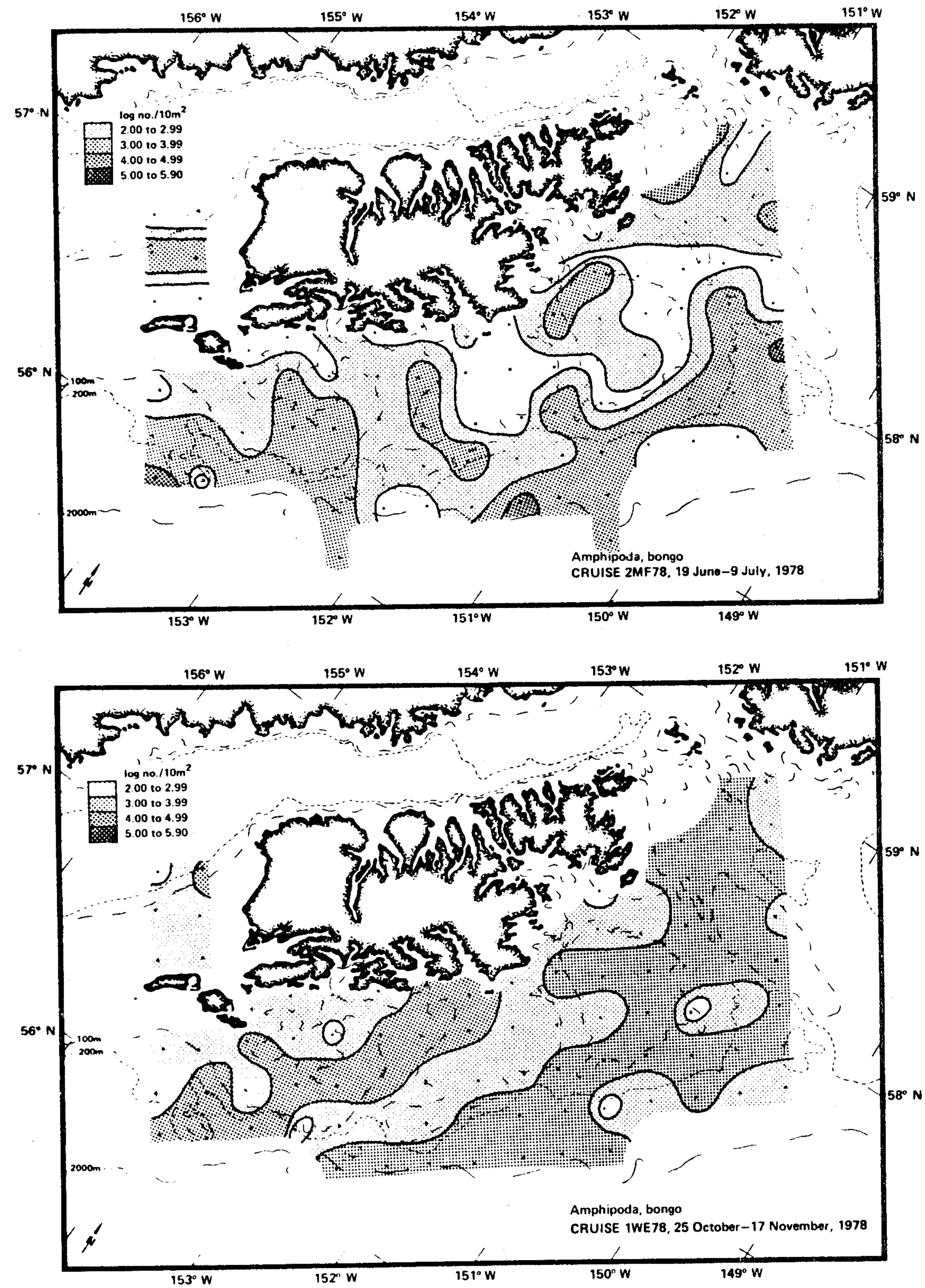


Figure 64.--Distribution and abundance of Amphipoda in bongo tows from the summer (top) and fall 1978 (bottom) OCSEAP plankton cruises.

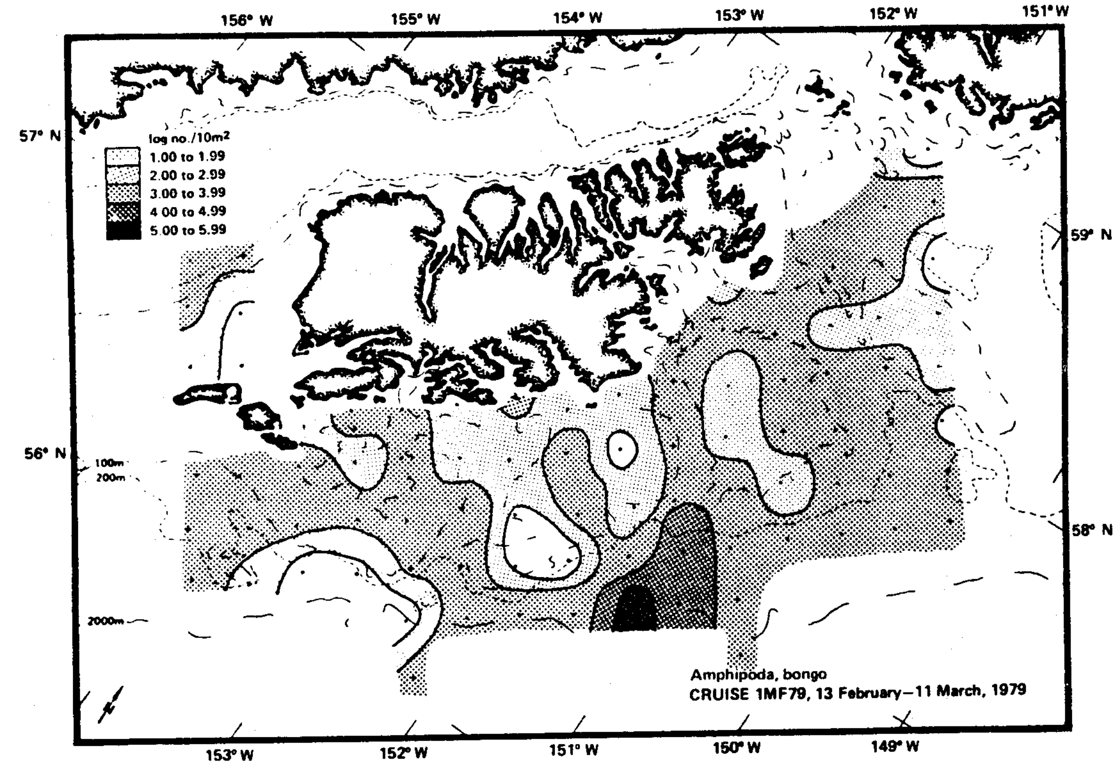


Figure 65.--Distribution and abundance of Amphipoda in bongo tows from the winter 1979 OCSEAP plankton cruise.

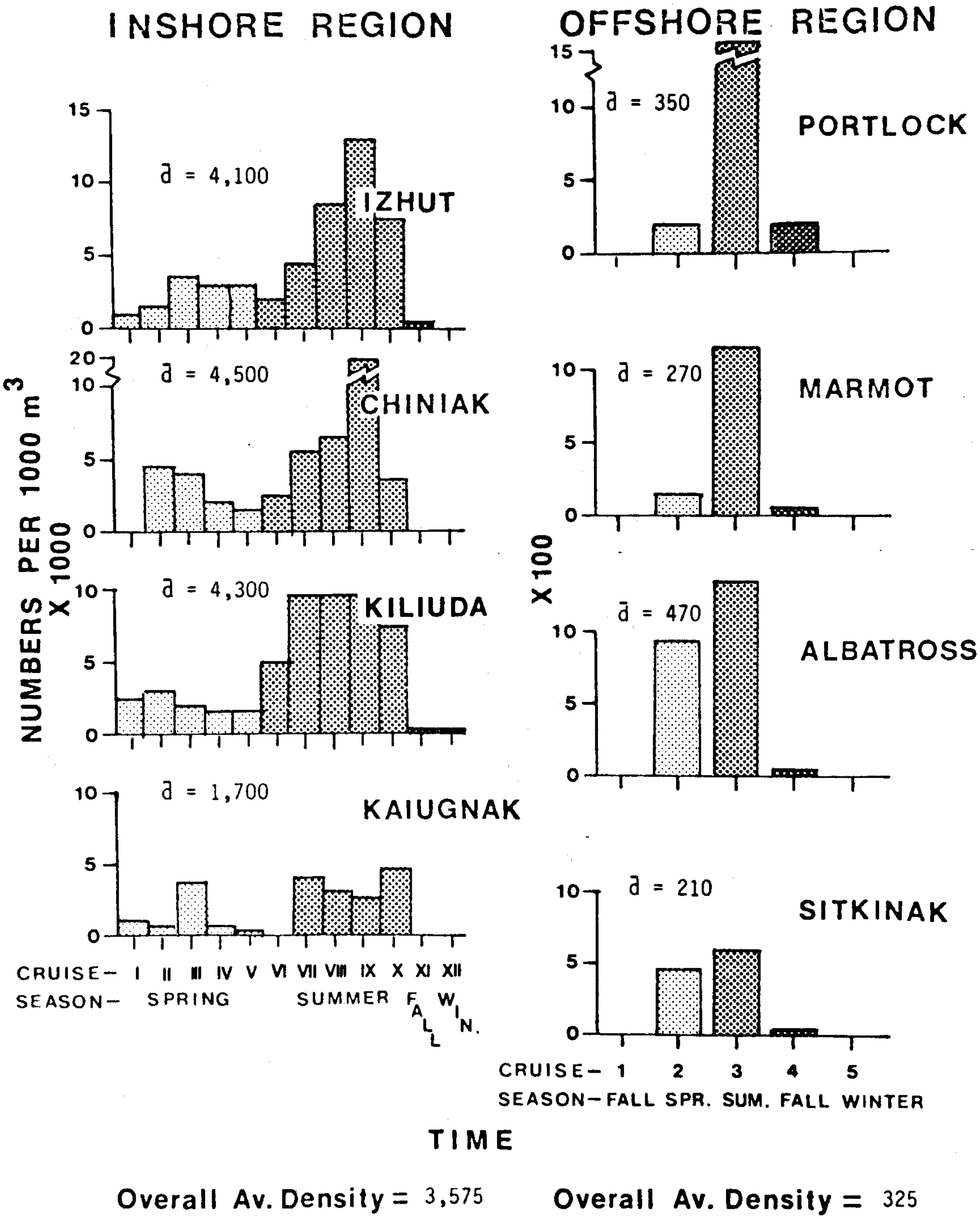
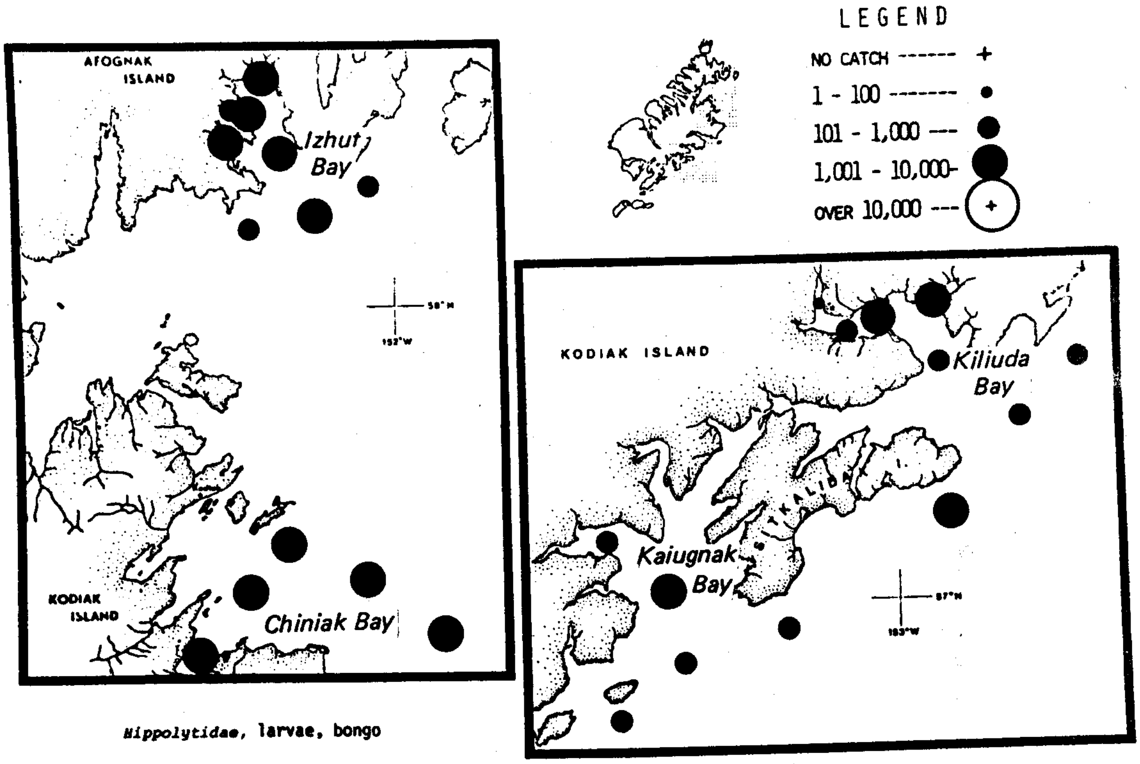


Figure 66.--Average density (numbers per 1000 m^3) by cruise, season, bay, subarea, and region for hippolytid shrimp larvae, Hippolytidae, in the Kodiak Island study area. 1977-1979 OCSEAP plankton cruises. Bongo net data.



Hippolytidae, larvae, bongo

Figure 67.--Average density per station (numbers per 1000 m^3) of hippolytid shrimp larvae, Hippolytidae, in bongo tows from the spring 1978 OCSEAP inshore plankton cruises.

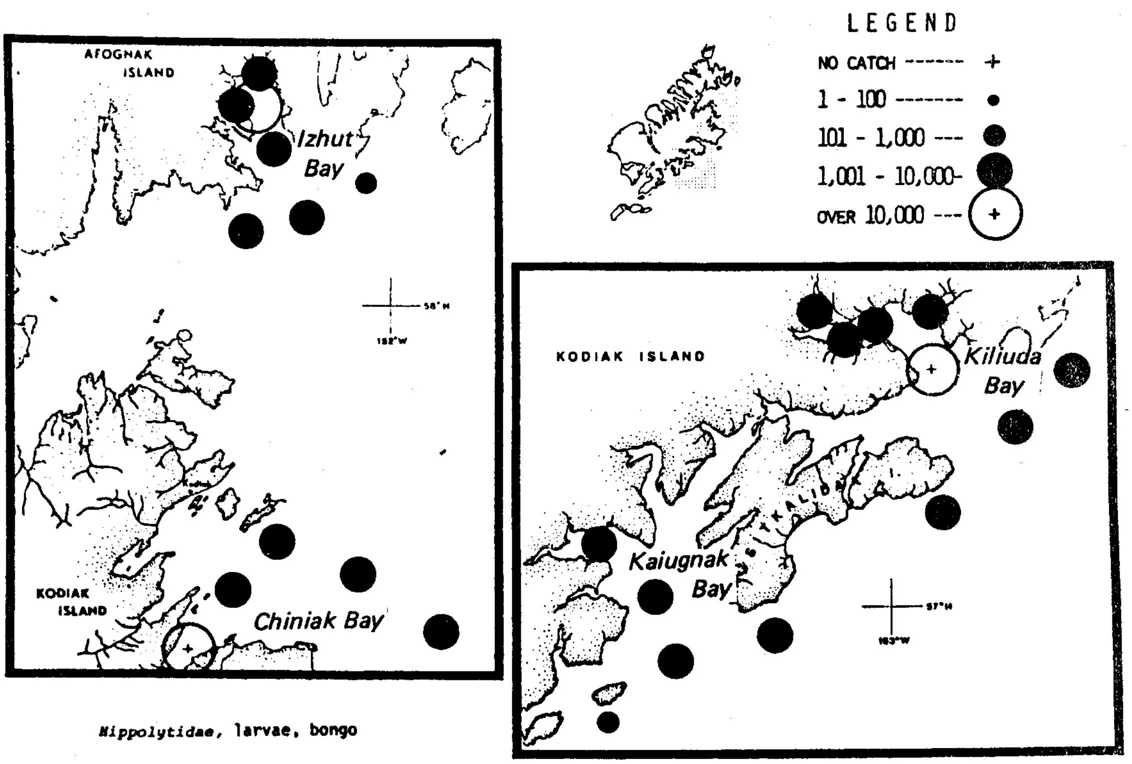


Figure 68.--Average density per station (numbers per 1000 m^3) of hippolytid shrimp larvae, Hippolytidae, in bongo tows from the summer 1978 OCSEAP inshore plankton cruises.

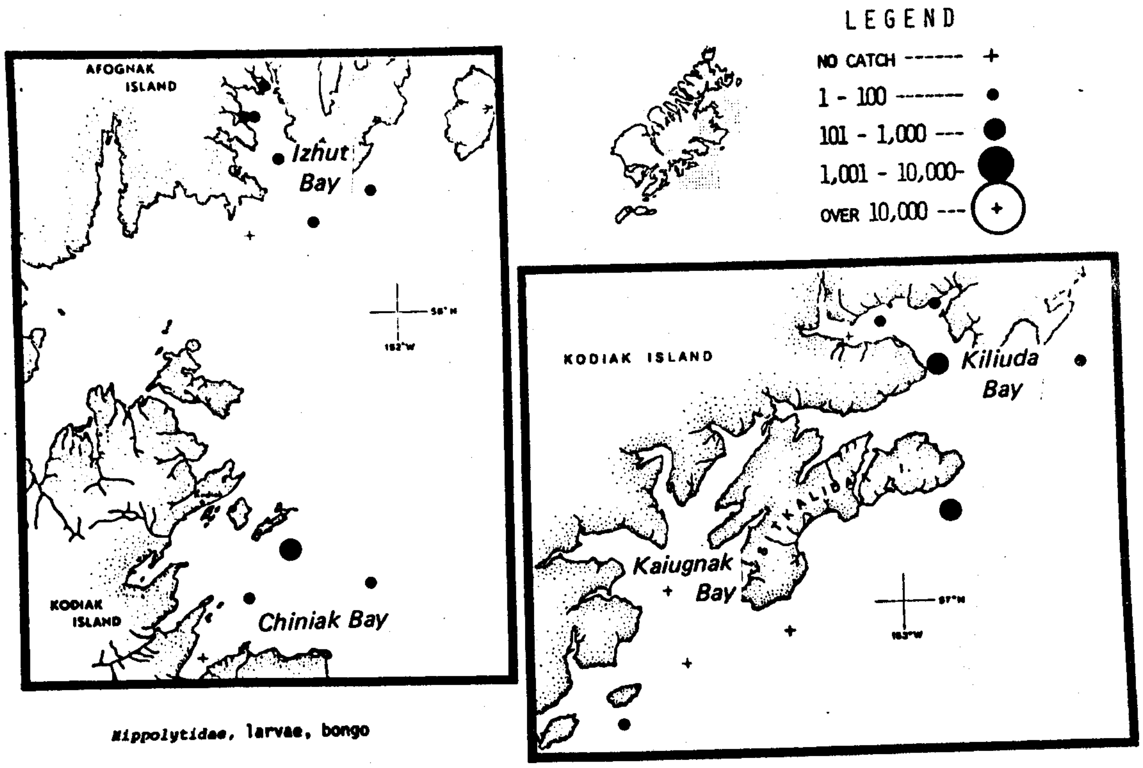


Figure 69.--Average density per station (numbers per 1000 m^3) of hippolytid shrimp larvae, Hippolytidae, in bongo tows from the late winter 1979 OCSEAP inshore plankton cruise.

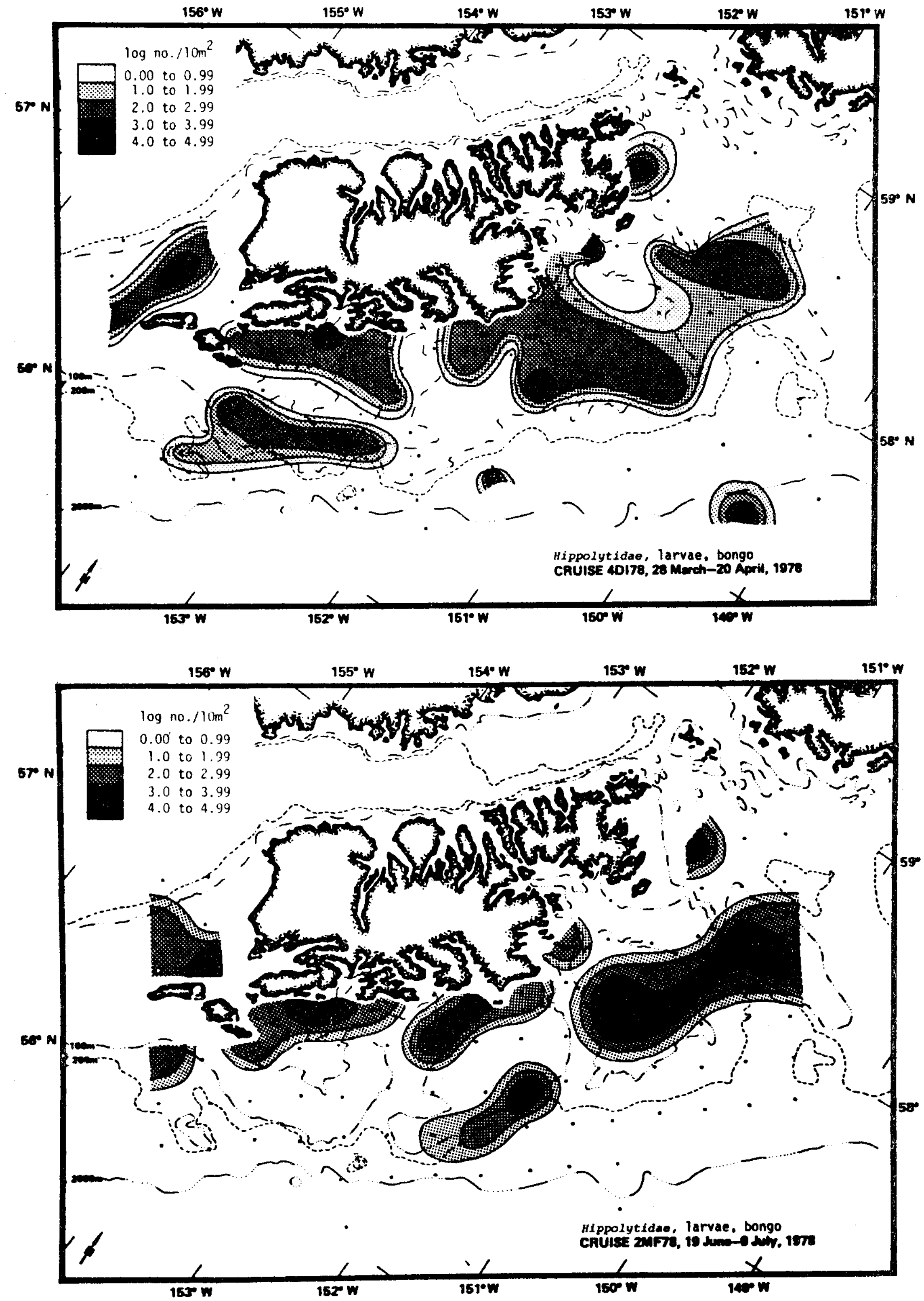


Figure 70.--Distribution and relative abundance of hippolytid shrimp larvae, Hippolytidae, during the spring (top) and summer (bottom) 1978 OCSEAP offshore plankton cruises. Bongo net data.

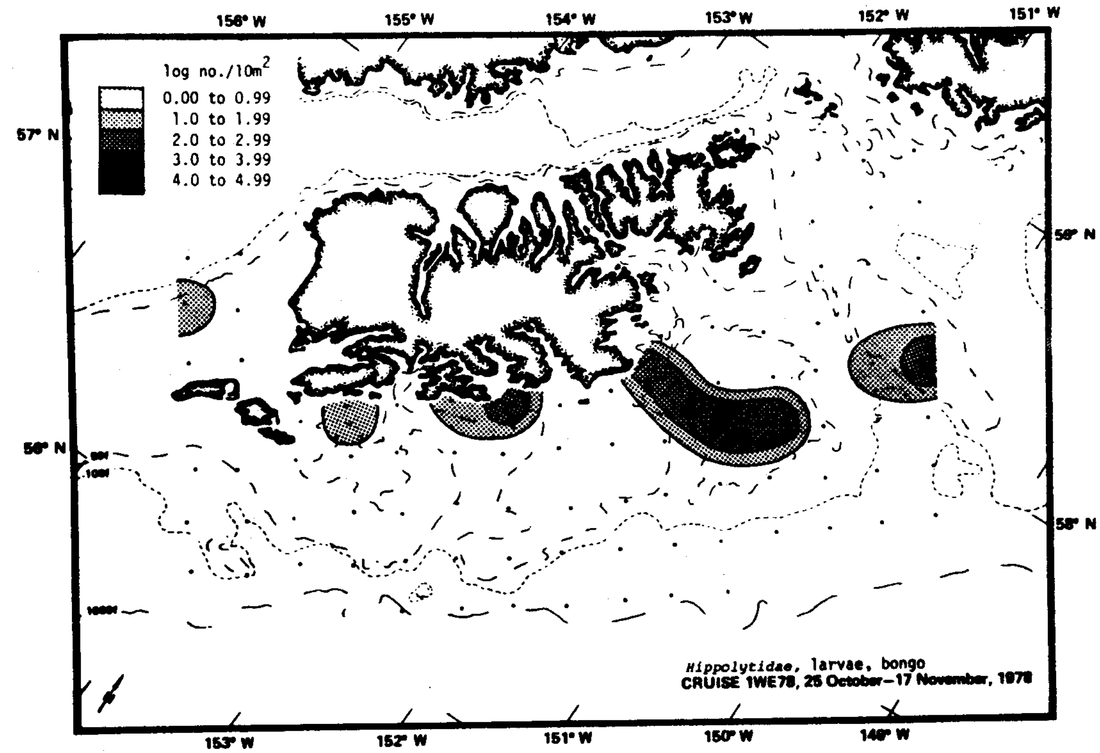


Figure 71.--Distribution and relative abundance of hippolytid shrimp larvae, Hippolytidae, during the fall 1978 OCSEAP offshore plankton cruise. Bongo net data.

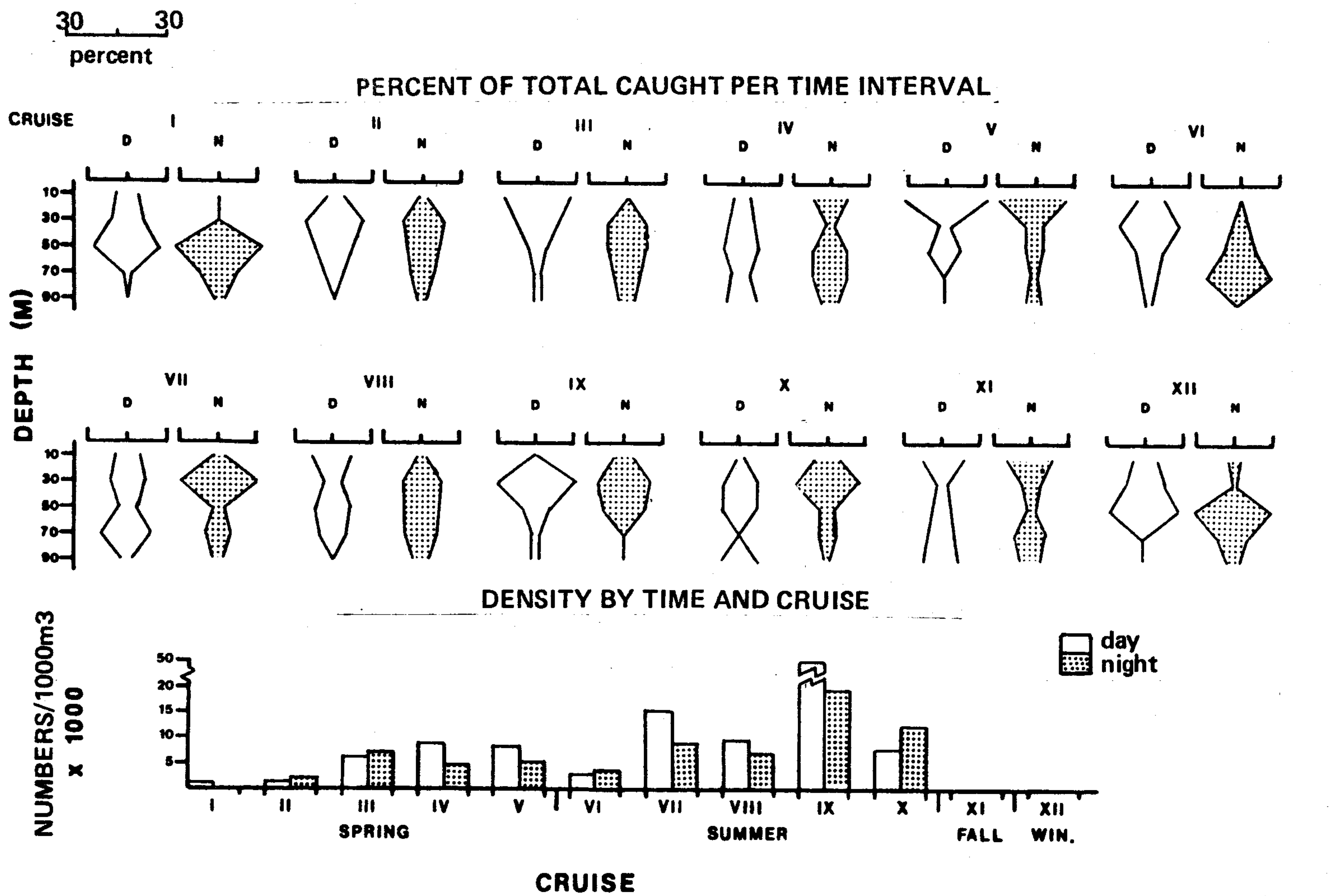


Figure 72.--Percent of total numbers caught by depth stratum per time interval and cruise, and density by time and cruise of hippolytid shrimp larvae, Hippolytidae, at diel stations in the inshore region. Tucker trawl data. D = day, N = night.

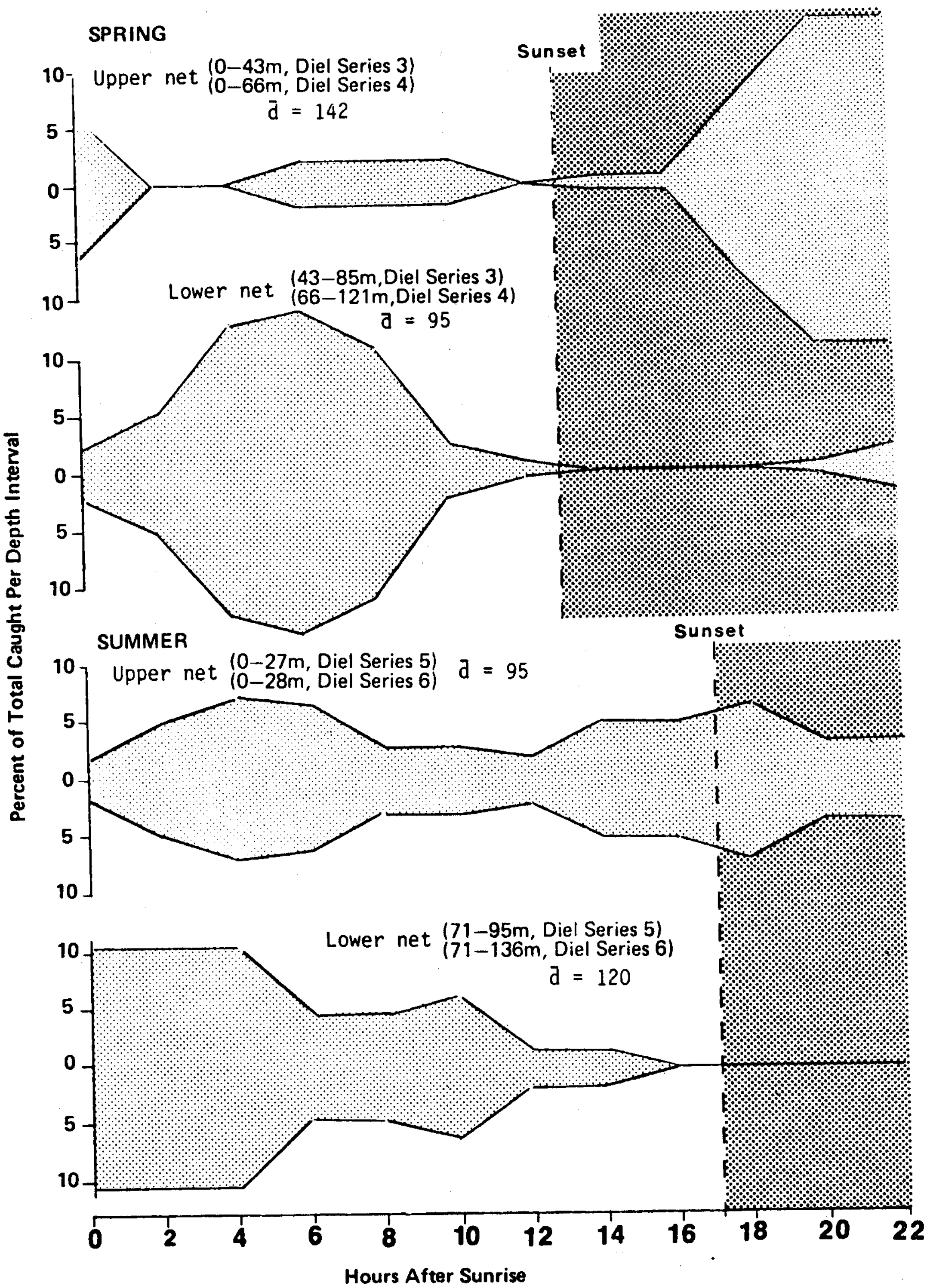


Figure 73.--Percent of total numbers of hippolytid shrimp larvae, Hippolytidae, caught by time interval per depth stratum during spring and summer 1978 diel studies in the offshore region. Tucker trawl data. d = mean density (no./1000 m^3) for all time periods per depth stratum.

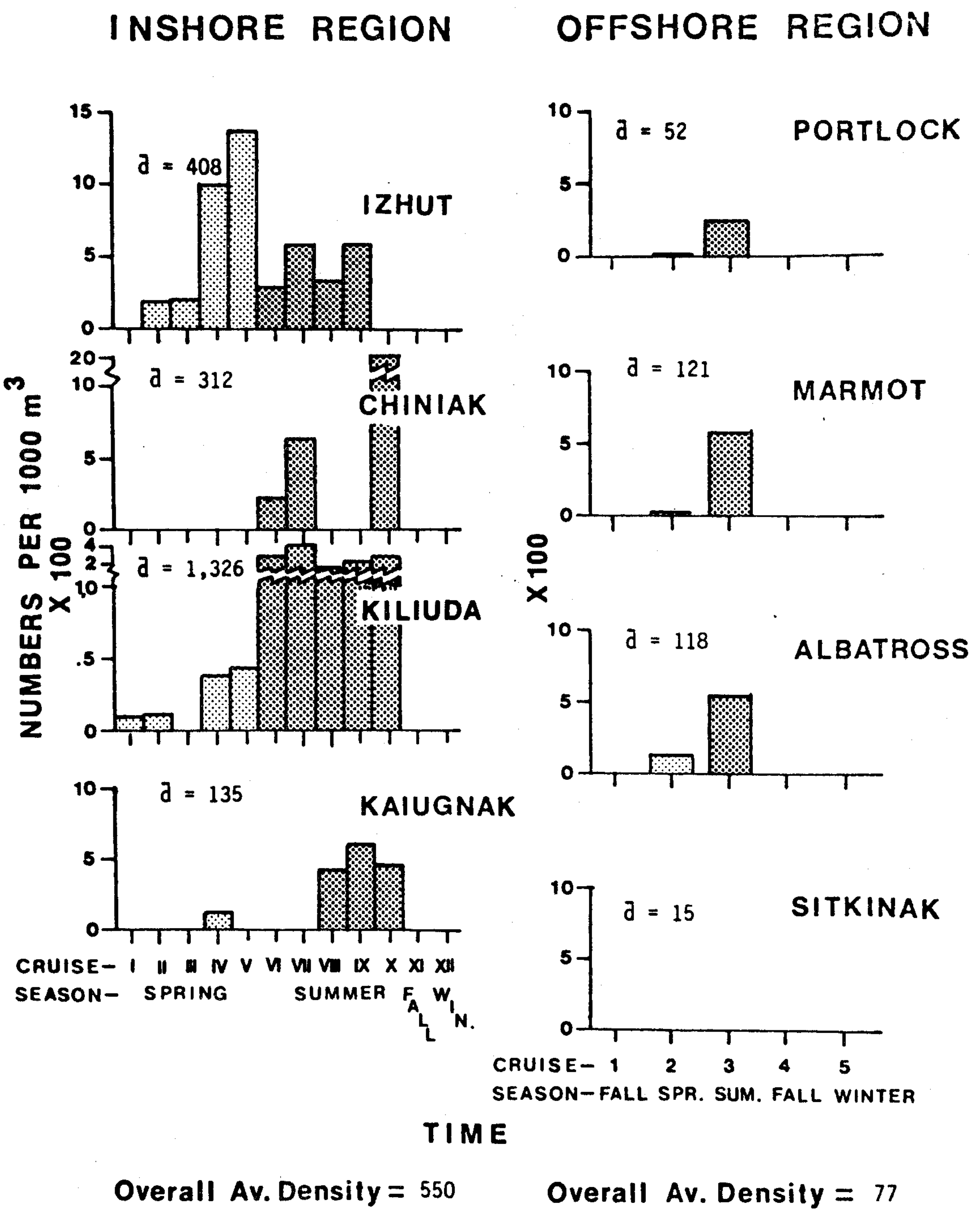


Figure 74.--Average density (numbers per 1000 m^3) by cruise, season, bay, subarea, and region for crangonid shrimp larvae, Crangonidae, in the Kodiak Island study area. 1977-1979 OCSEAP plankton cruises. Bongo net data.

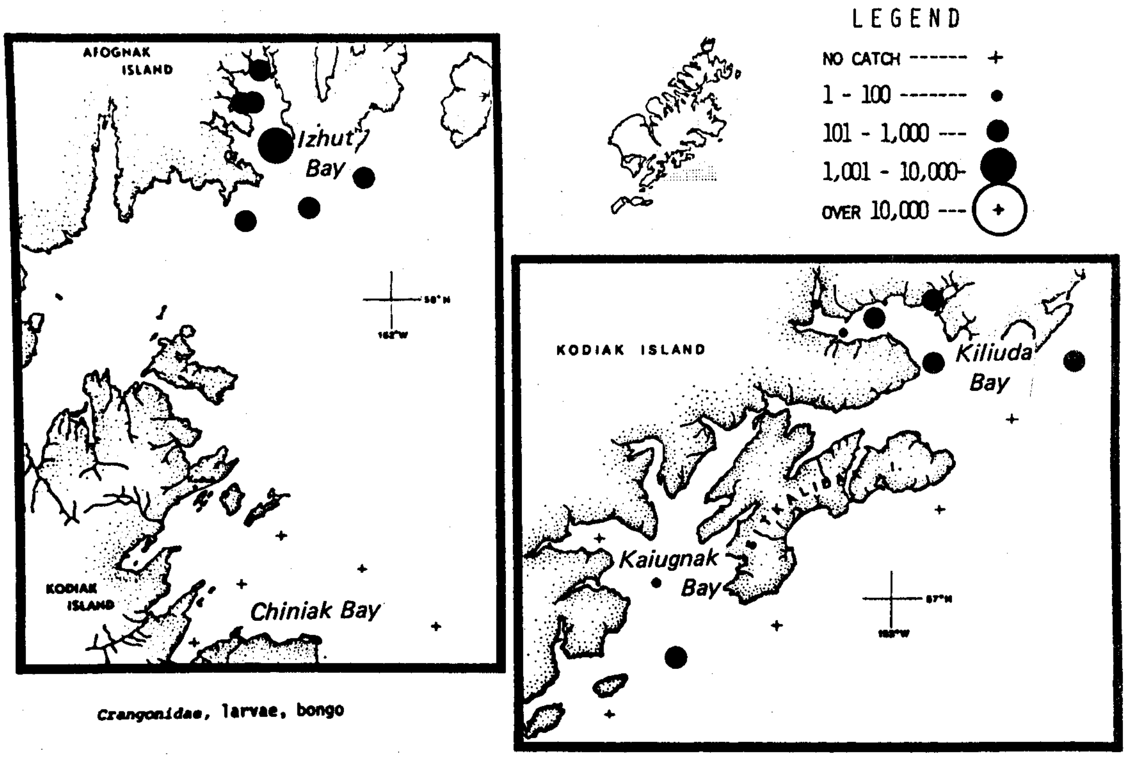


Figure 75.--Average density per station (numbers per 1000 m^3) of crangonid shrimp larvae, Crangonidae, in bongo tows from the spring 1978 OCSEAP inshore plankton cruises.

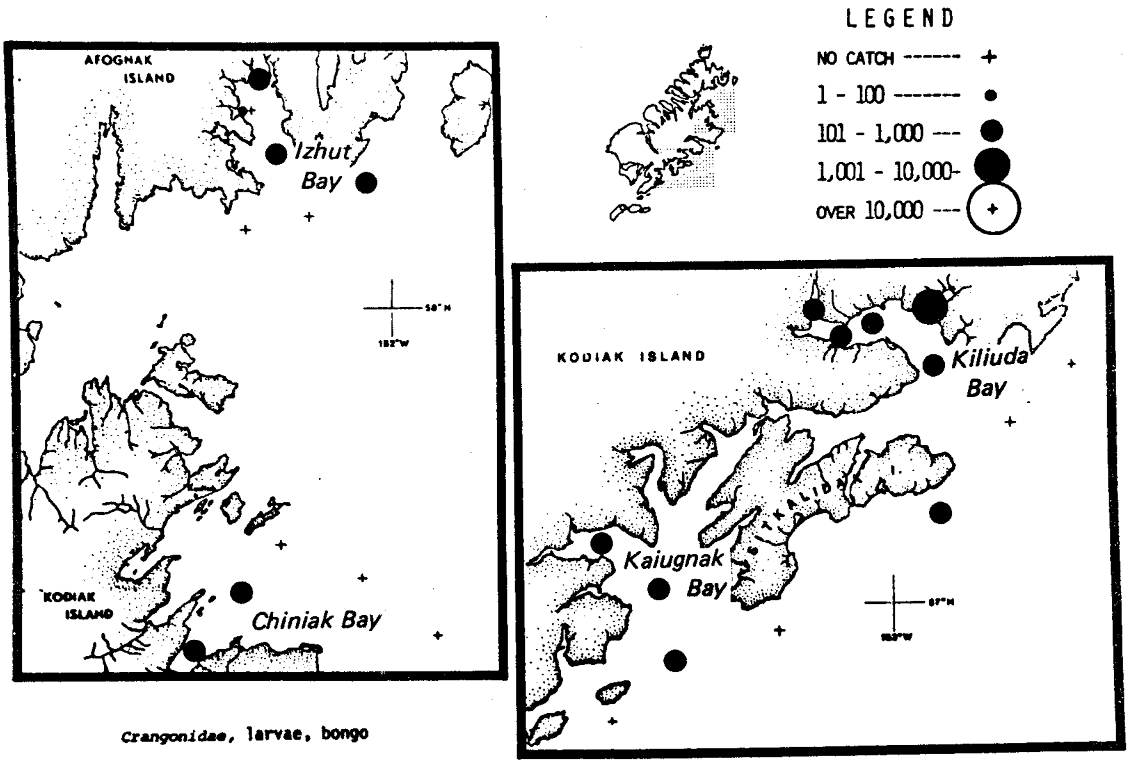
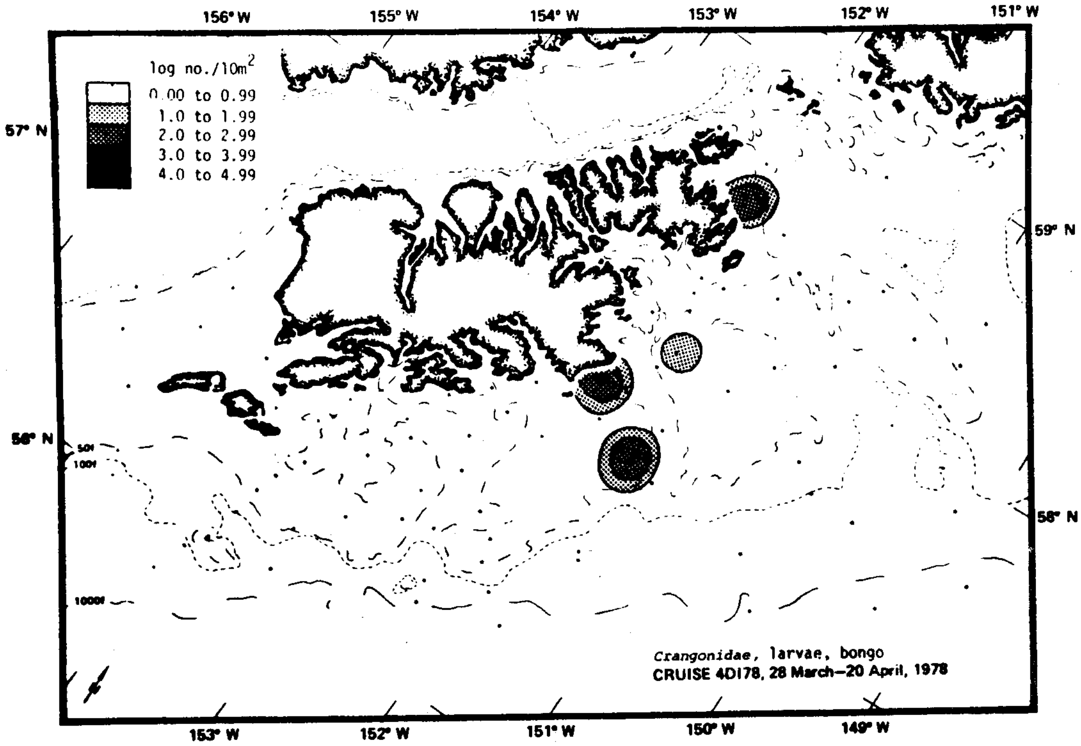


Figure 76.--Average density per station (numbers per 1000 m^3) of crangonid shrimp larvae, Crangonidae, in bongo tows from the summer 1978 OCSEAP inshore plankton cruises.



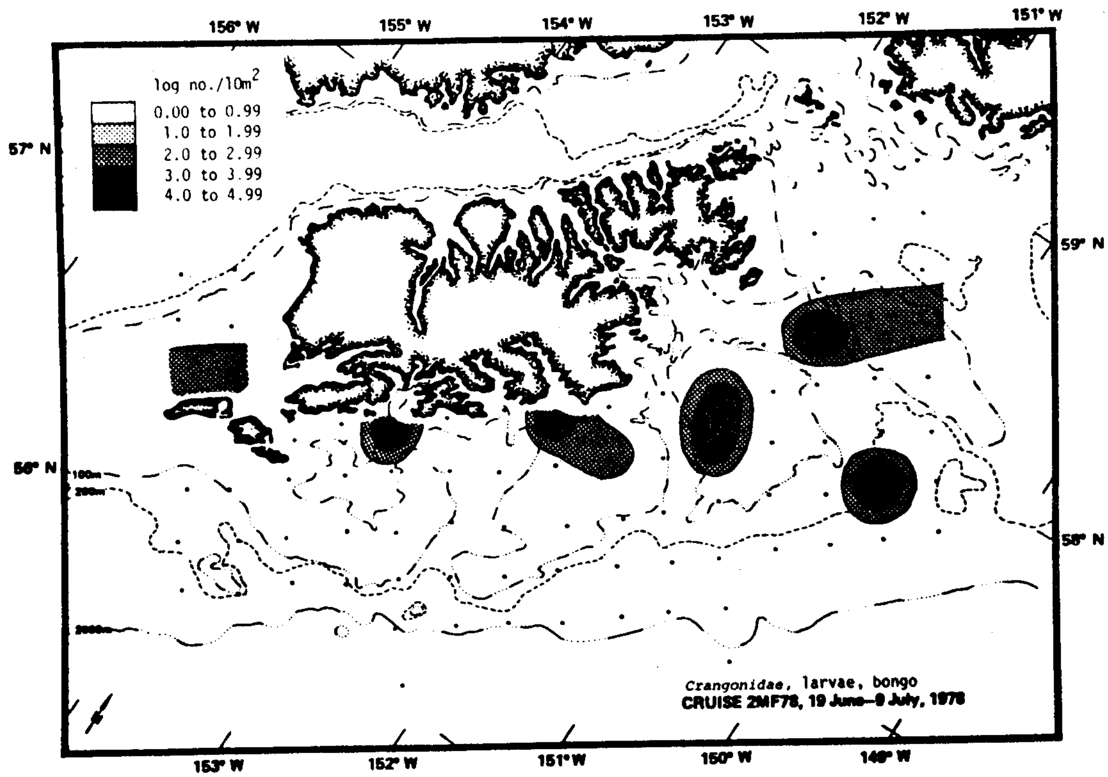


Figure 77.--Distribution and relative abundance of crangonid shrimp larvae, Crangonidae, during the spring (top) and summer (bottom) 1978 OCSEAP offshore plankton cruises. Bongo net data.

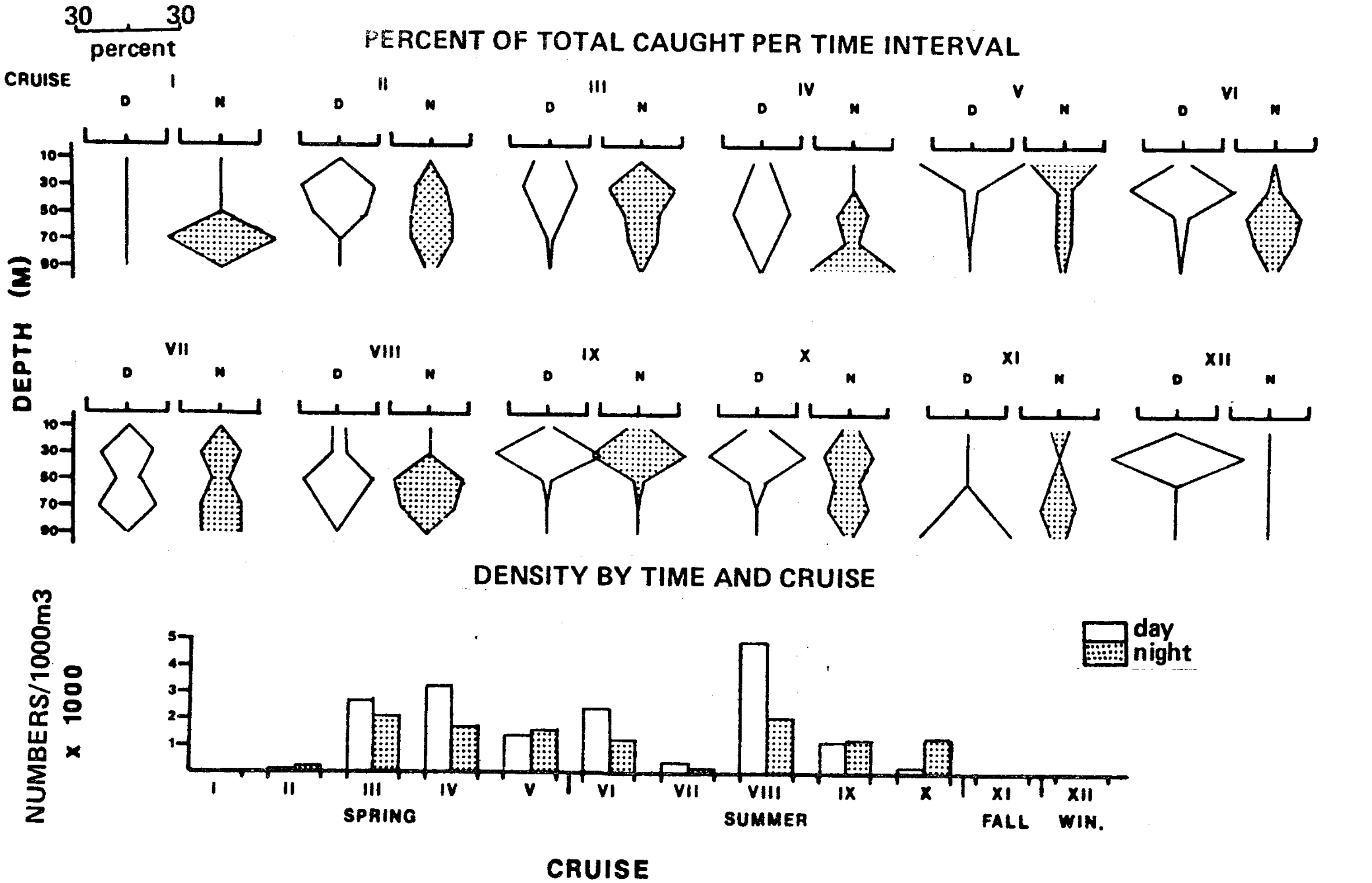


Figure 78.--Percent of total numbers caught by depth stratum per time interval and cruise, and density by time and cruise of crangonid shrimp, Crangonidae, at diel stations in the inshore region. Tucker trawl data. D = day, N = night.

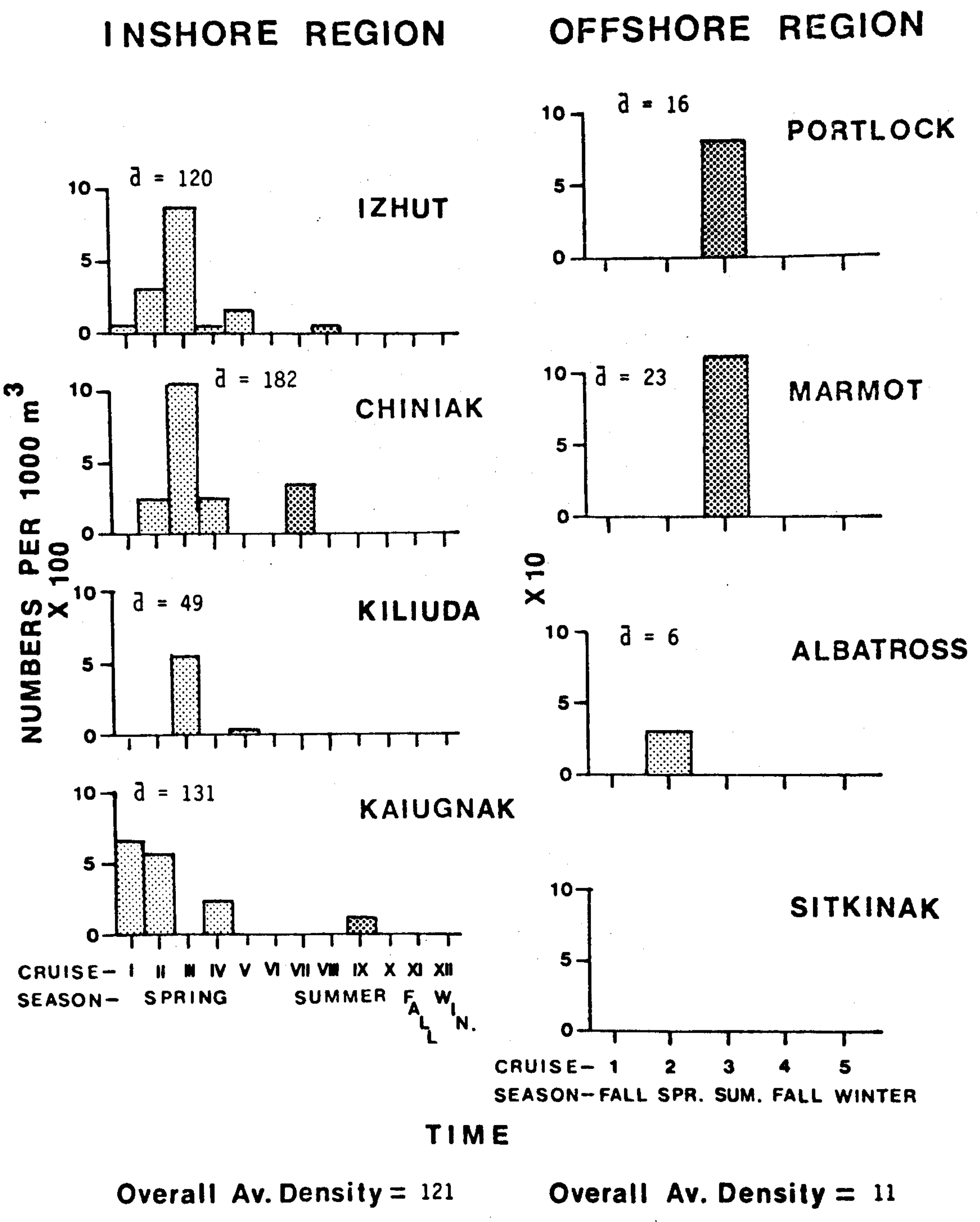


Figure 79.--Average density (numbers per 1000 m^3) by cruise, season, bay, subarea, and region for pink shrimp larvae, *Pandalus borealis*, in the Kodiak Island study area. 1977-79 OCSEAP plankton cruises. Bongo net data.

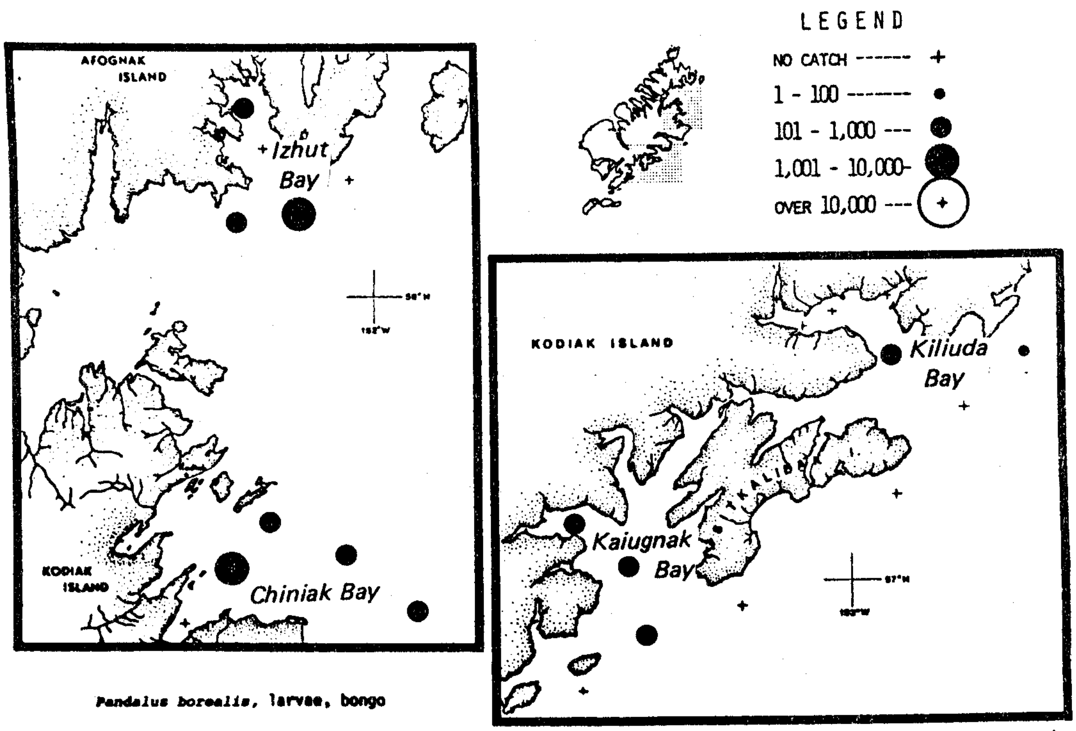


Figure 80.--Average density per station (numbers per 1000 m^3) of pink shrimp larvae, Pandalus borealis, in bongo tows from the spring 1978 OCSEAP inshore plankton cruises.

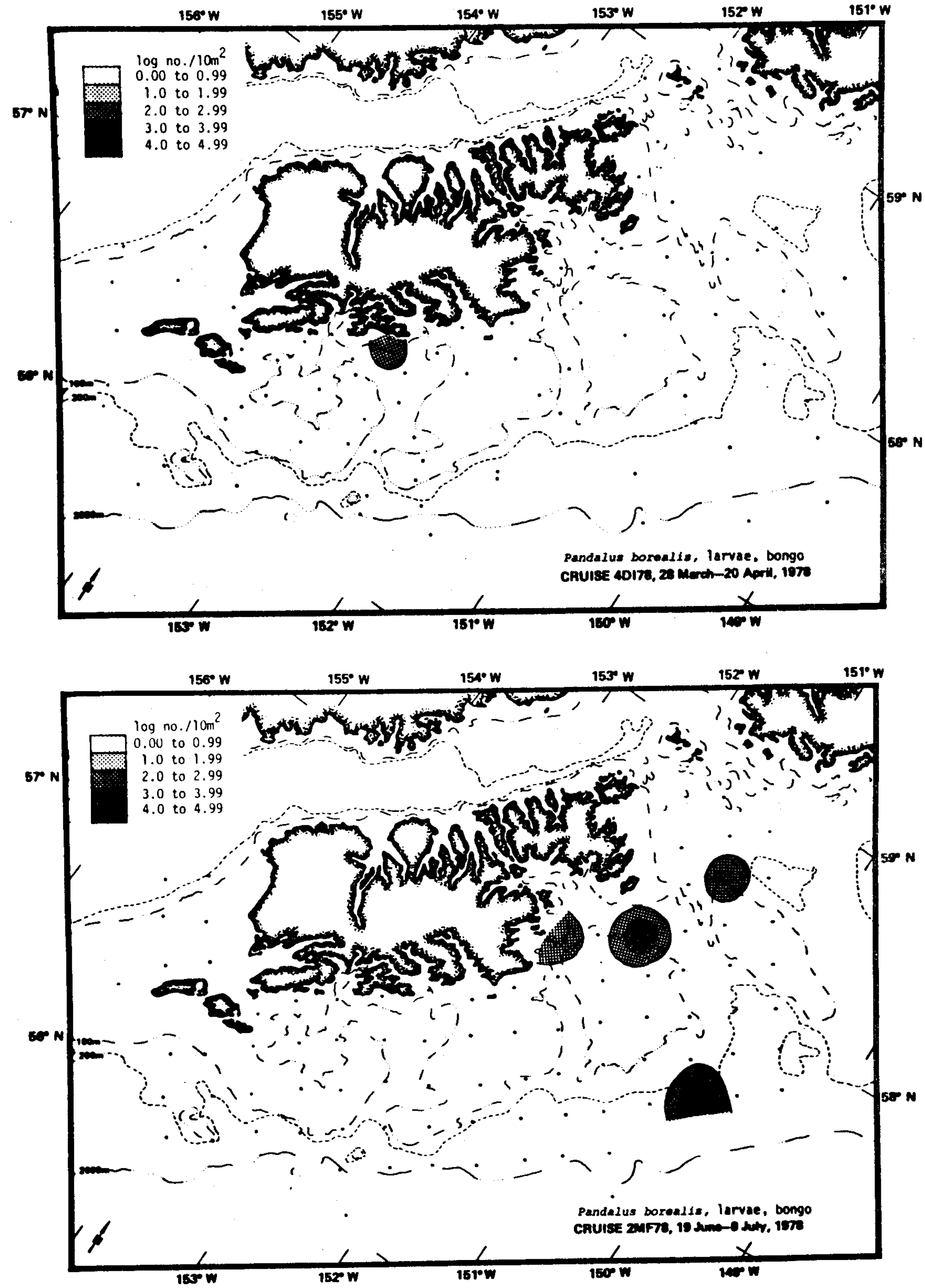


Figure 81.--Distribution and relative abundance of pink shrimp larvae, Pandalus borealis, during the spring (top) and summer (bottom) 1978 OCSEAP offshore plankton cruises. Bongo net data.

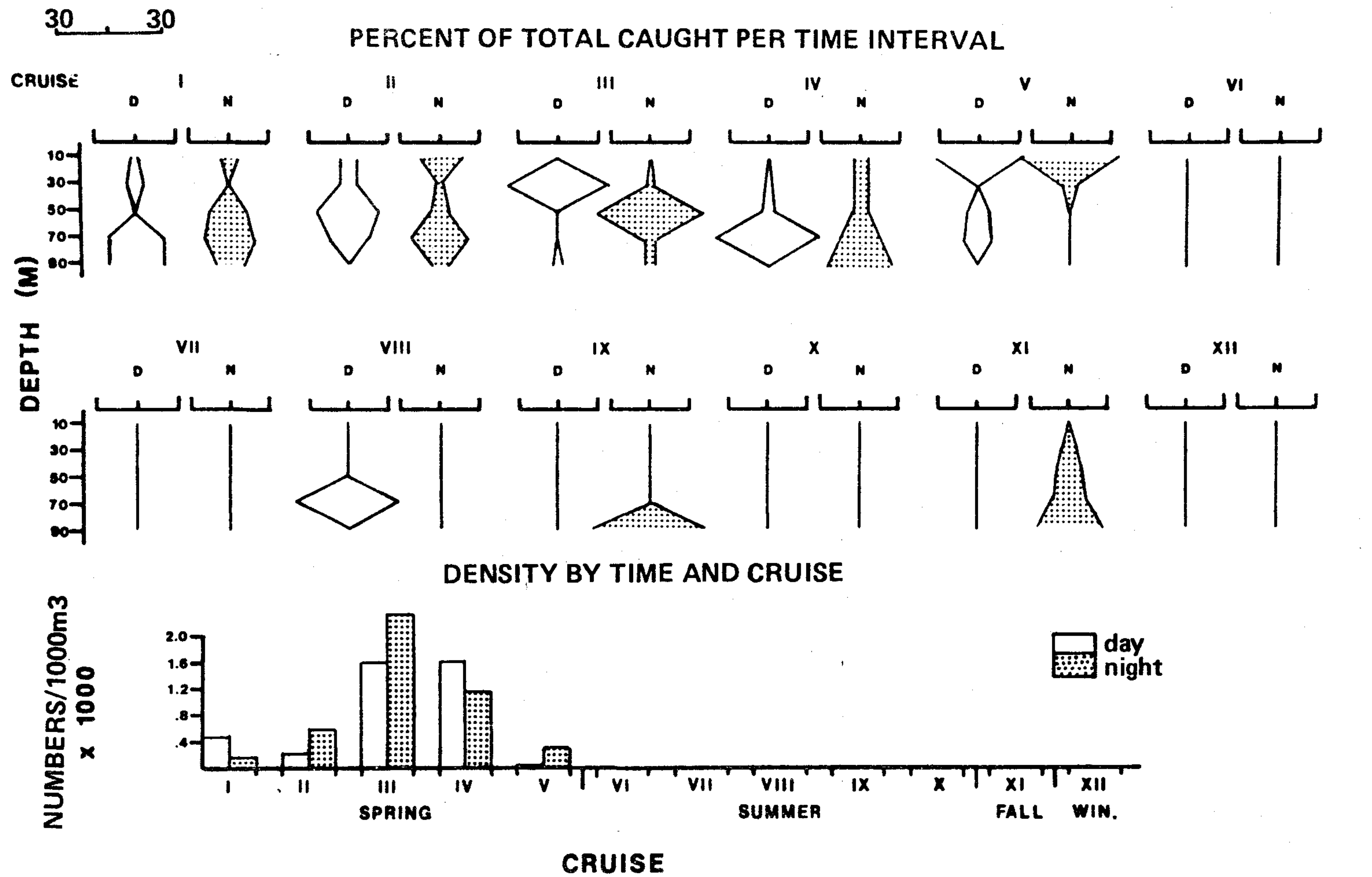


Figure 82.--Percent of total numbers caught by depth stratum per time interval and cruise, and density by time and cruise of pink shrimp larvae, Pandalus borealis, at diel stations in the inshore region. Tucker trawl data. D = day, N = night.

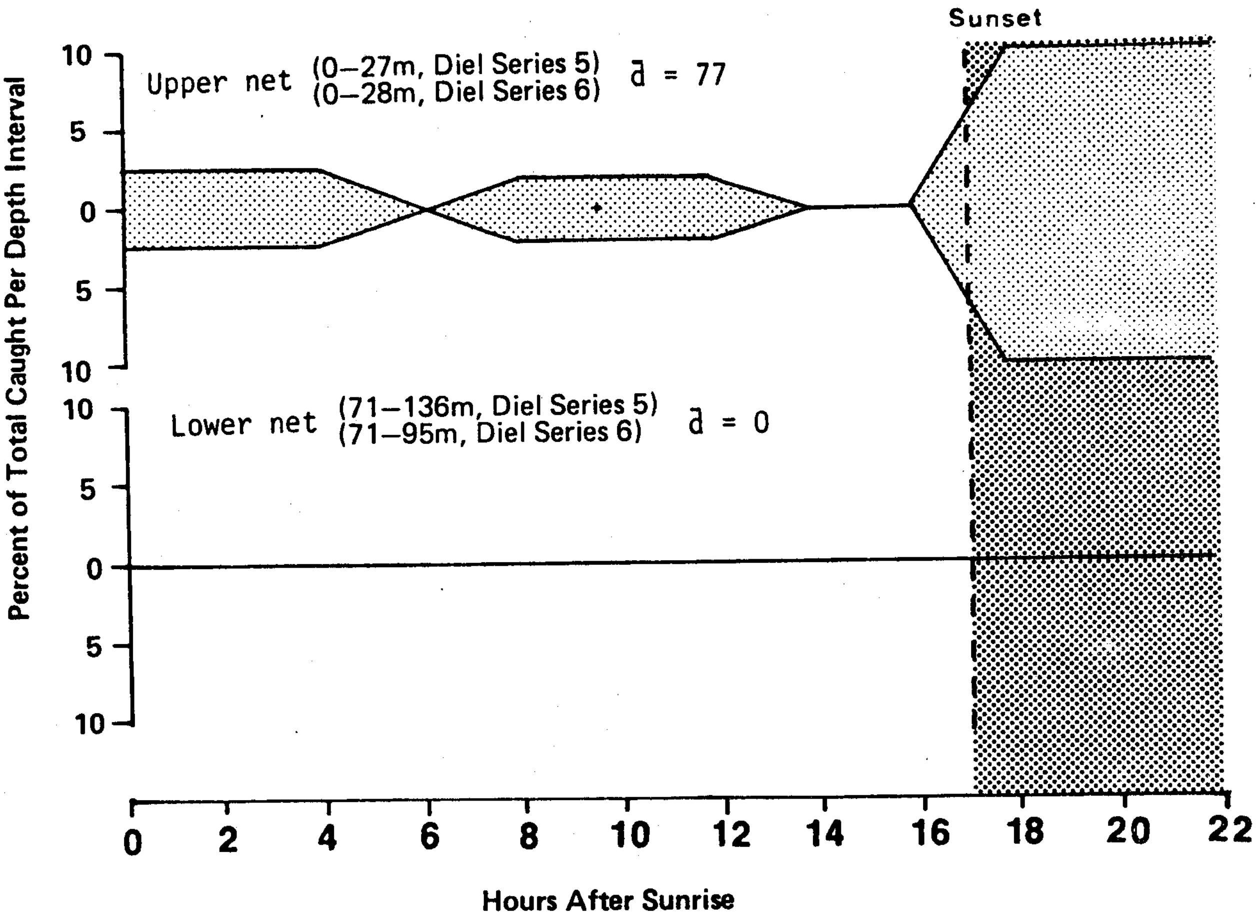


Figure 83.--Percent of total numbers of pink shrimp larvae, __Pandalus borealis__, caught by time interval per depth stratum during summer 1978 diel studies in the offshore region. Tucker trawl data. d = mean density (no./1000 m^3) for all time periods per depth stratum.

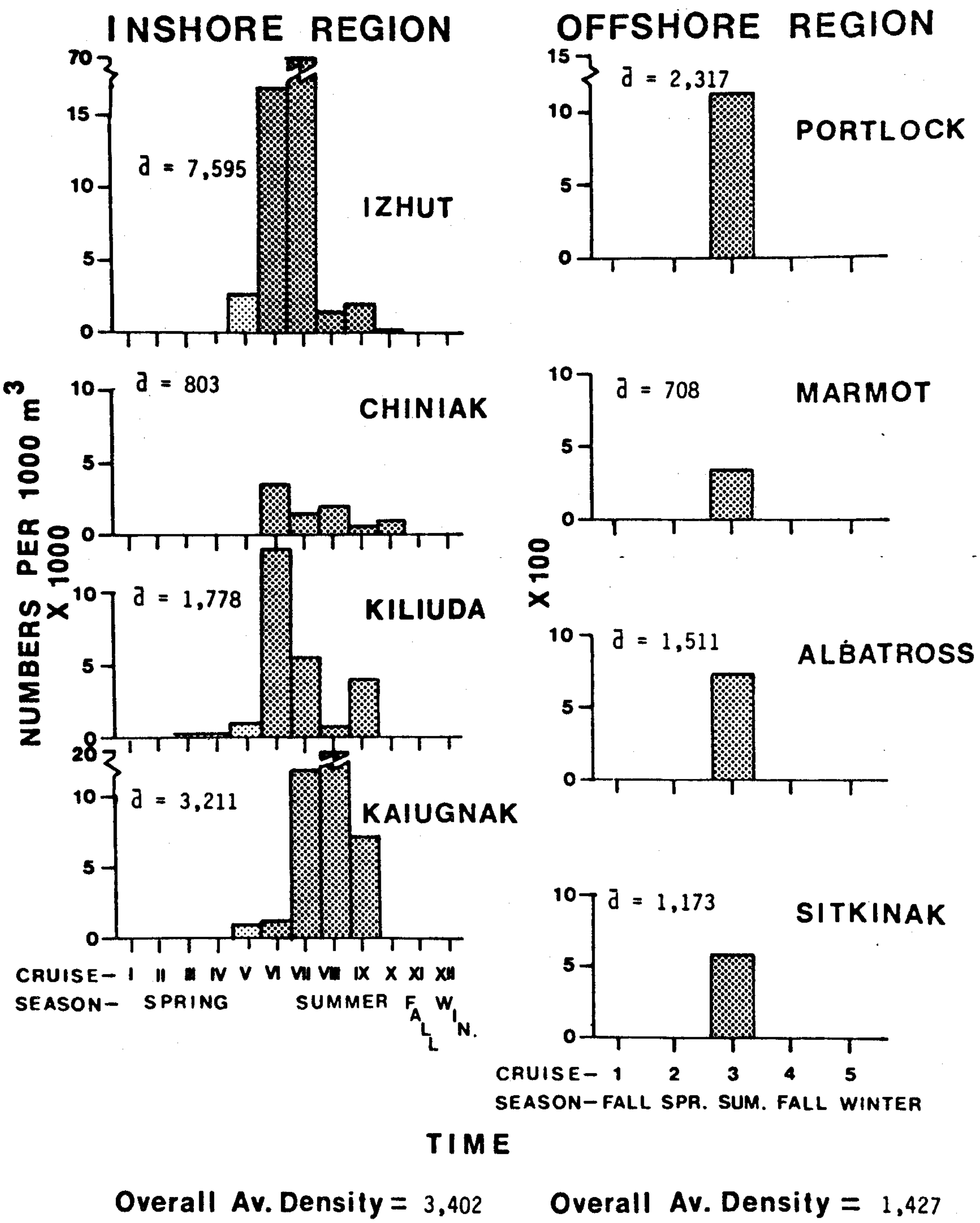


Figure 84.--Average density (numbers per 1000 m^3) by cruise, season, bay, subarea, and region for anomuran crab larvae, Anomura, in the Kodiak Island study area. Bongo net data.

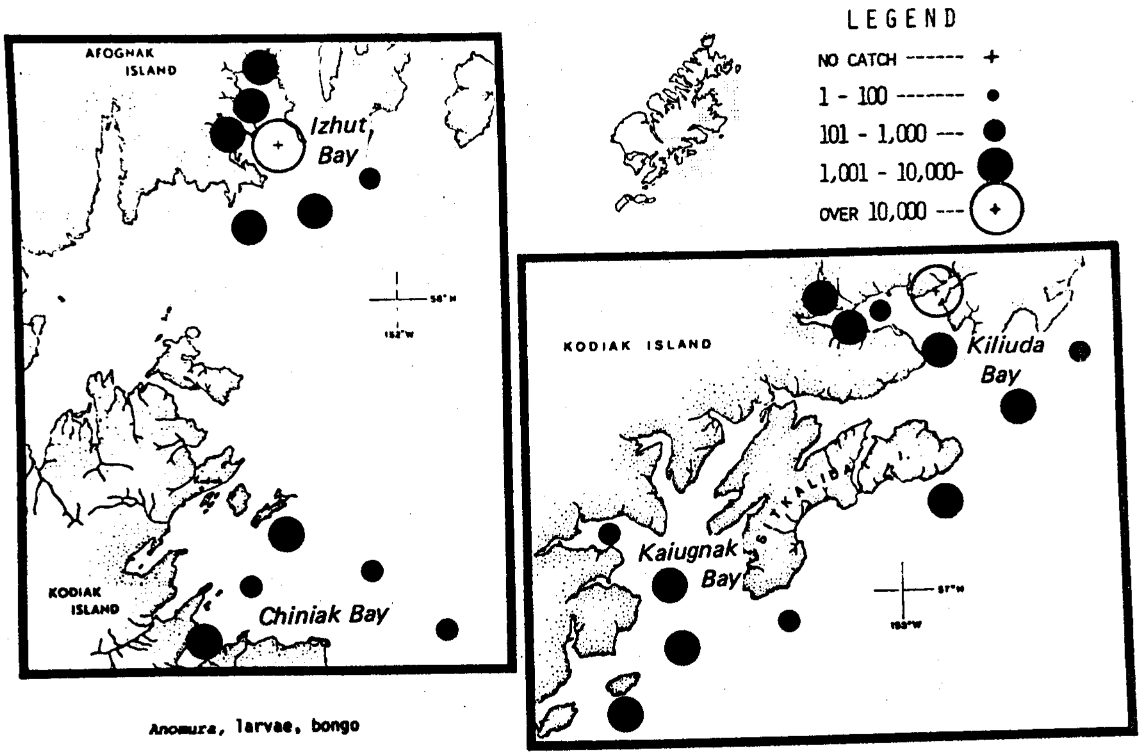


Figure 85.--Average density per station (numbers per 1000 m^3) of anomuran crab larvae, Anomura, in bongo tows from the spring 1978 OCSEAP inshore plankton cruises.

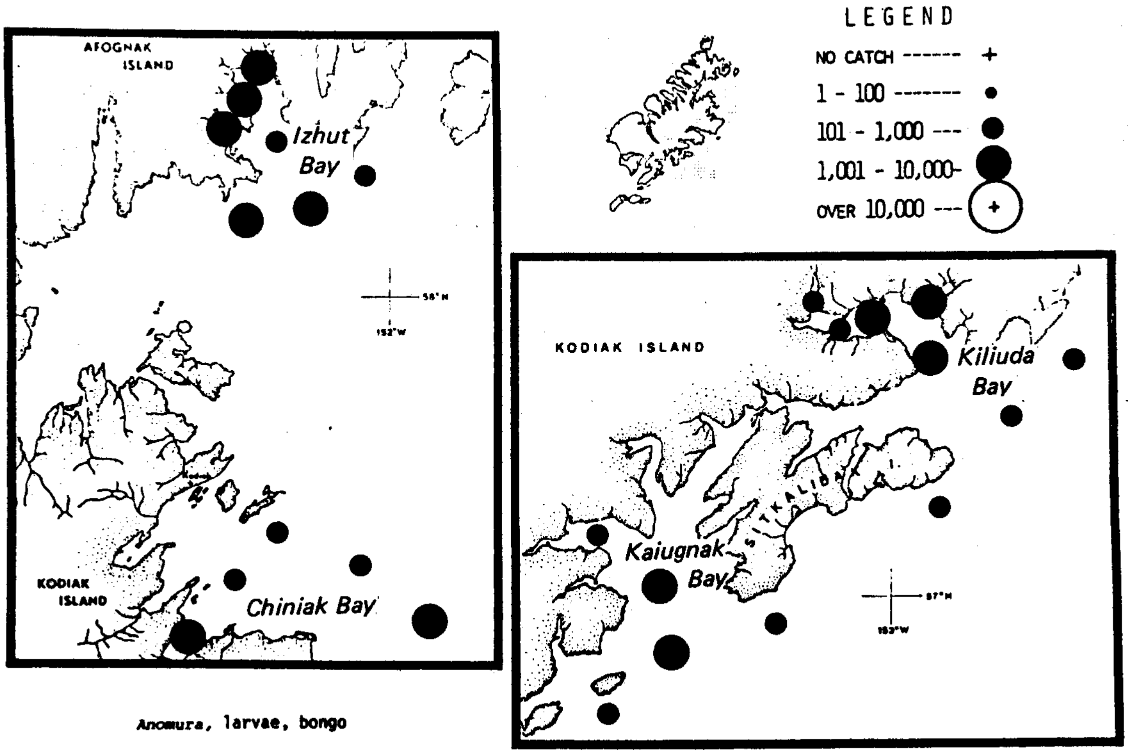


Figure 86.--Average density per station (numbers per 1000 m^3) of anomuran crab larvae, Anomura, in bongo tows from the summer 1978 OCSEAP inshore plankton cruises.

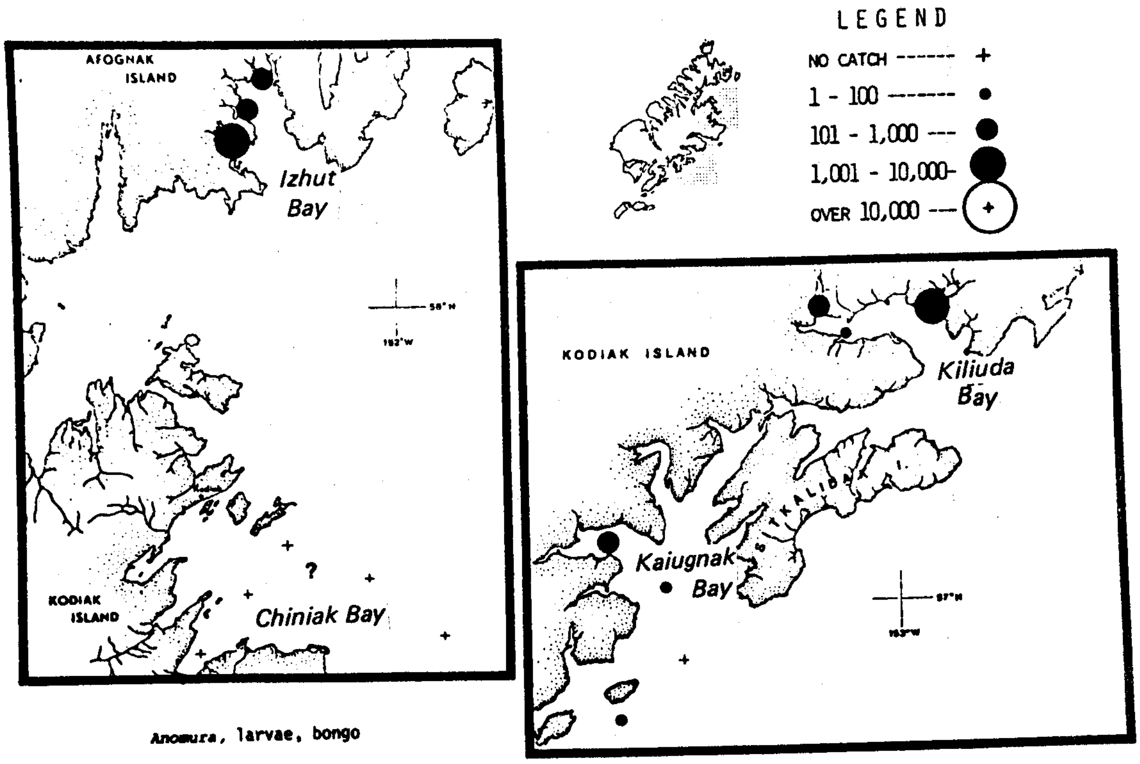


Figure 87.--Average density per station (numbers per 1000 m^3) of anomuran crab larvae, Anomura, in bongo tows from the fall 1978 OCSEAP inshore plankton cruise.

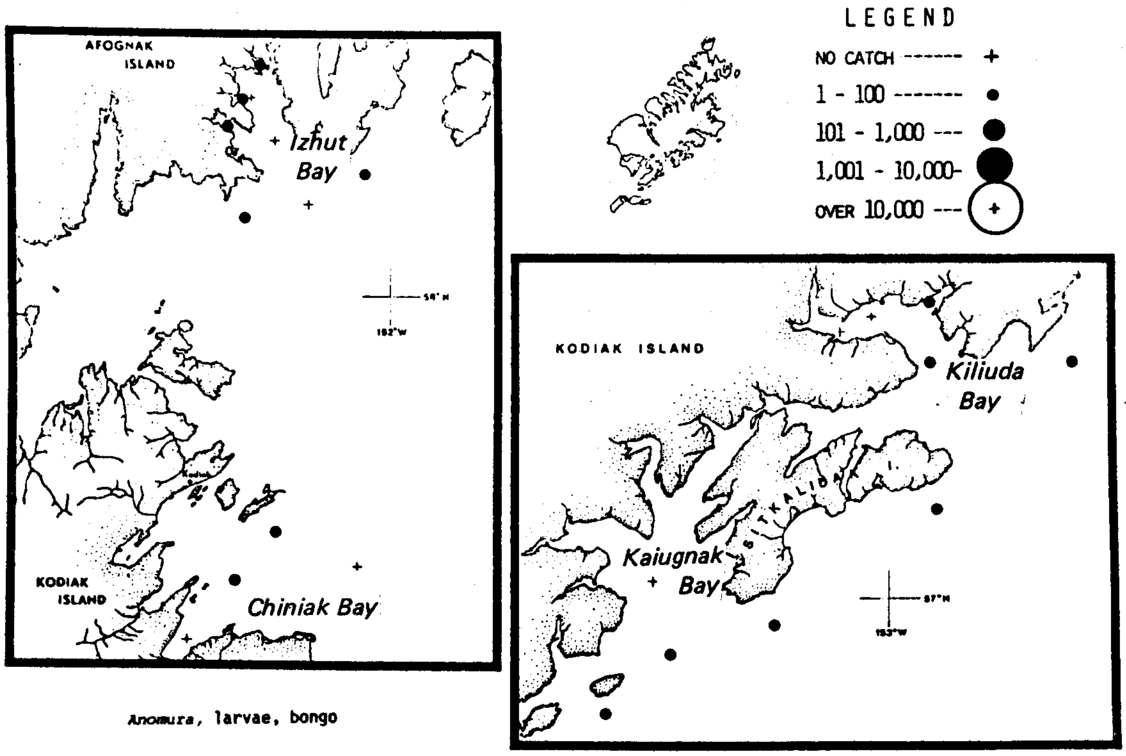


Figure 88.--Average density per station (numbers per 1000 m^3) of anomuran crab larvae, Anomura, in bongo tows from the late winter 1979 OCSEAP inshore plankton cruise.

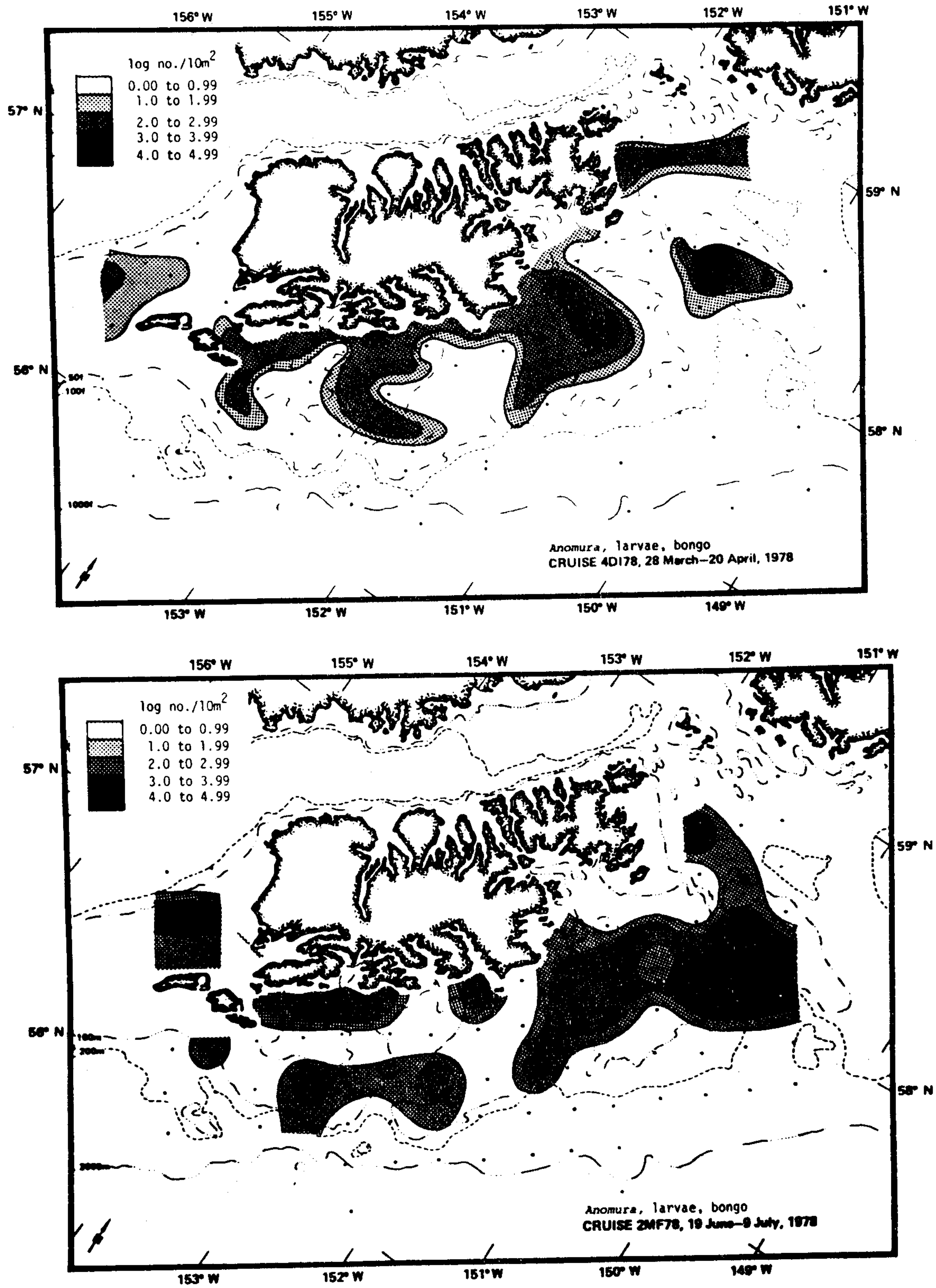
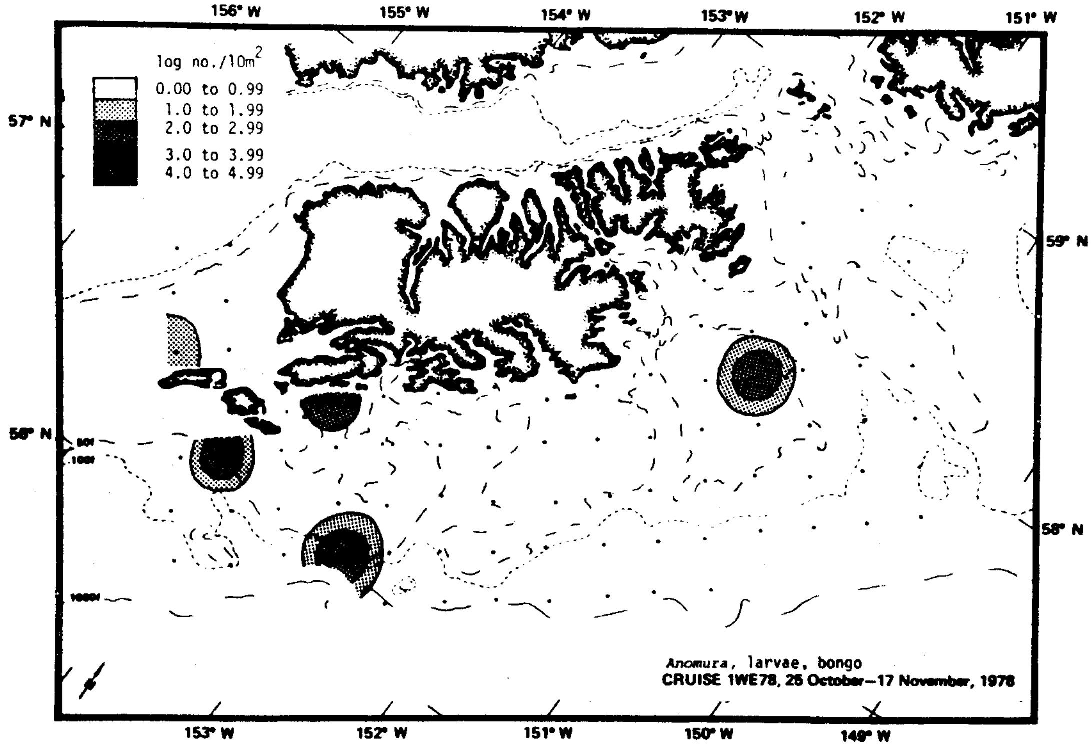


Figure 89.--Distribution and relative abundance of anomuran crab larvae, Anomura, during the spring (top) and summer (bottom) 1978 OCSEAP offshore plankton cruises. Bongo net data.



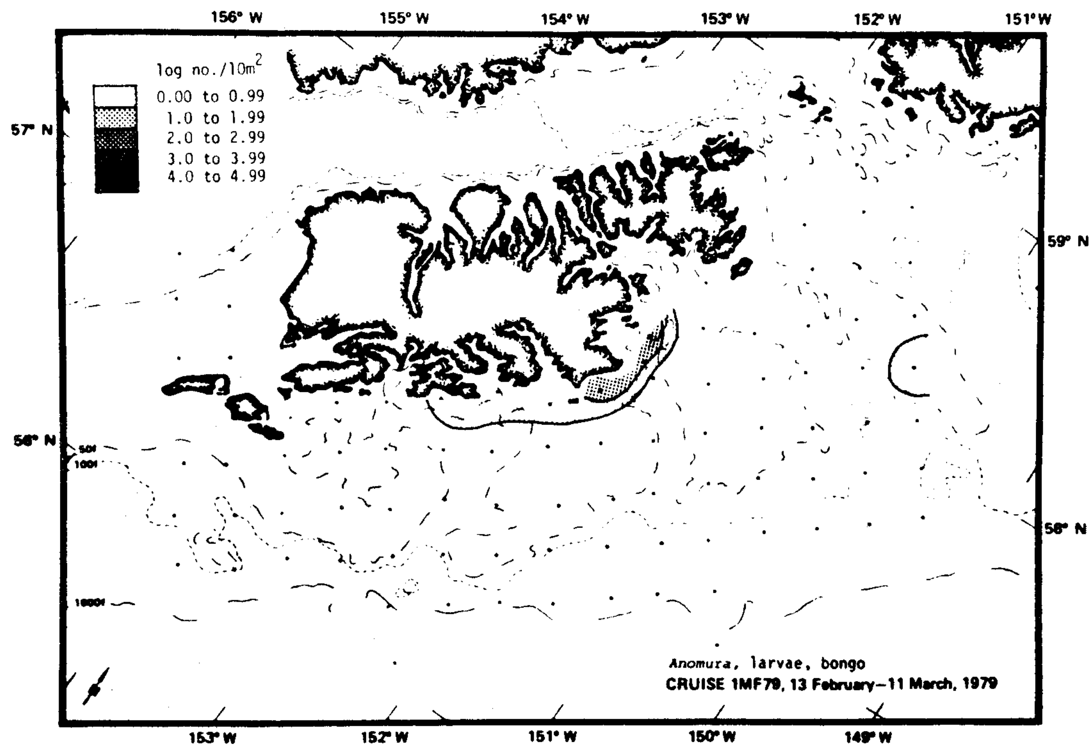


Figure 90.--Distribution and relative abundance of anomuran crab larvae Anomura, during the fall 1978 (top) and winter 1979 (bottom) OCSEAP offshore plankton cruises. Bongo net data.

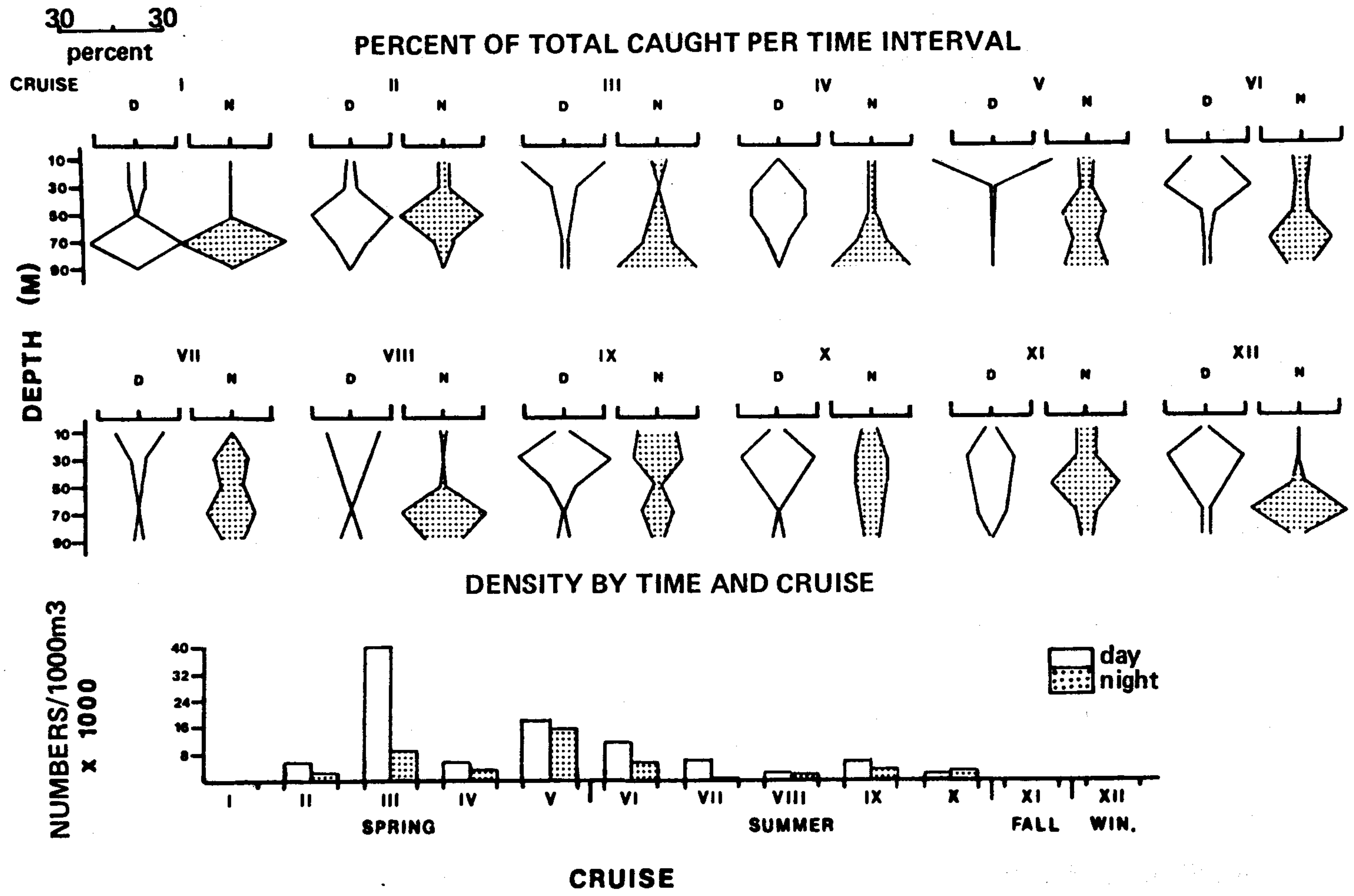


Figure 91.--Percent of total numbers caught by depth stratum per time interval and cruise, and density by time and cruise of anomuran crab larvae, Anomura, at diel stations in the inshore region. Tucker trawl data. D = day, N = night.

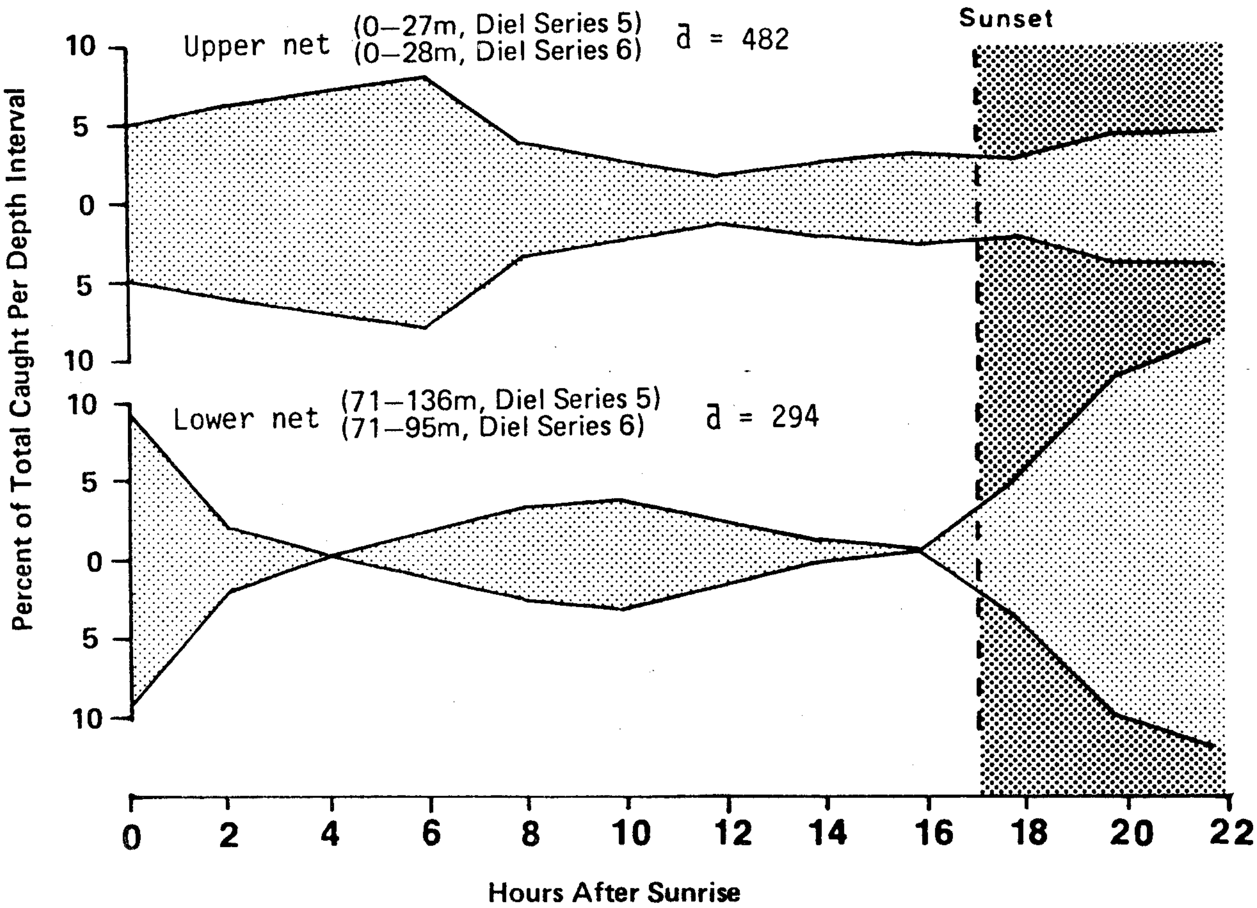


Figure 92.--Percent of total numbers of anomuran crab larvae, Anomura, caught by time interval per depth stratum during summer 1978 diel studies in the offshore region. Tucker trawl data. d = mean density (no./1000 m^3) for all time periods per depth stratum.

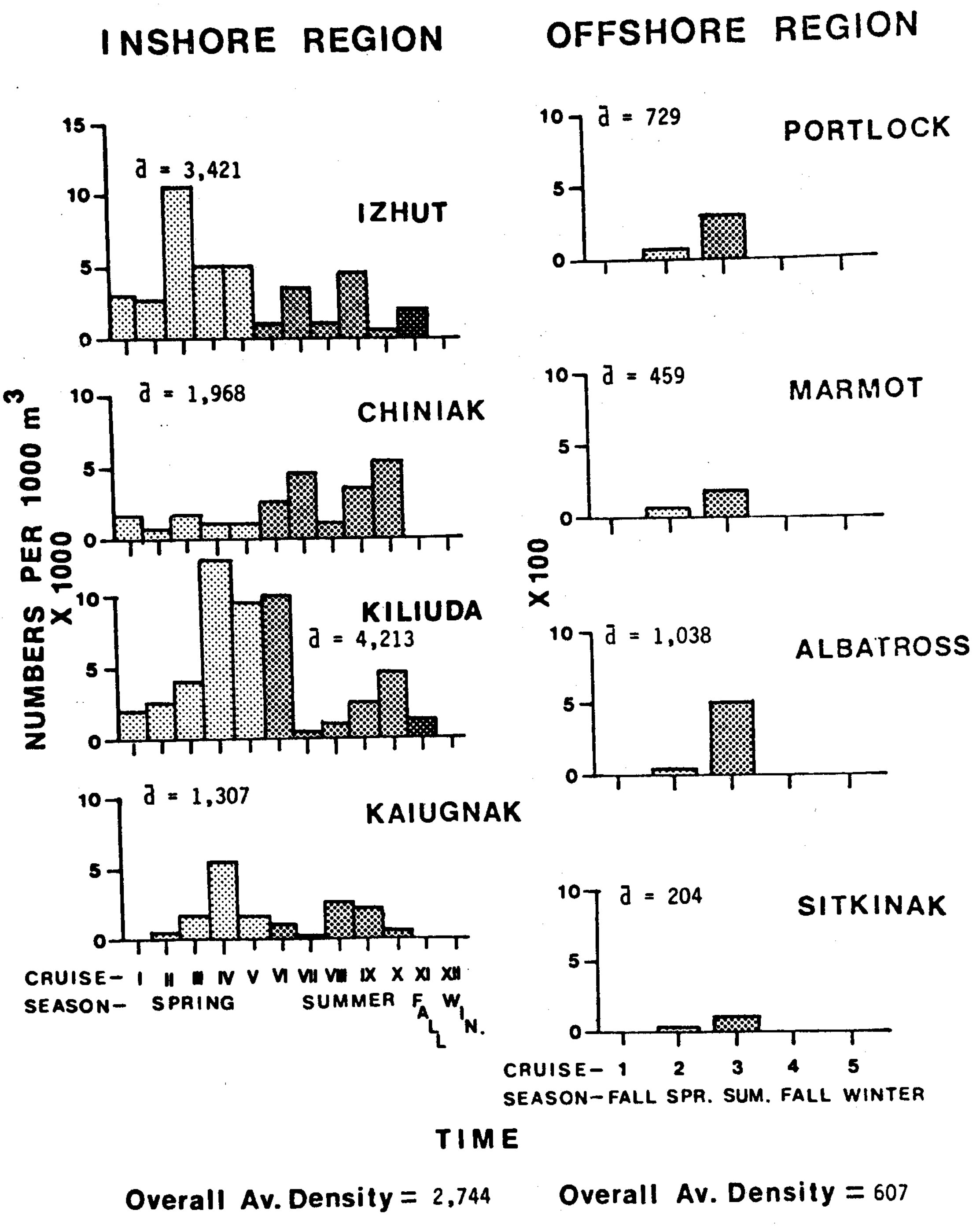


Figure 93.--Average density (numbers per 1000 m^3) by cruise, season, bay, subarea, and region for cancer crab larvae, Cancer I, in the Kodiak Island study area. 1977-1979 OCSEAP plankton cruises. Bongo net data.

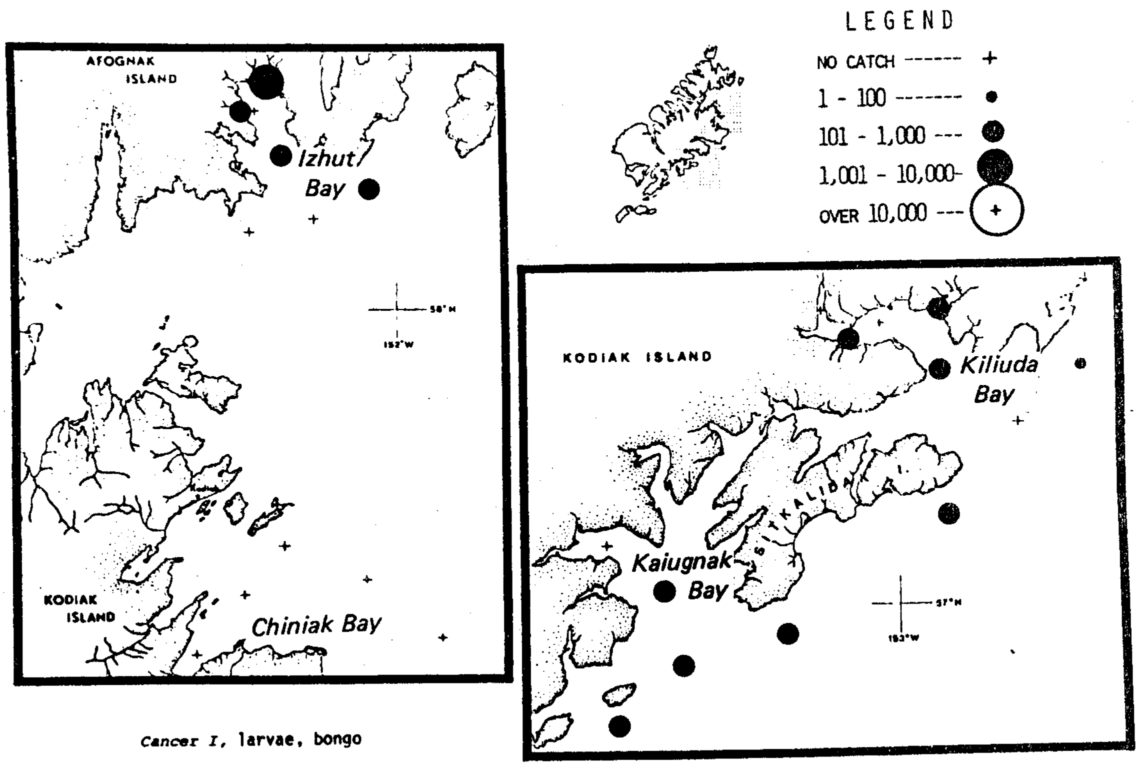


Figure 94.--Average density per station (numbers per 1000 m^3) of cancer crab larvae, Cancer I, in bongo tows from the spring 1978 OCSEAP inshore plankton cruise.

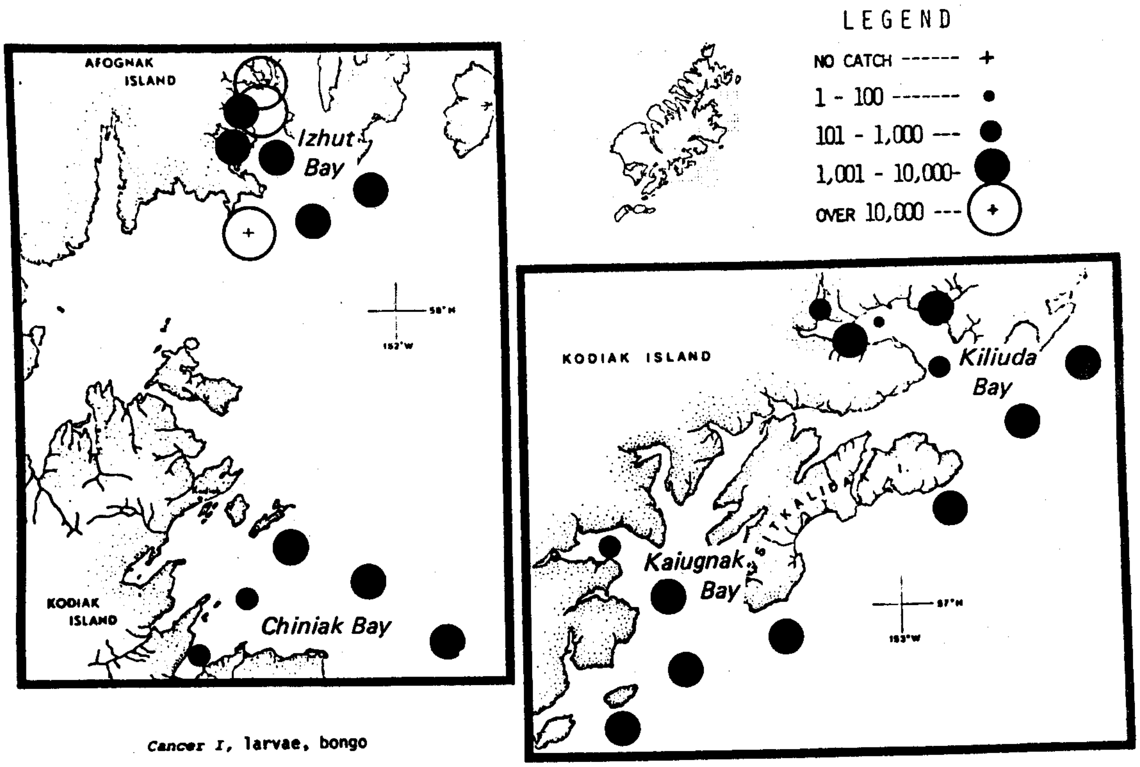


Figure 95.--Average density per station (numbers per 1000 m^3) of cancer crab larvae, Cancer I, in bongo tows from the summer 1978 OCSEAP inshore plankton cruises.

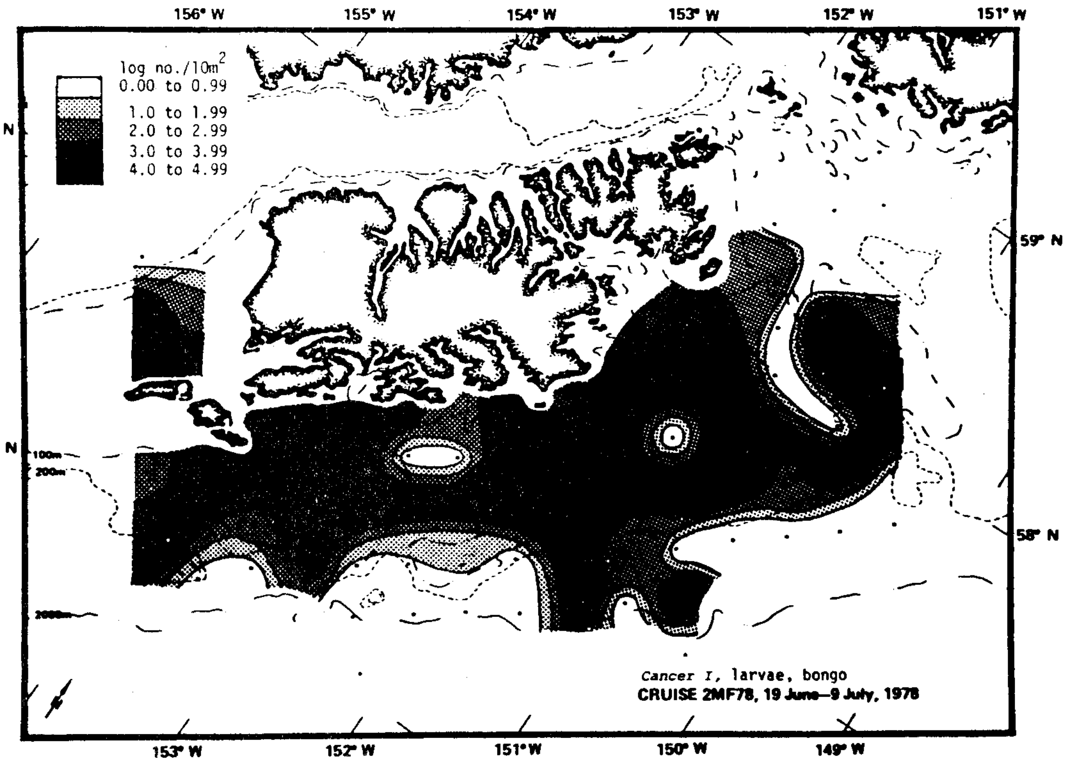


Figure 96.--Distribution and relative abundance of cancer crab larvae, Cancer I, during the summer 1978 OCSEAP offshore plankton cruise. Bongo net data.

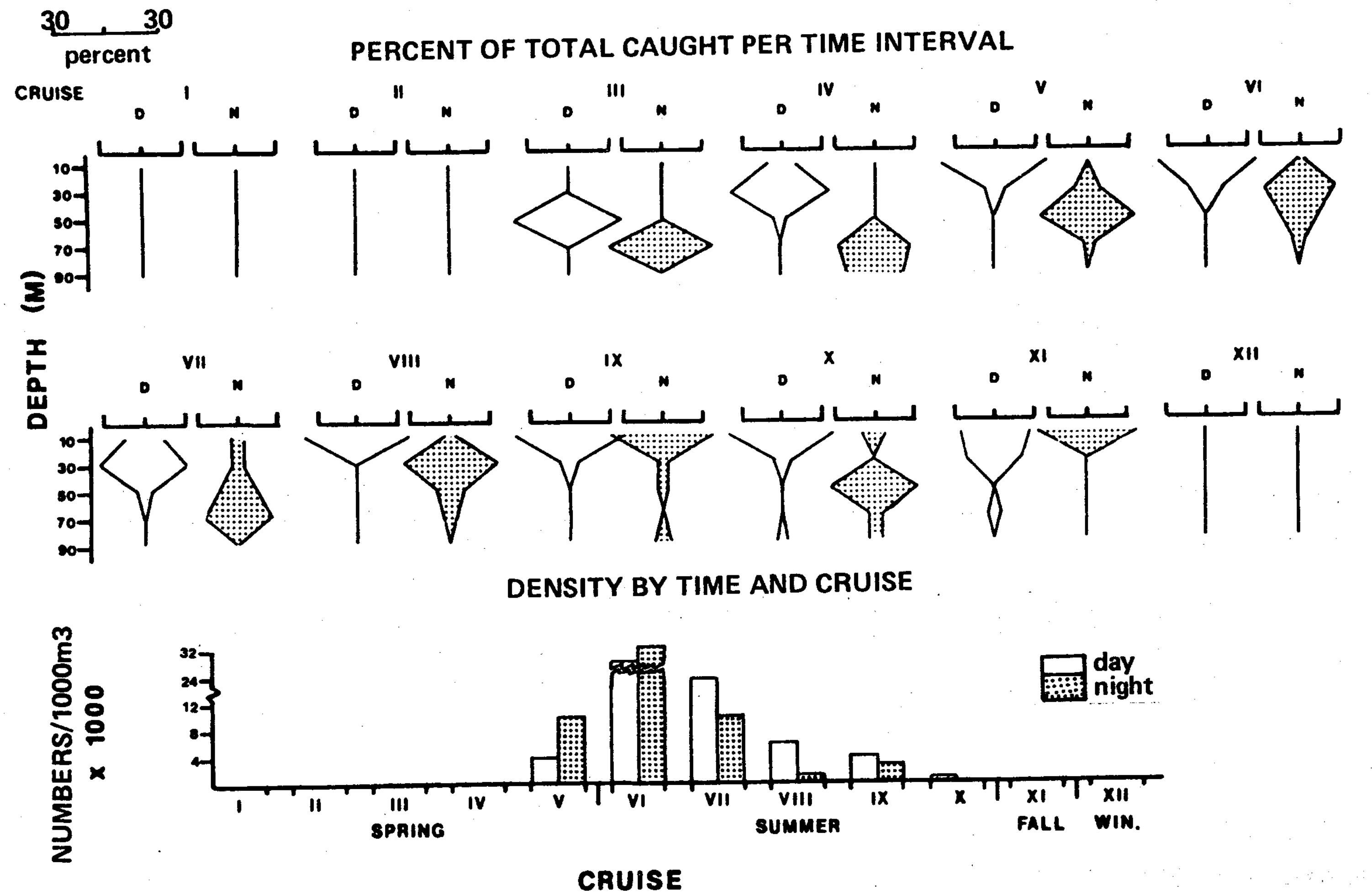


Figure 97.--Percent of total numbers caught by depth stratum per time interval and cruise, and density by time and cruise of cancer crab larvae, Cancer I, at diel stations in the inshore region. Tucker trawl data. D = day, N = night.

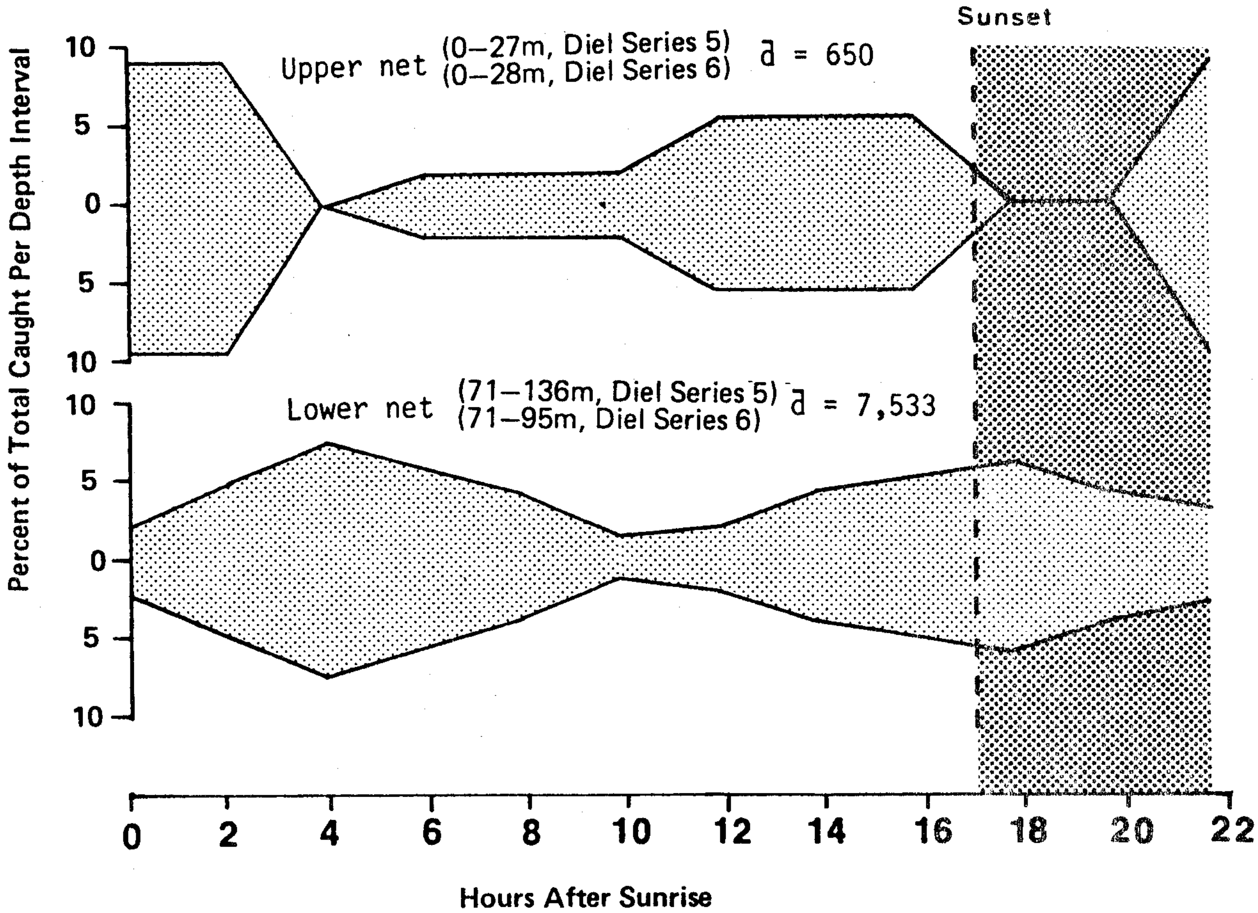


Figure 98.--Percent of total numbers of cancer crab larvae, Cancer I, caught by time interval per depth stratum during summer 1978 diel studies in the offshore region. Tucker trawl data. d = mean density (no./1000 m^3) for all time periods per depth stratum.

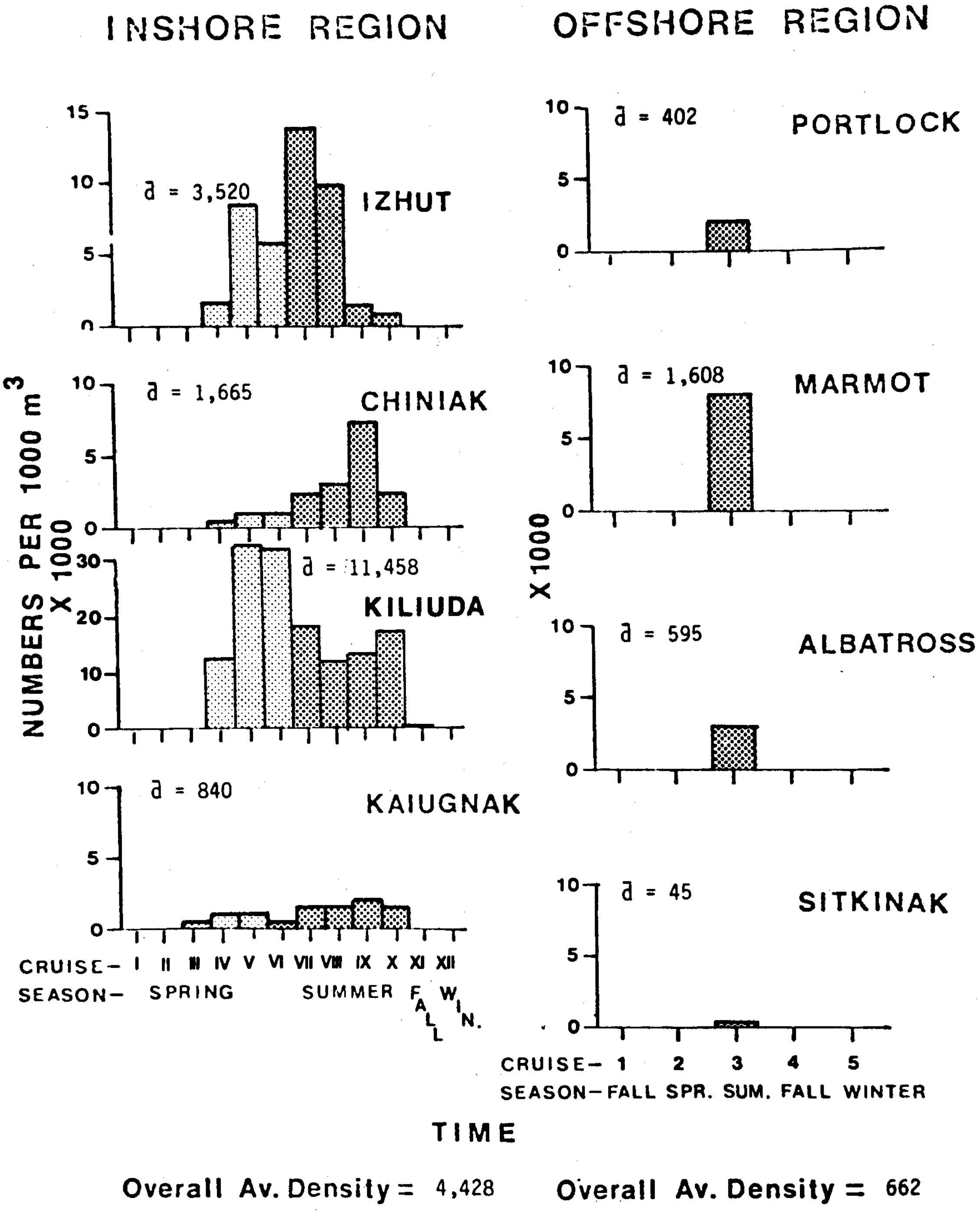


Figure 99.--Average density (numbers per 1000 m^3) by cruise, season, bay, subarea, and region for pea crab larvae, Pinnotheridae, in the Kodiak Island study area. Bongo net data.

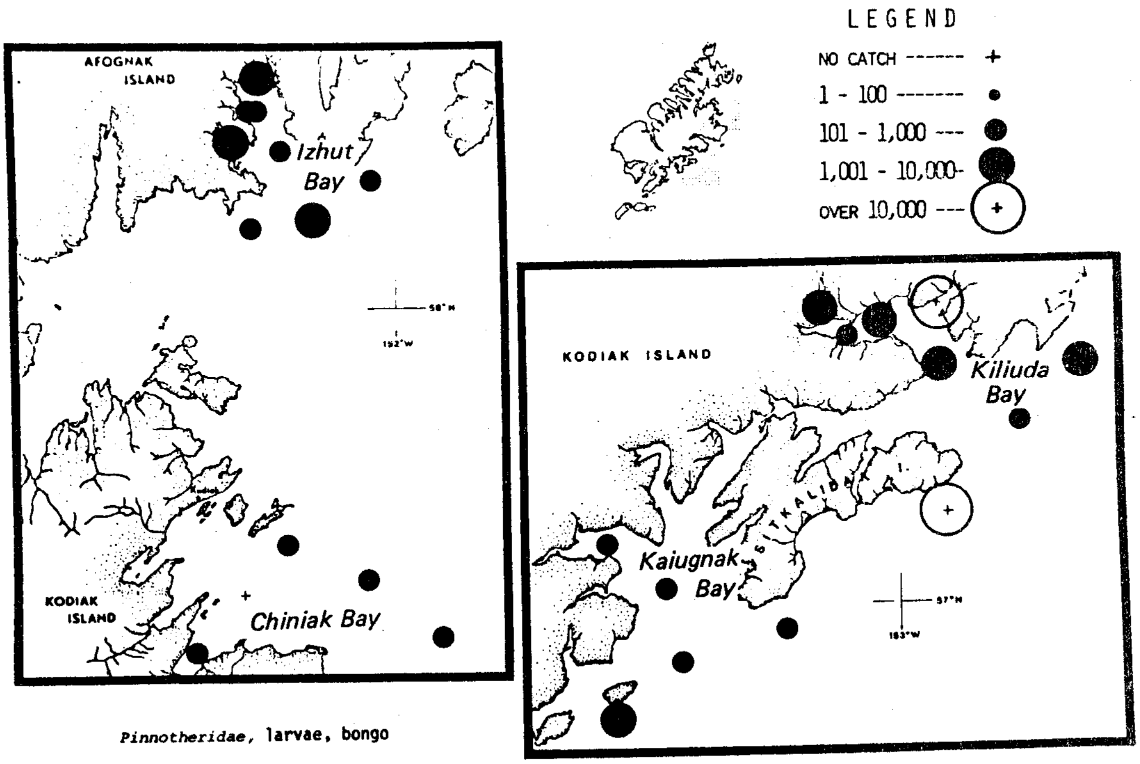


Figure 100.--Average density per station (numbers per 1000 m^3) of pea crab larvae, Pinnotheridae, in bongo tows from the spring 1978 OCSEAP inshore plankton cruises.

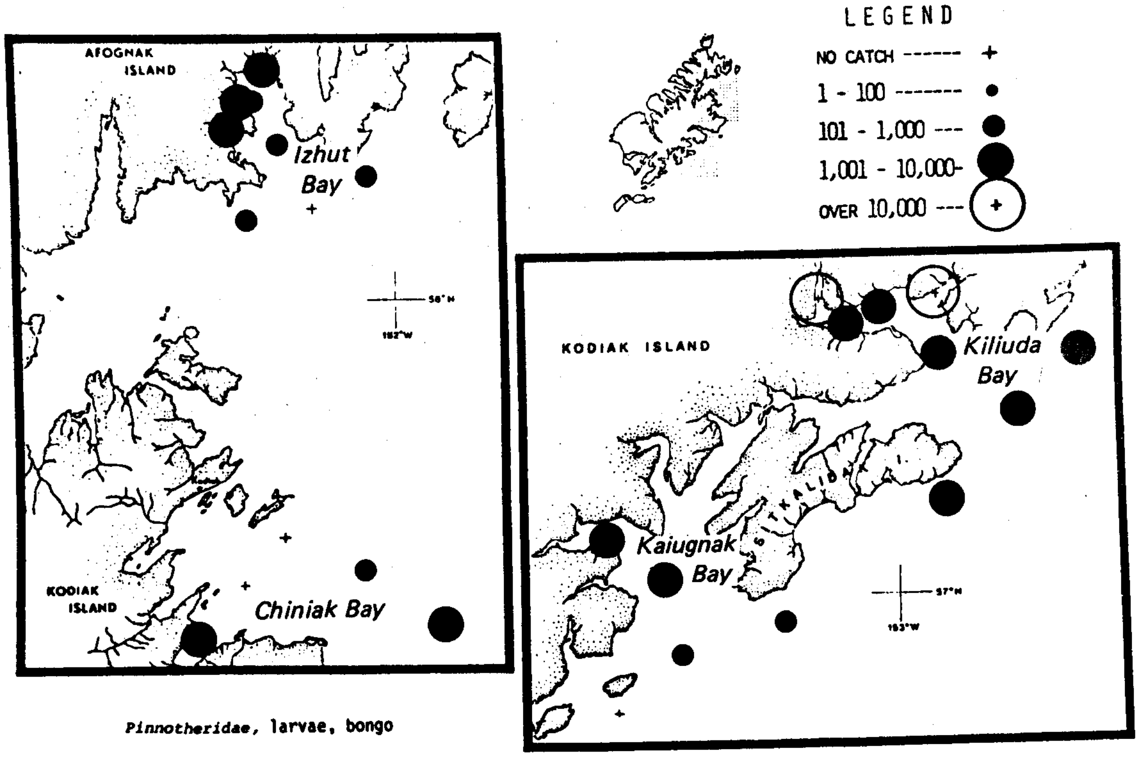


Figure 101.--Average density per station (numbers per 1000 m^3) of pea crab larvae, Pinnotheridae, in bongo tows from the summer 1978 OCSEAP inshore plankton cruises.

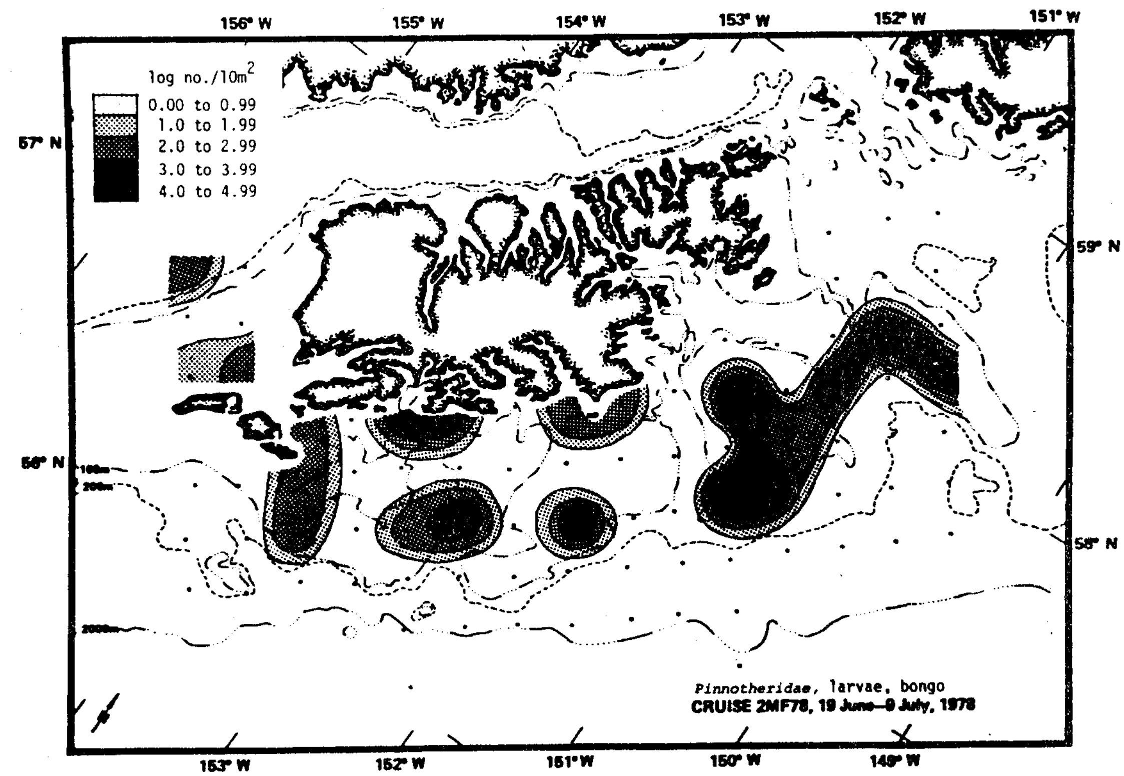


Figure 102.--Distribution and relative abundance of pea crab larvae, Pinnotheridae, during the summer 1978 OCSEAP offshore plankton cruise. Bongo net data.

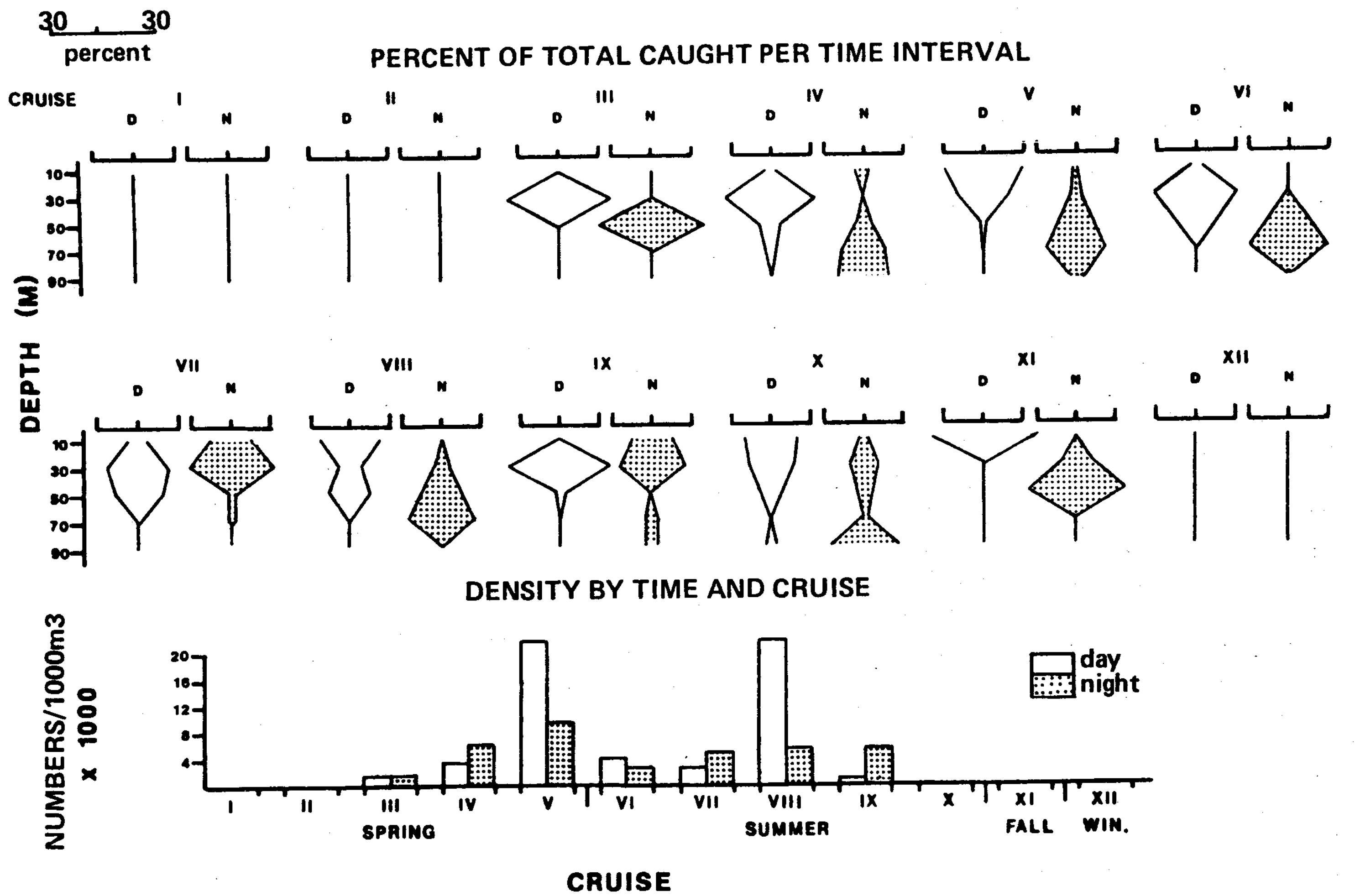


Figure 103.--Percent of total numbers caught by depth stratum per time interval and cruise, and density by time and cruise of pea crab larvae, Pinnotheridae, at diel stations in the inshore region. Tucker trawl data. D = day, N = night.

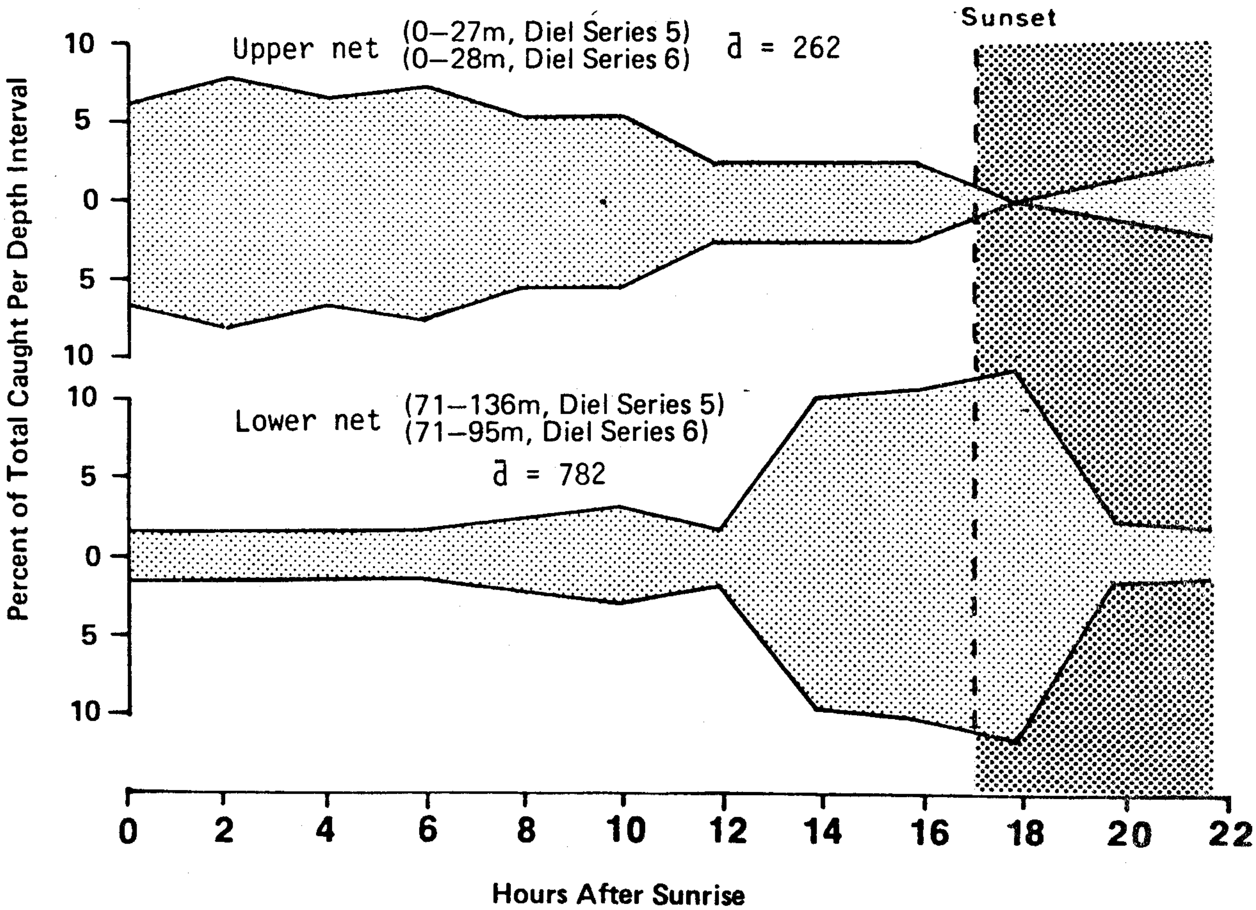


Figure 104.--Percent of total numbers of pea crab larvae, Pinnotheridae, caught by time interval per depth stratum during summer 1978 diel studies in the offshore region. Tucker trawl data. d = mean density (no./1000 m^3) for all time periods per depth stratum.

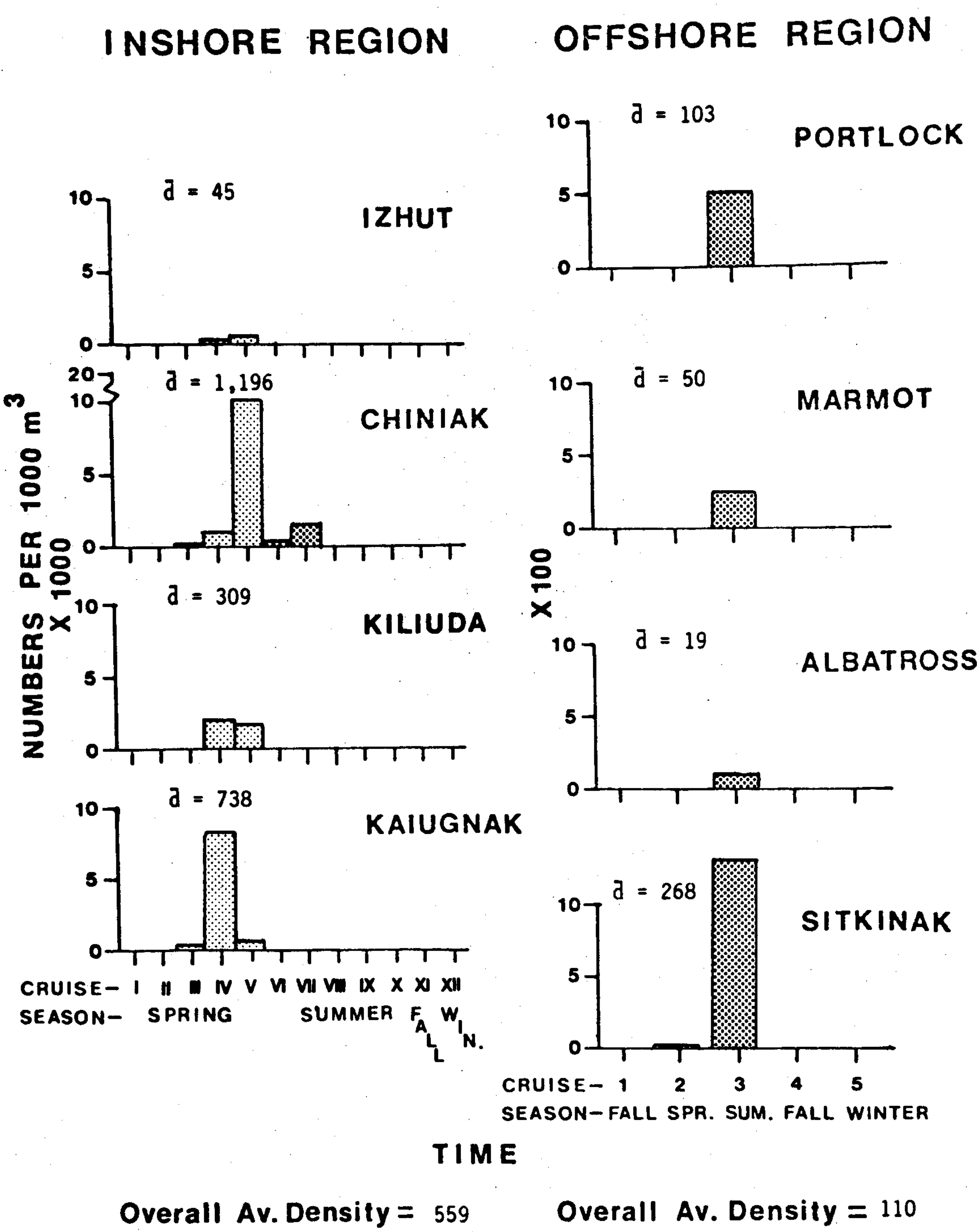


Figure 105.--Average density (numbers per 1000 m ^{3}) by cruise, season, bay, subarea, and region for Tanner crab larvae, Chionoecetes bairdi, in the Kodiak Island study area. Bongo net data.

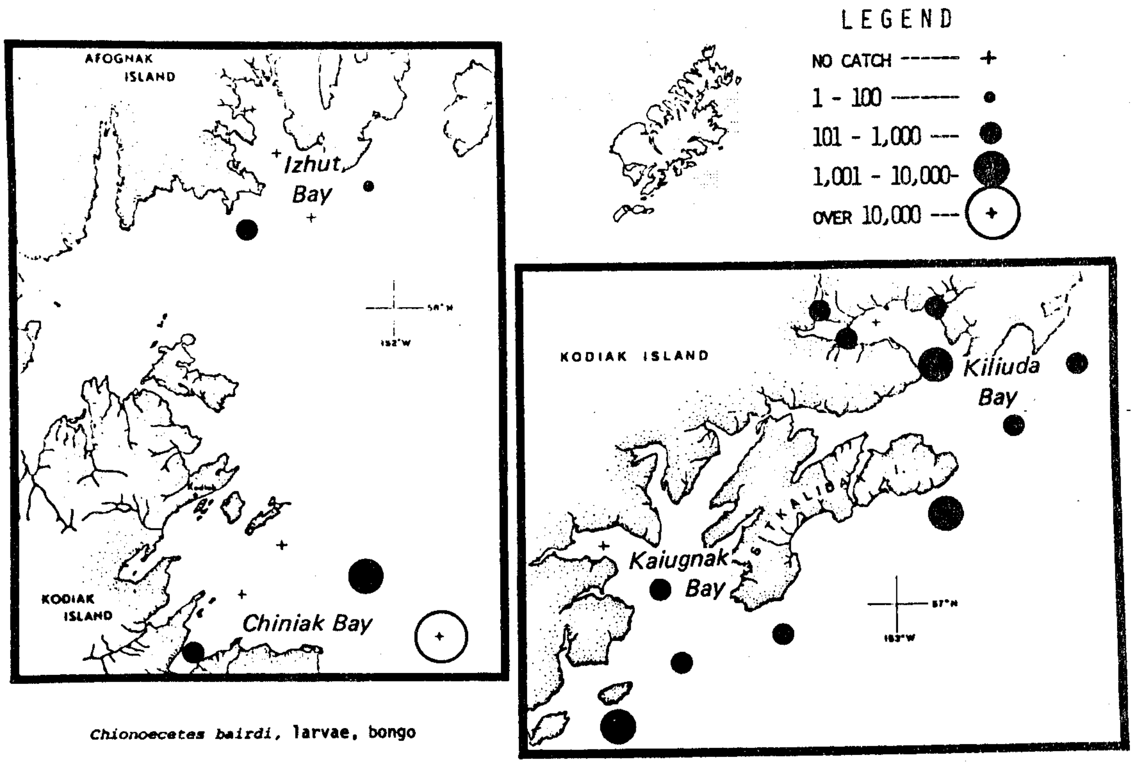


Figure 106.--Average density per station (numbers per 1000 m^3) of Tanner crab larvae, Chionoecetes bairdi, in bongo tows from the spring 1978 OCSEAP inshore plankton cruises.

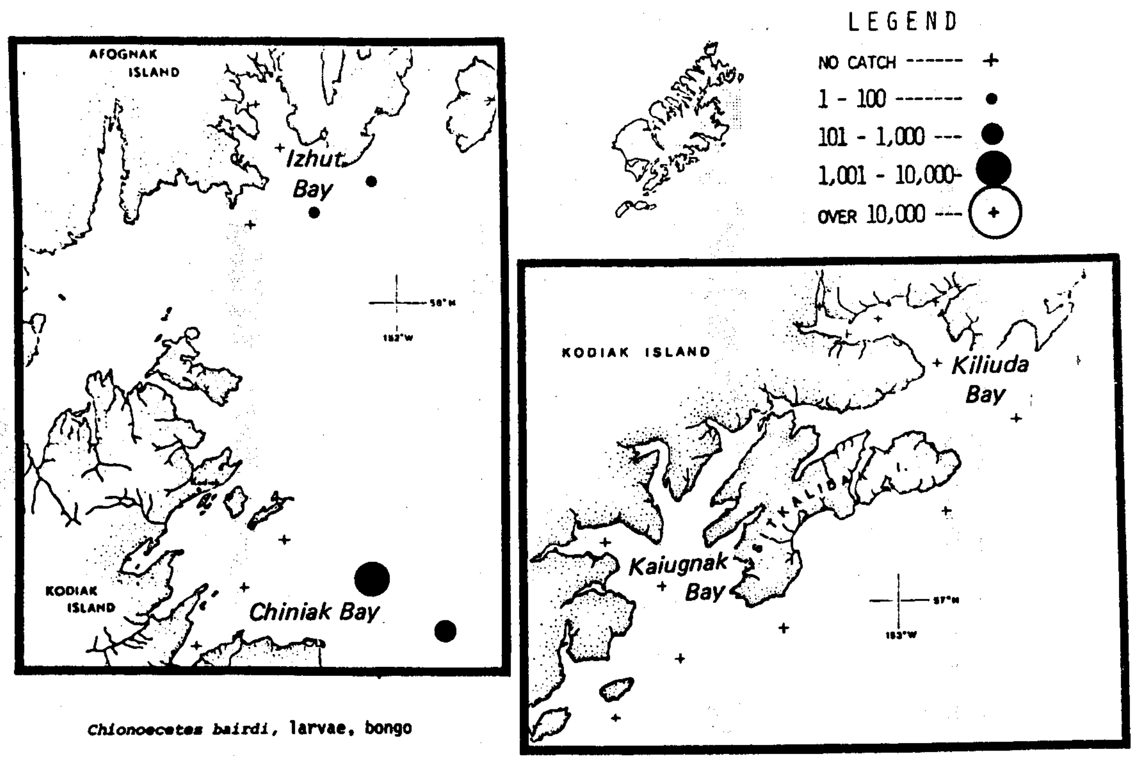


Figure 107.--Average density per station (numbers per 1000 m^3) of Tanner crab larvae, Chionoecetes bairdi, in bongo tows from the summer 1978 OCSEAP inshore plankton cruises.

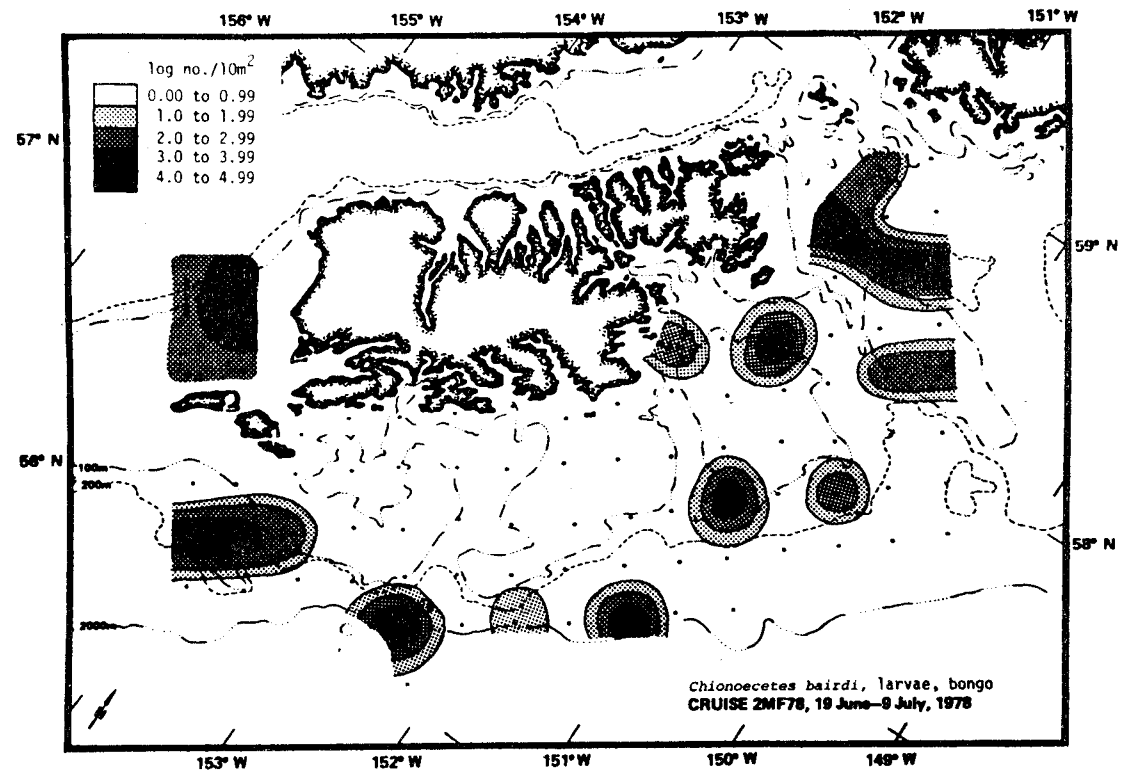


Figure 108.--Distribution and relative abundance of Tanner crab larvae, Chionoecetes bairdi, during the summer 1978 OCSEAP offshore plankton cruise. Bongo net data.

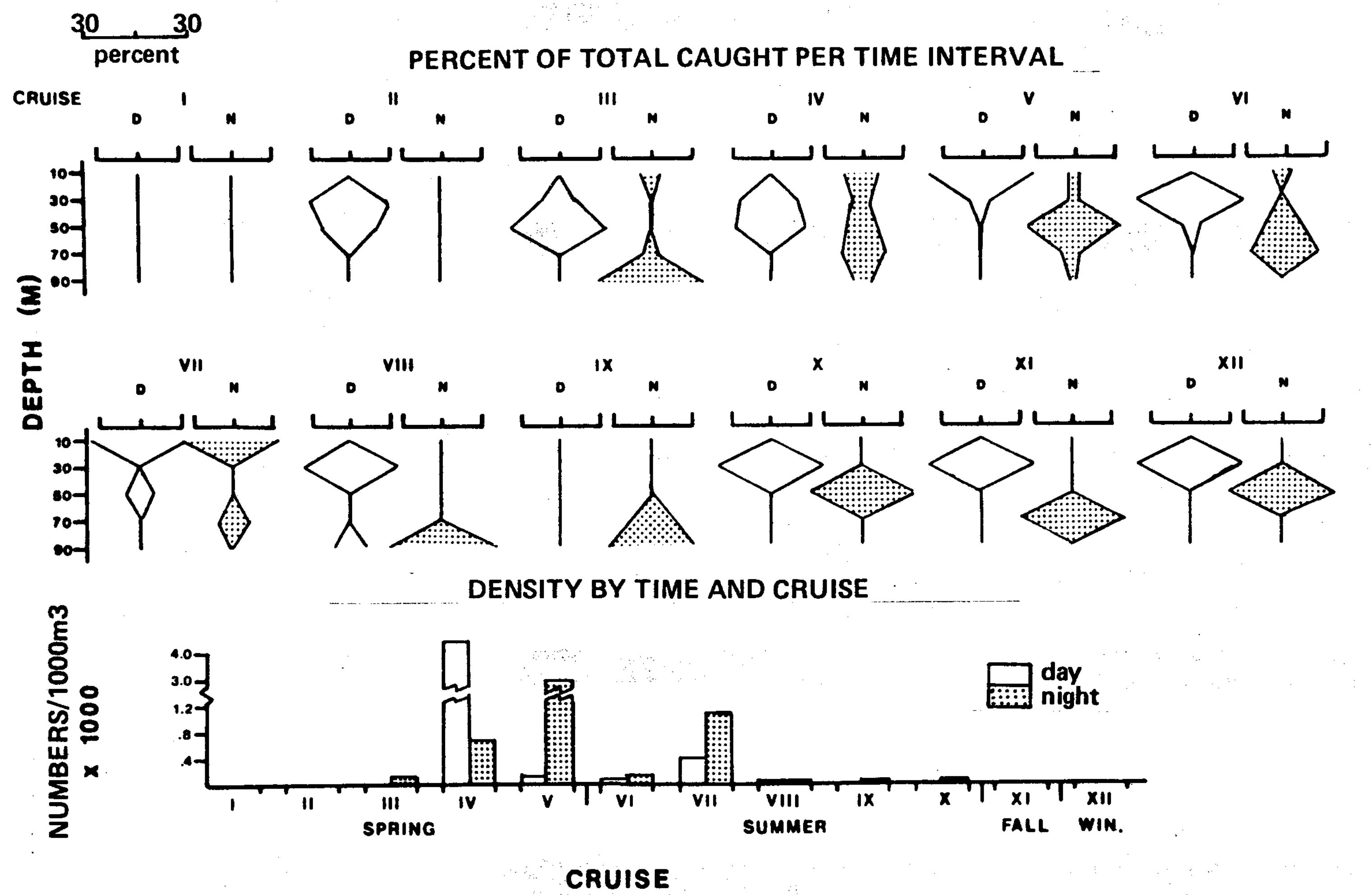


Figure 109.--Percent of total numbers caught by depth stratum per time interval and cruise, and density by time and cruise of Tanner crab larvae, Chionoecetes bairdi, at diel stations in the inshore region. Tucker trawl data. D = day, N = night.

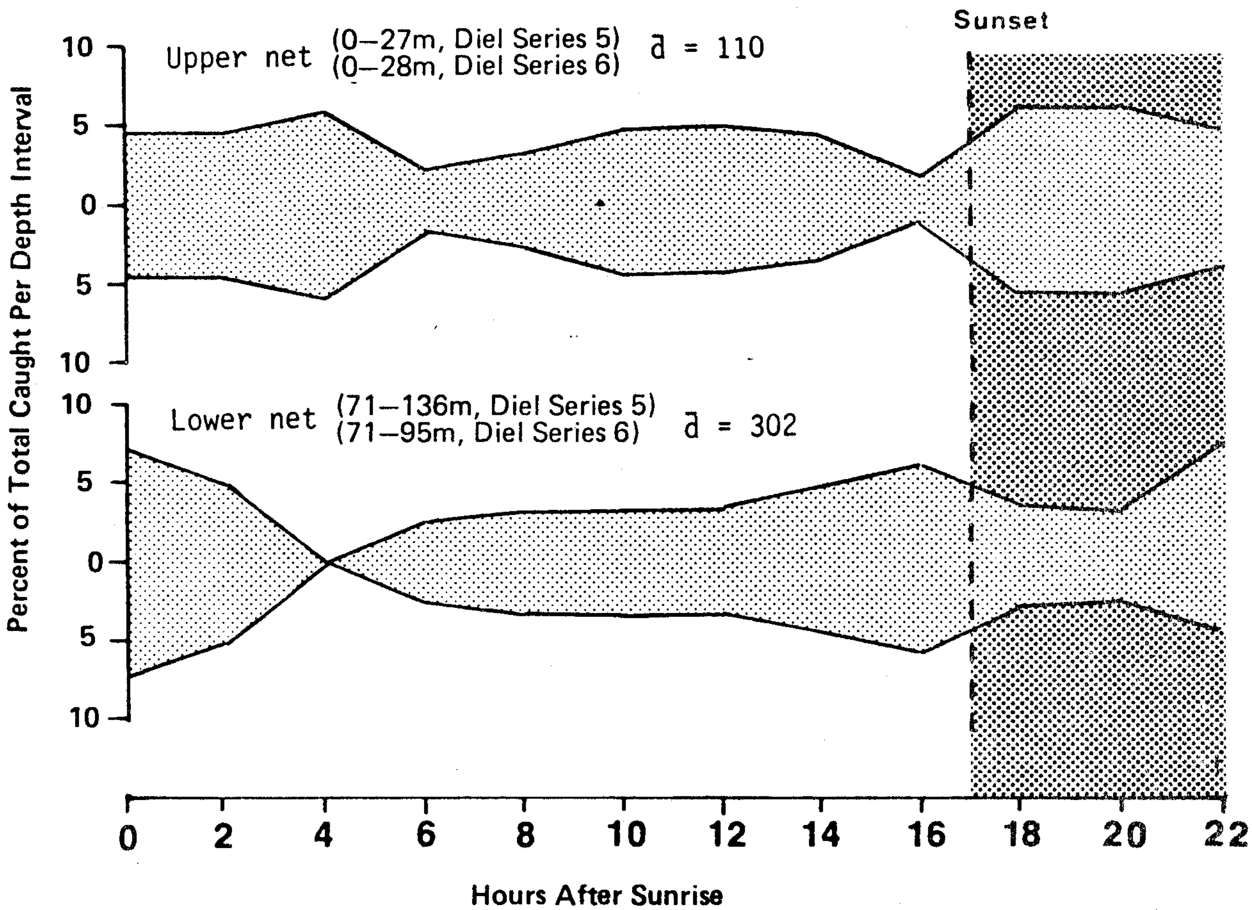


Figure 110.--Percent of total numbers of Tanner crab larvae, Chionoecetes bairdi, caught by time interval per depth stratum during summer 1978 diel studies in the offshore region. Tucker trawl data. d = mean density (no./1000 m^3) for all time periods per depth stratum.

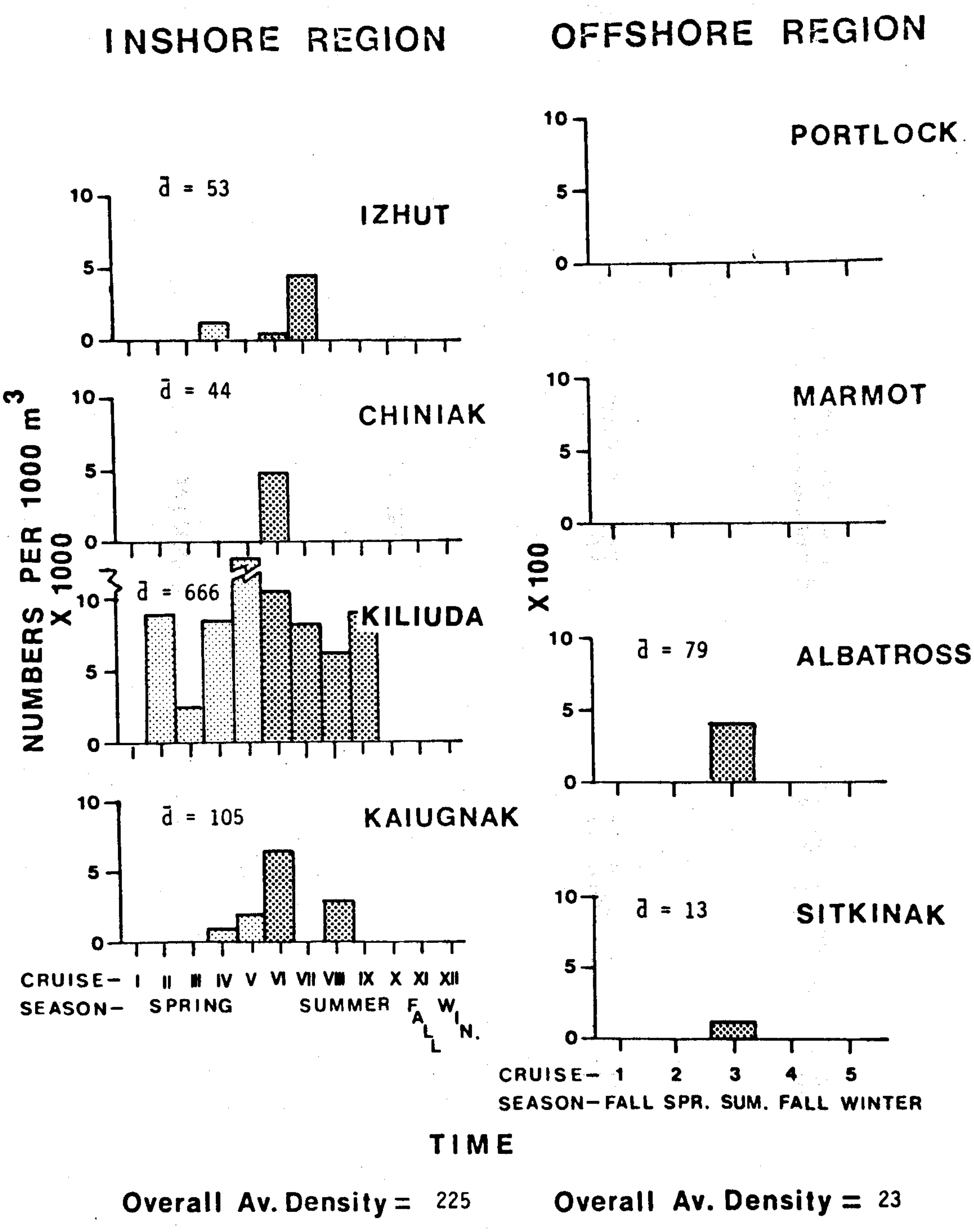


Figure 111.--Average density (numbers per 1000 m^3) by cruise, season, bay, subarea, and region for Dungeness crab larvae, Cancer magister, in the Kodiak Island study area. Bongo net data.

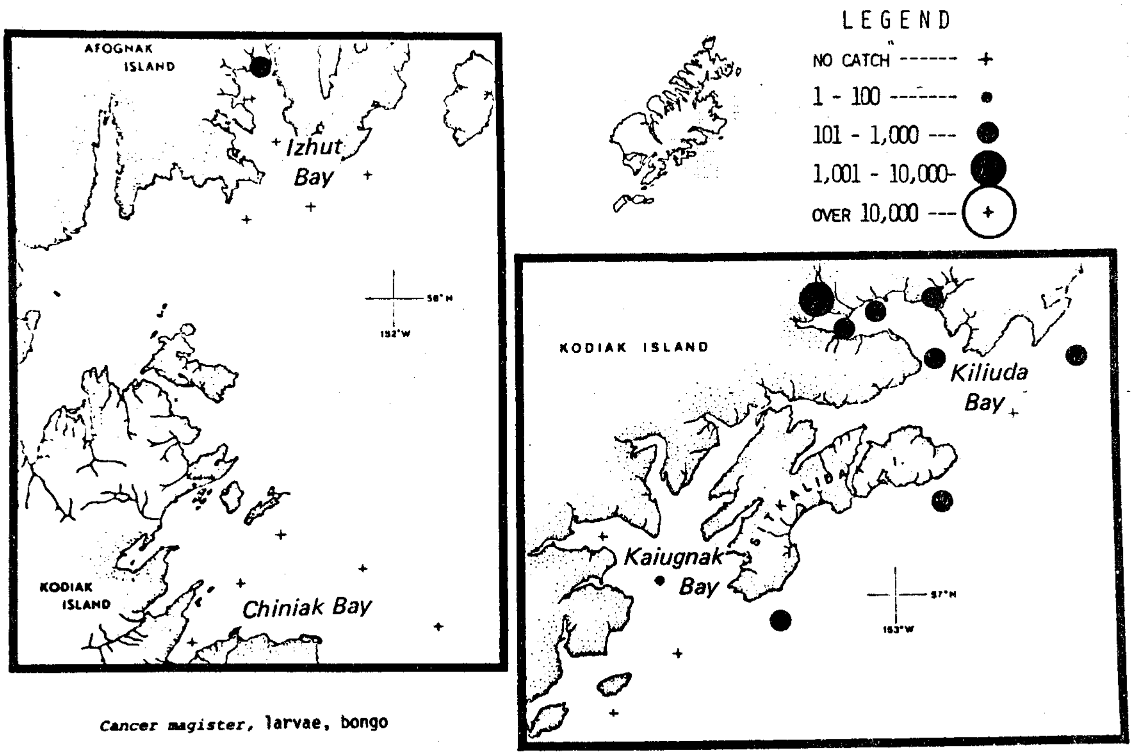
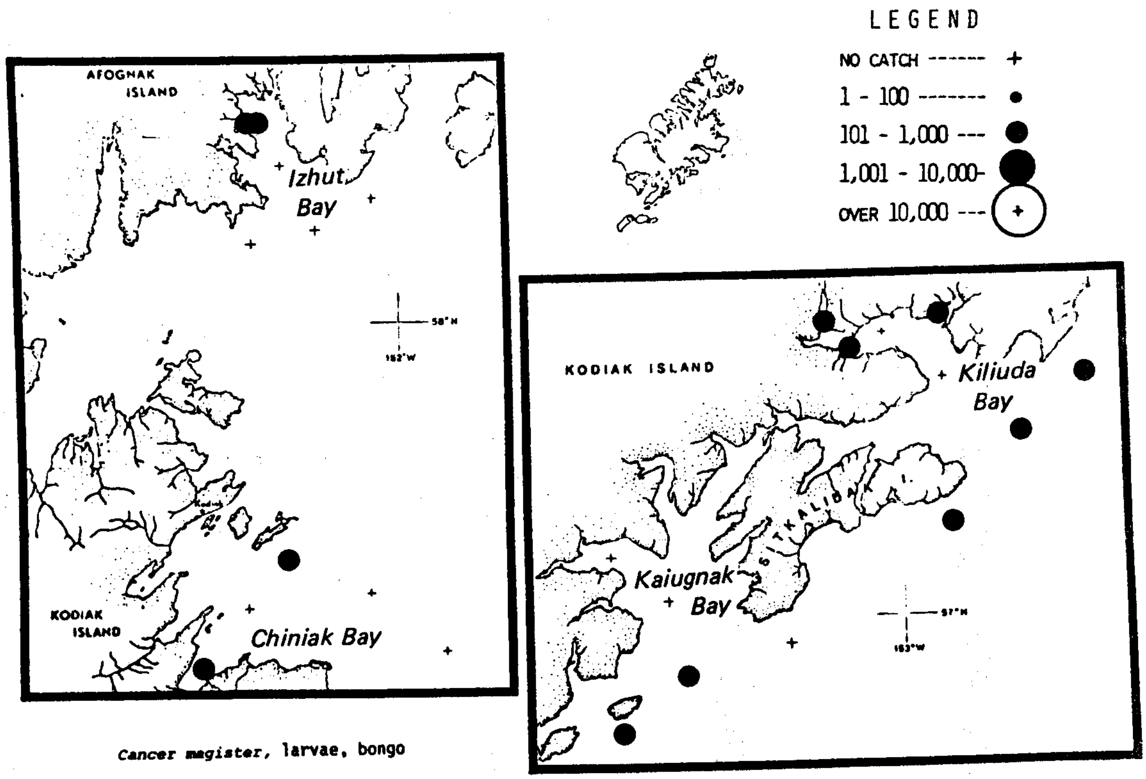


Figure 112.--Average density per station (numbers per 1000 m^3) of Dungeness crab larvae, Cancer magister, in bongo tows from the spring 1978 OCSEAP inshore plankton cruises.



Cancer magister, larvae, bongo

Figure 113.--Average density per station (numbers per 1000 m^3) of Dungeness crab larvae, Cancer magister, in bongo tows from the summer 1978 OCSEAP inshore plankton cruises.

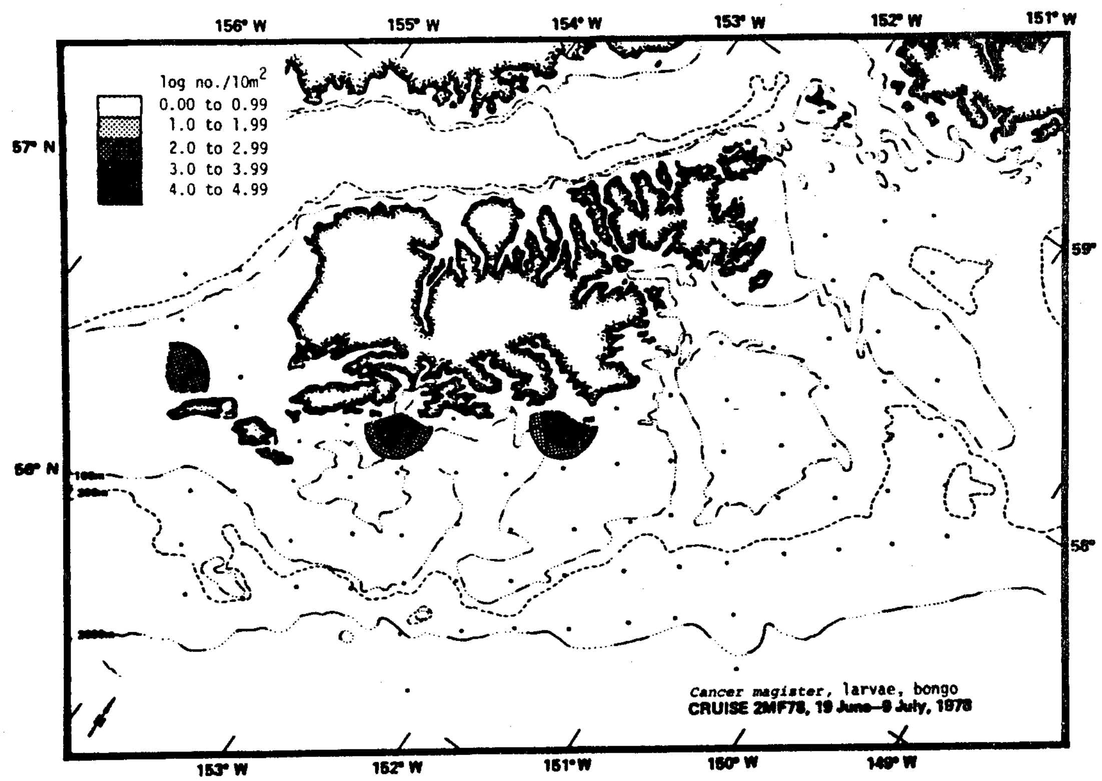


Figure 114.--Distribution and relative abundance of Dungeness crab larvae, Cancer magister, during the summer 1978 OCSEAP offshore plankton cruise. Bongo net data.

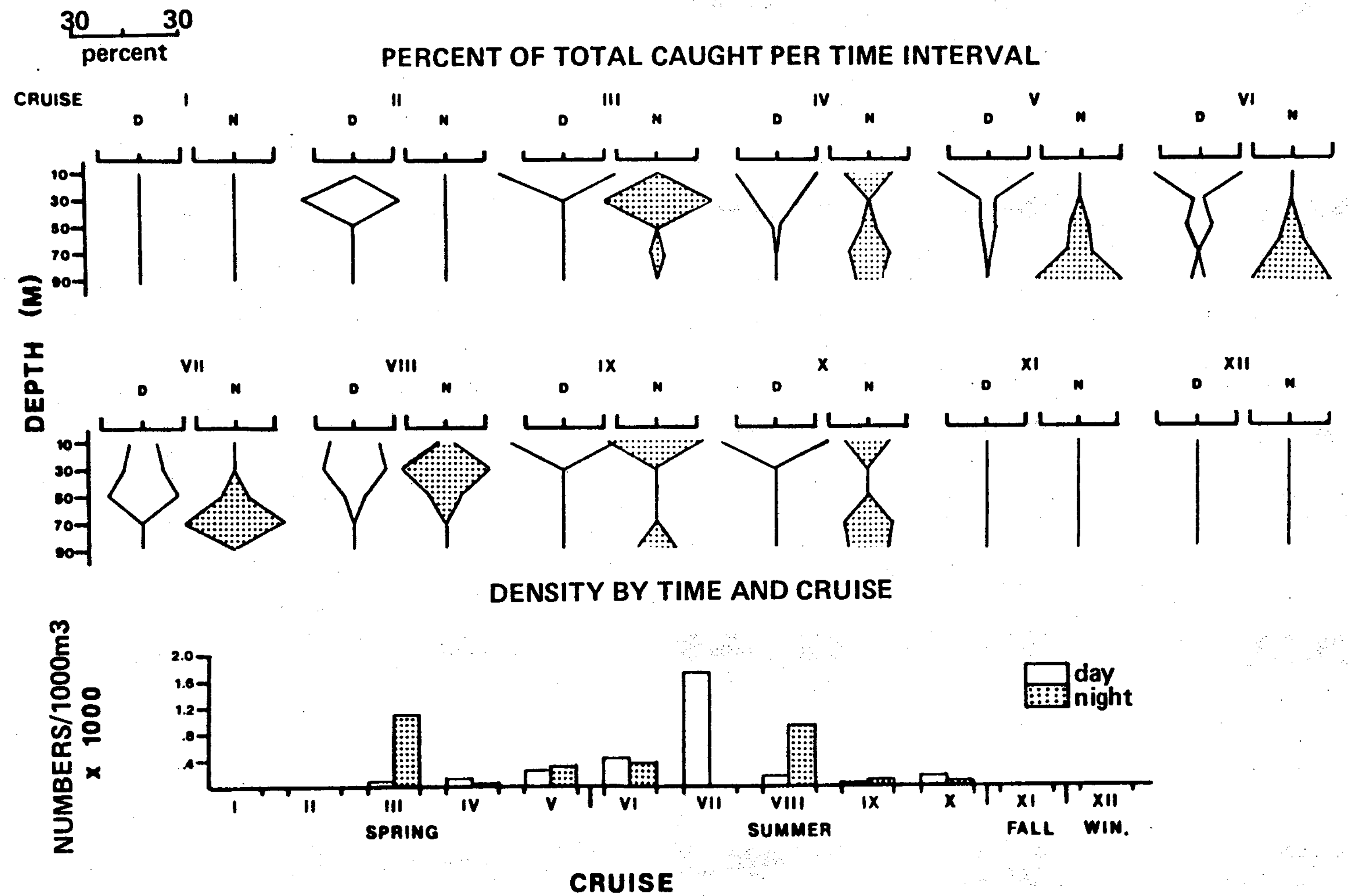


Figure 115.--Percent of total numbers caught by depth stratum per time interval and cruise, and density by time and cruise of Dungeness crab larvae, Cancer magister, at diel stations in the inshore region. Tucker trawl data. D = day, N = night.

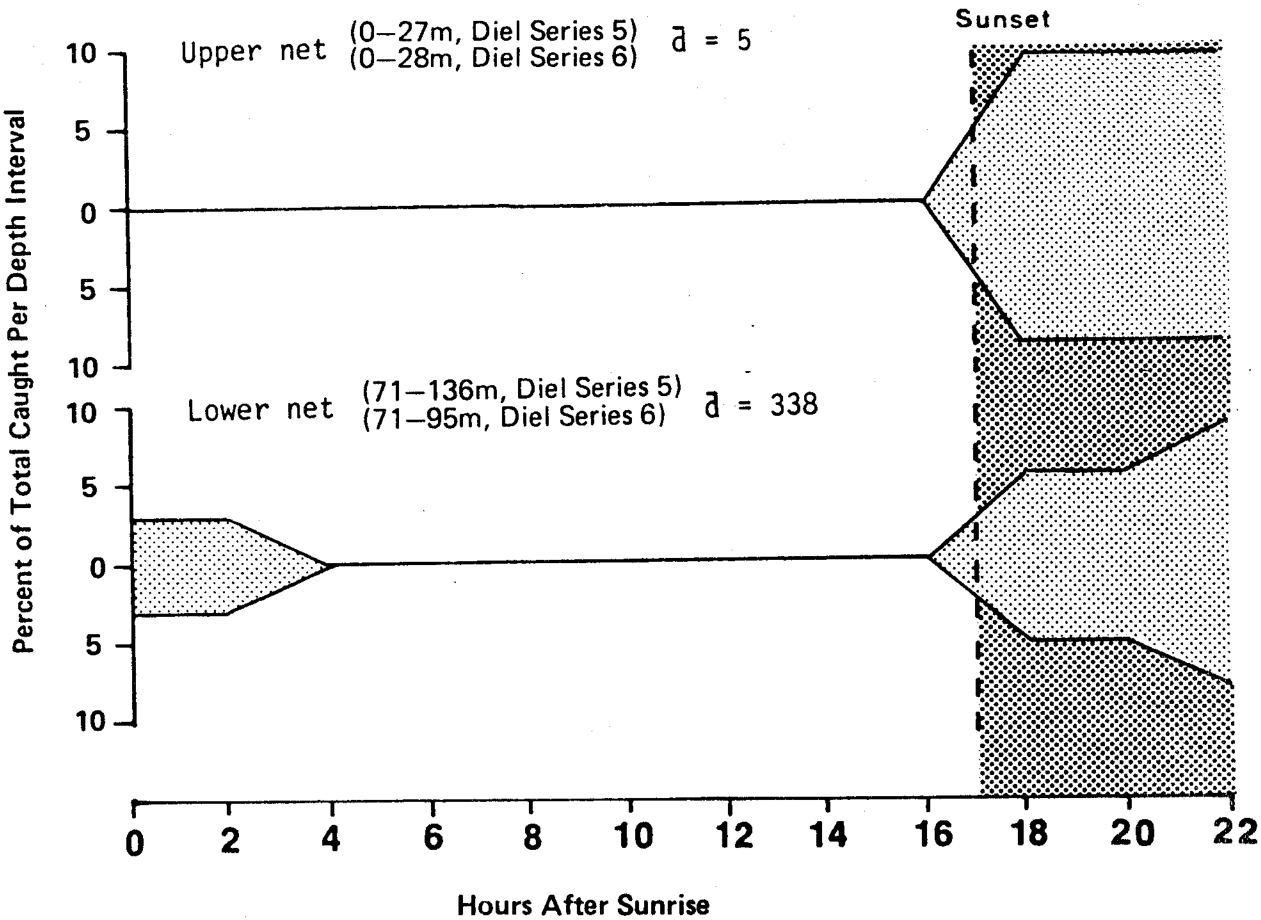


Figure 116.--Percent of total numbers of Dungeness crab larvae, <u>Cancer magister</u>, caught by time interval per depth stratum during summer 1978 diel studies in the offshore region. Tucker trawl data. d = mean density (no./1000 m^3) for all time periods per depth stratum.

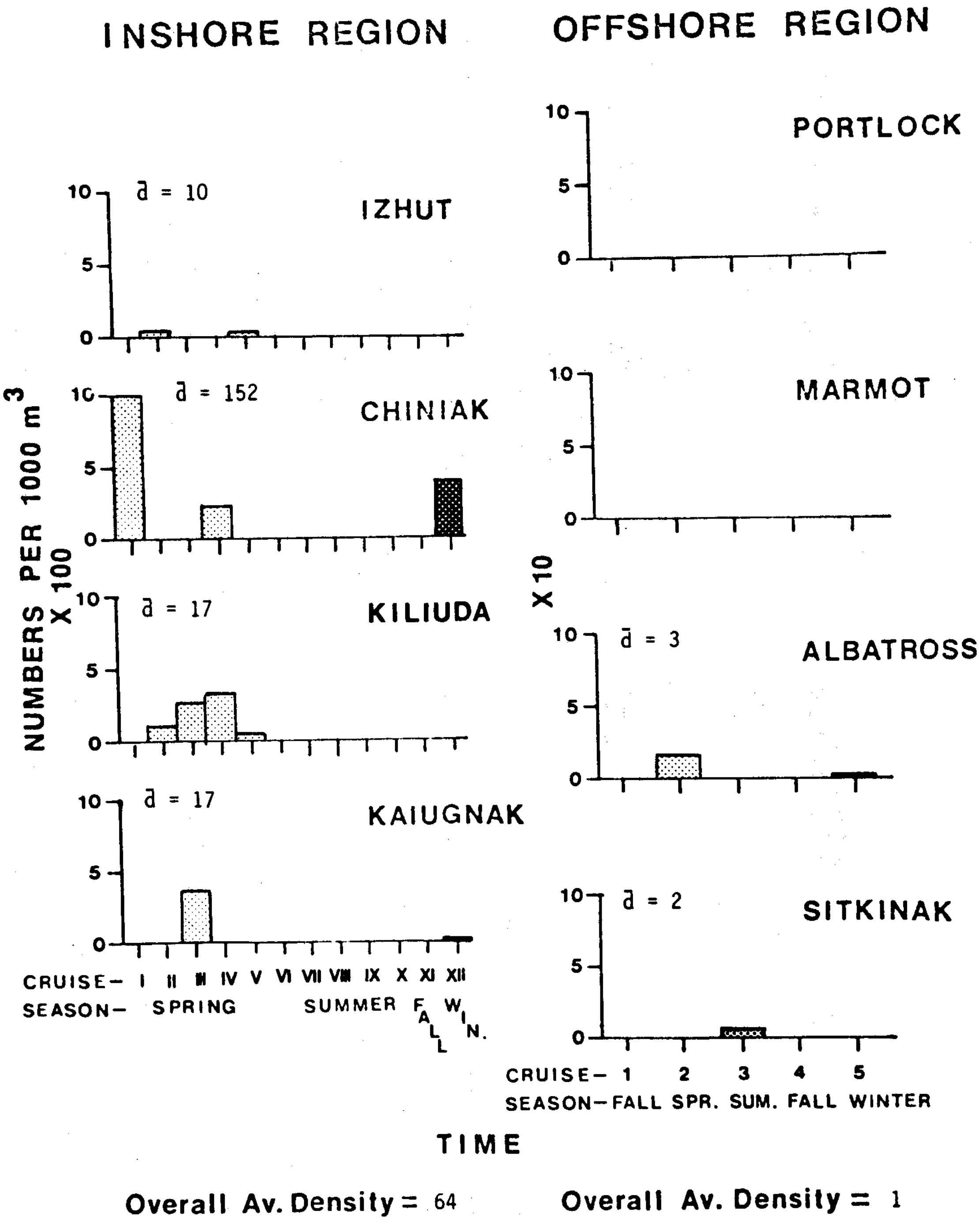


Figure 117.--Average density (numbers per 1000 m^3) by cruise, season, bay, subarea, and region for red king crab larvae, Paralithodes camtschatica, in the Kodiak Island study area. Bongo net data.

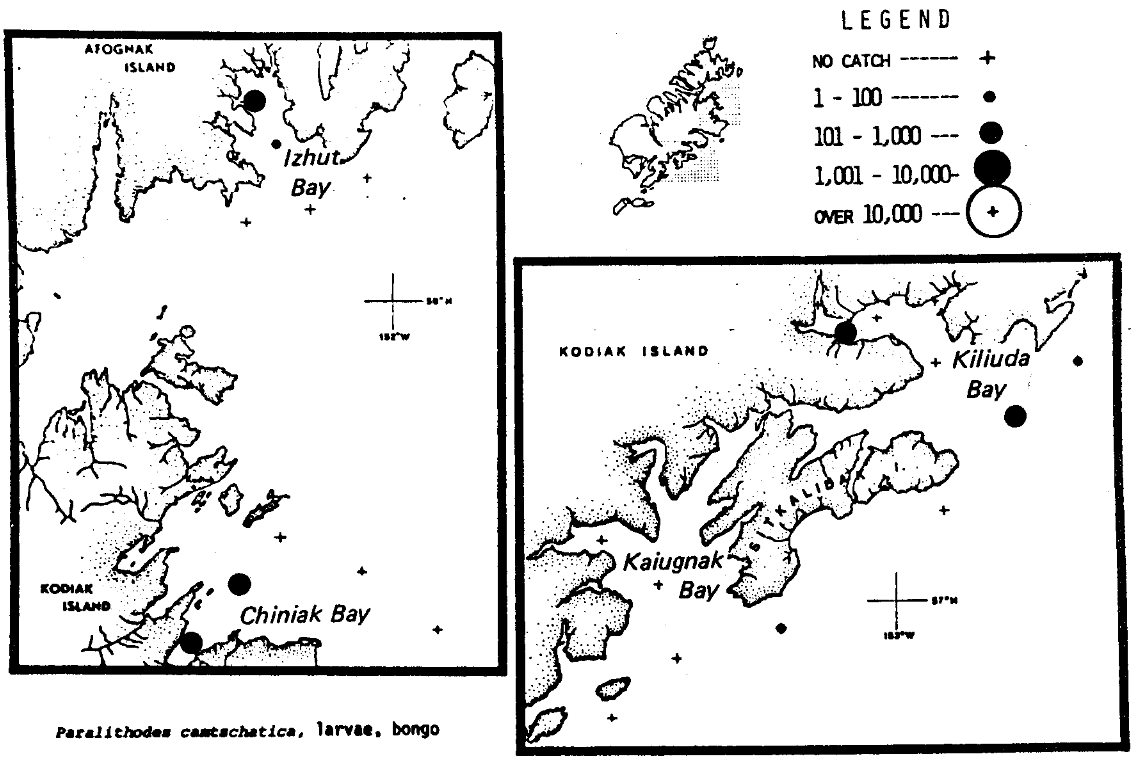


Figure 118.--Average density per station (numbers per 1000 m^3) of red king crab larvae, Paralithodes camtschatica, in bongo tows from the spring 1978 OCSEAP inshore plankton cruises.

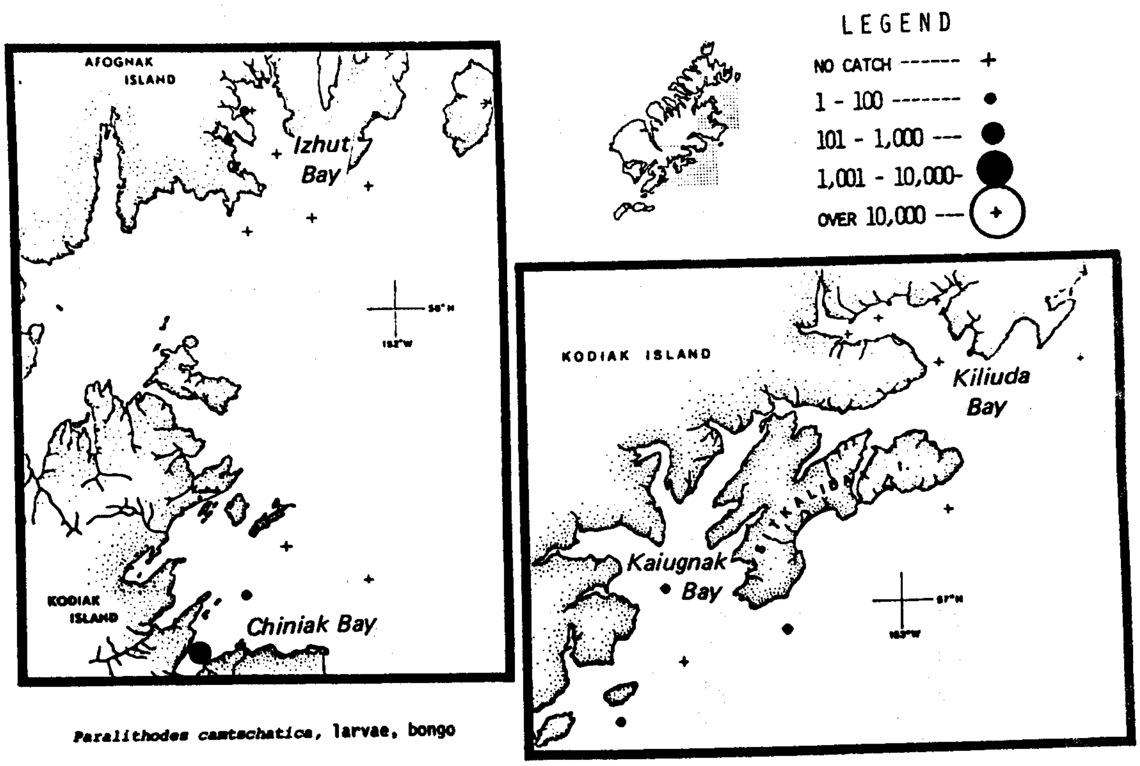


Figure 119.--Average density per station (numbers per 1000 m^3) of red king crab larvae, Paralithodes camtschatica, in bongo tows from the summer 1978 OCSEAP inshore plankton cruises.

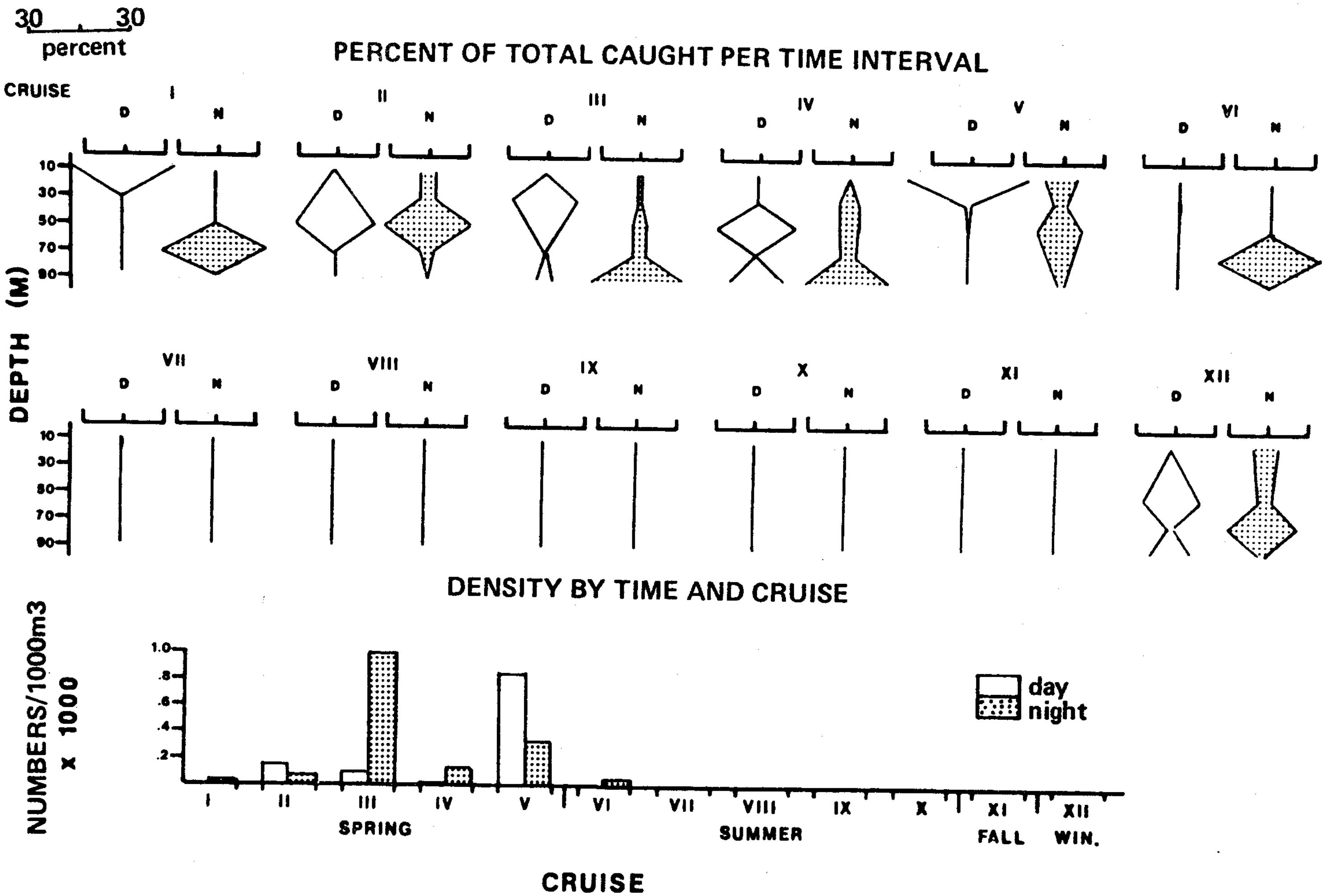


Figure 120.--Percent of total numbers caught by depth stratum per time interval and cruise, and density by time and cruise of red king crab larvae, Paralithodes camtschatica, at diel stations in the inshore region. Tucker trawl data. D = day, N = night.

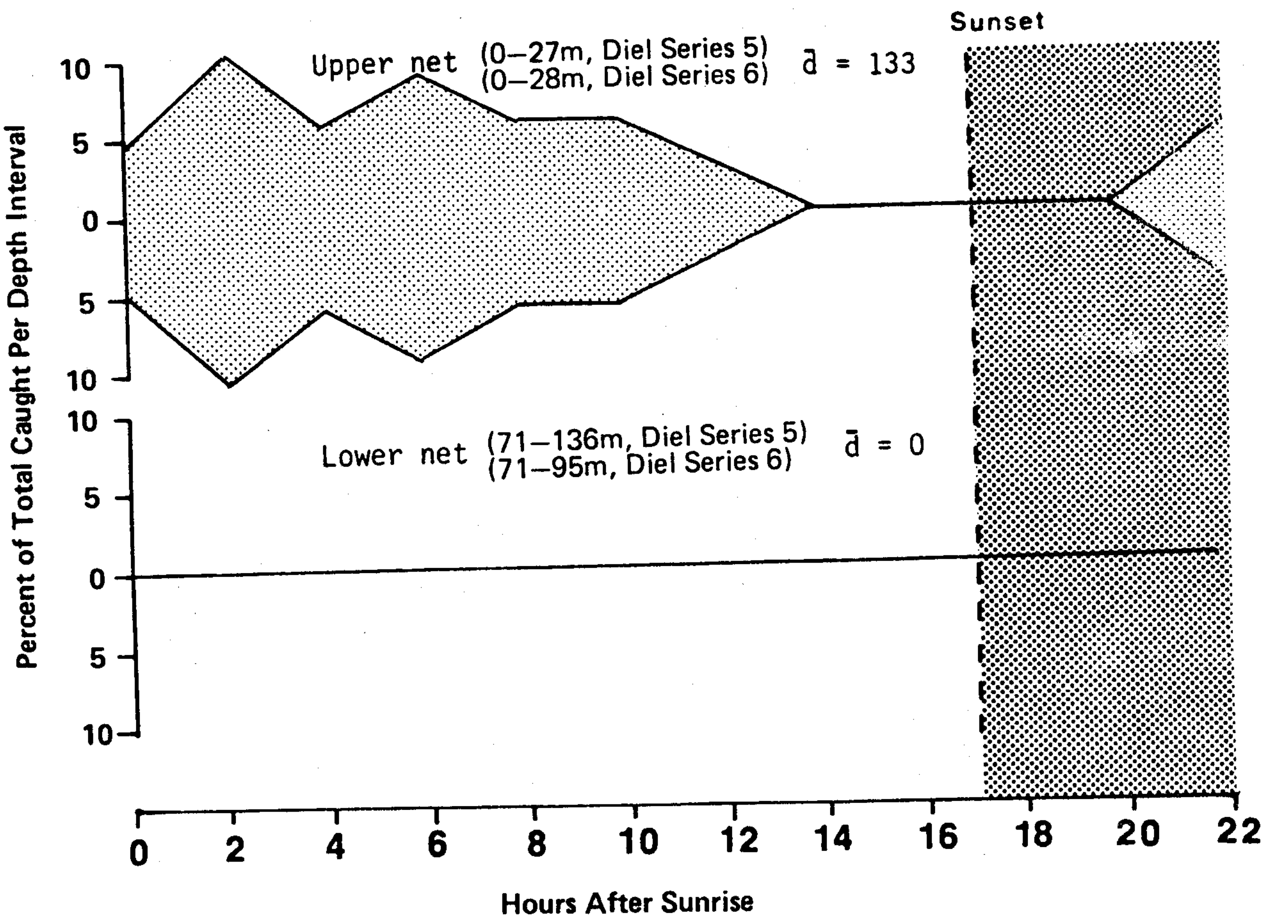
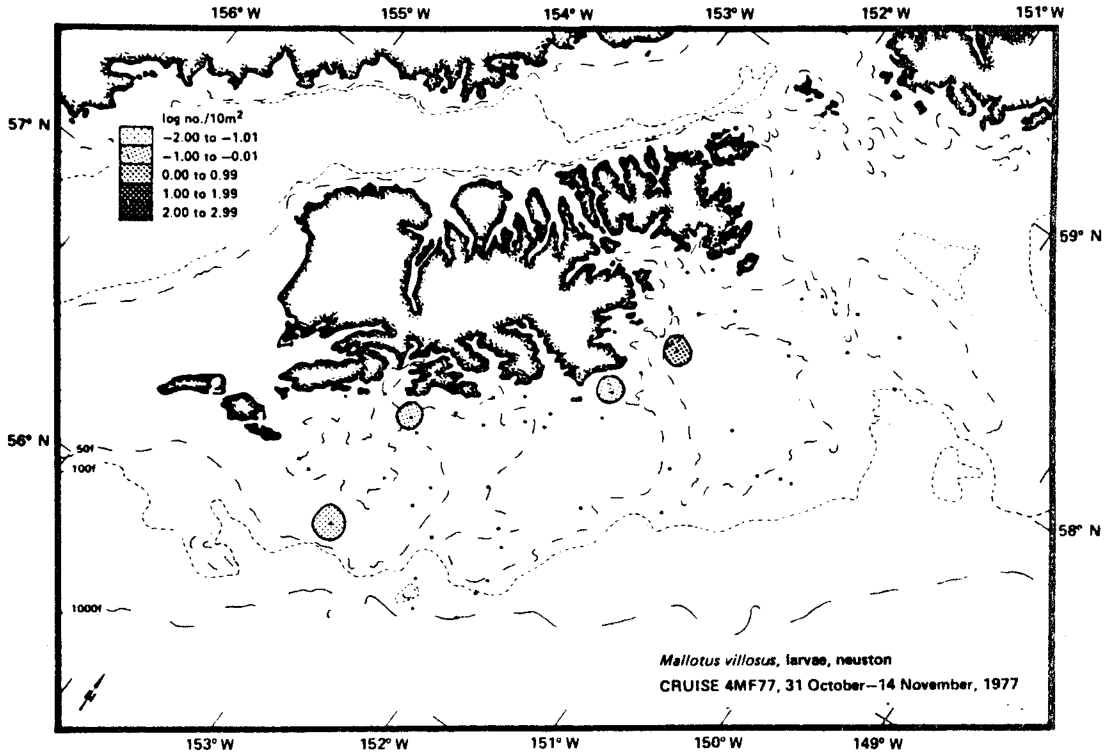


Figure 121.--Percent of total numbers of red king crab larvae, Paralithodes camtschatica, caught by time interval per depth stratum during summer 1978 diel studies in the offshore region. Tucker trawl data. d = mean density (no./1000 m^3) for all time periods per depth stratum.



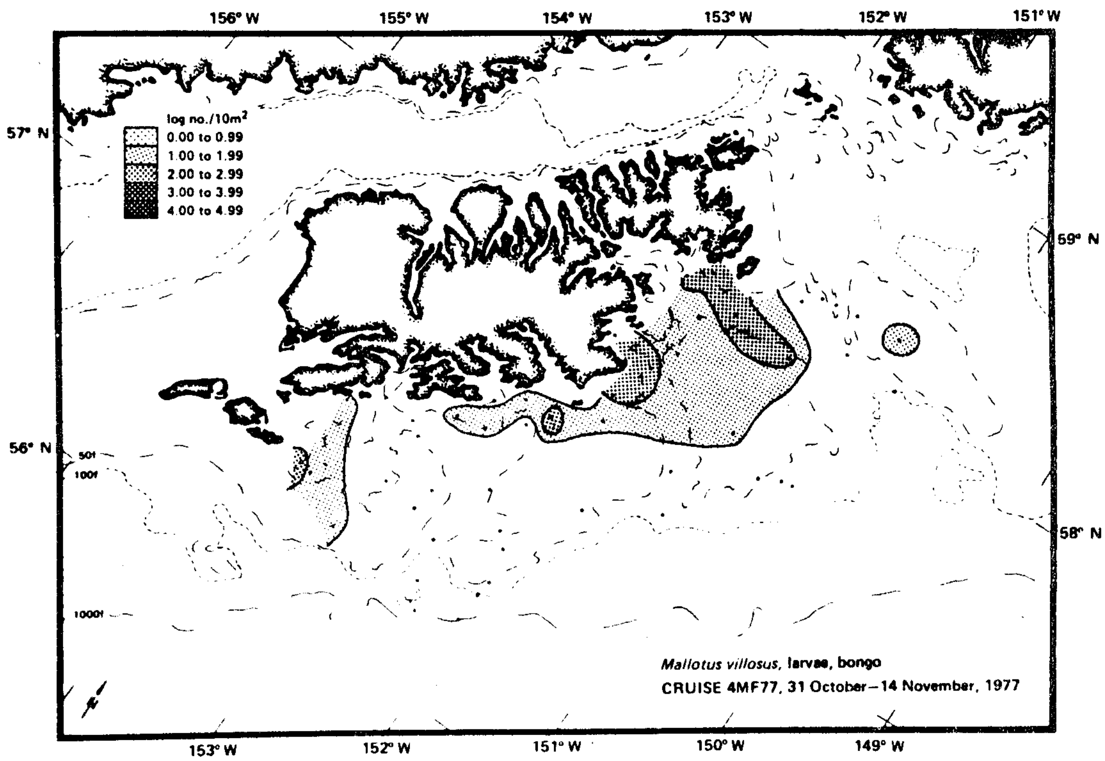


Figure 122.--Distribution and abundance of *Mallotus villosus* larvae in neuston (top) and bongo (bottom) tows from the fall 1977 OCSEAP plankton cruise.

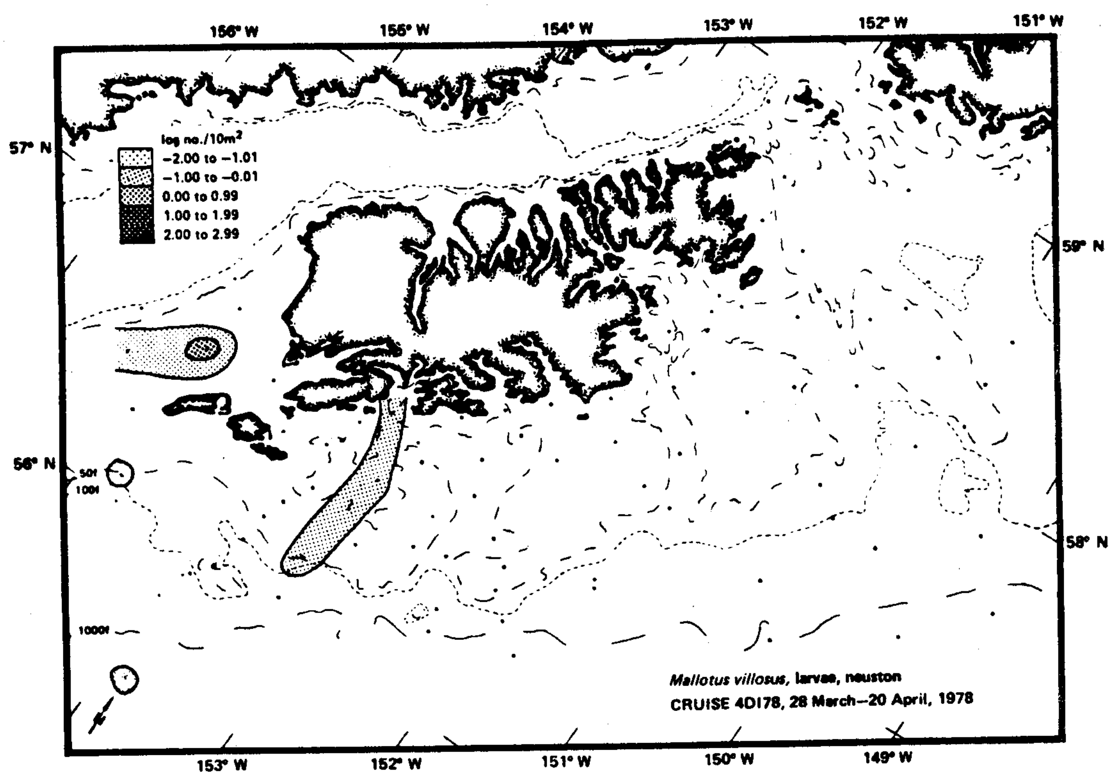
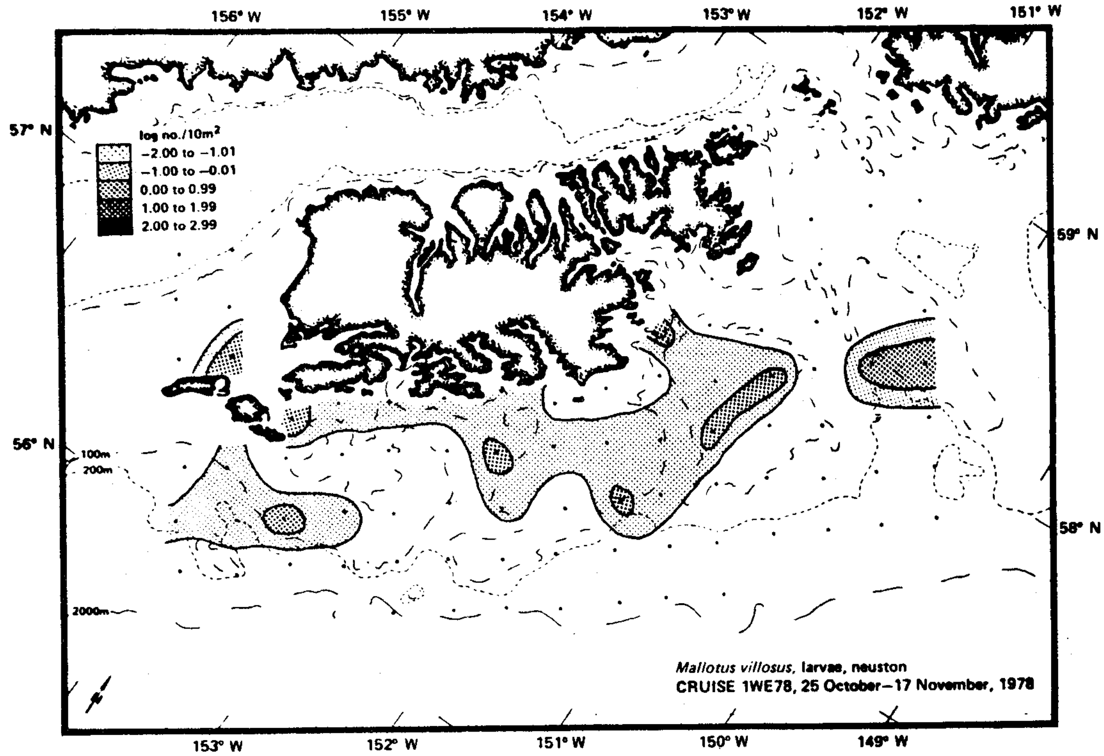


Figure 123.--Distribution and abundance of Mallotus villosus larvae in neuston tows from the spring 1978 OCSEAP plankton cruise.



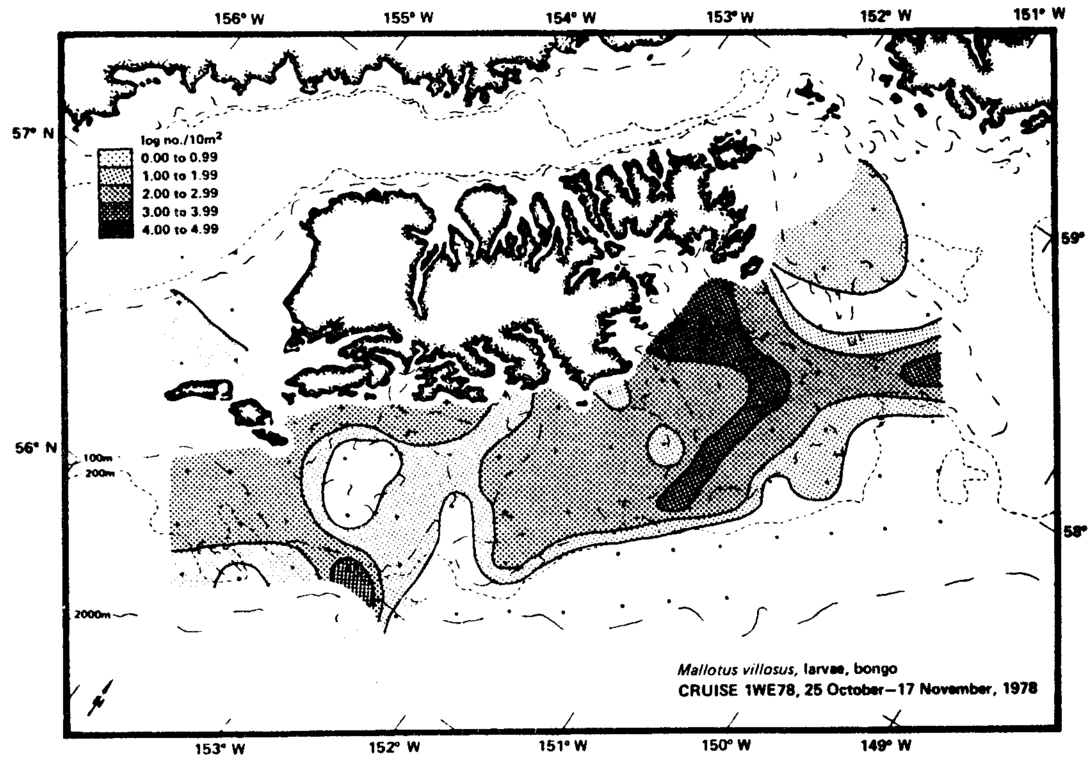


Figure 124.--Distribution and abundance of *Mallotus villosus* larvae in neuston (top) and bongo (bottom) tows from the fall 1978 OCSEAP plankton cruise.

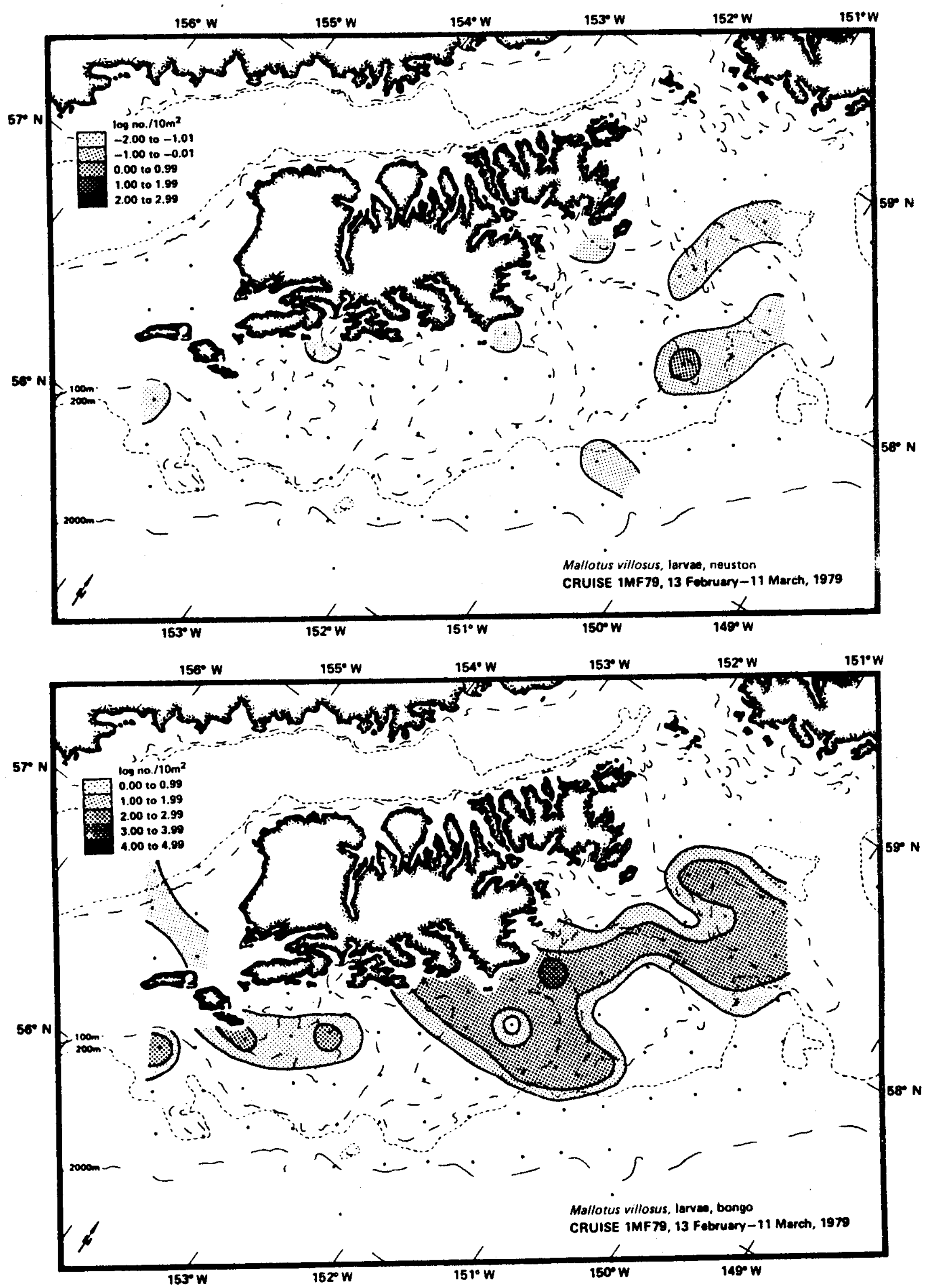


Figure 125.--Distribution and abundance of Mallotus villosus larvae in neuston (top) and bongo (bottom) tows from the winter 1979 OCSEAP plankton cruise.

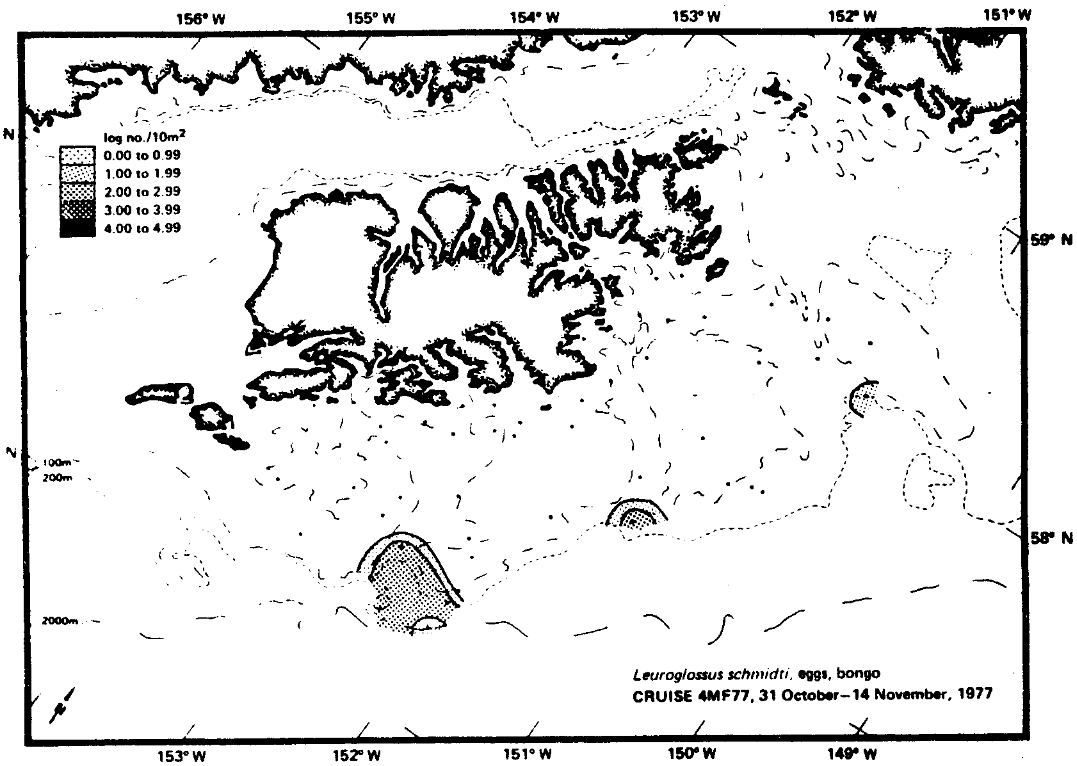


Figure 126.--Distribution and abundance of Leuroglossus schmidti eggs in bongo tows from the fall 1977 OCSEAP plankton cruise.

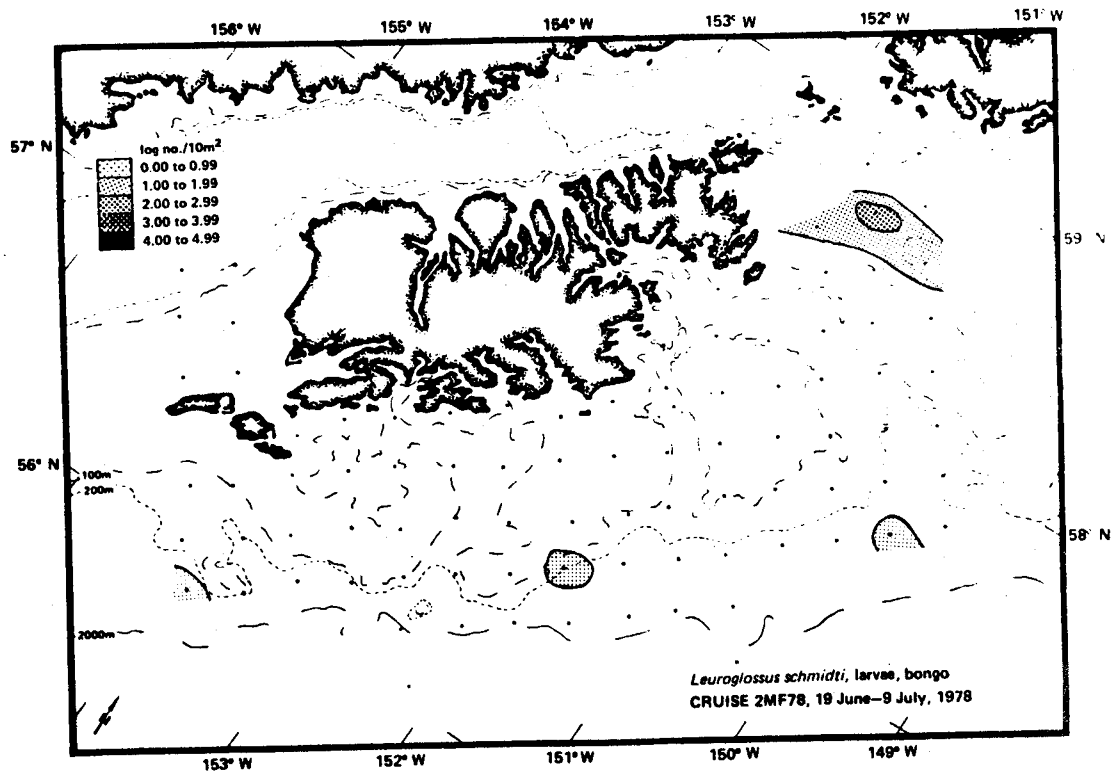


Figure 127.--Distribution and abundance of Leuroglossus schmidti larvae in bongo tows from the summer 1978 OCSEAP plankton cruise.

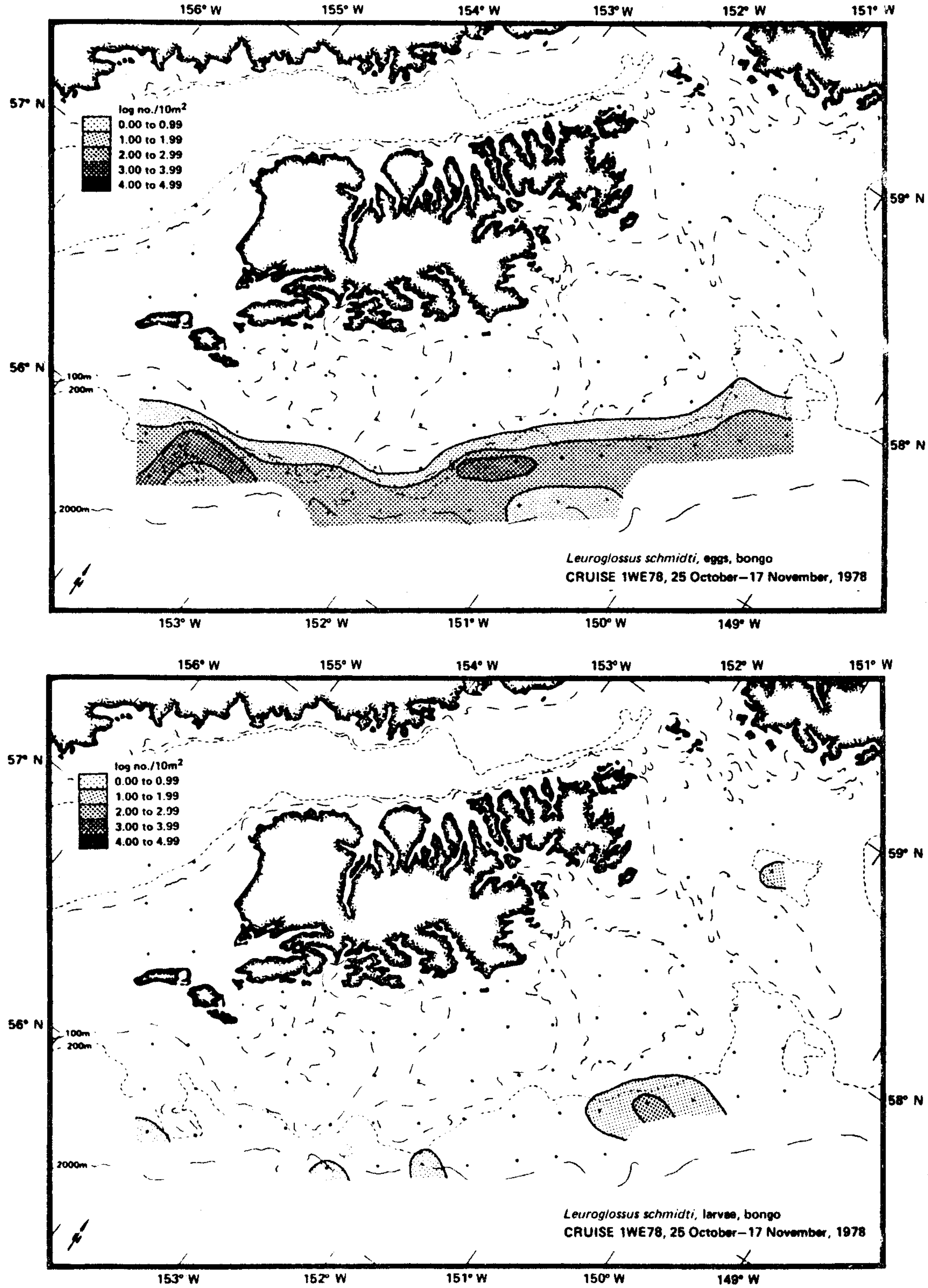


Figure 128.--Distribution and abundance of Leuroglossus schmidti eggs (top) and larvae (bottom) in bongo tows from the fall 1978 OCSEAP plankton cruise.

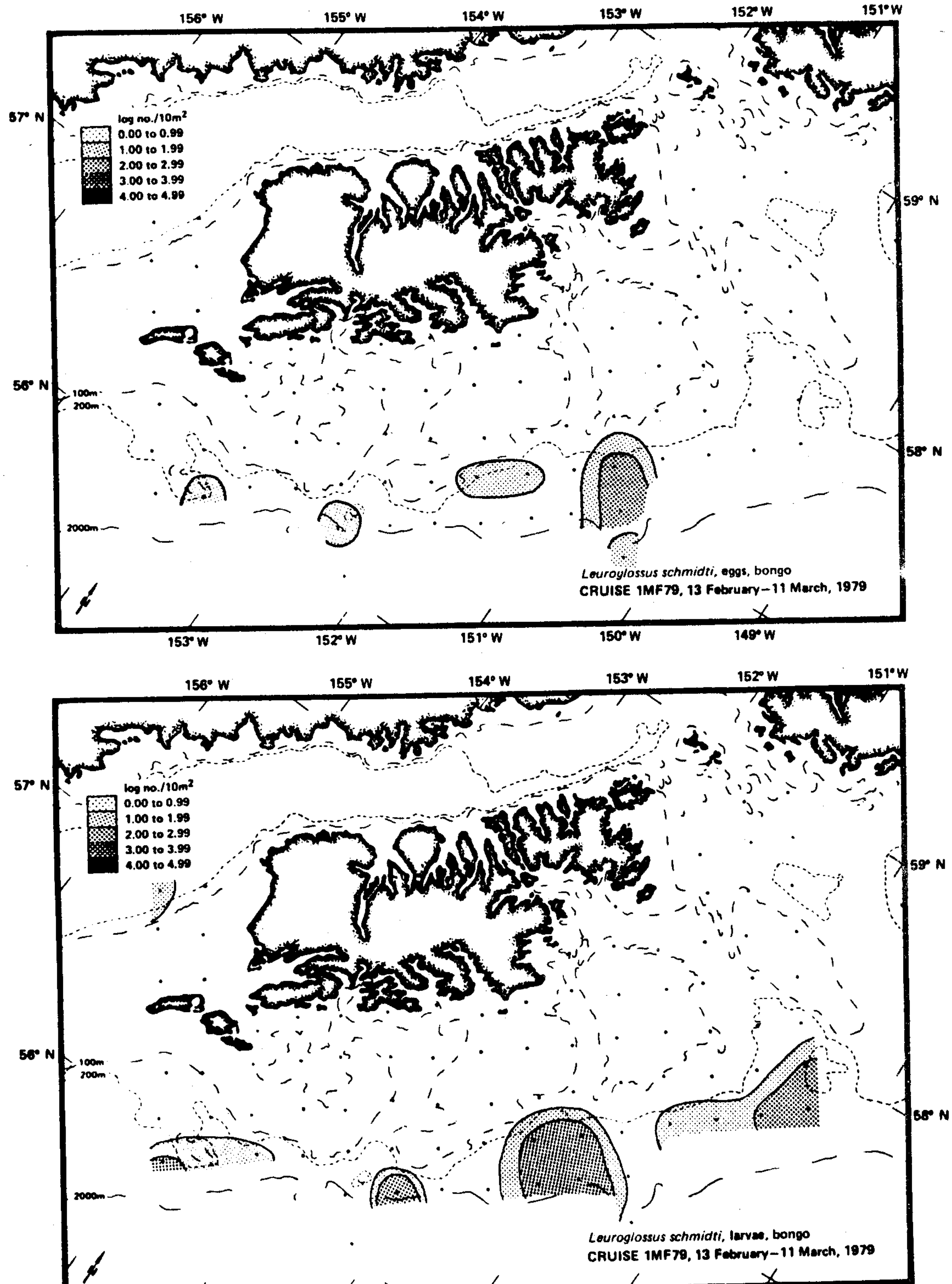


Figure 129.--Distribution and abundance of Leuroglossus schmidti eggs (top) and larvae (bottom) in bongo tows from the winter 1979 OCSEAP plankton cruise.

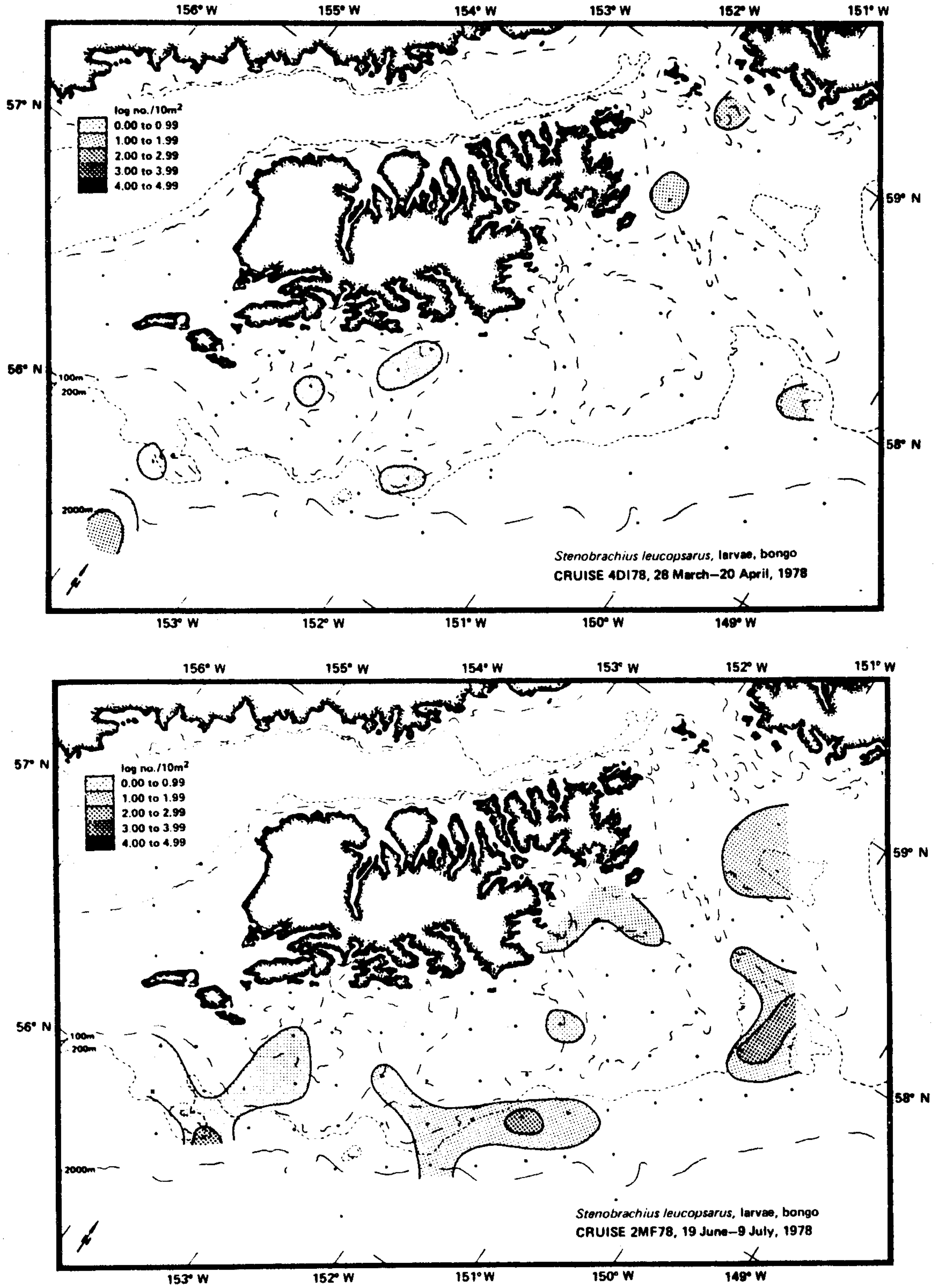
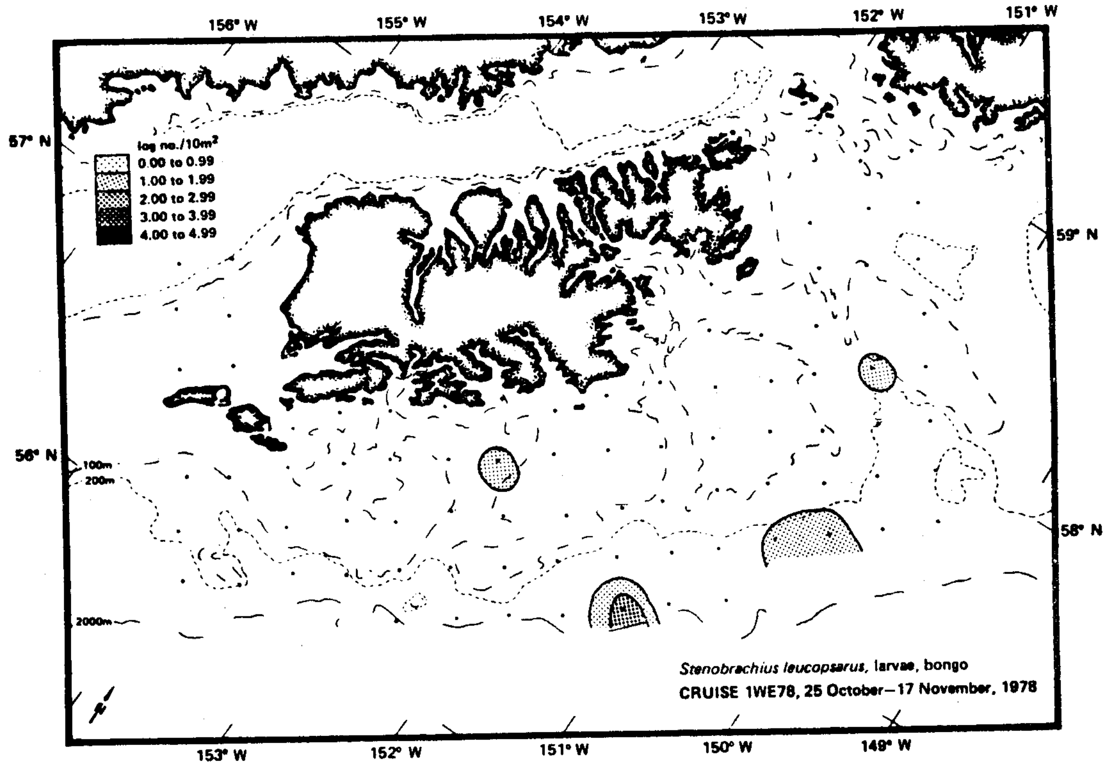


Figure 130.--Distribution and abundance of Stenobrachius leucopsarus larvae in bongo tows from the spring (top) and summer (bottom) 1978 OCSEAP plankton cruises.



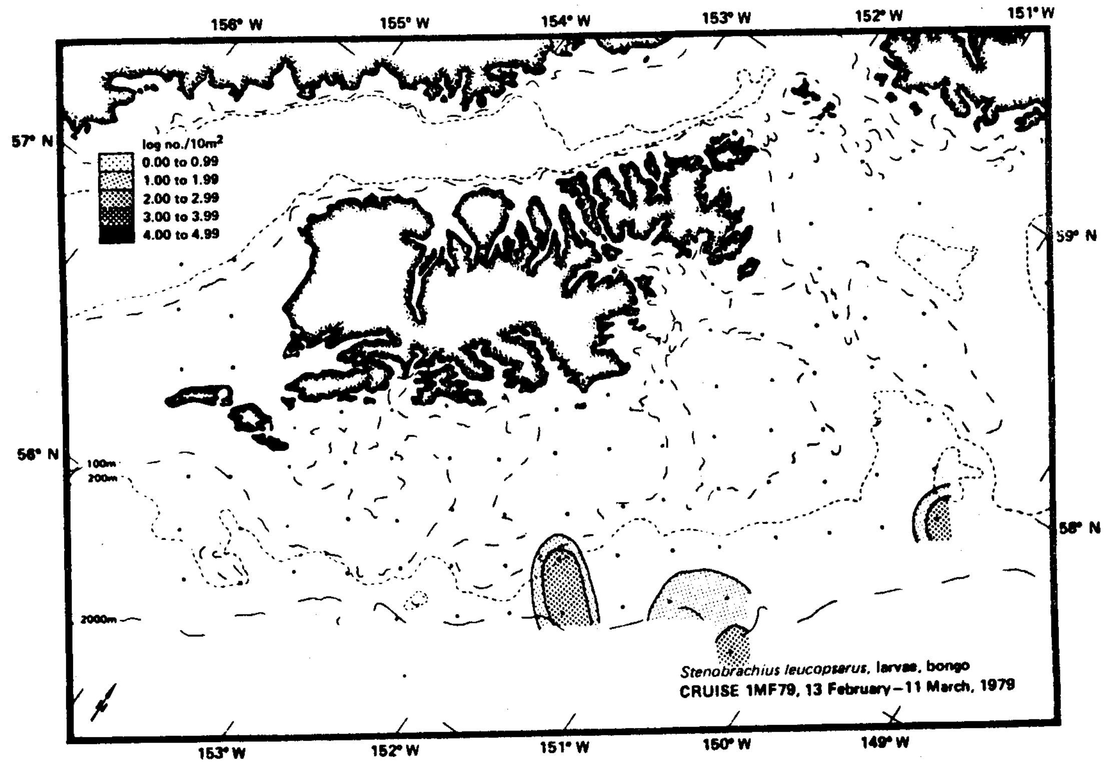
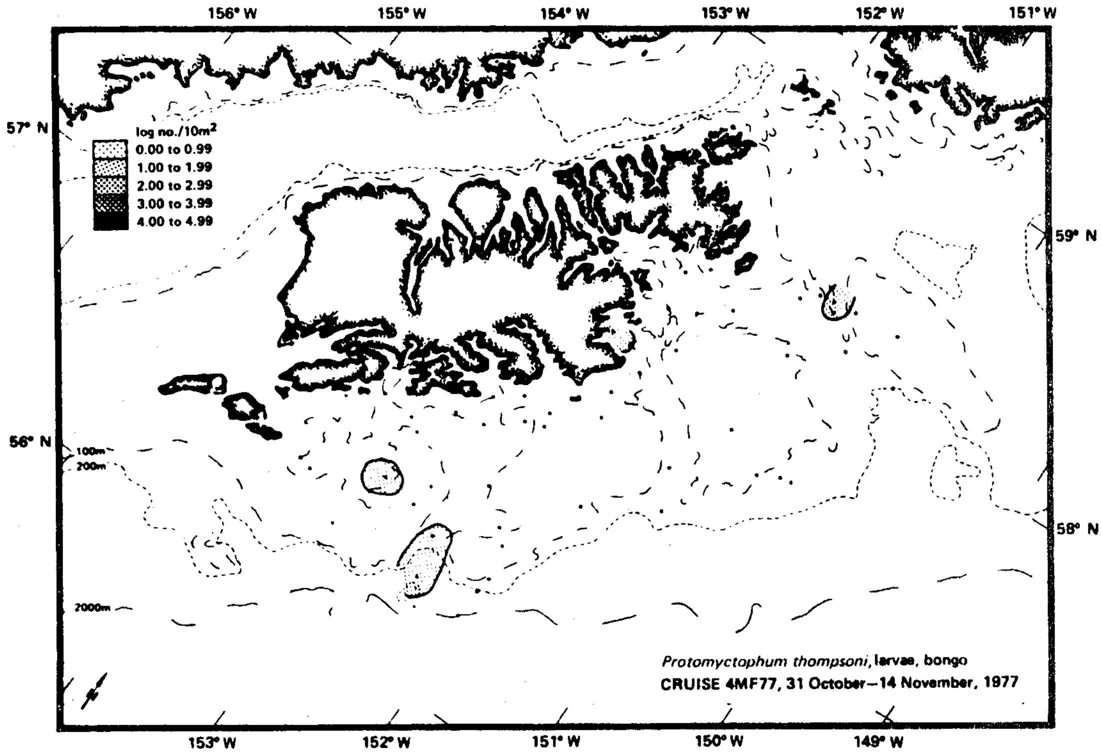


Figure 131.--Distribution and abundance of Stenobrachius leucopsarus larvae in bongo tows from the fall 1978 (top) and winter 1979 (bottom) OCSEAP plankton cruises.



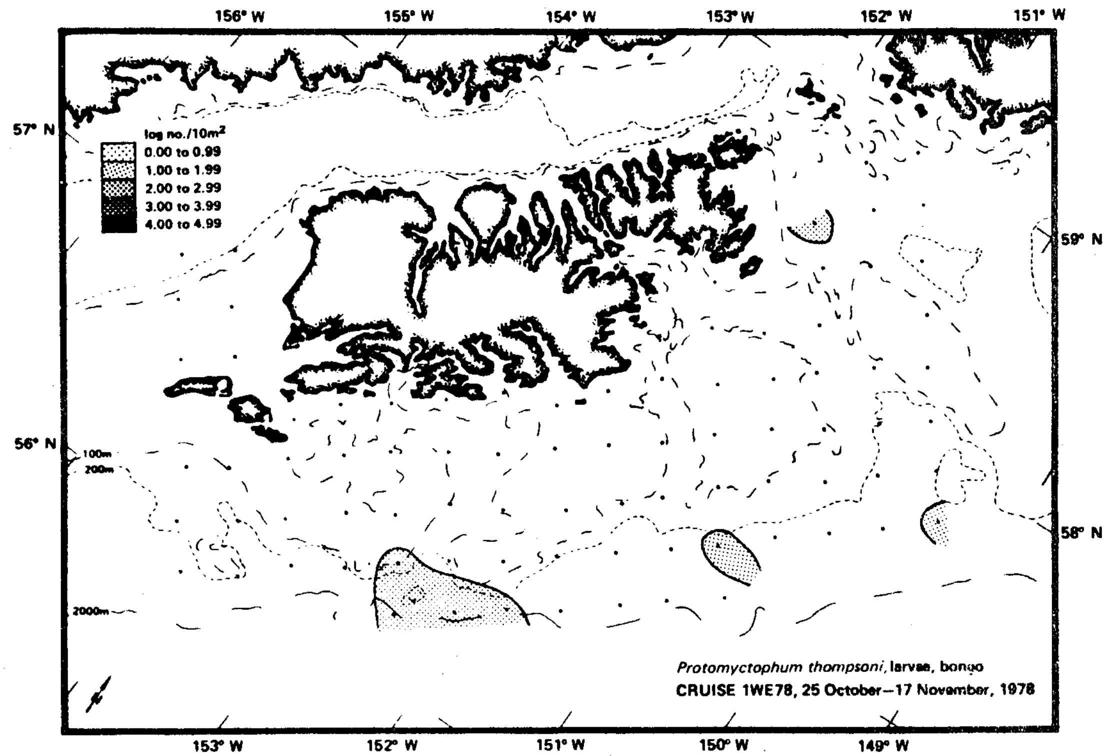


Figure 132.--Distribution and abundance of Protomyctophum thompsoni larvae in bongo tows from the fall 1977 (top) and fall 1978 (bottom) OCSEAP plankton cruises.

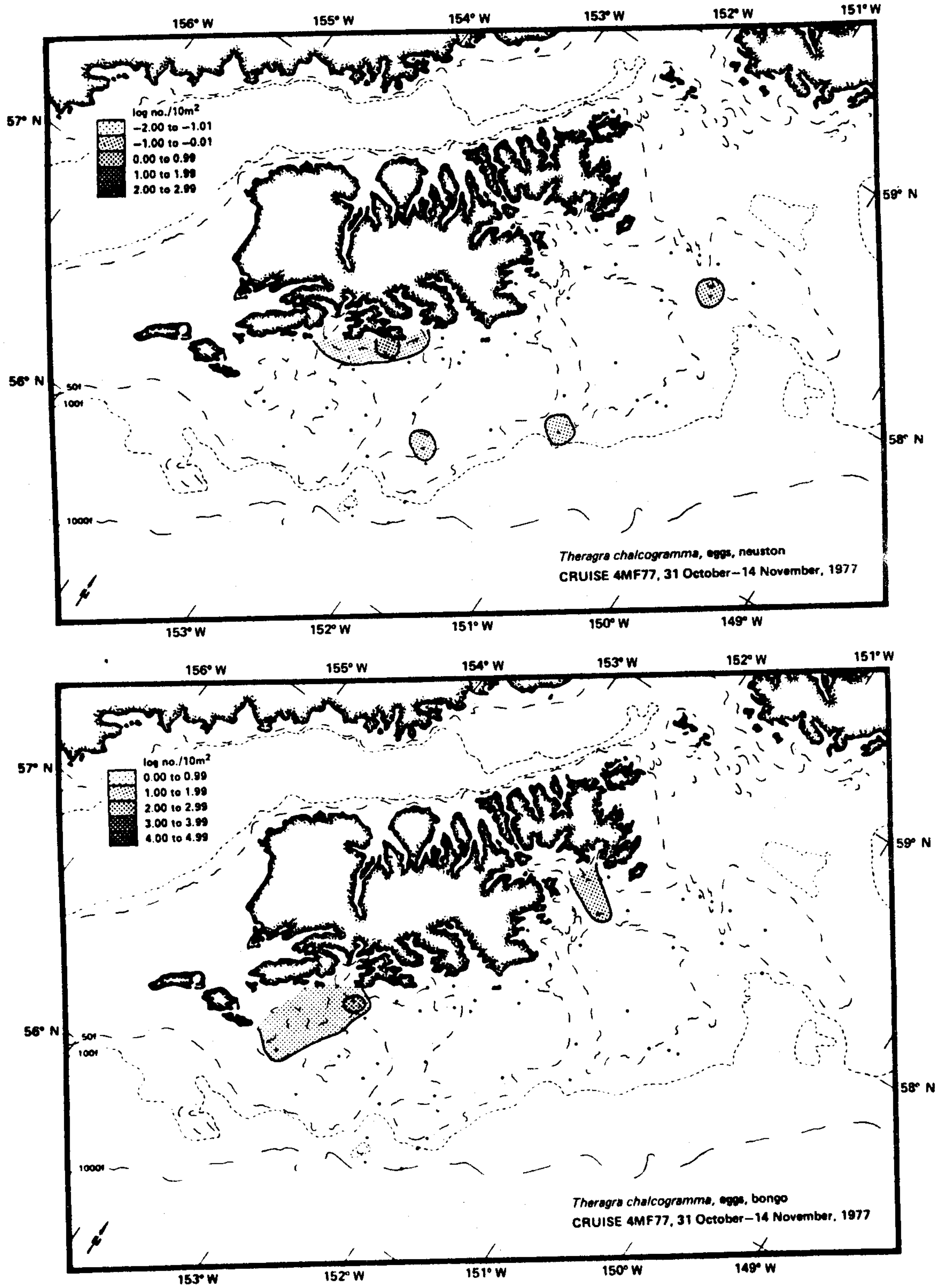
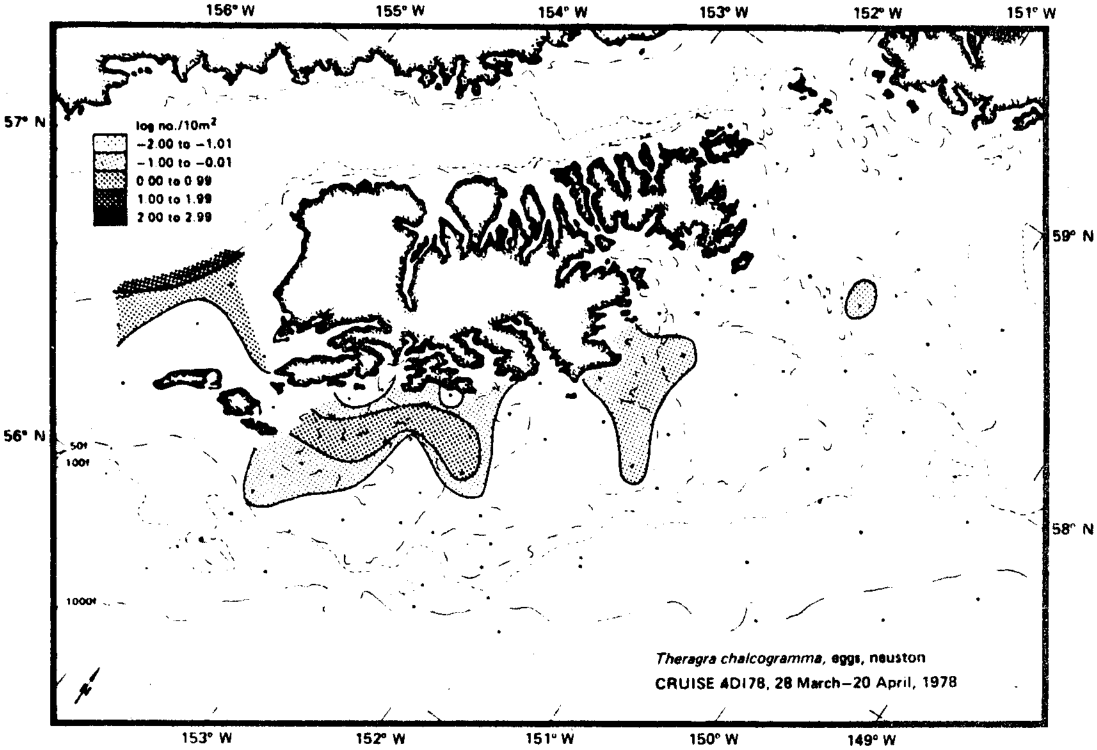


Figure 133.--Distribution and abundance of Theragra chalcogramma eggs in neuston (top) and bongo (bottom) tows from the fall 1977 OCSEAP plankton cruise.



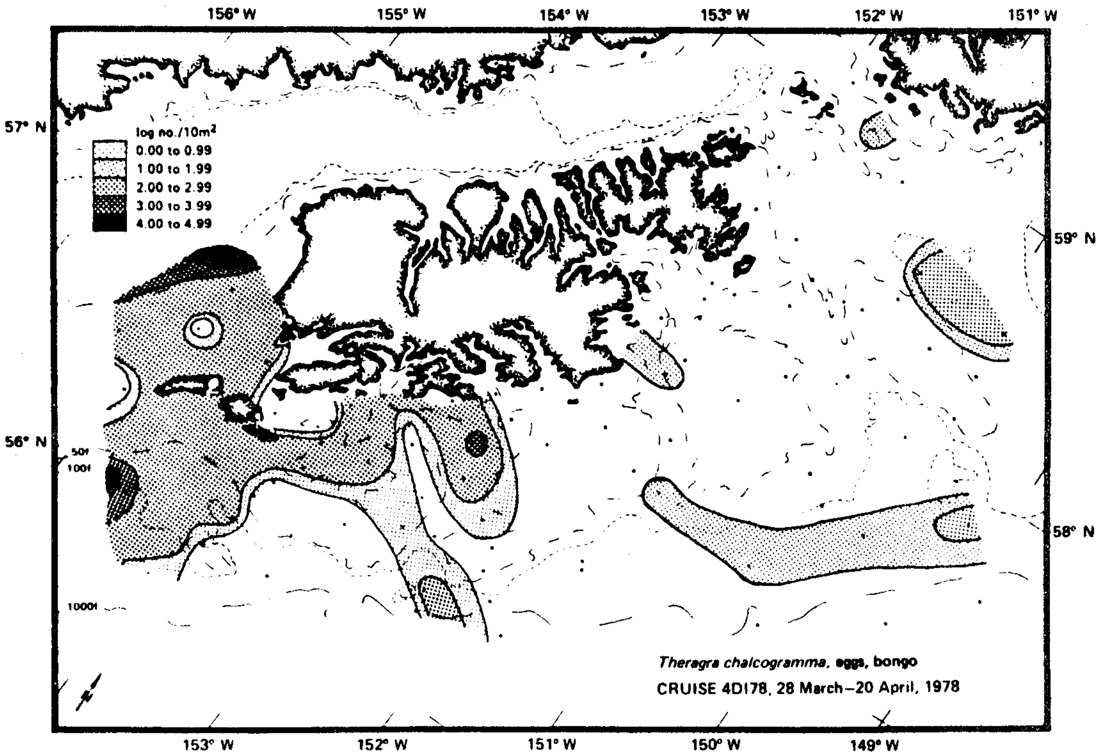


Figure 134.--Distribution and abundance of Theragra chalcogramma eggs in neuston (top) and bongo (bottom) tows from the spring 1978 OCSEAP plankton cruise.

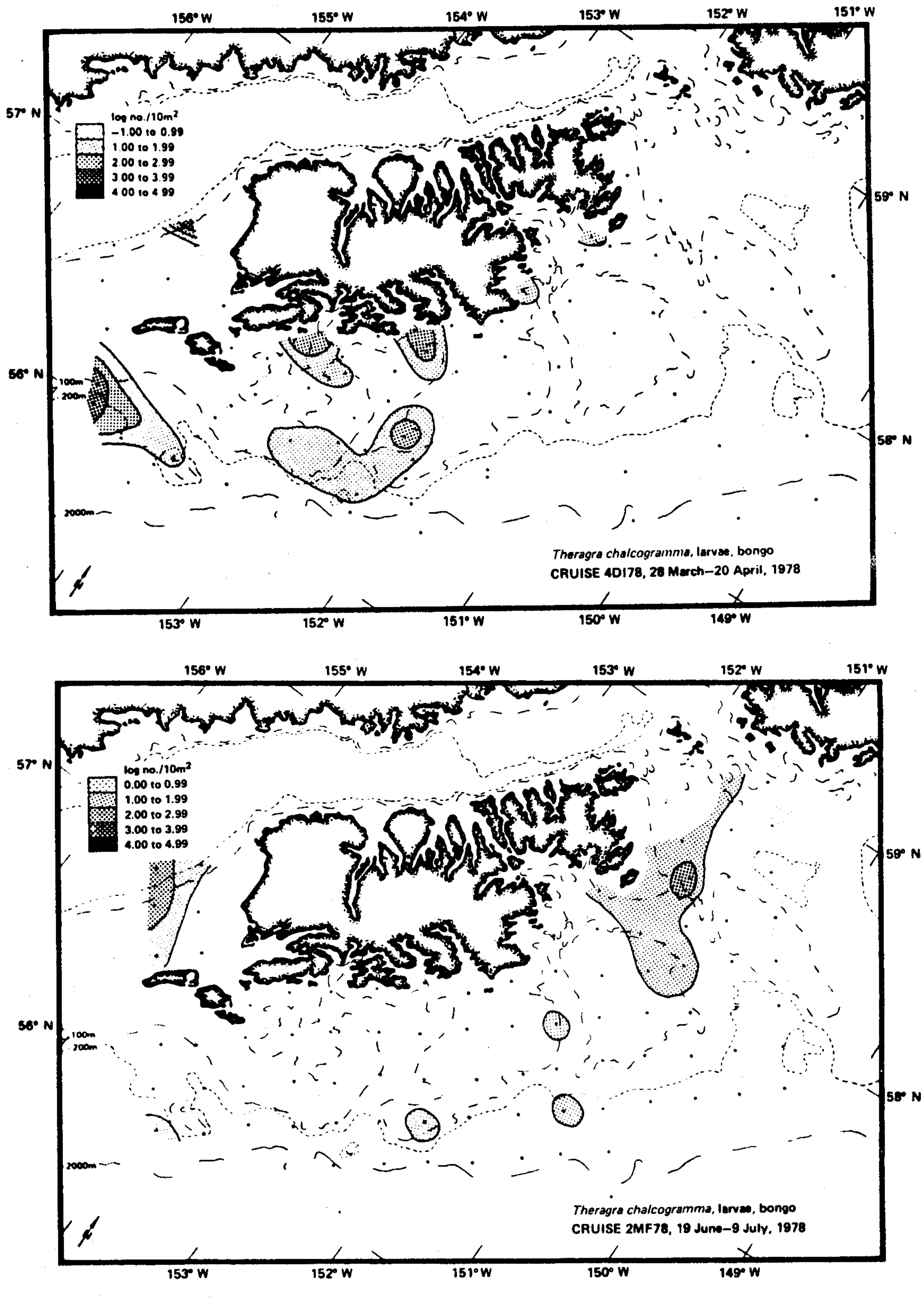
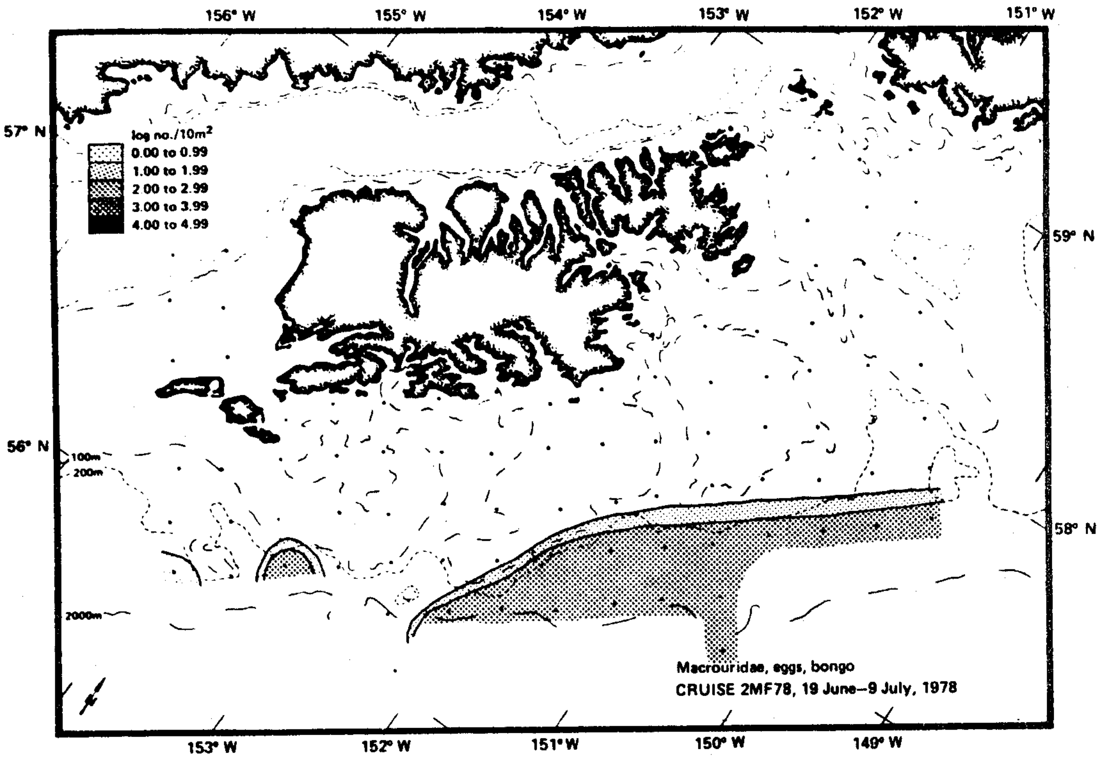


Figure 135.--Distribution and abundance of Theragra chalcogramma larvae in bongo tows from the spring (top) and summer (bottom) 1978 OCSEAP plankton cruises.



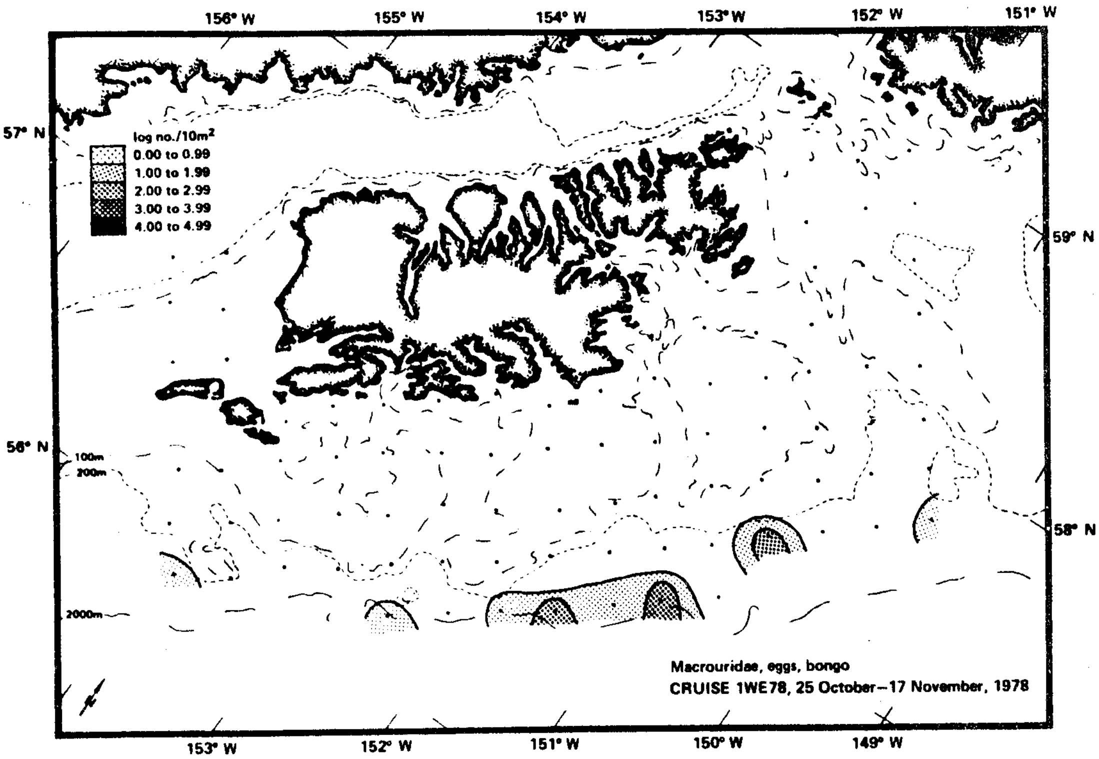


Figure 136.--Distribution and abundance of Macrouridae eggs in bongo tows from the summer (top) and fall (bottom) 1978 OCSEAP plankton cruises.

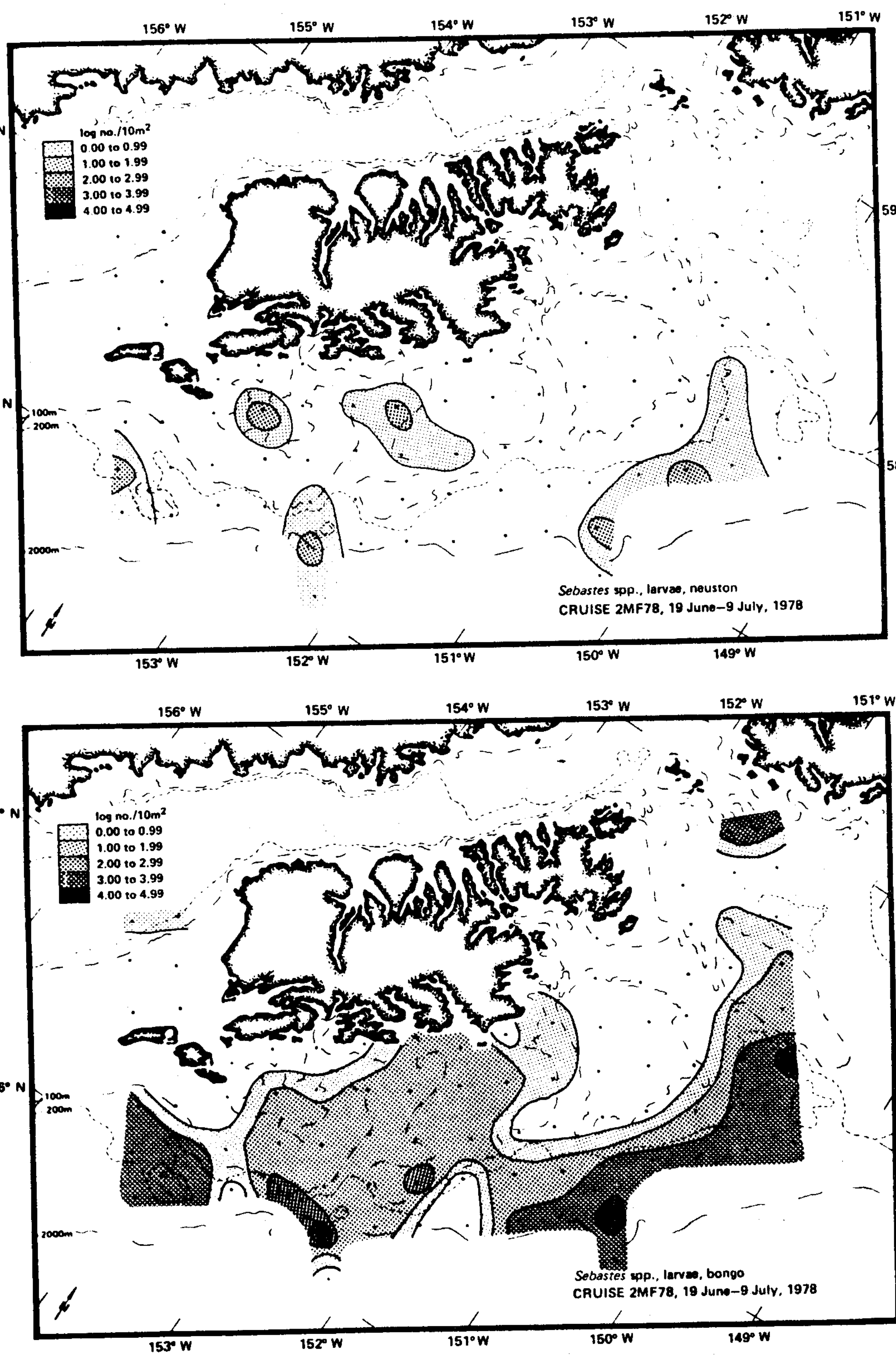
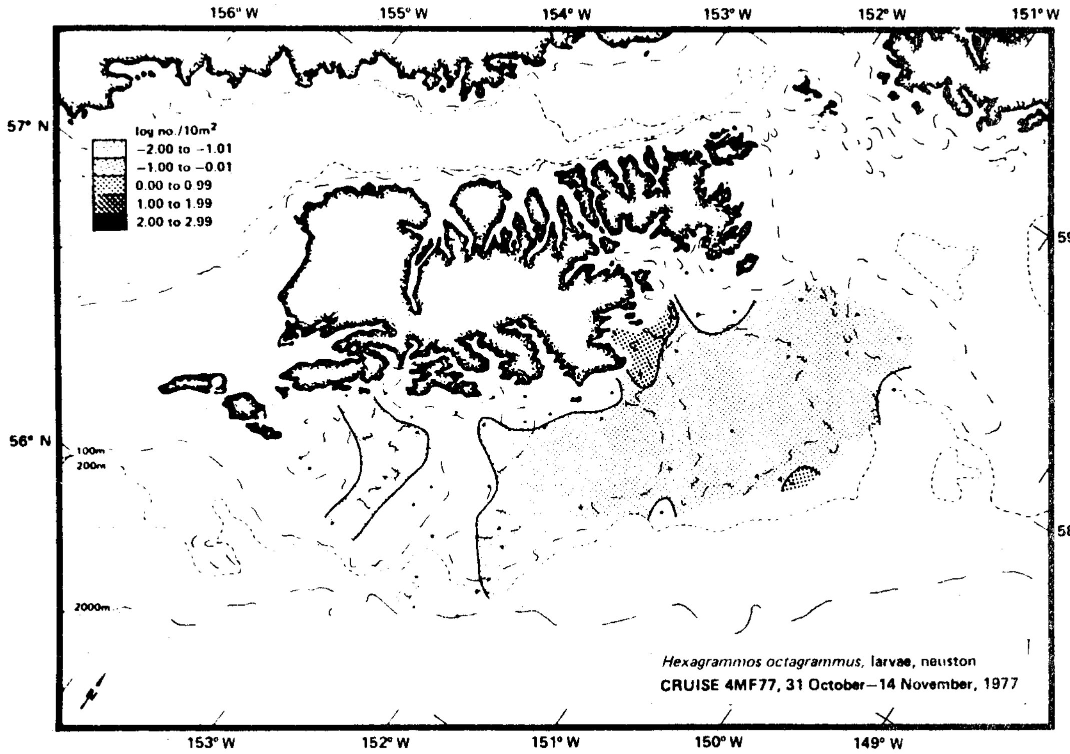


Figure 137.--Distribution and abundance of Sebastes spp. larvae in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.



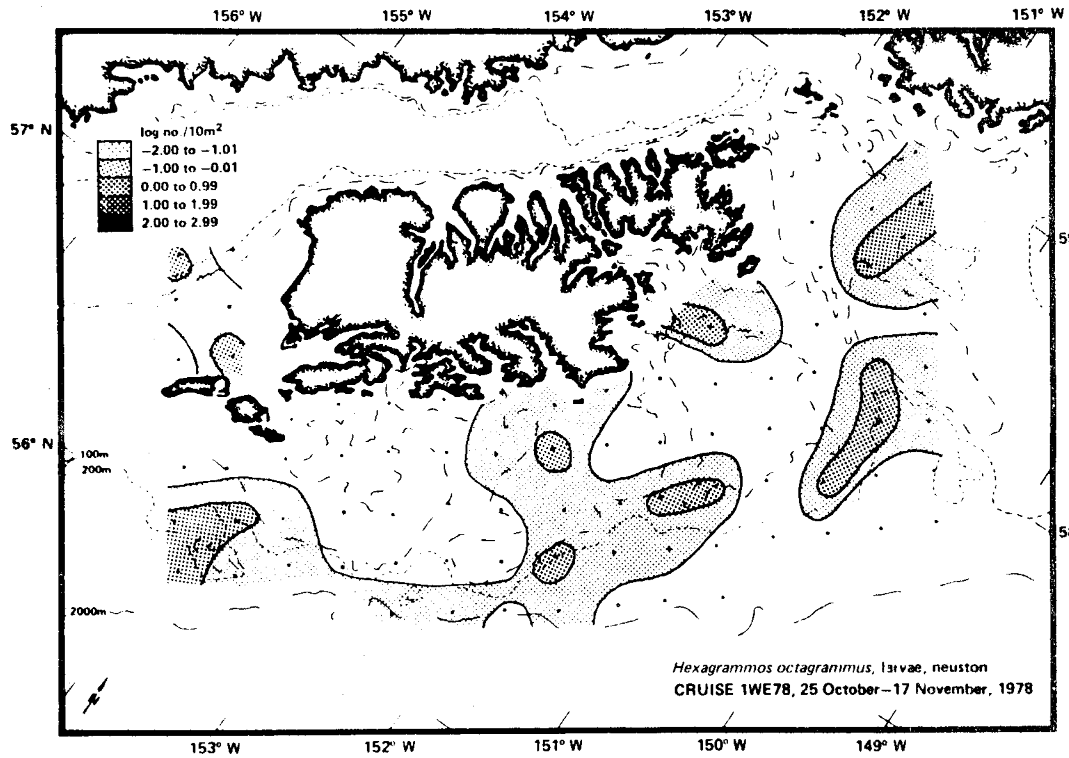


Figure 138.--Distribution and abundance of Hexagrammos octogrammus larvae in neuston tows from the fall 1977 (top) and fall 1978 (bottom) OCSEAP plankton cruises.

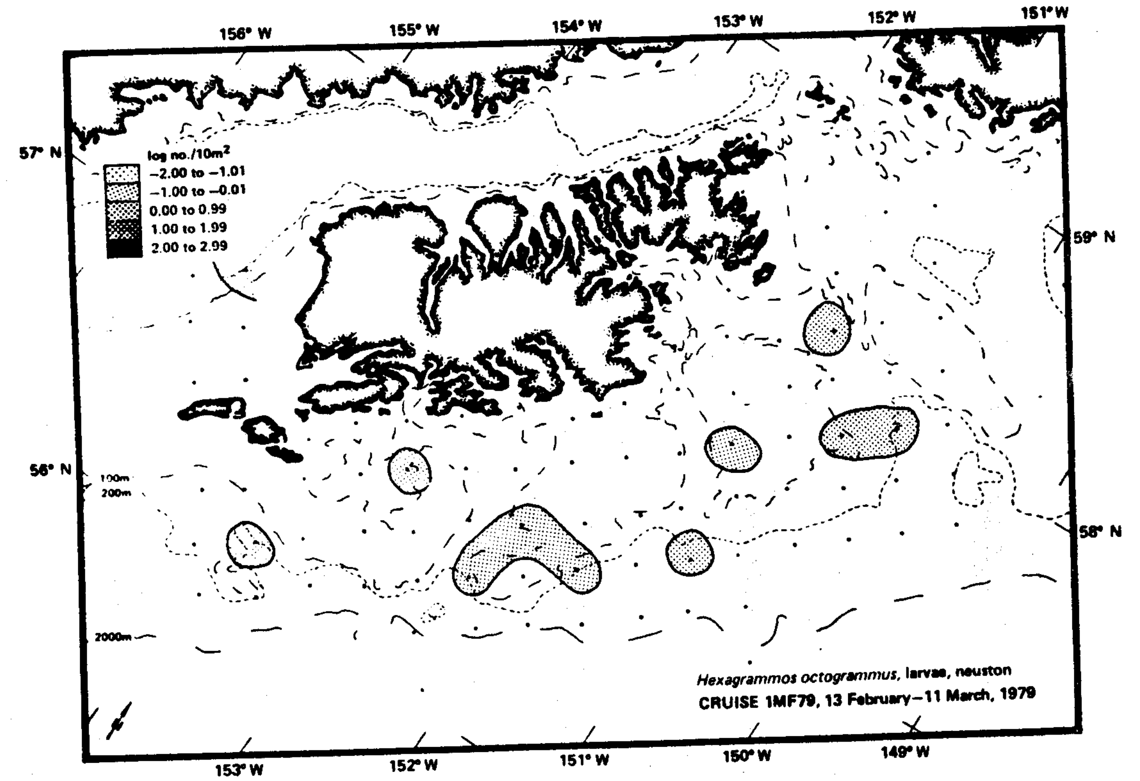
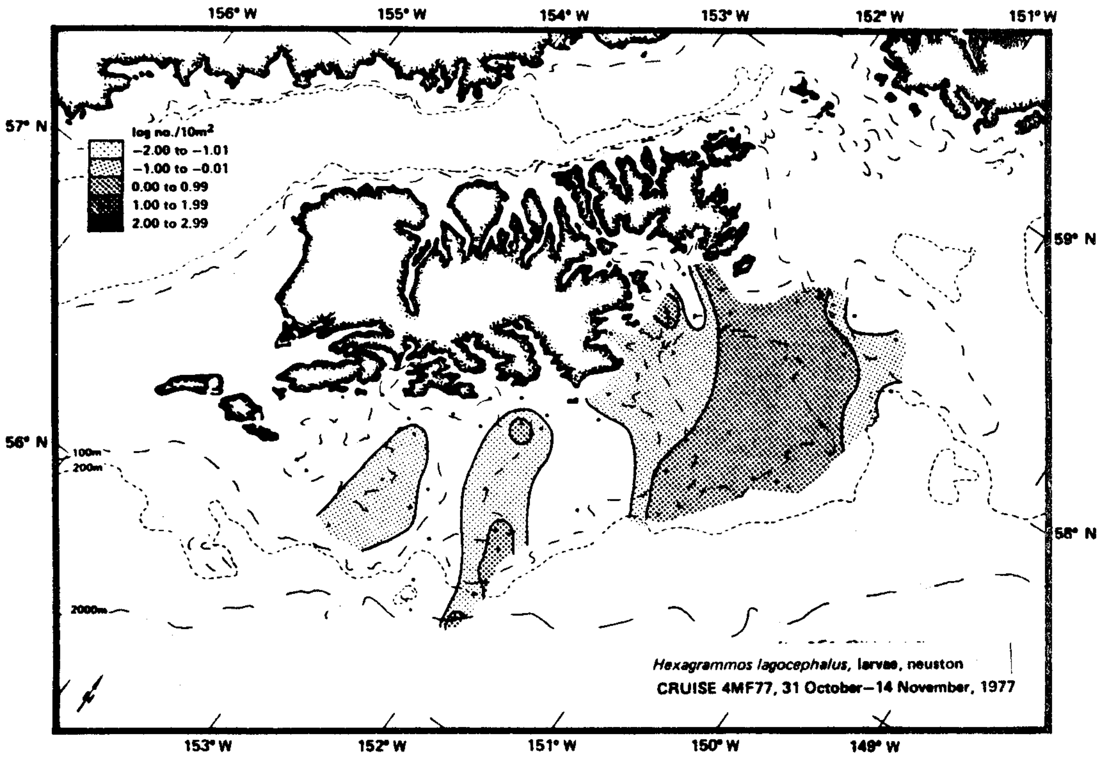


Figure 139.--Distribution and abundance of Hexagrammos octogrammus larvae in neuston tows from the winter 1979 OCSEAP plankton cruise.



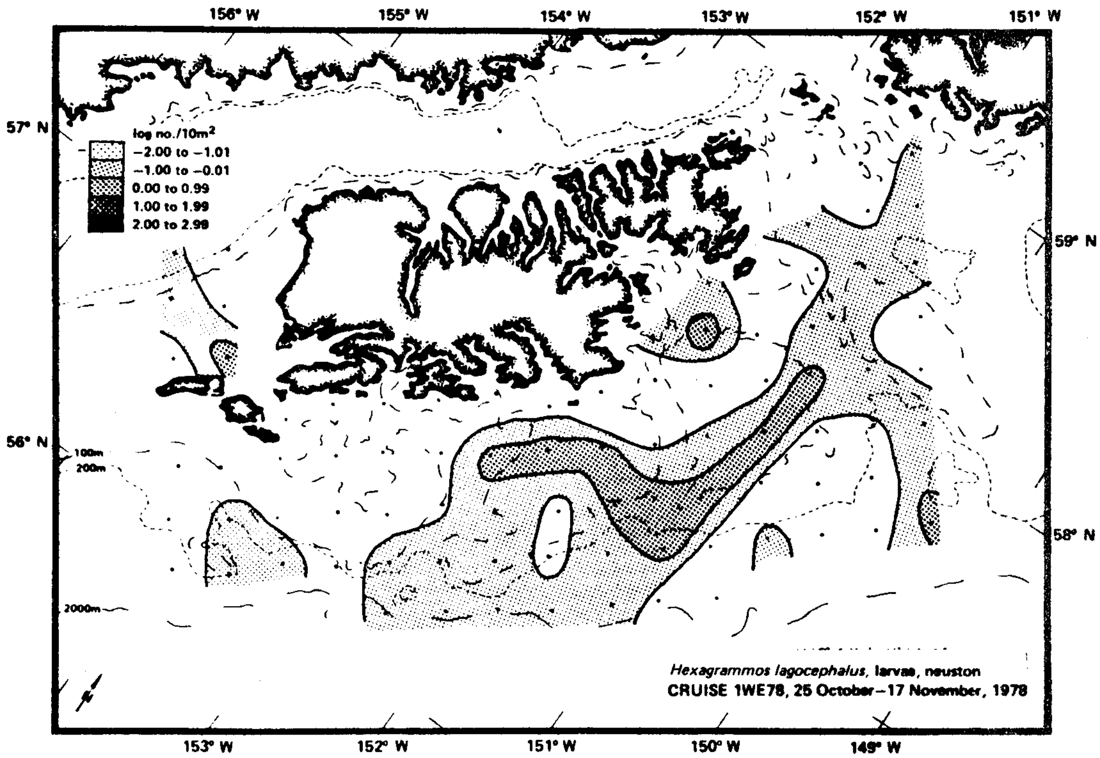


Figure 140.--Distribution and abundance of Hexagrammos lagocephalus larvae in neuston tows from the fall 1977 (top) and fall 1978 (bottom) OCSEAP plankton cruises.

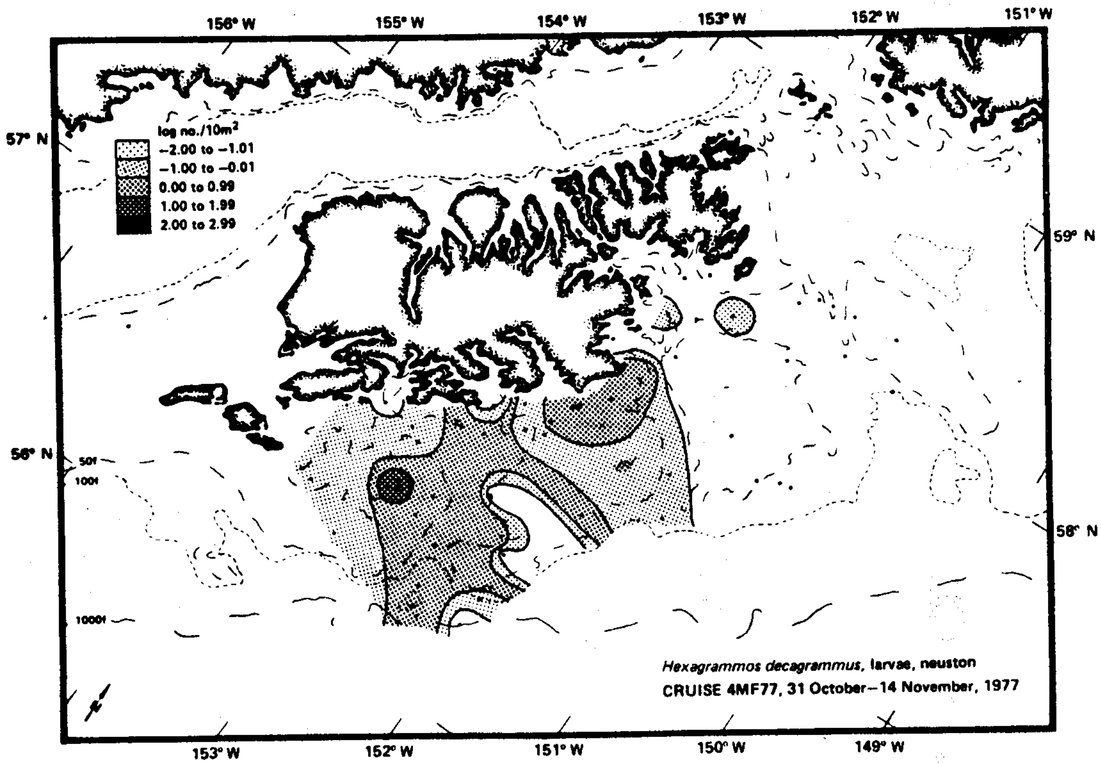


Figure 141.--Distribution and abundance of Hexagrammos decagrammus larvae in neuston tows from the fall 1977 OCSEAP plankton cruise.

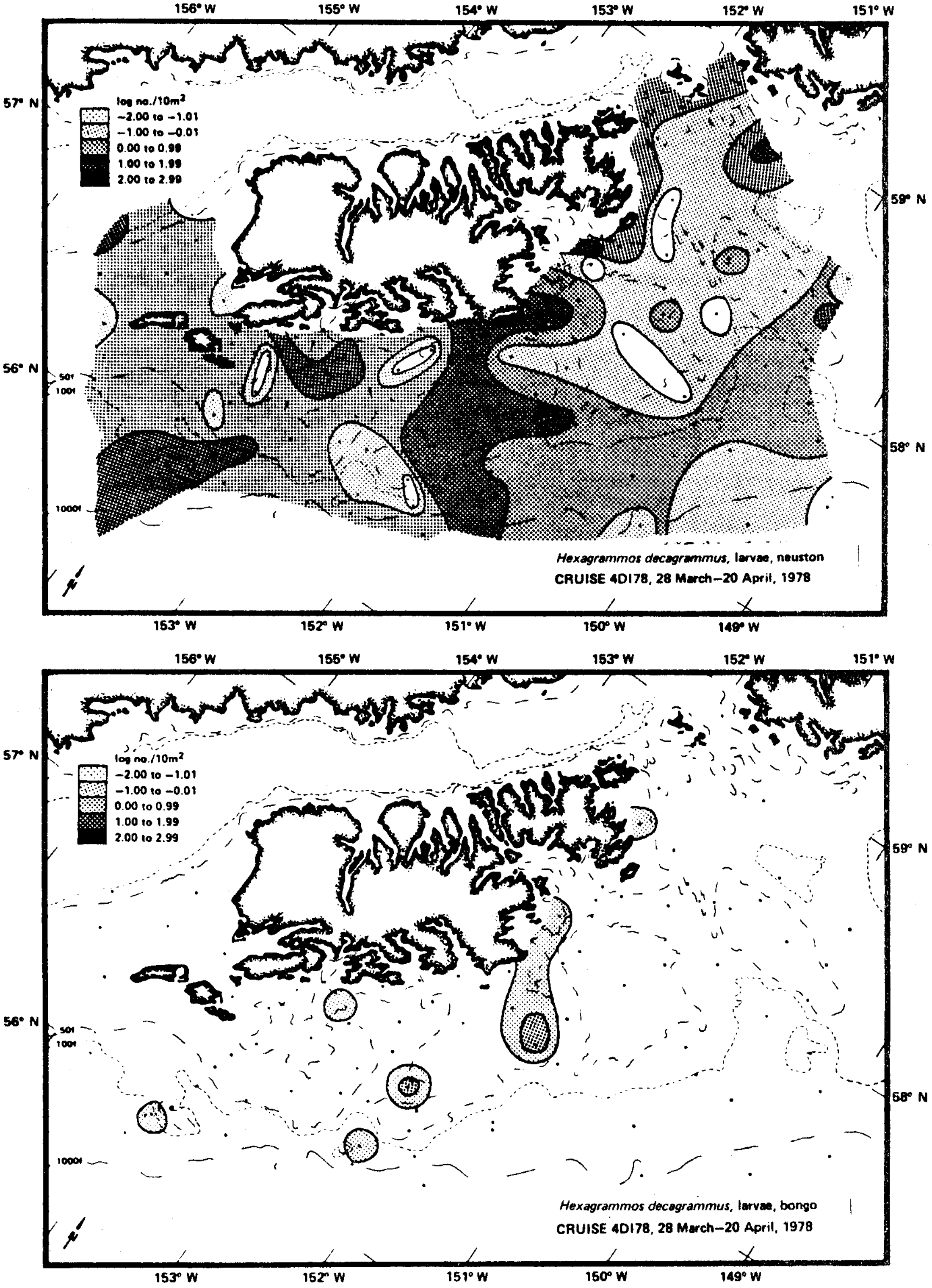


Figure 142.--Distribution and abundance of Hexagrammos decagrammus larvae in neuston (top) and bongo (bottom) tows from the spring 1978 OCSEAP plankton cruise.

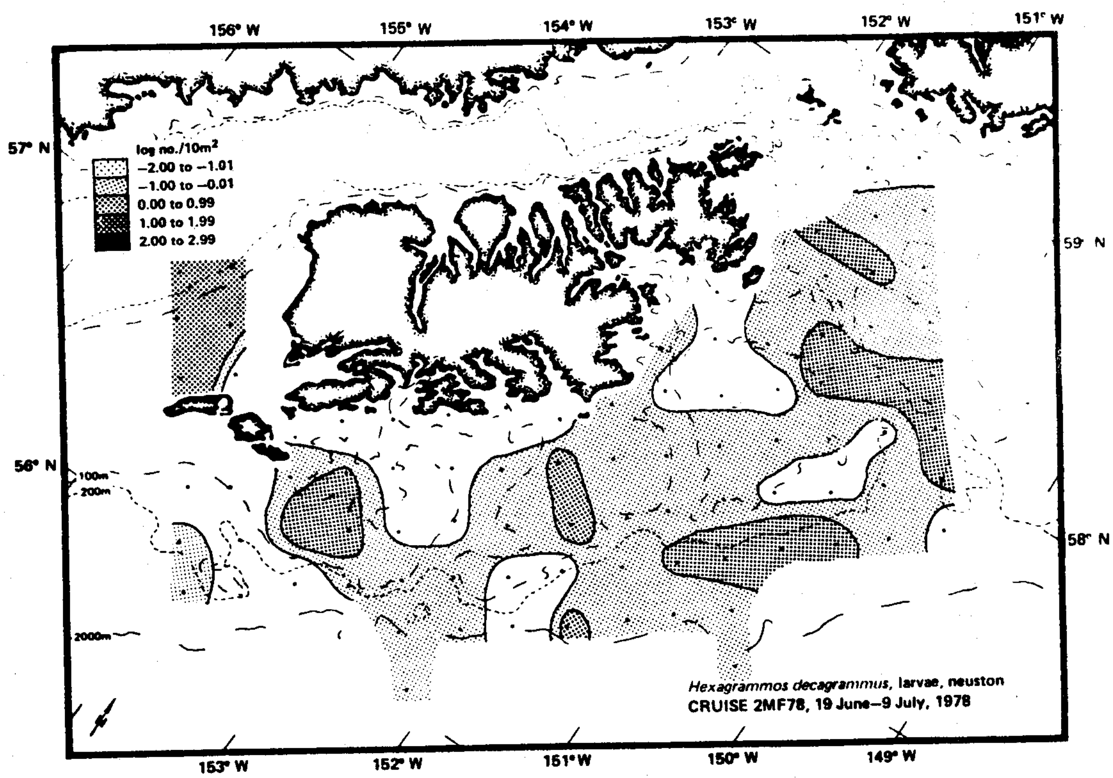


Figure 143.--Distribution and abundance of Hexagrammos decagrammus larvae in neuston tows from the summer 1978 OCSEAP plankton cruise.

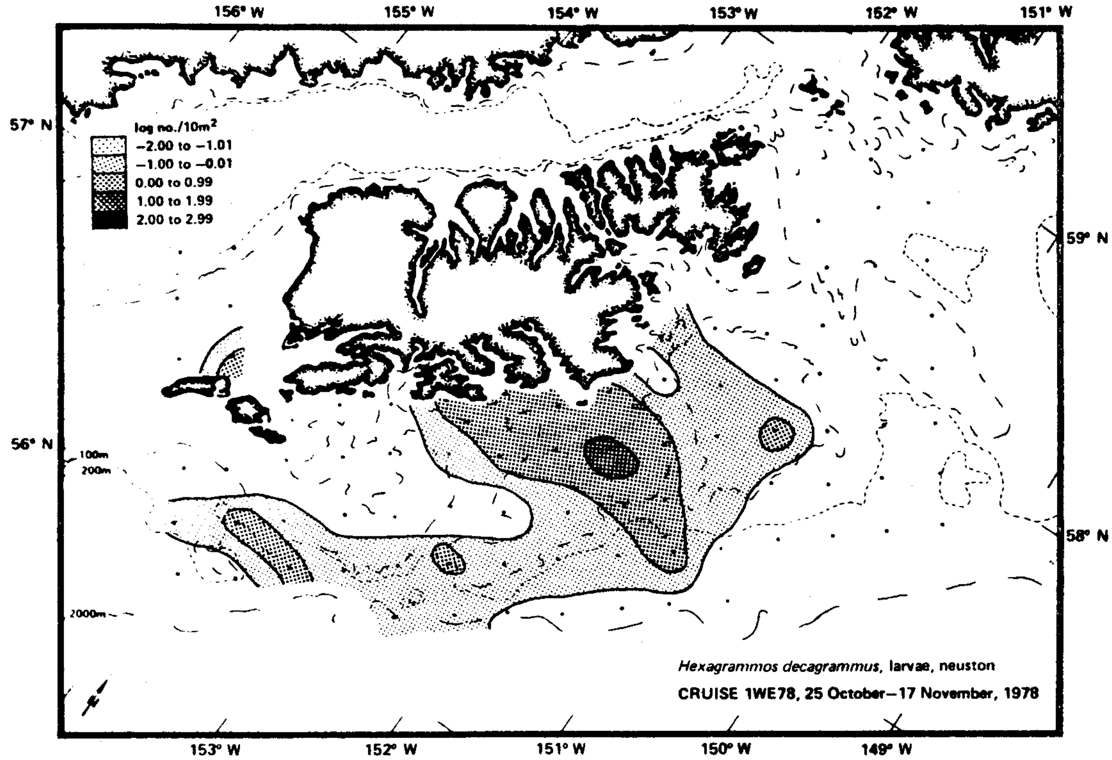
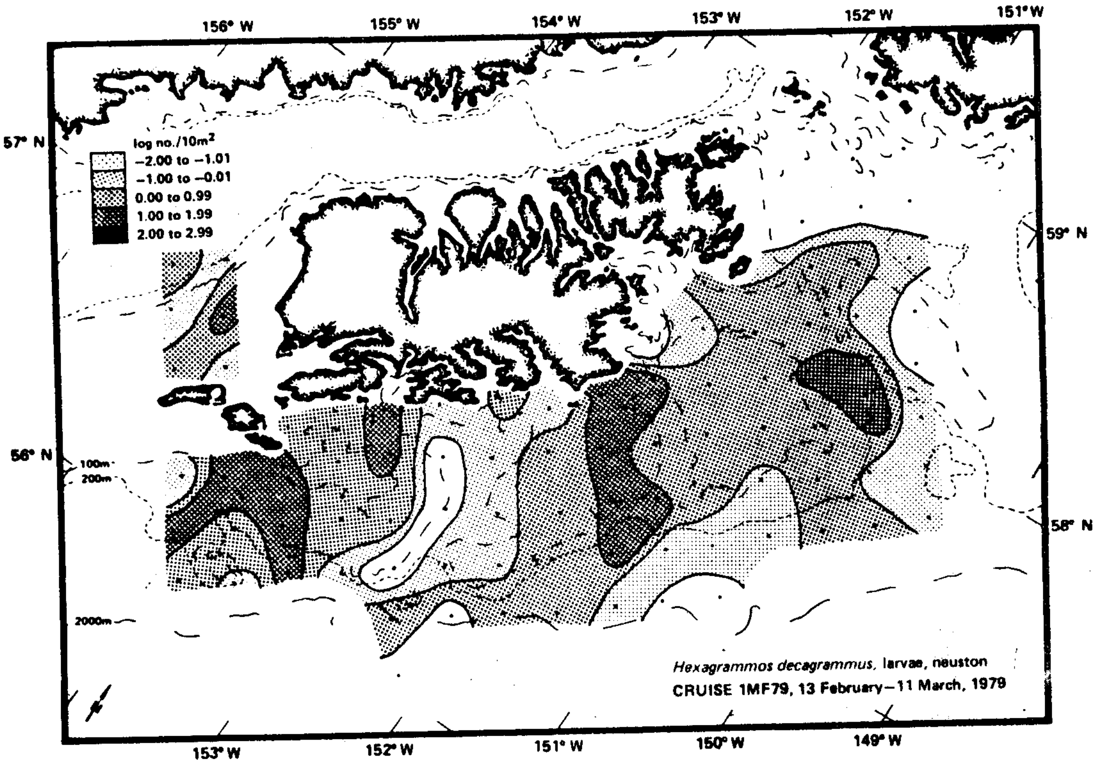


Figure 144.--Distribution and abundance of Hexagrammos decagrammus larvae in neuston tows from the fall 1978 OCSEAP plankton cruise.



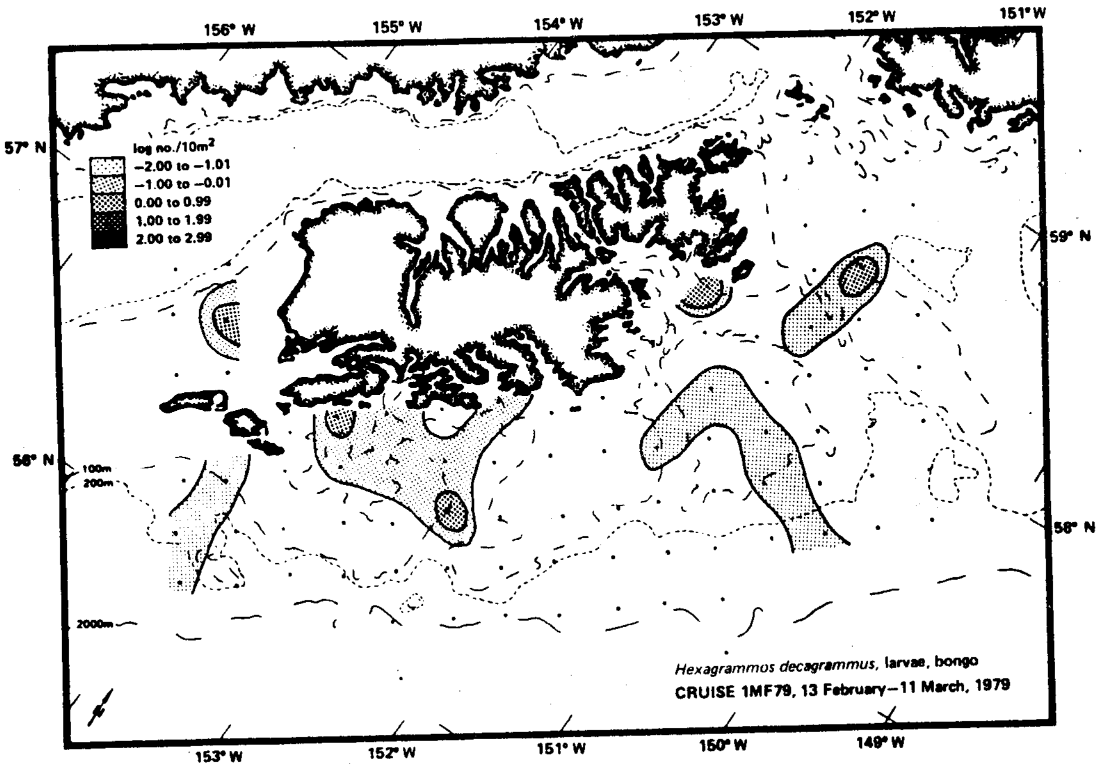
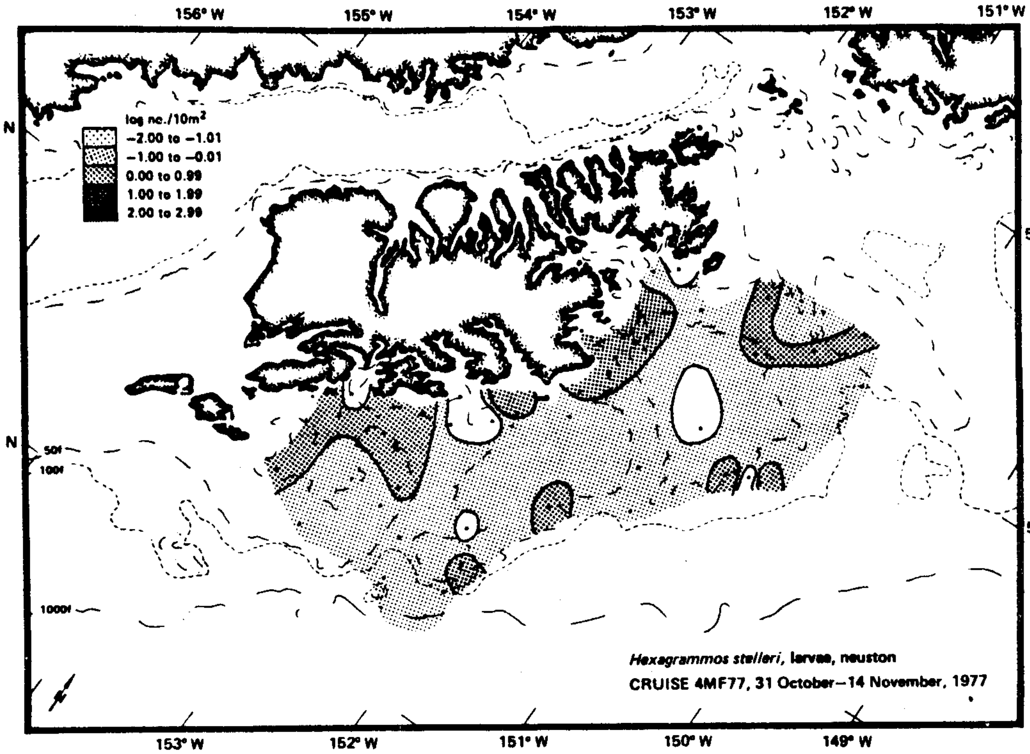


Figure 145.--Distribution and abundance of Hexagrammos decagrammus larvae in neuston (top) and bongo (bottom) tows from the winter 1979 OCSEAP plankton cruise.



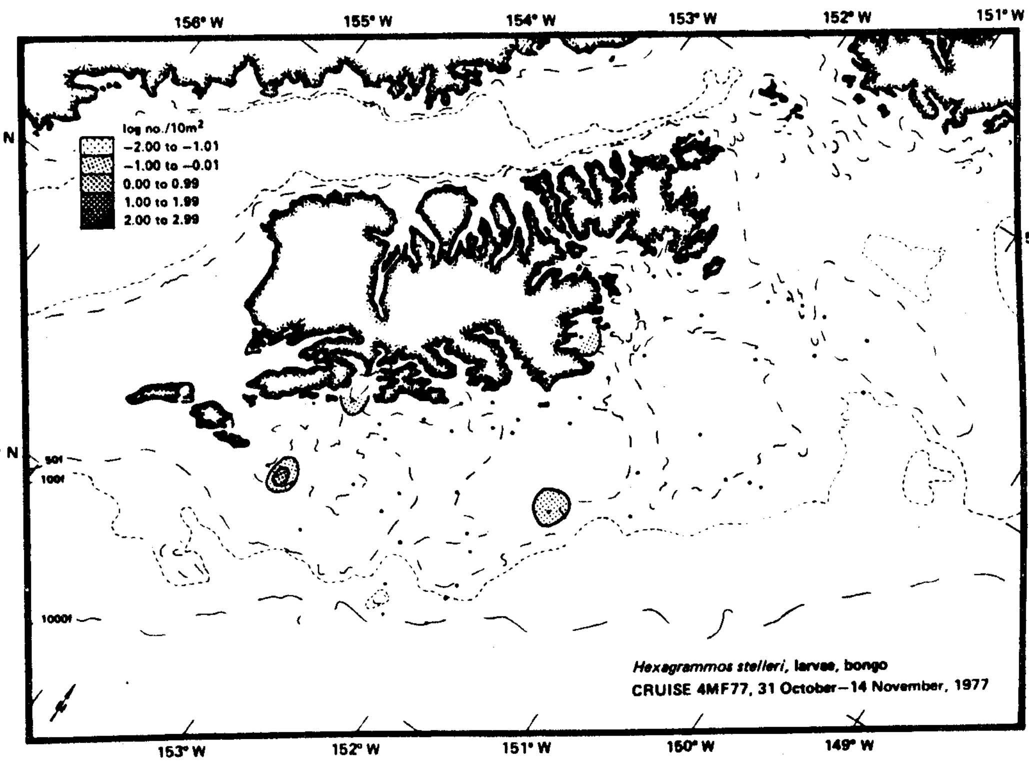


Figure 146.--Distribution and abundance of Hexagrammos stelleri larvae in neuston (top) and bongo (bottom) tows from the fall 1977 OCSEAP plankton cruise.

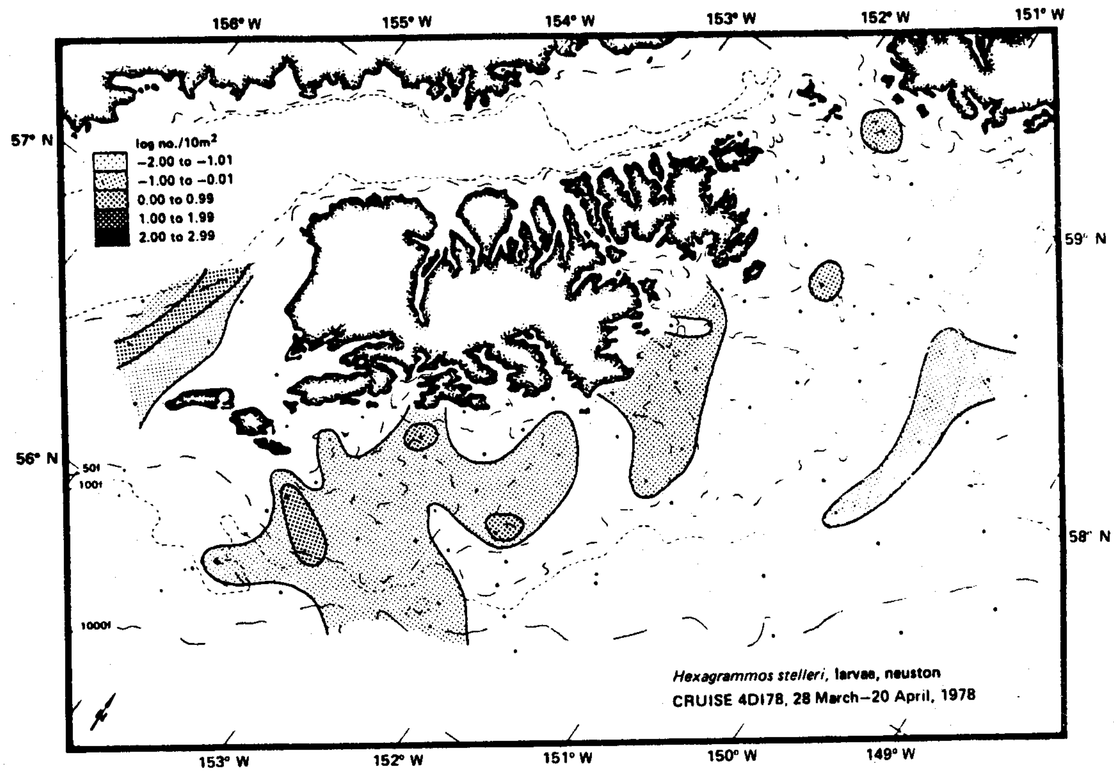


Figure 147.--Distribution and abundance of <u>Hexagrammos stelleri</u> larvae in neuston tows from the spring 1978 OCSEAP plankton cruise.

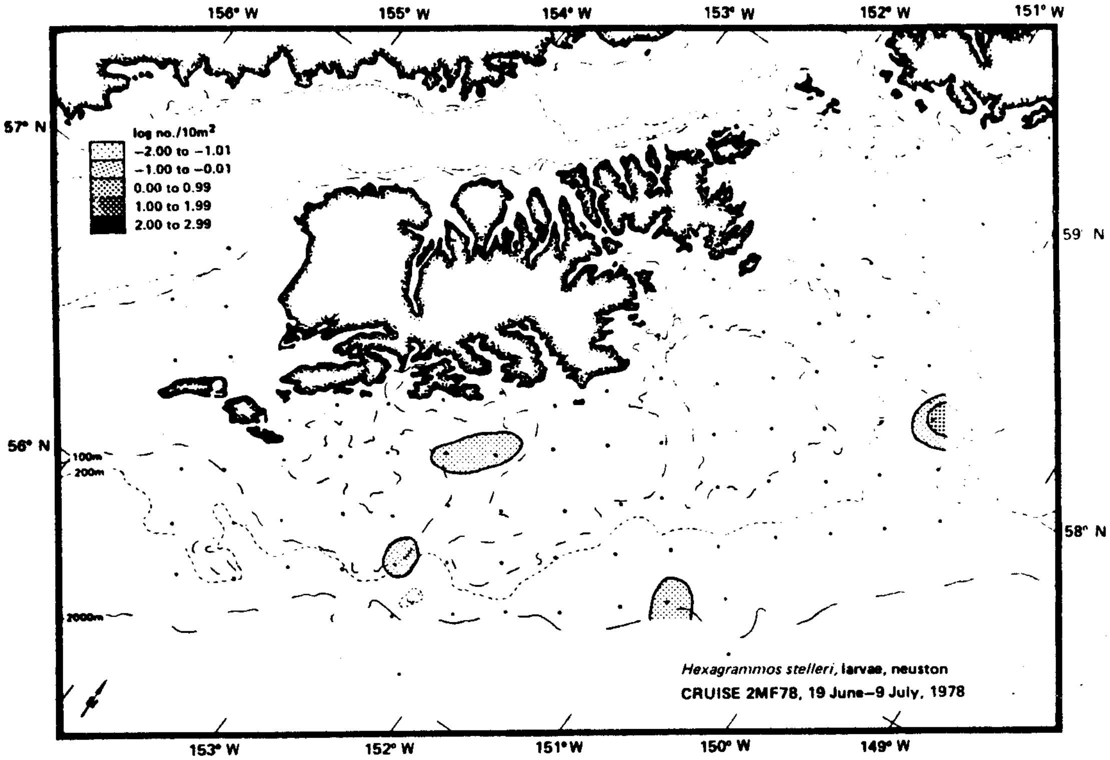


Figure 148.--Distribution and abundance of <u>Hexagrammos</u> <u>stelleri</u> larvae in neuston tows from the summer 1978 OCSEAP plankton cruise.

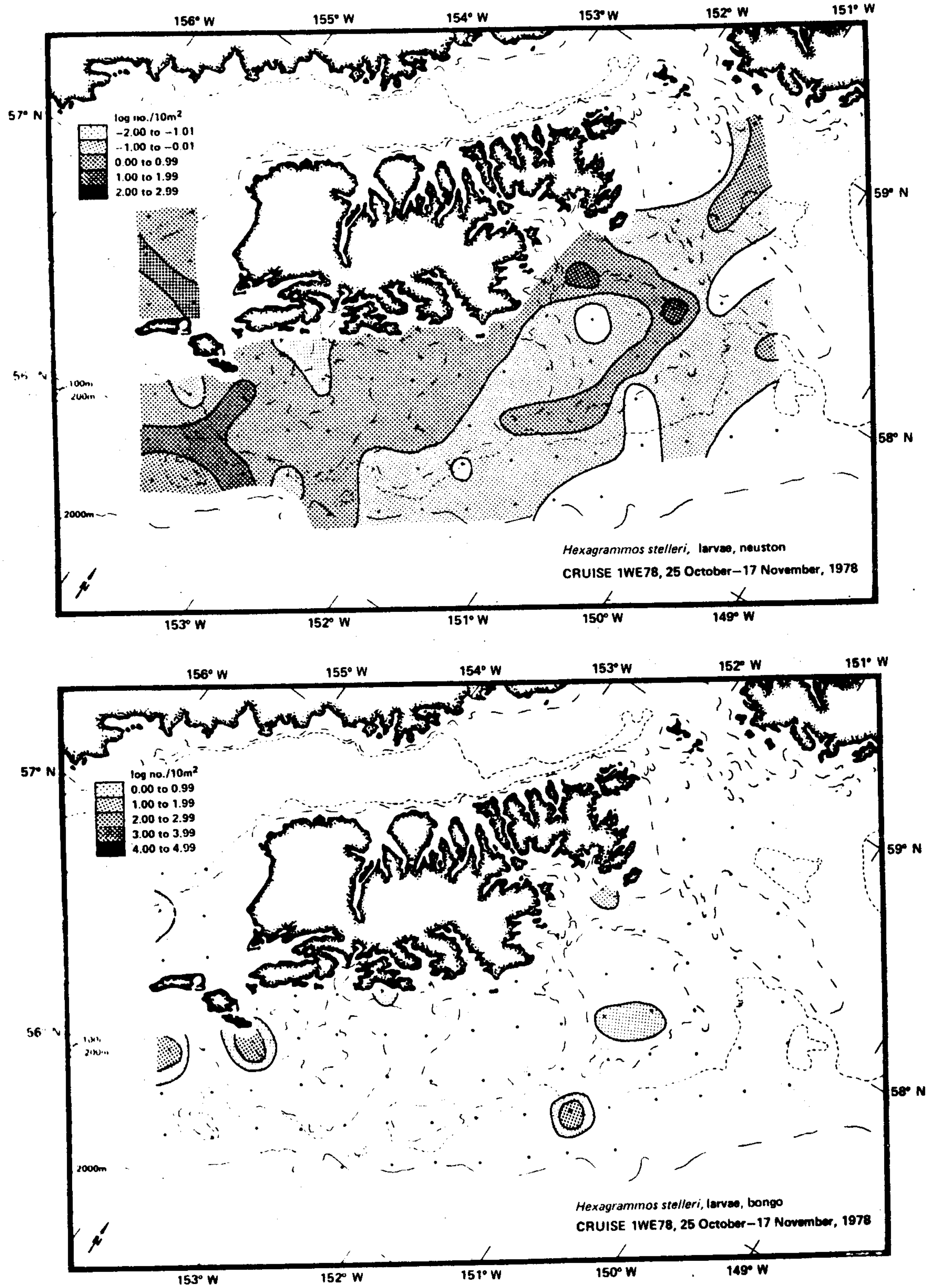


Figure 149.--Distribution and abundance of Hexagrammos stelleri larvae in neuston (top) and bongo (bottom) tows from the fall 1978 OCSEAP plankton cruise.

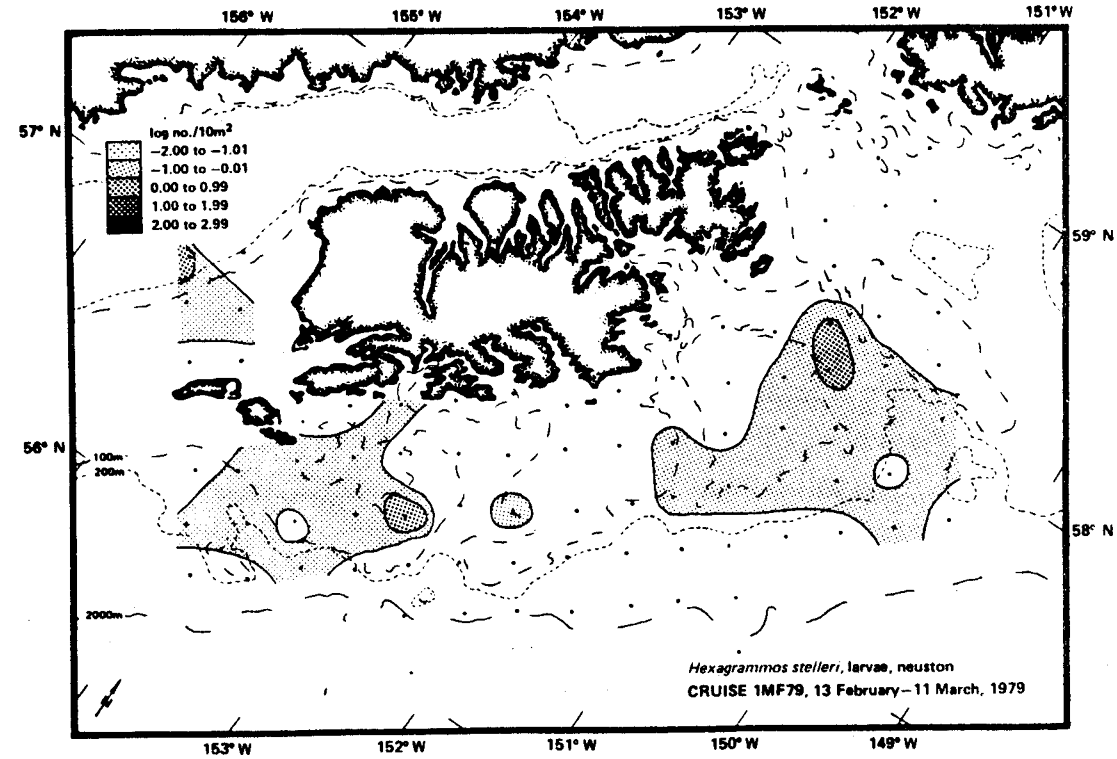


Figure 150.--Distribution and abundance of Hexagrammos stelleri larvae in neuston tows from the winter 1979 OCSEAP plankton cruise.

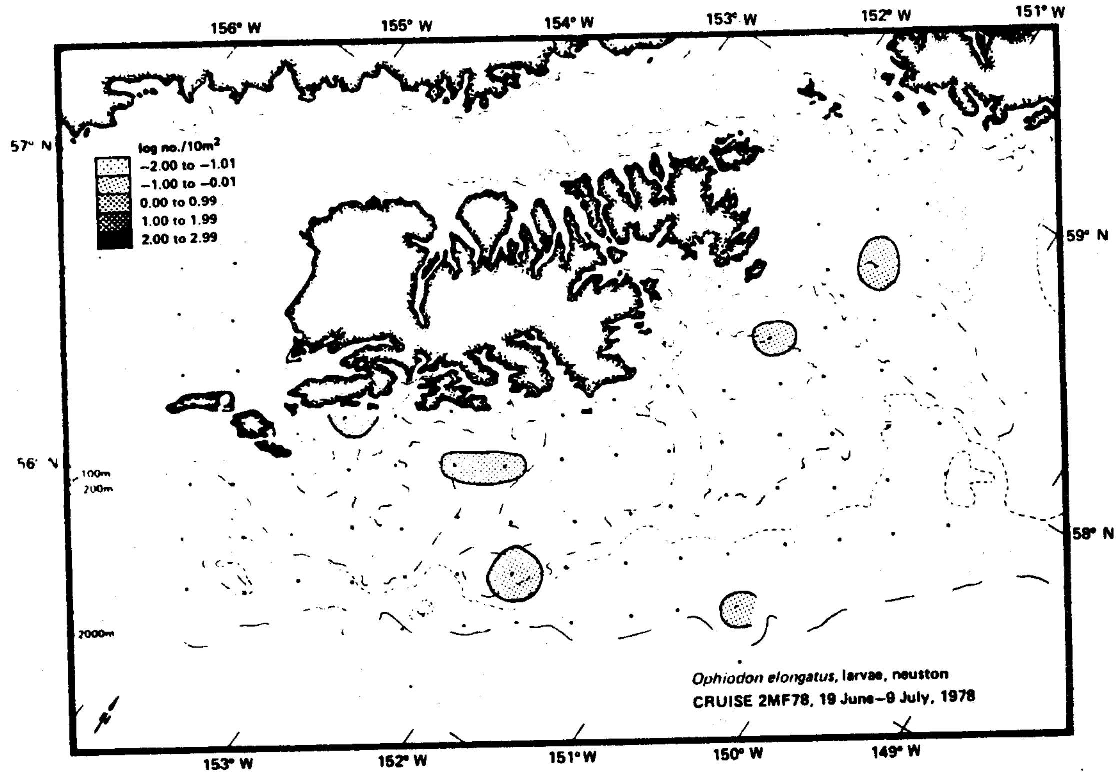


Figure 151.--Distribution and abundance of Ophiodon elongatus larvae in neuston tows from the summer 1978 OCSEAP plankton cruise.

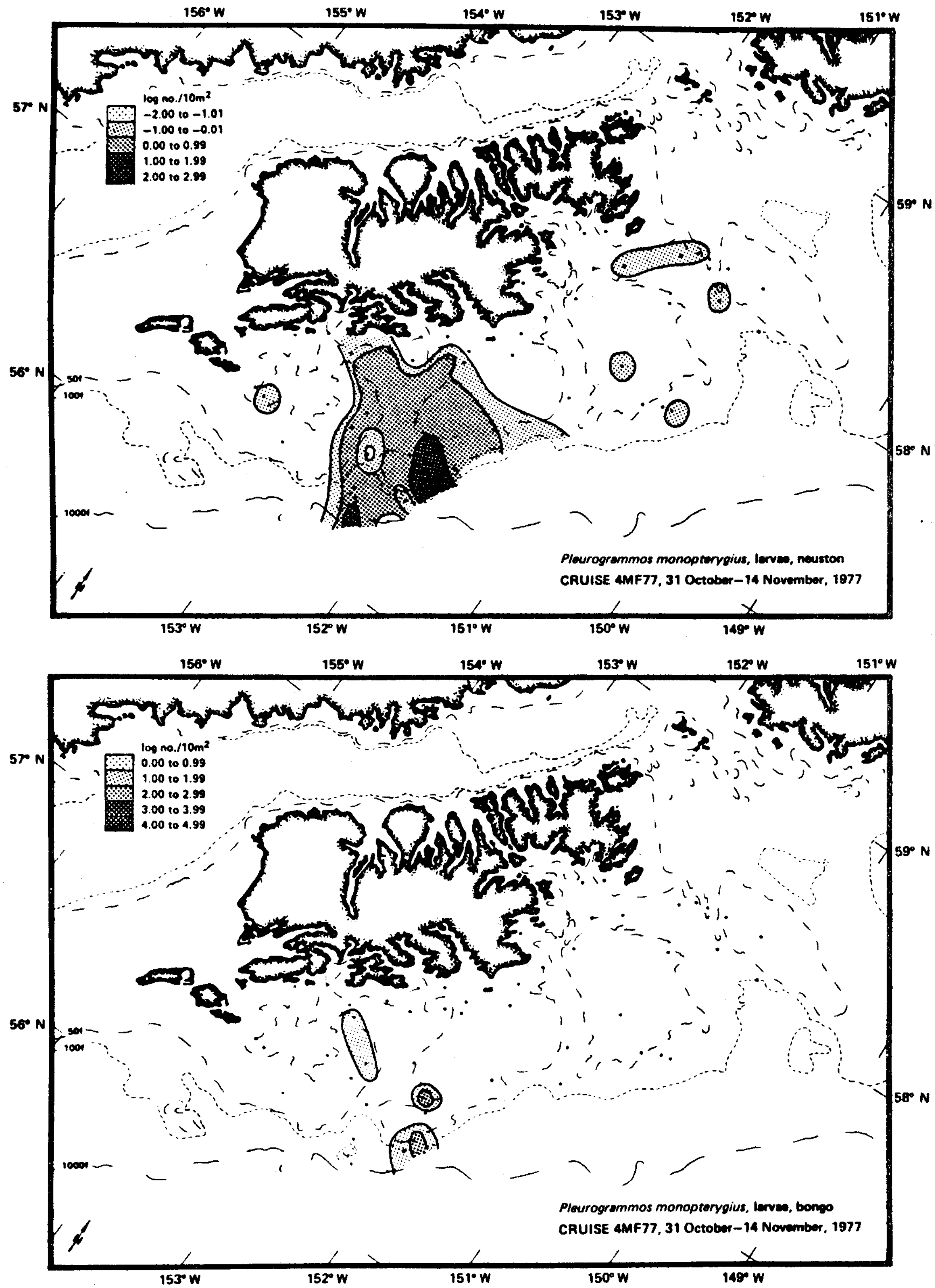


Figure 152.--Distribution and abundance of Pleurogrammus monopterygius larvae in neuston (top) and bongo (bottom) tows from the fall 1977 OCSEAP plankton cruise.

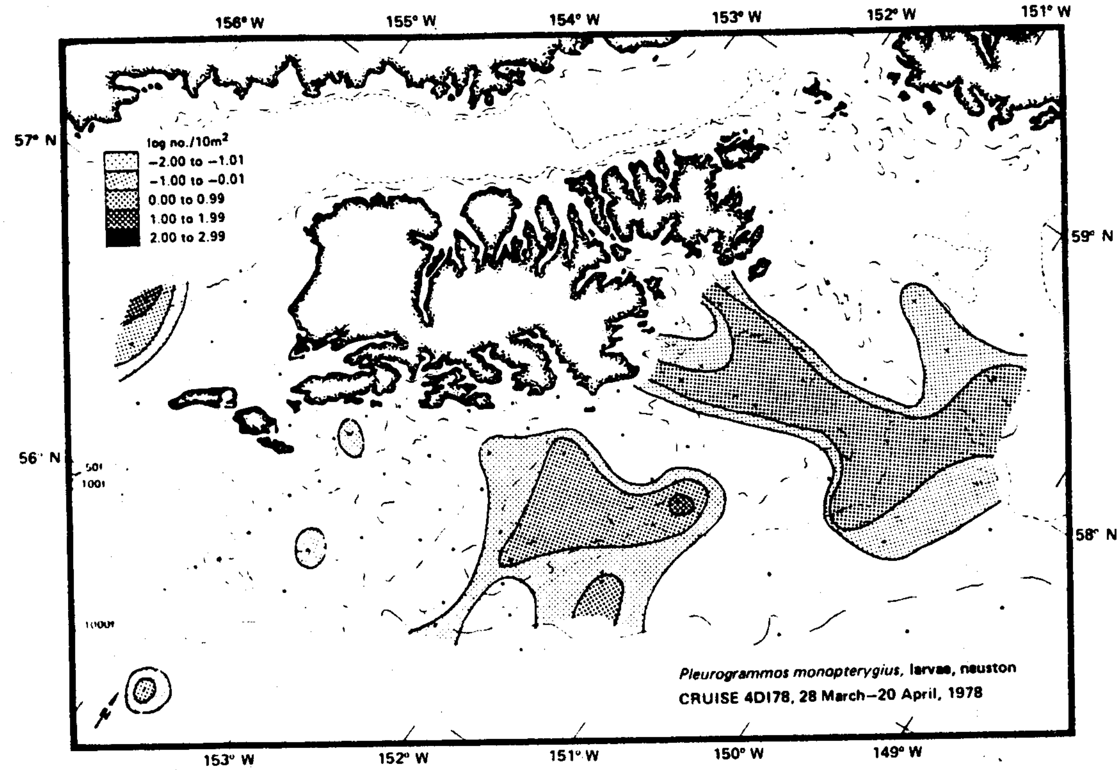


Figure 153.--Distribution and abundance of Pleurogrammus monopterygius larvae in neuston tows from the spring 1978 OCSEAP plankton cruise.

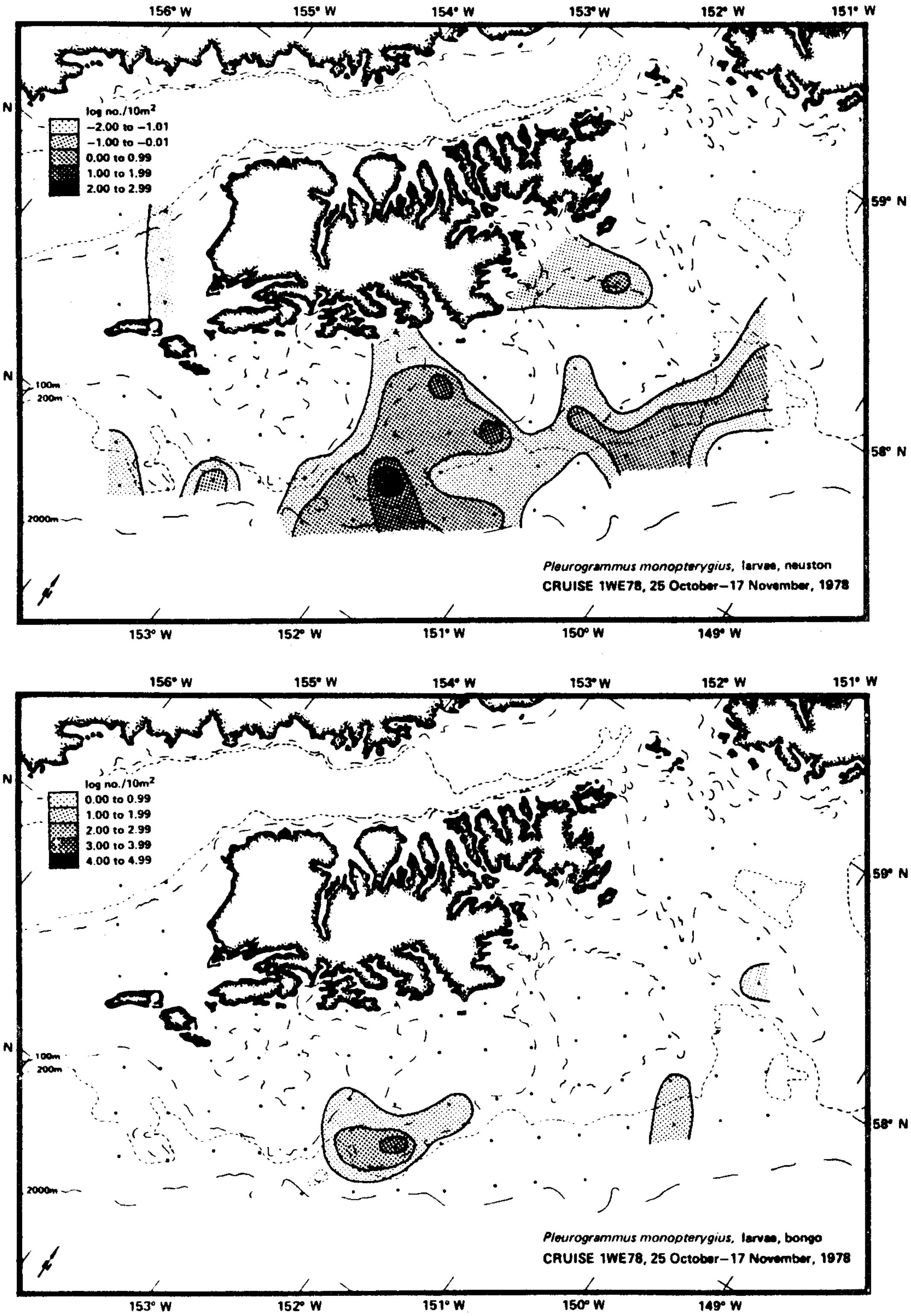
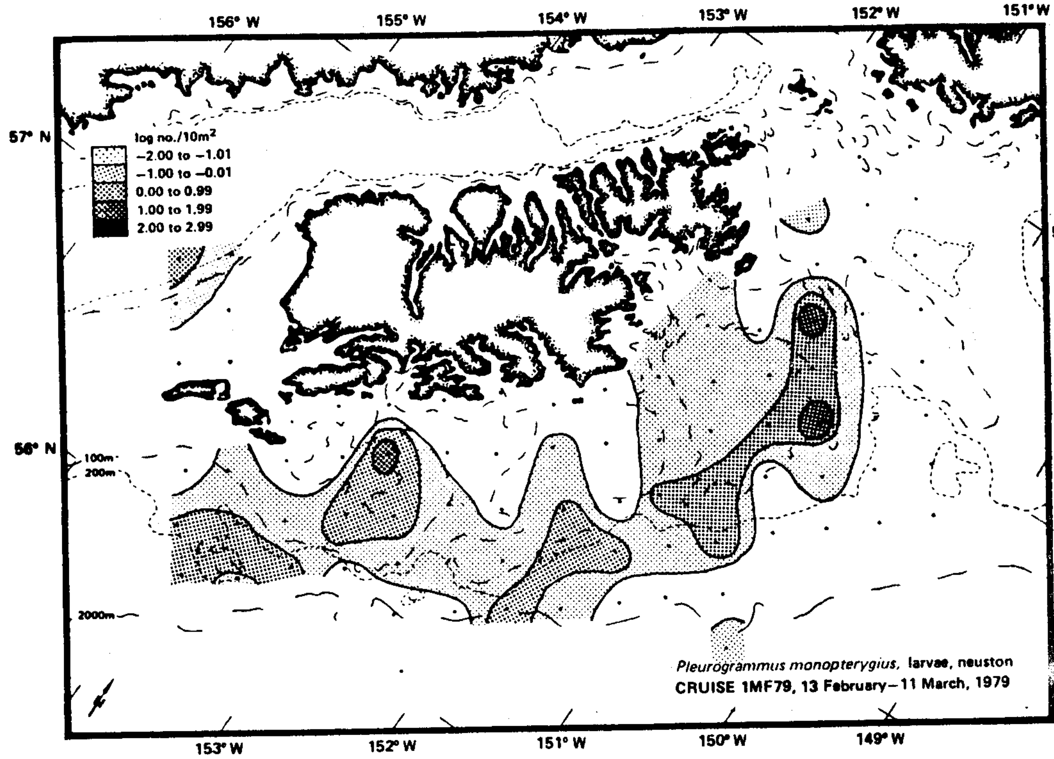


Figure 154.--Distribution and abundance of Pleurogrammus monopterygius larvae in neuston (top) and bongo (bottom) tows from the fall 1978 OCSEAP plankton cruise.



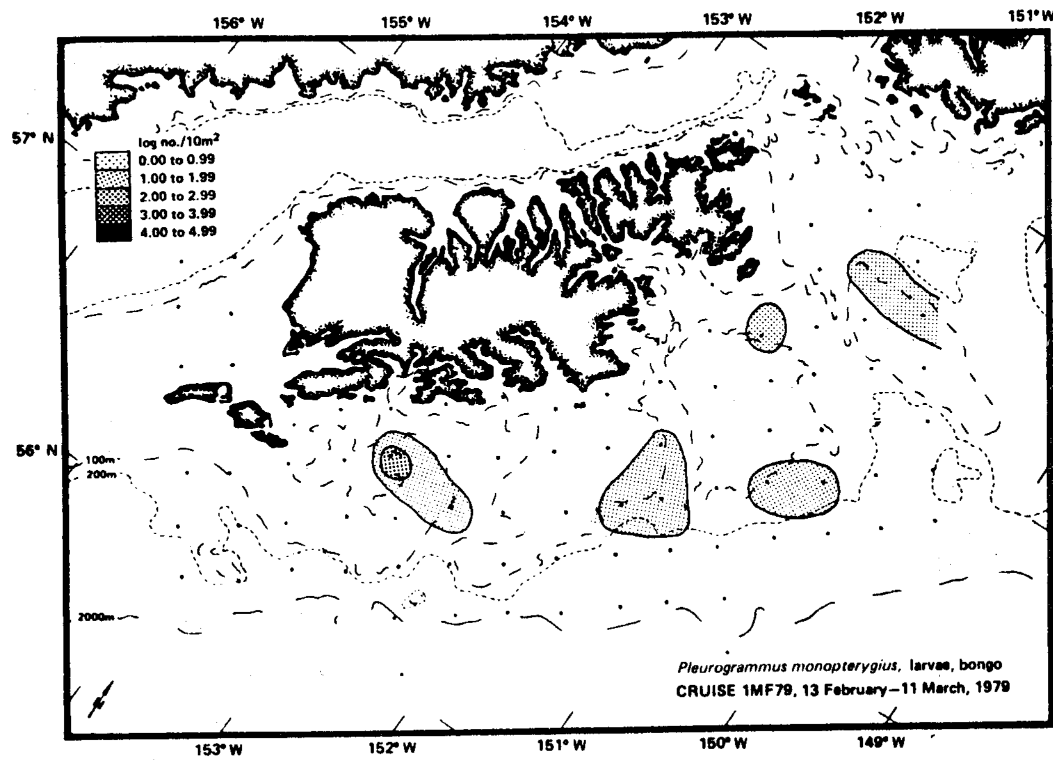


Figure 155.--Distribution and abundance of Pleurogrammus monopterygius larvae in neuston (top) and bongo (bottom) tows from the winter 1979 OCSEAP plankton cruise.

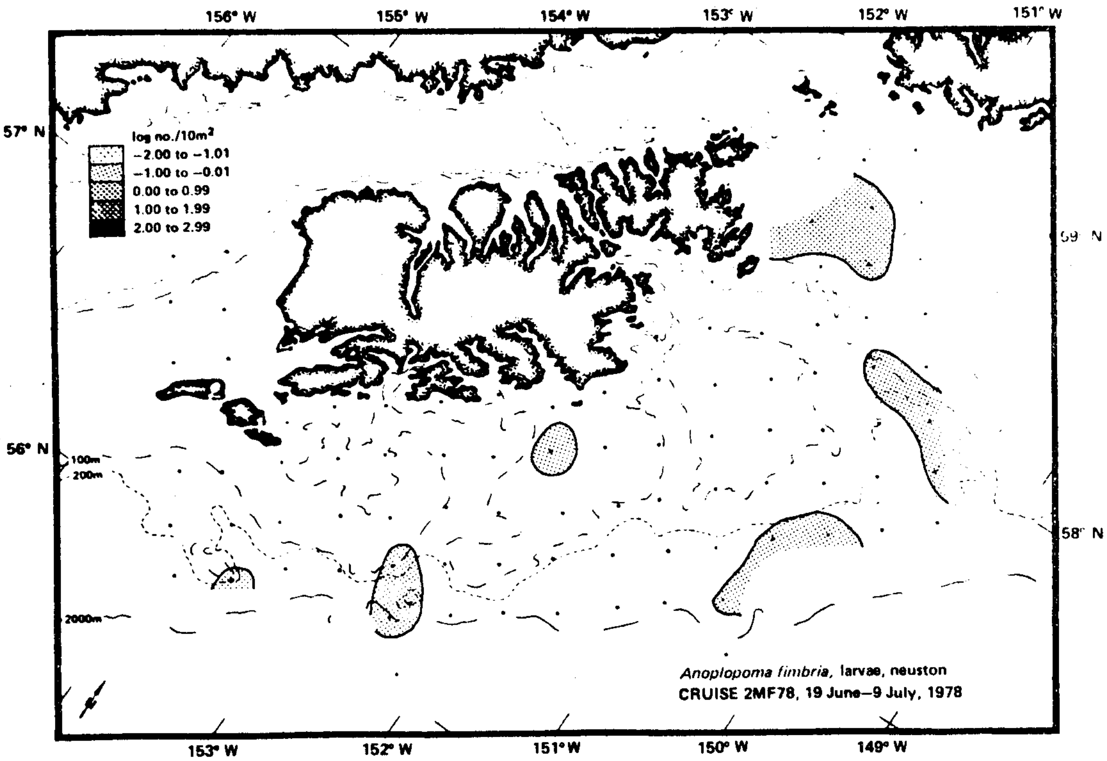


Figure 156.--Distribution and abundance of Anoplopoma fimbria larvae in neuston tows from the summer 1978 OCSEAP plankton cruise.

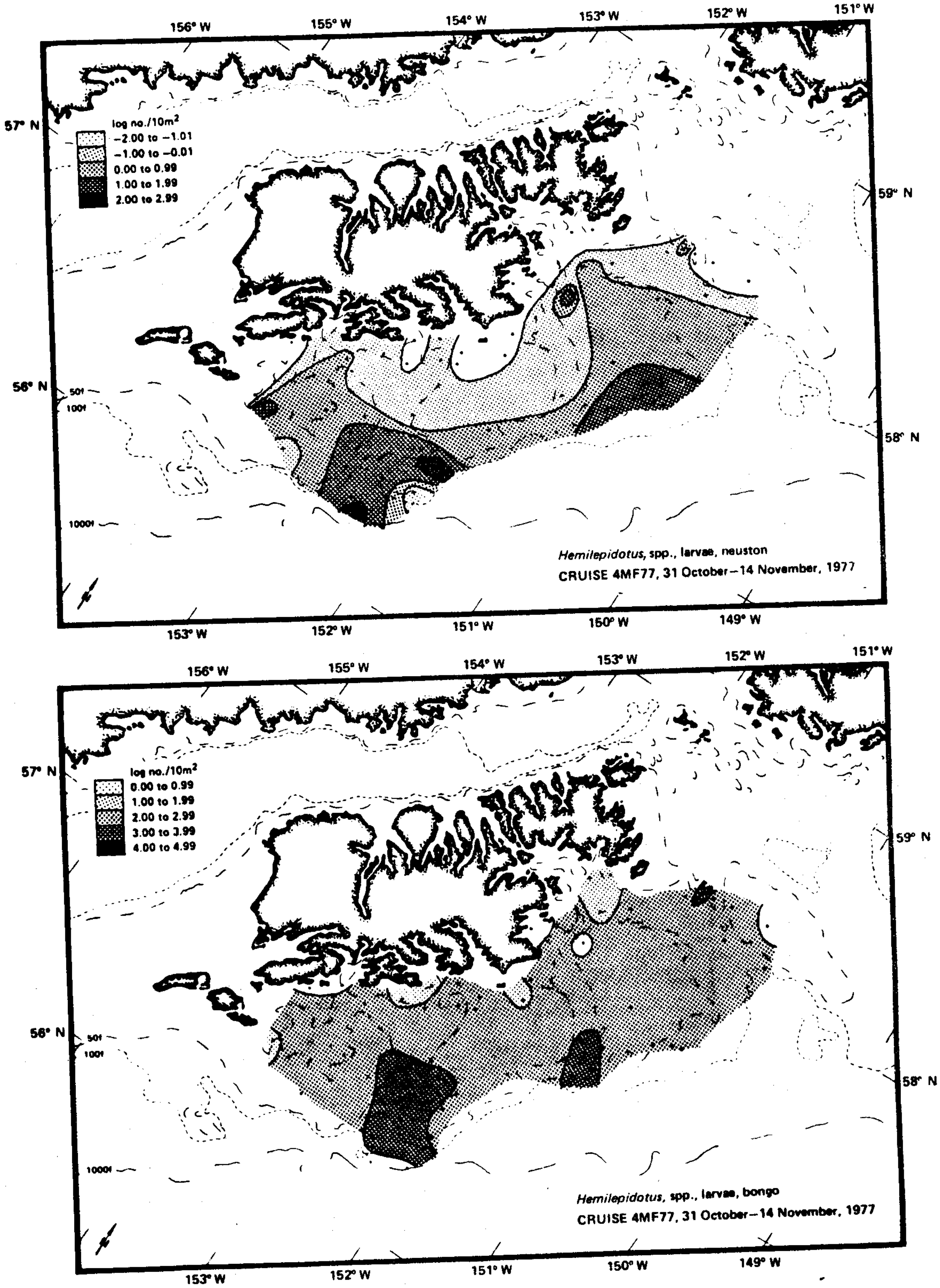


Figure 157.--Distribution and abundance of Hemilepidotus spp. larvae in neuston (top) and bongo (bottom) tows from the fall 1977 OCSEAP plankton cruise.

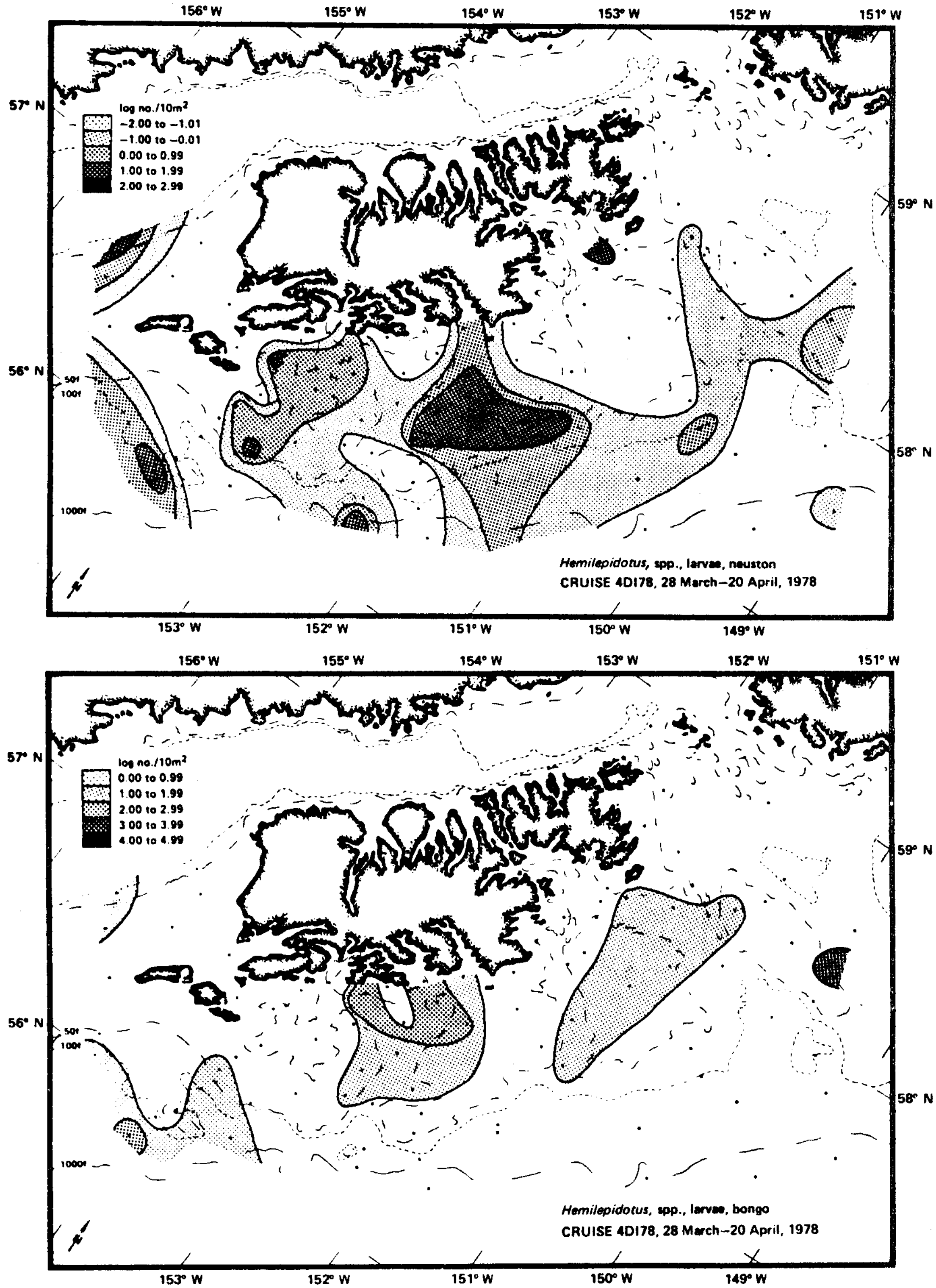


Figure 158.--Distribution and abundance of Hemilepidotus spp. larvae in neuston (top) and bongo (bottom) tows from the spring 1978 OCSEAP plankton cruise.

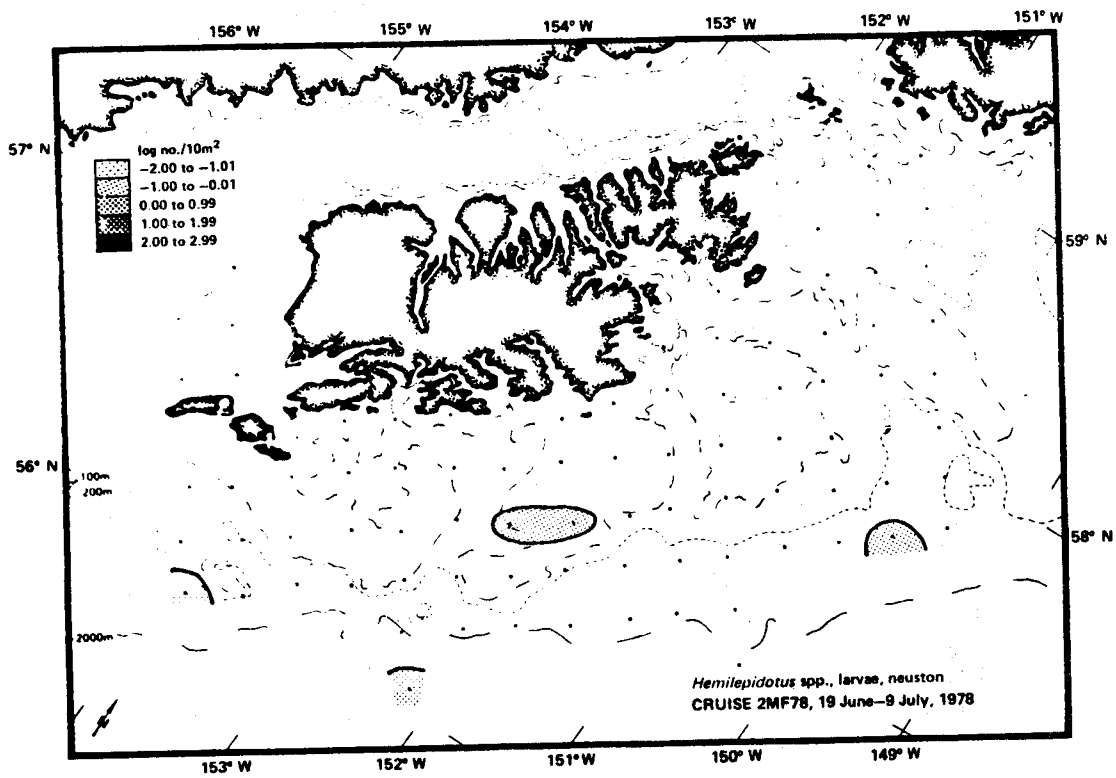
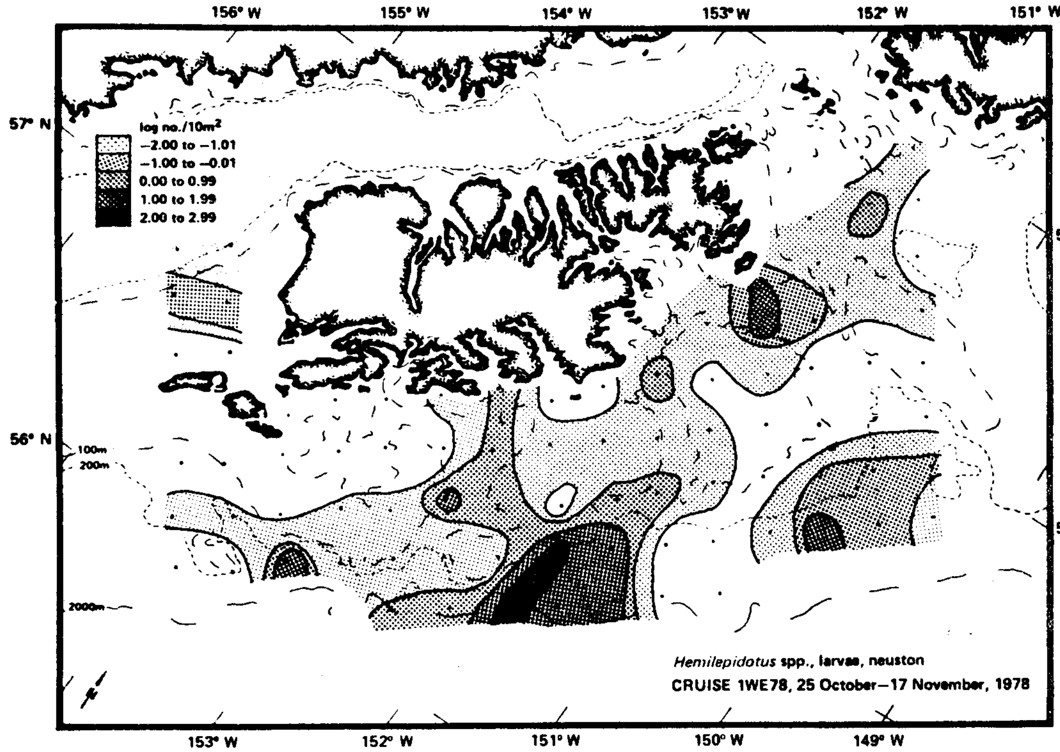


Figure 159.--Distribution and abundance of Hemilepidotus spp. larvae in neuston tows from the summer 1978 OCSEAP plankton cruise.



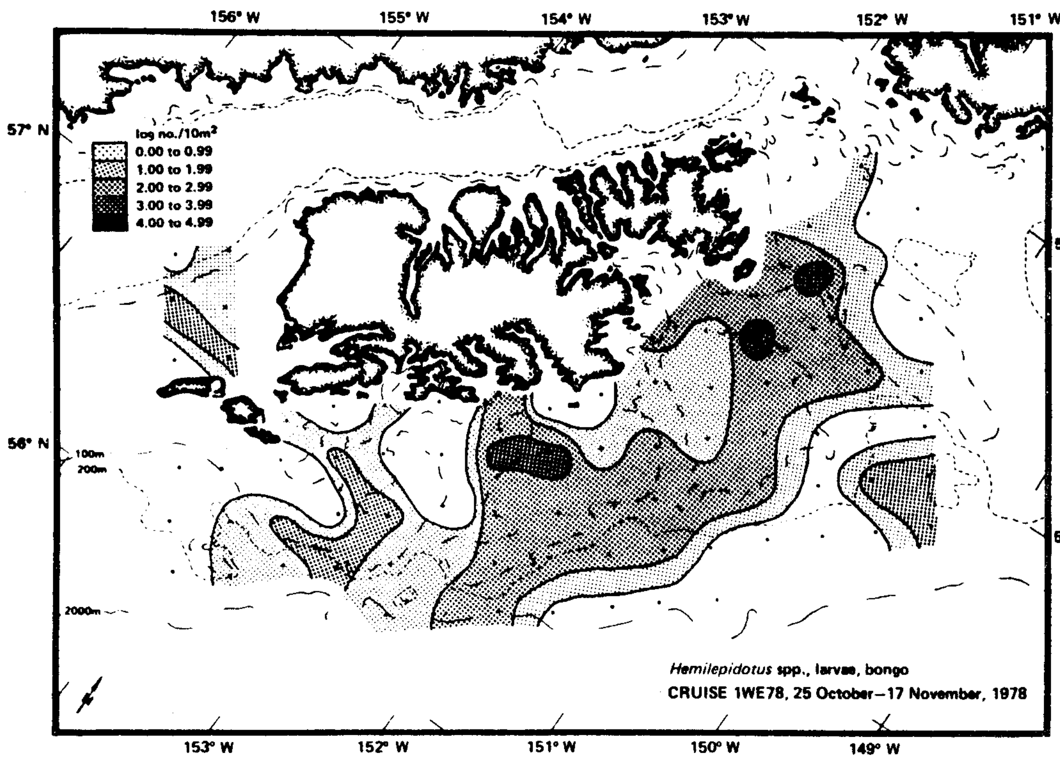


Figure 160.--Distribution and abundance of Hemilepidotus spp. larvae in neuston (top) and bongo (bottom) tows from the fall 1978 OCSEAP plankton cruise.

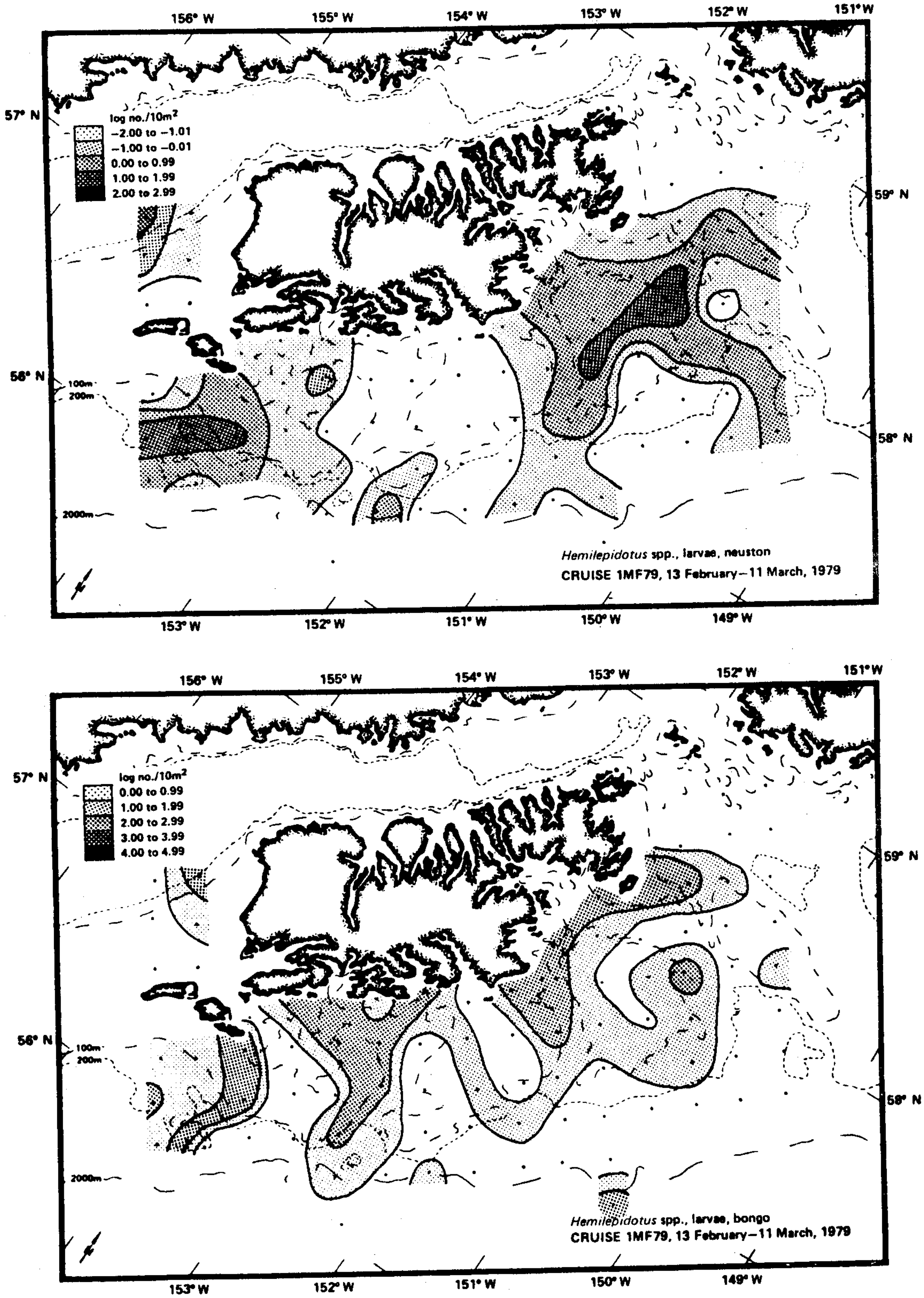


Figure 161.--Distribution and abundance of Hemilepidotus spp. larvae in neuston (top) and bongo (bottom) tows from the winter 1979 OCSEAP plankton cruise.

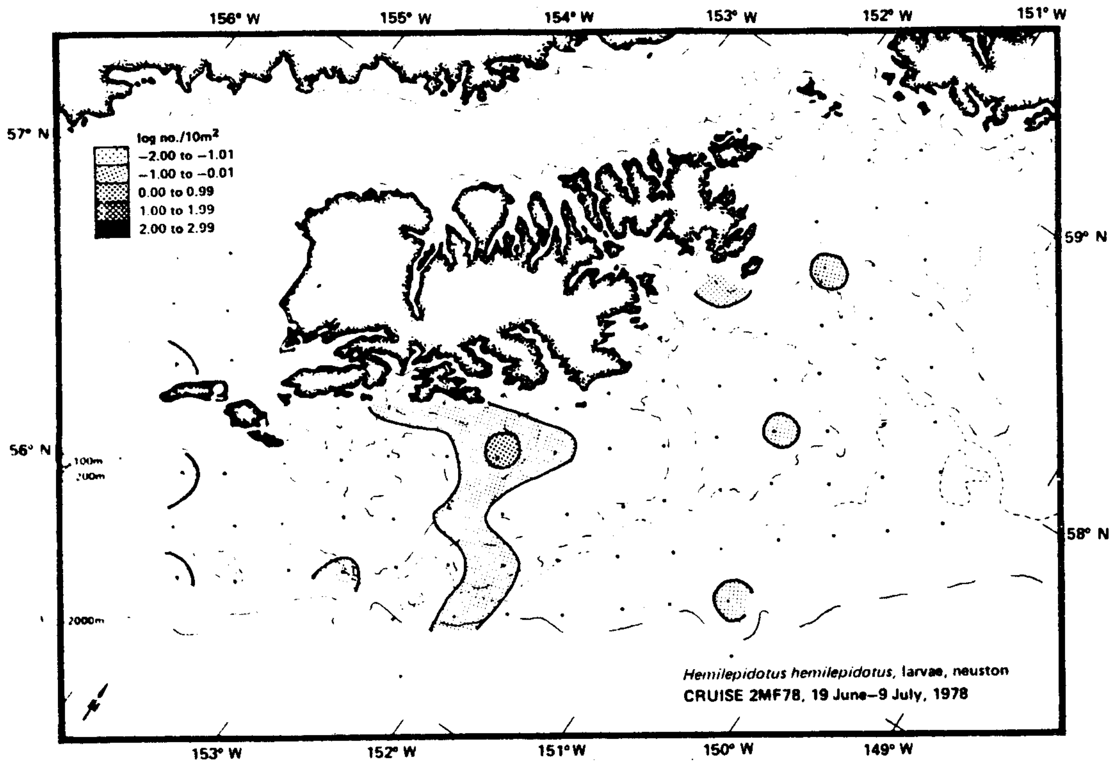


Figure 162.--Distribution and abundance of Hemilepidotus hemilepidotus larvae in neuston tows from the summer 1978 OCSEAP plankton cruise.

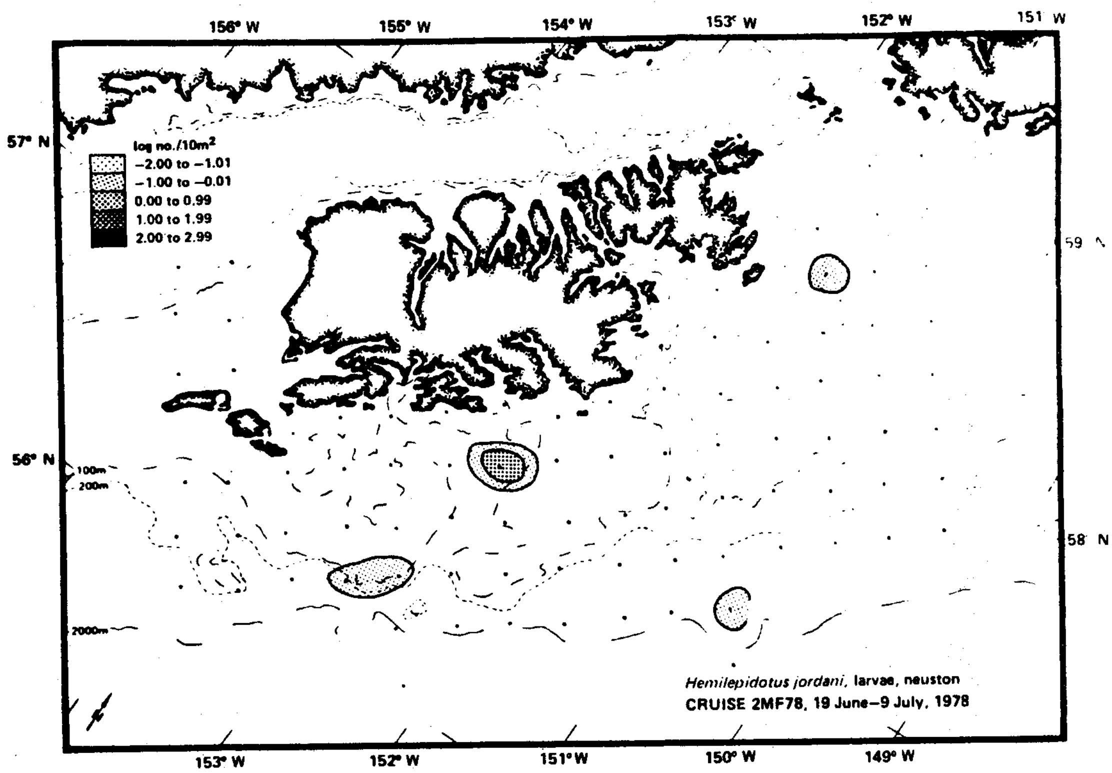


Figure 163.--Distribution and abundance of <u>Hemilepidotus jordani</u> larvae in neuston tows from the summer 1978 OCSEAP plankton cruise.

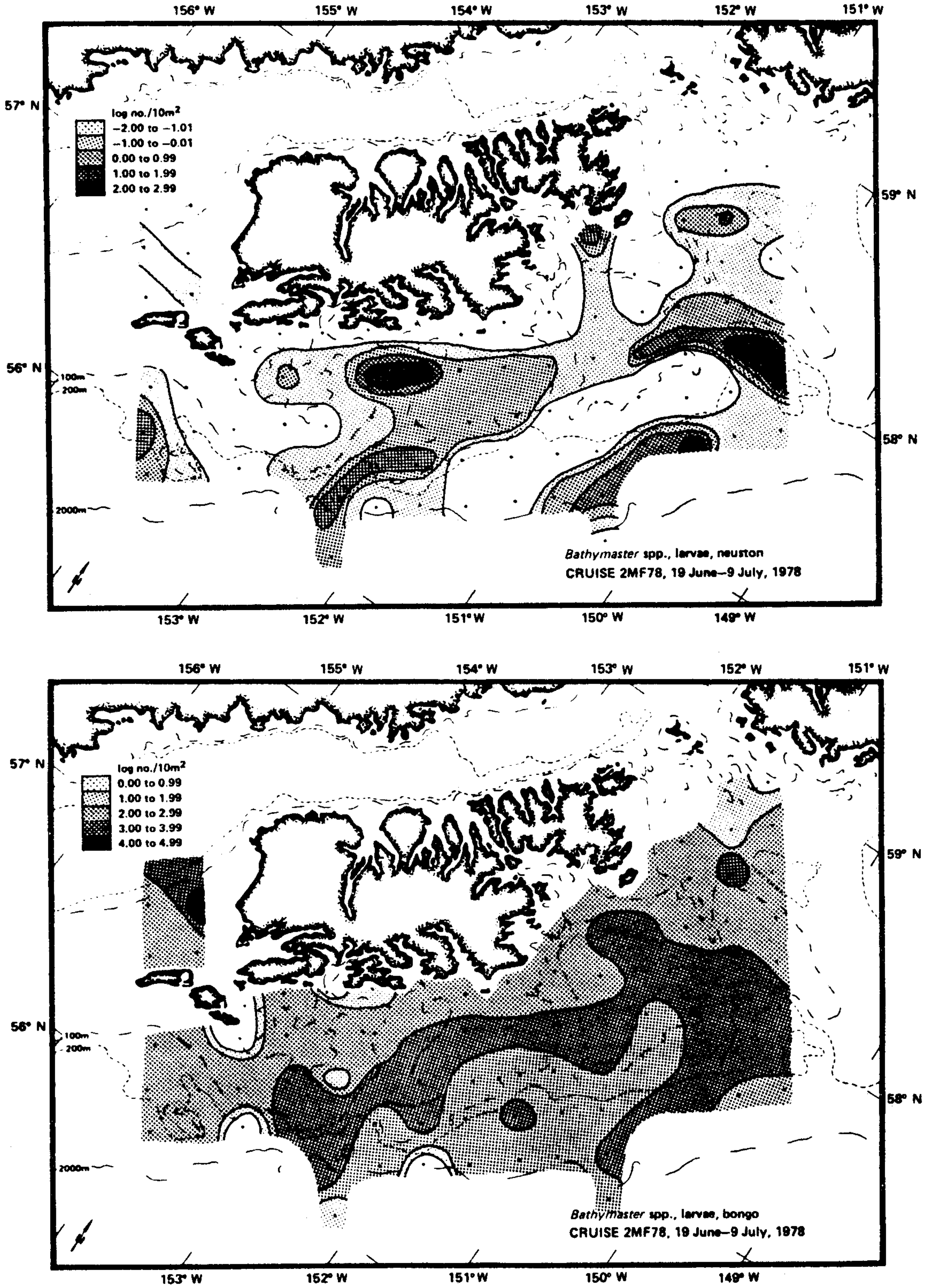


Figure 164.--Distribution and abundance of Bathymaster spp. larvae in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.

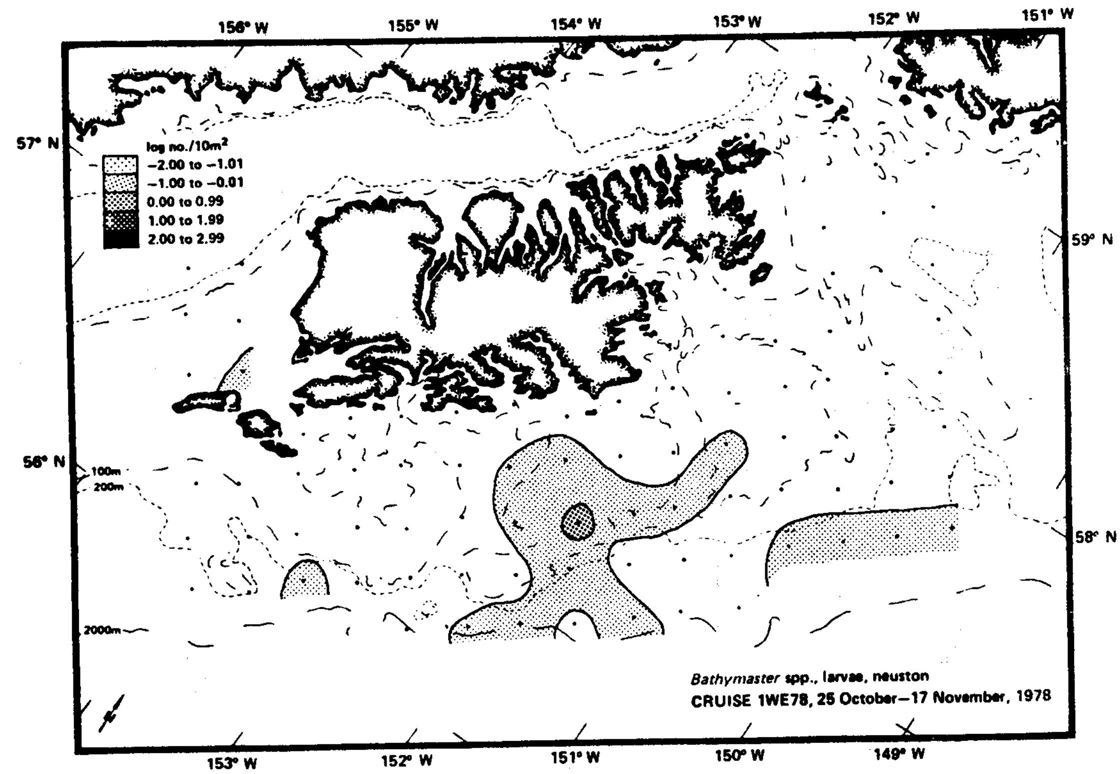


Figure 165.--Distribution and abundance of Bathymaster spp. larvae in neuston tows from the fall 1978 OCSEAP plankton cruise.

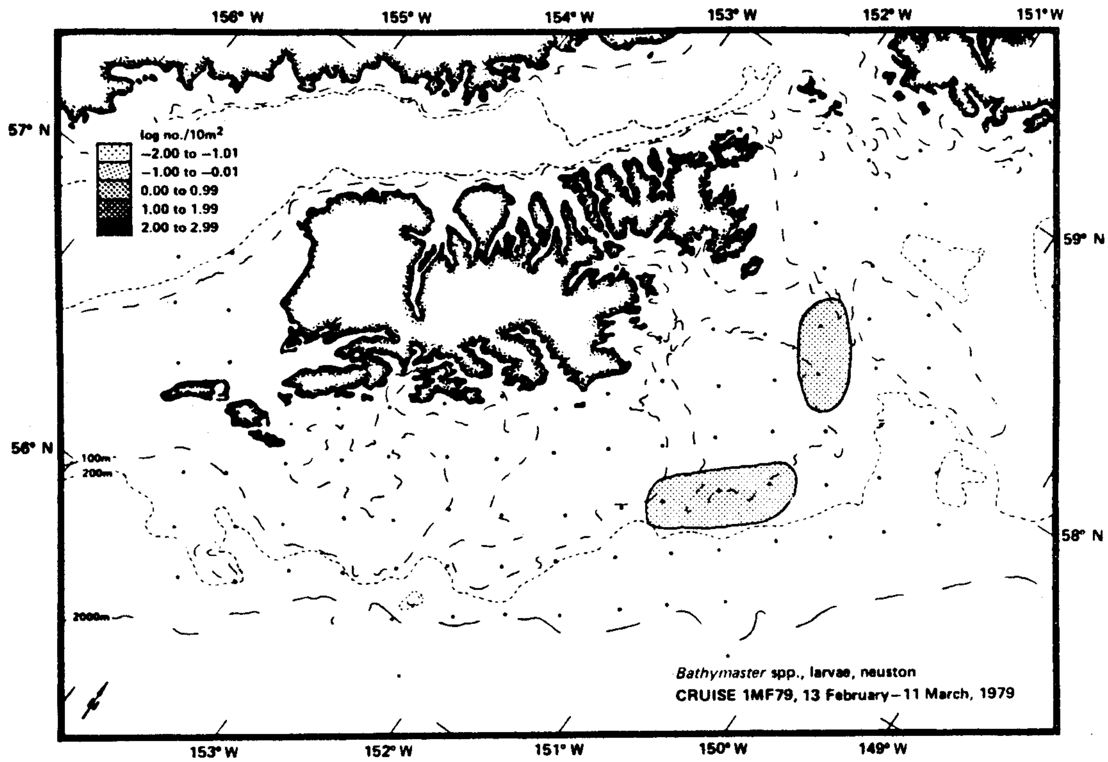


Figure 166.--Distribution and abundance of Bathymaster spp. larvae in neuston tows from the winter 1979 OCSEAP plankton cruise.

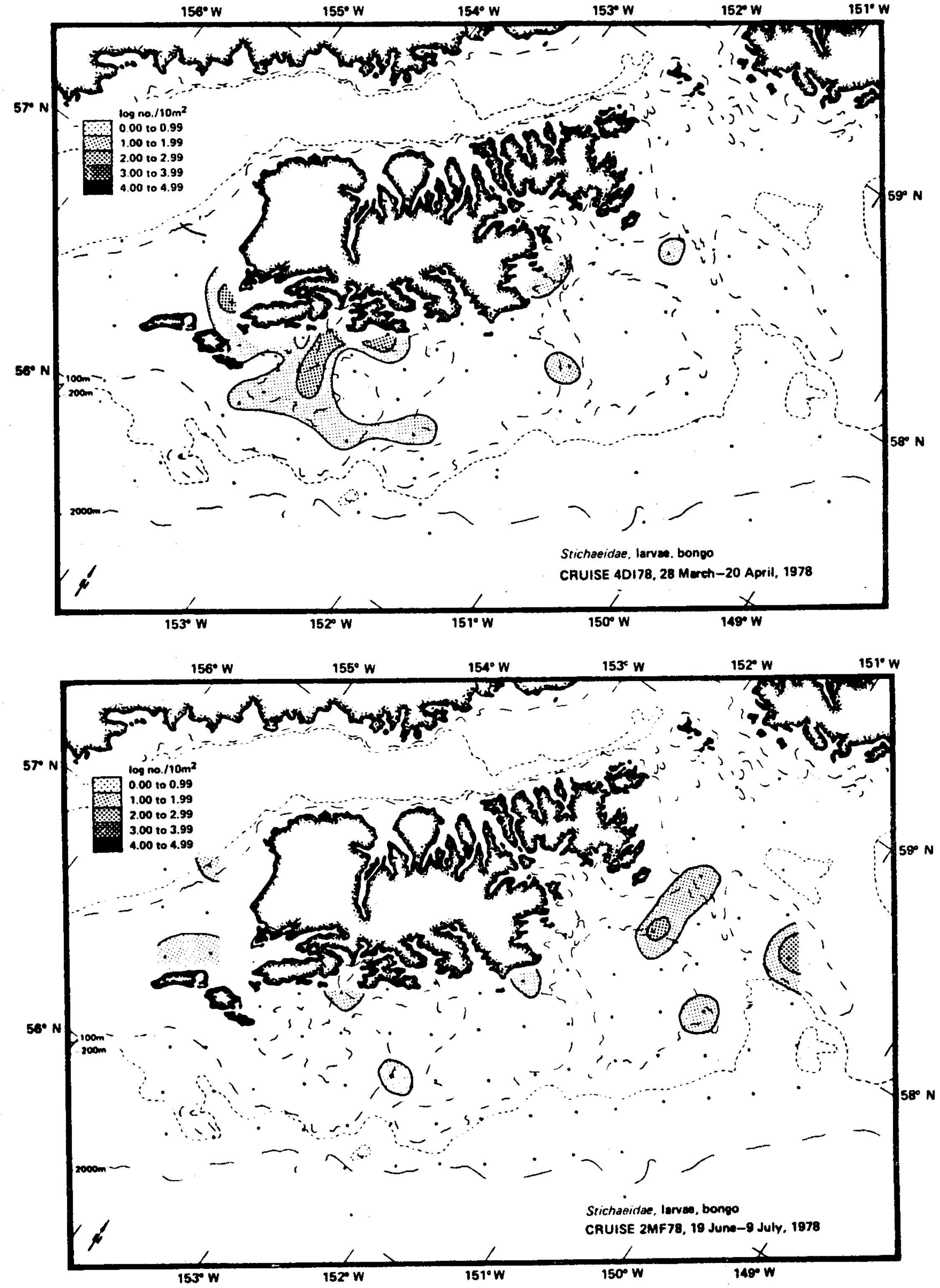


Figure 167.--Distribution and abundance of Stichaeidae larvae in bongo tows from the spring (top) and summer (bottom) 1978 OCSEAP plankton cruises.

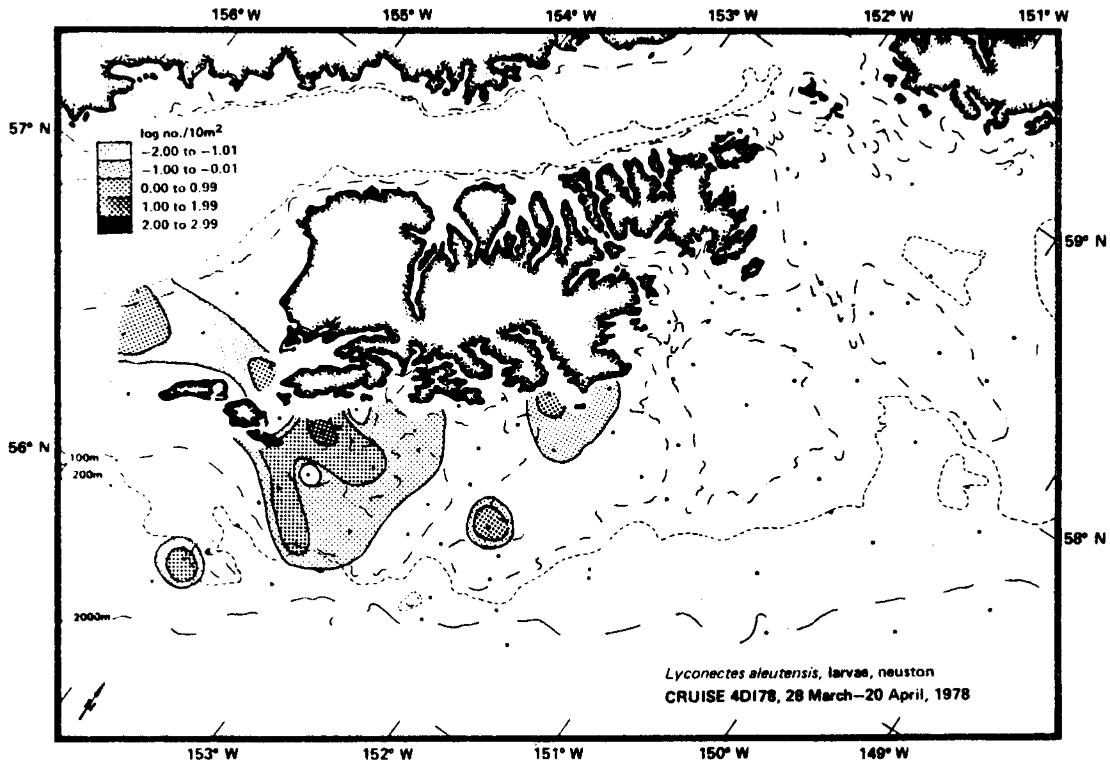


Figure 168.--Distribution and abundance of Lyconectes aleutensis larvae in neuston tows from the spring 1978 OCSEAP plankton cruise.

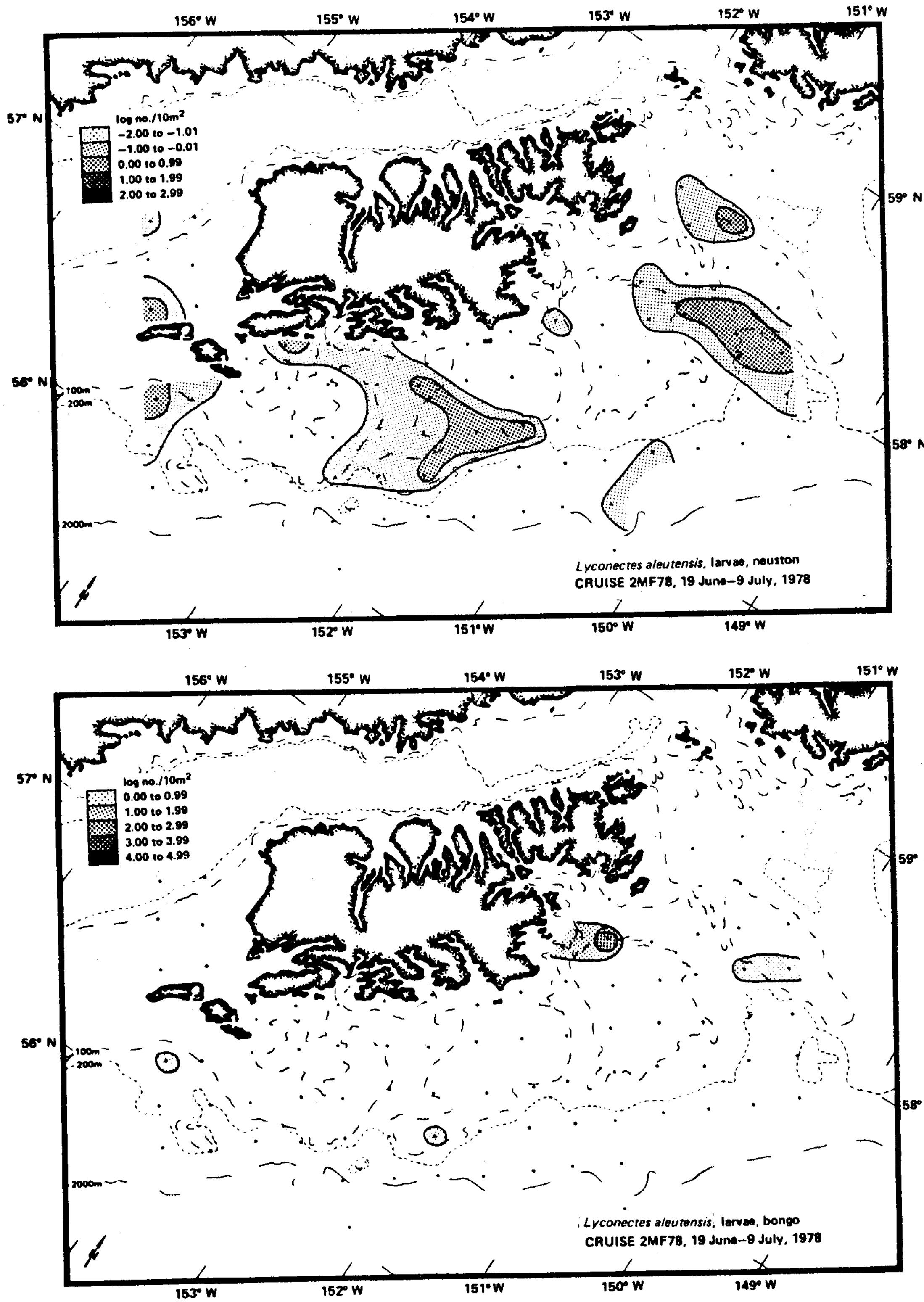


Figure 169.--Distribution and abundance of Lyconectes aleutensis larvae in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.

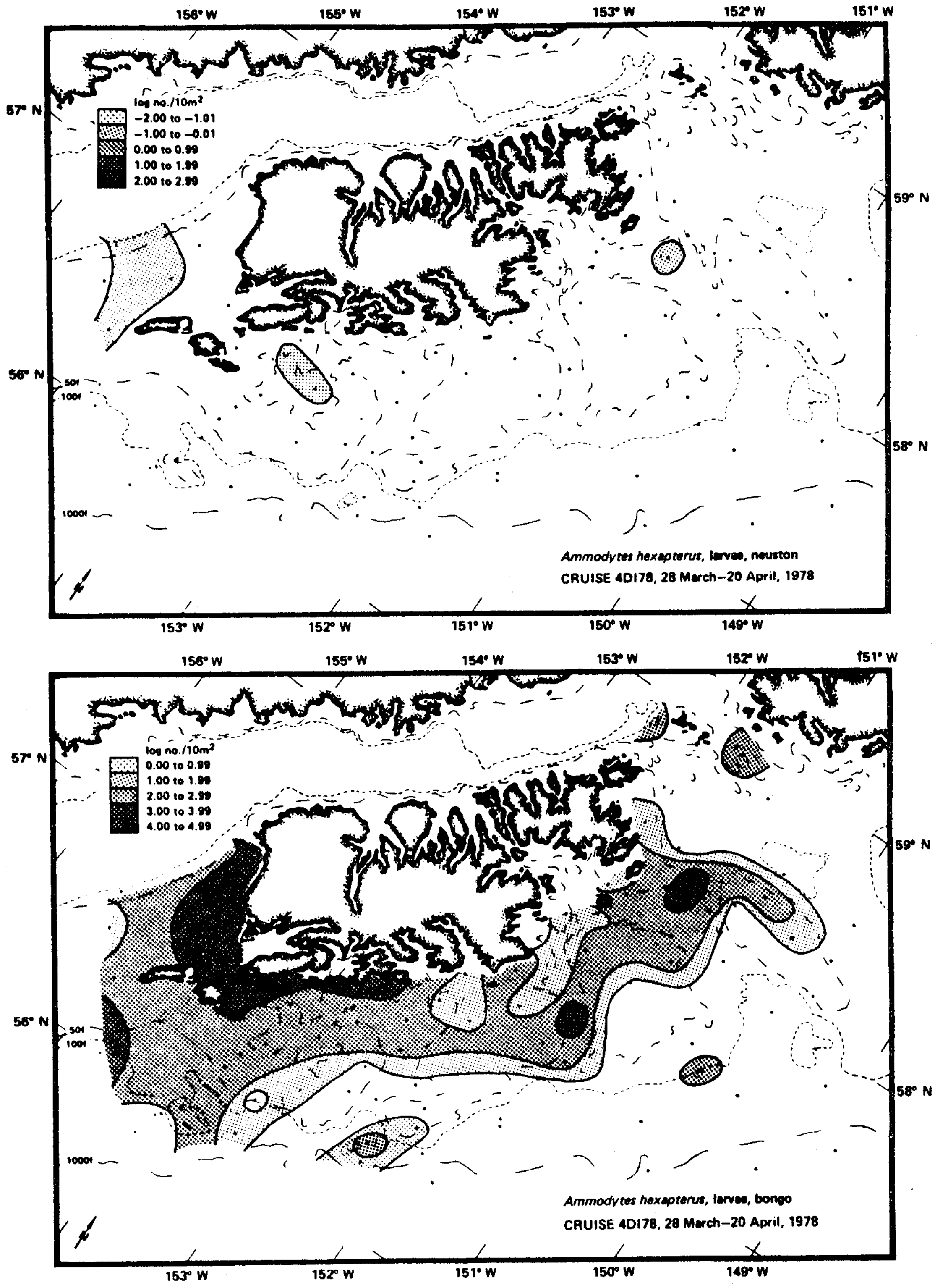


Figure 170.--Distribution and abundance of Ammodytes hexapterus larvae in neuston (top) and bongo (bottom) tows from the spring 1978 OCSEAP plankton cruise.

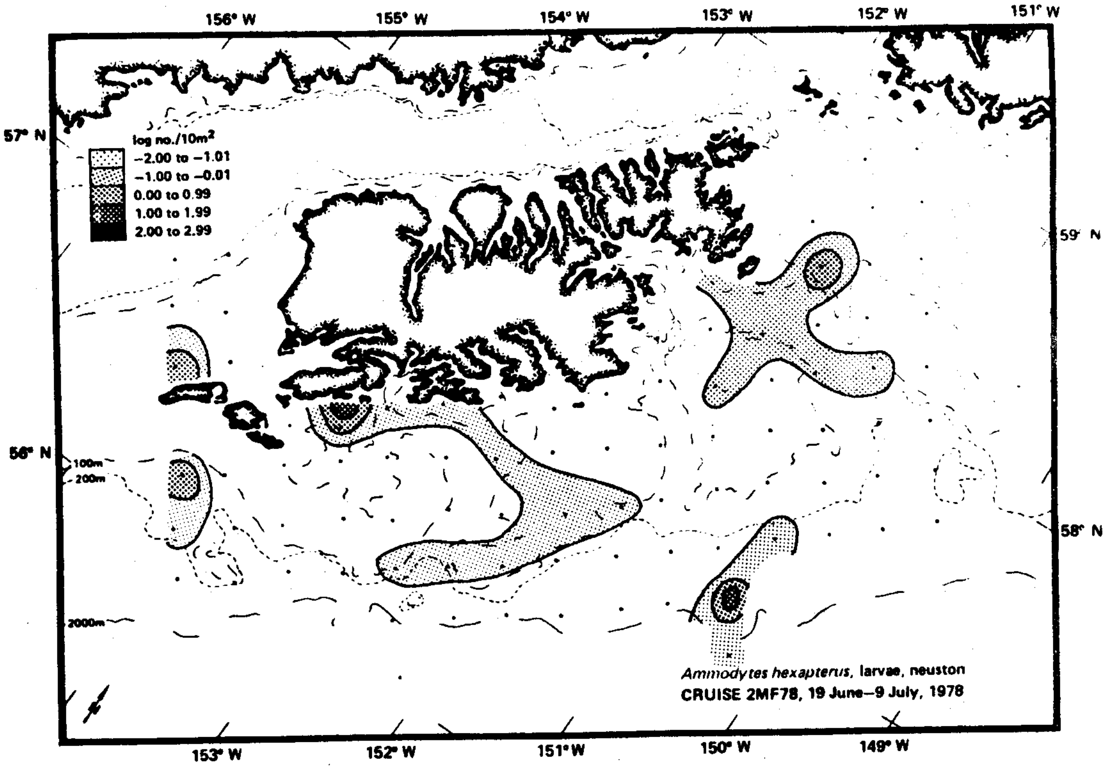


Figure 171.--Distribution and abundance of Ammodytes hexapterus larvae in neuston tows from the summer 1978 OCSEAP plankton cruise.

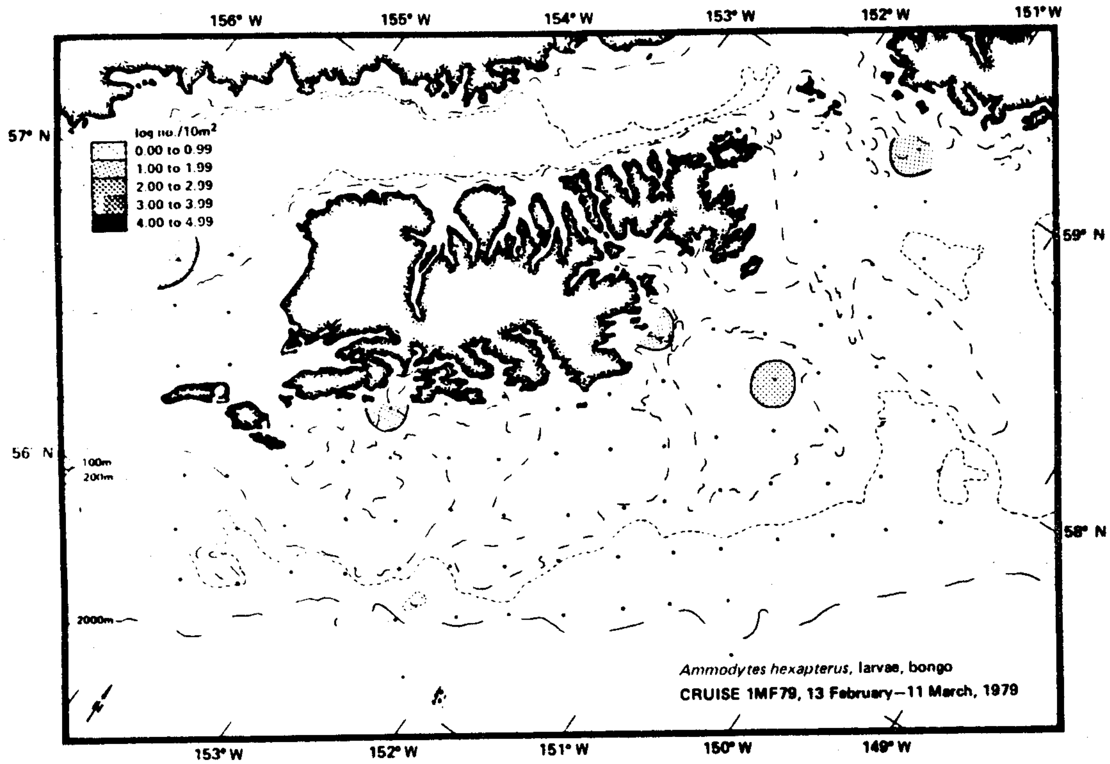


Figure 172.--Distribution and abundance of Ammodytes hexapterus larvae in bongo tows from the winter 1979 OCSEAP plankton cruise.

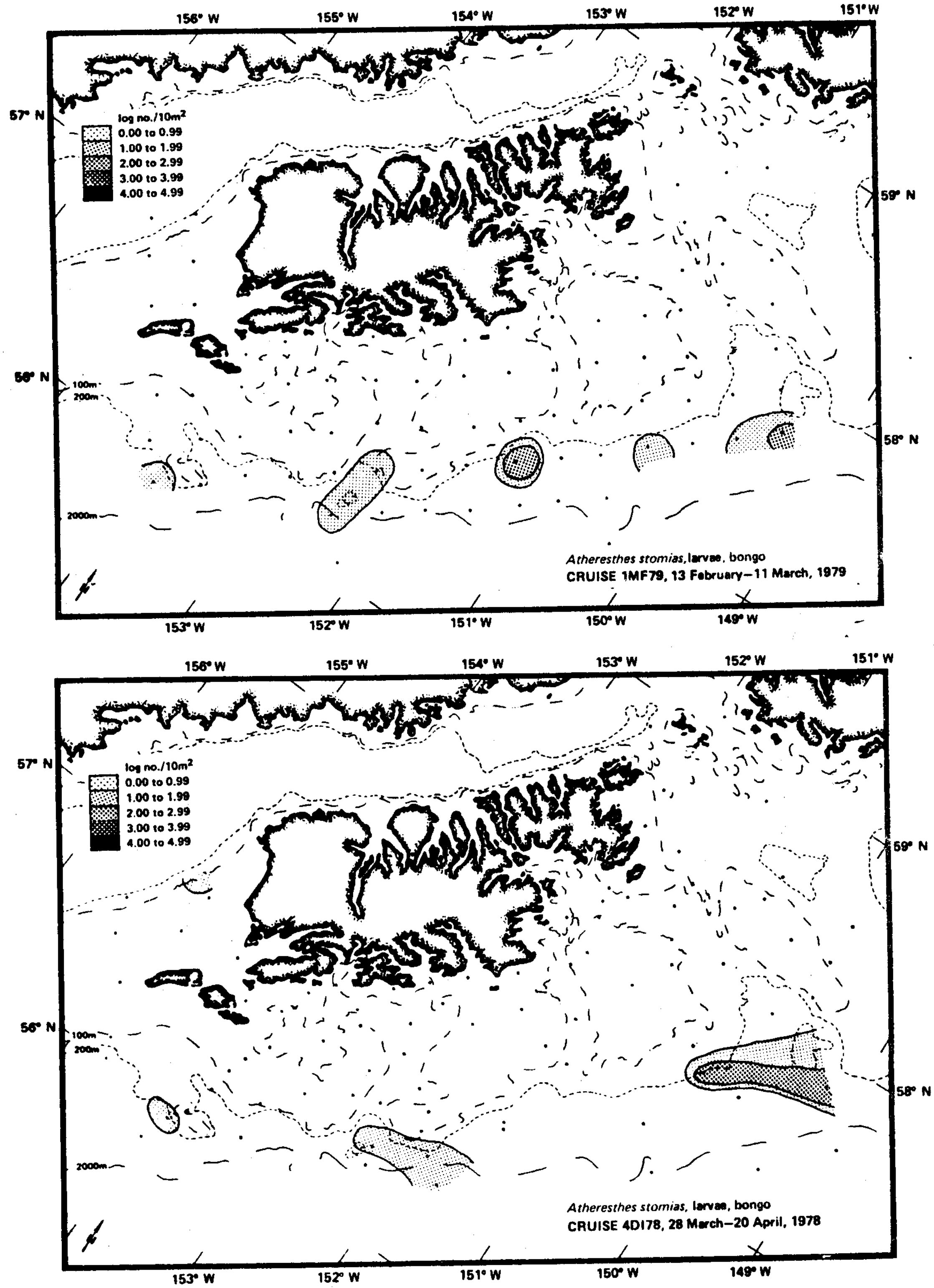
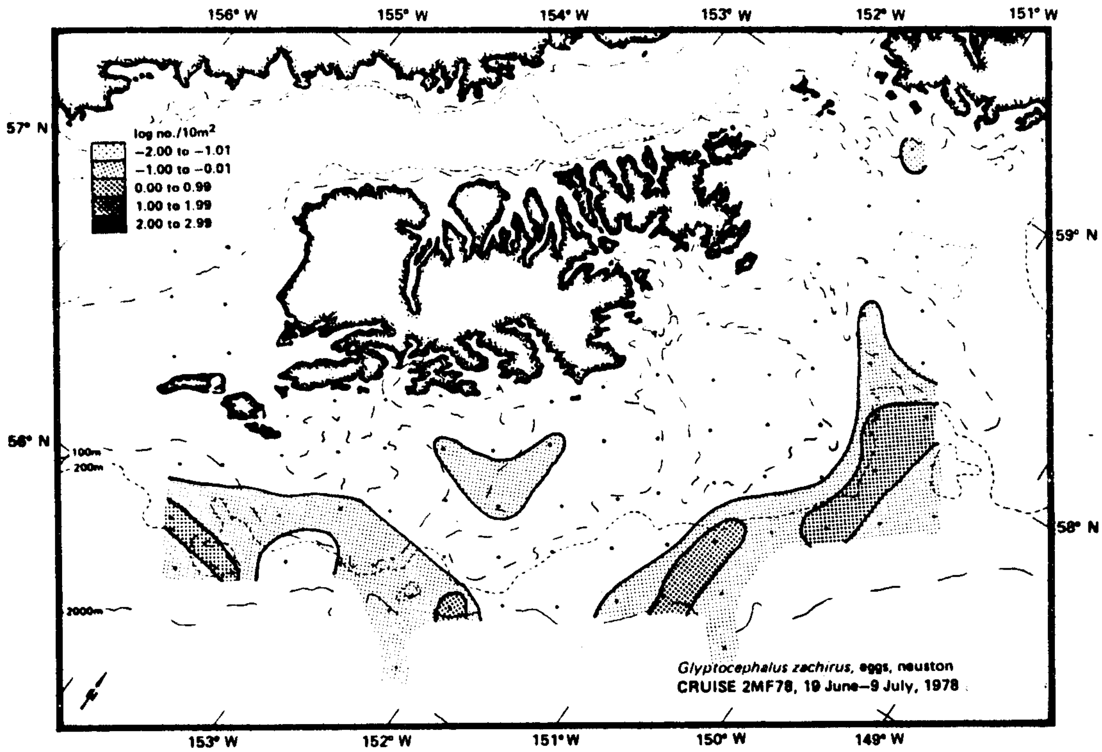


Figure 173.--Distribution and abundance of Atheresthes stomias larvae in bongo tows from the winter 1979 (top) and spring 1978 (bottom) OCSEAP plankton cruises.



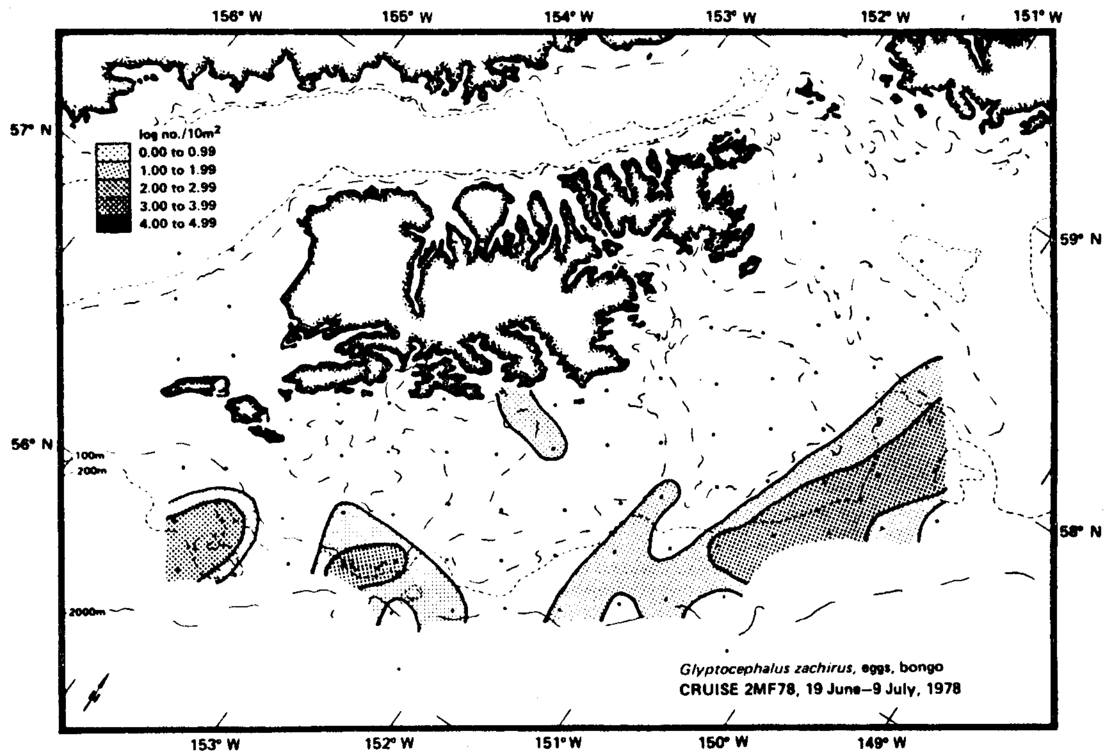


Figure 174.--Distribution and abundance of Glyptocephalus zachirus eggs in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.

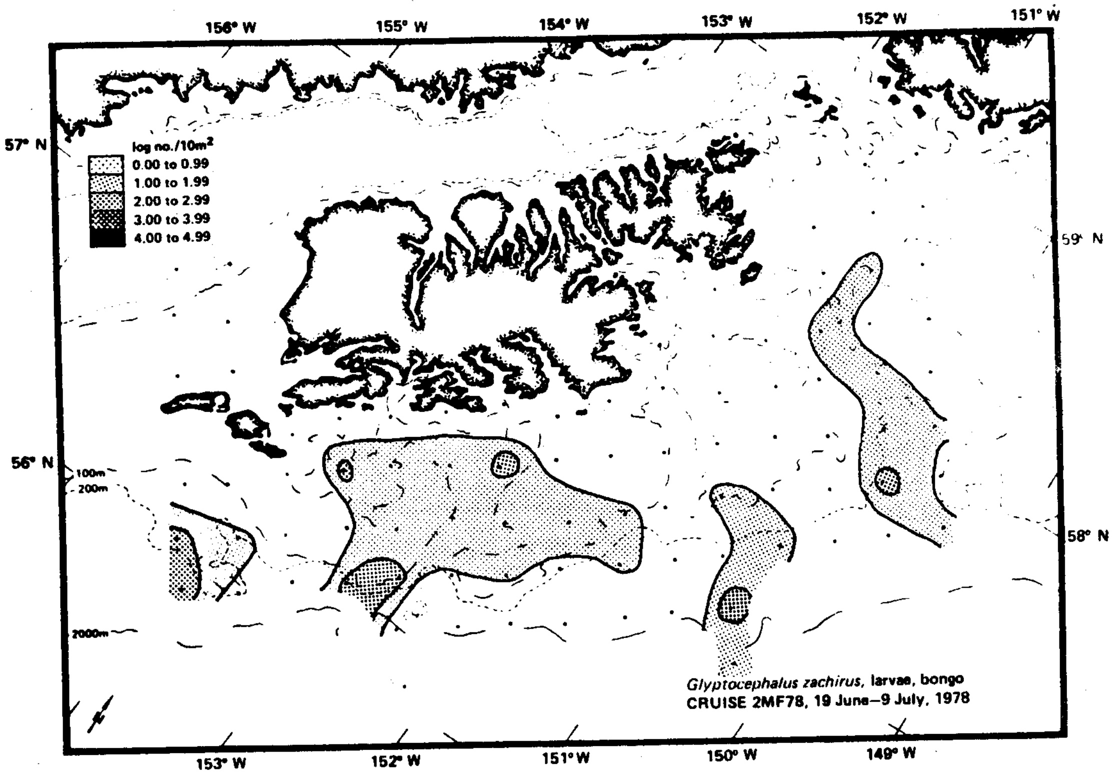
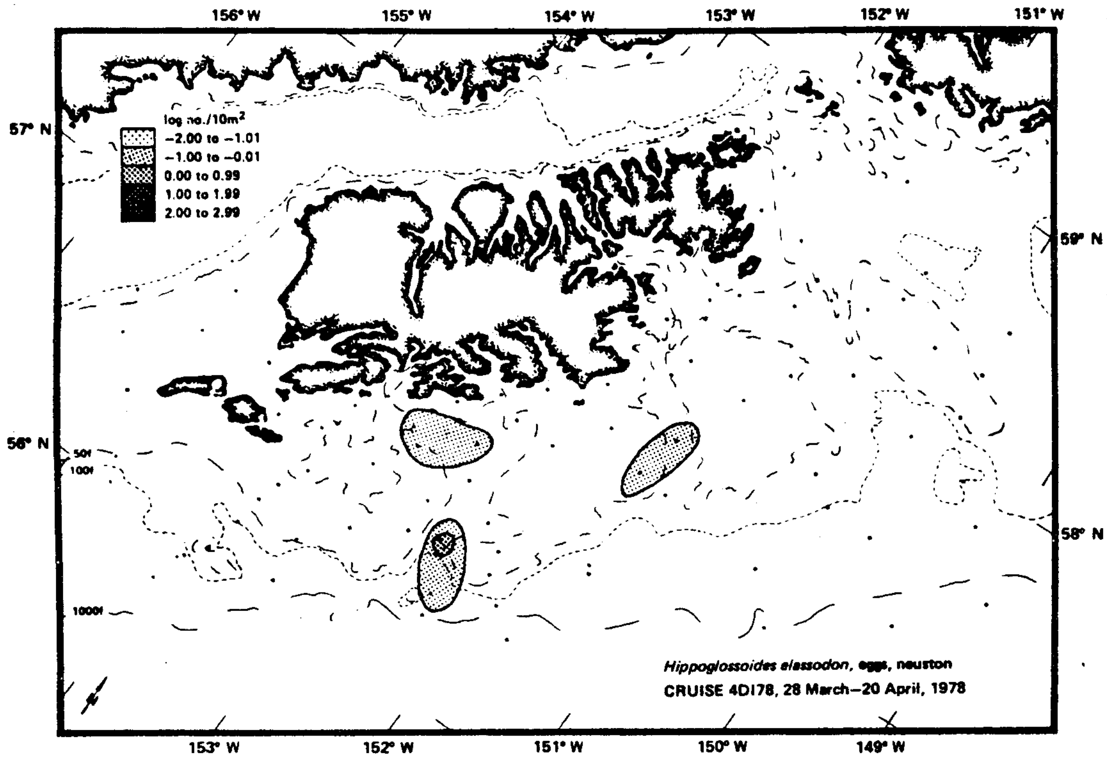


Figure 175.--Distribution and abundance of Glyptocephalus zachirus larvae in bongo tows from the summer 1978 OCSEAP plankton cruise.



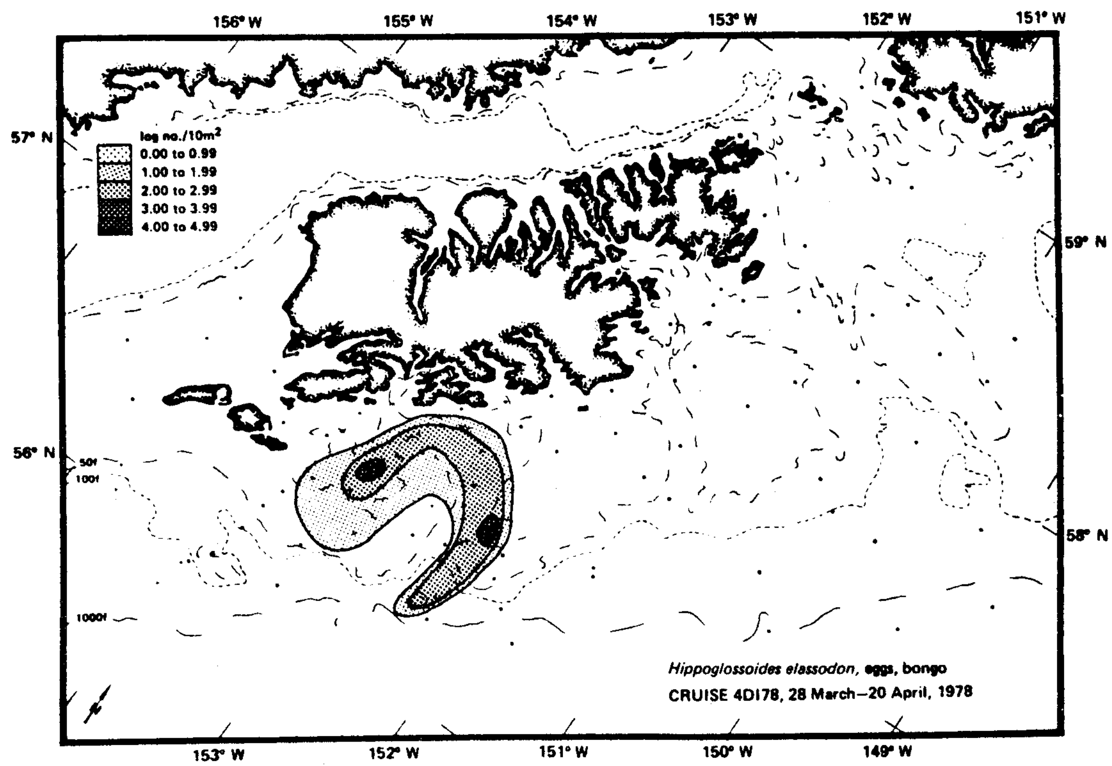


Figure 176.--Distribution and abundance of Hippoglossoides elassodon eggs in neuston (top) and bongo (bottom) tows from the spring 1978 OCSEAP plankton cruise.

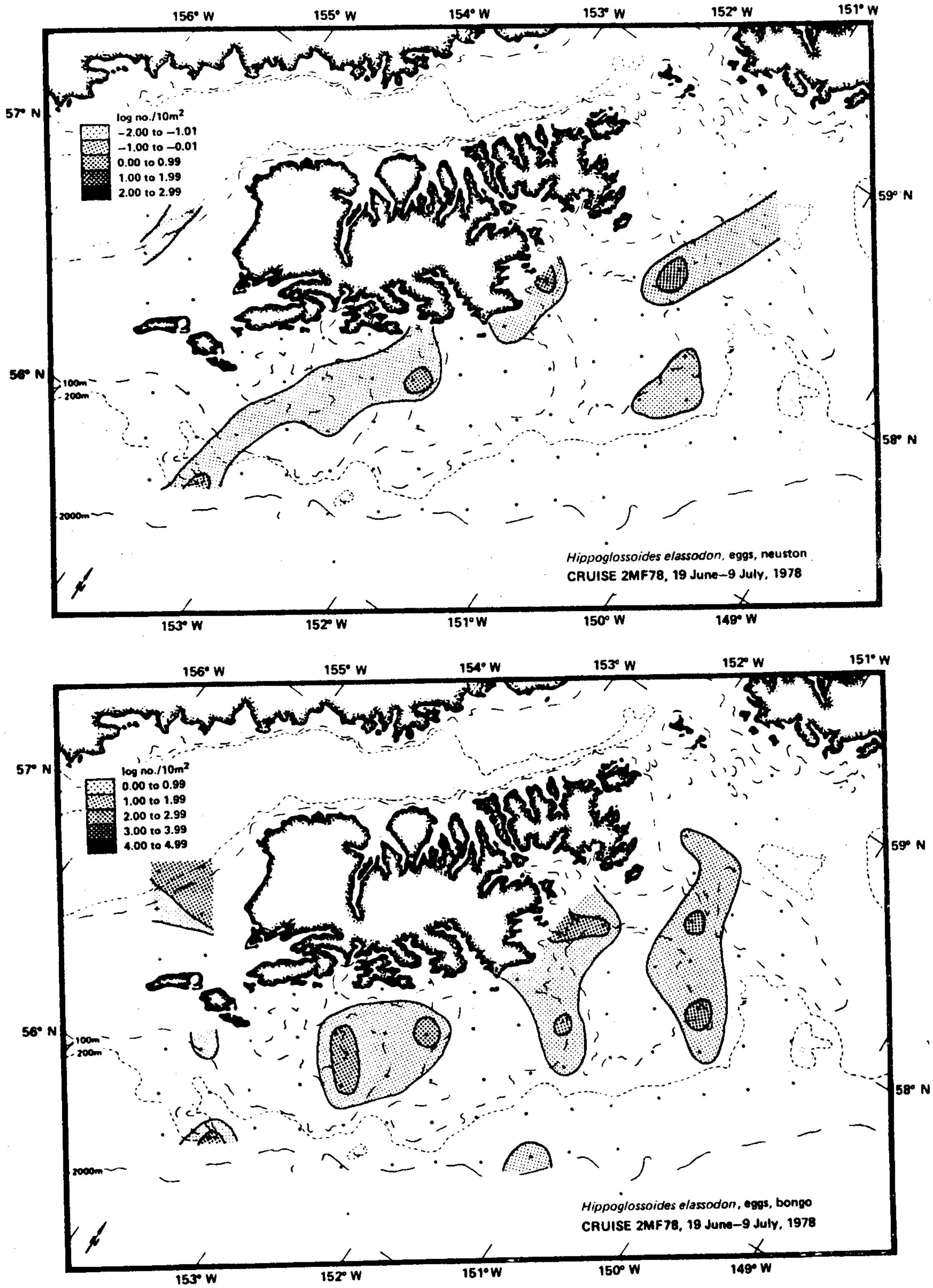


Figure 177.--Distribution and abundance of Hippoglossoides elassodon eggs in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.

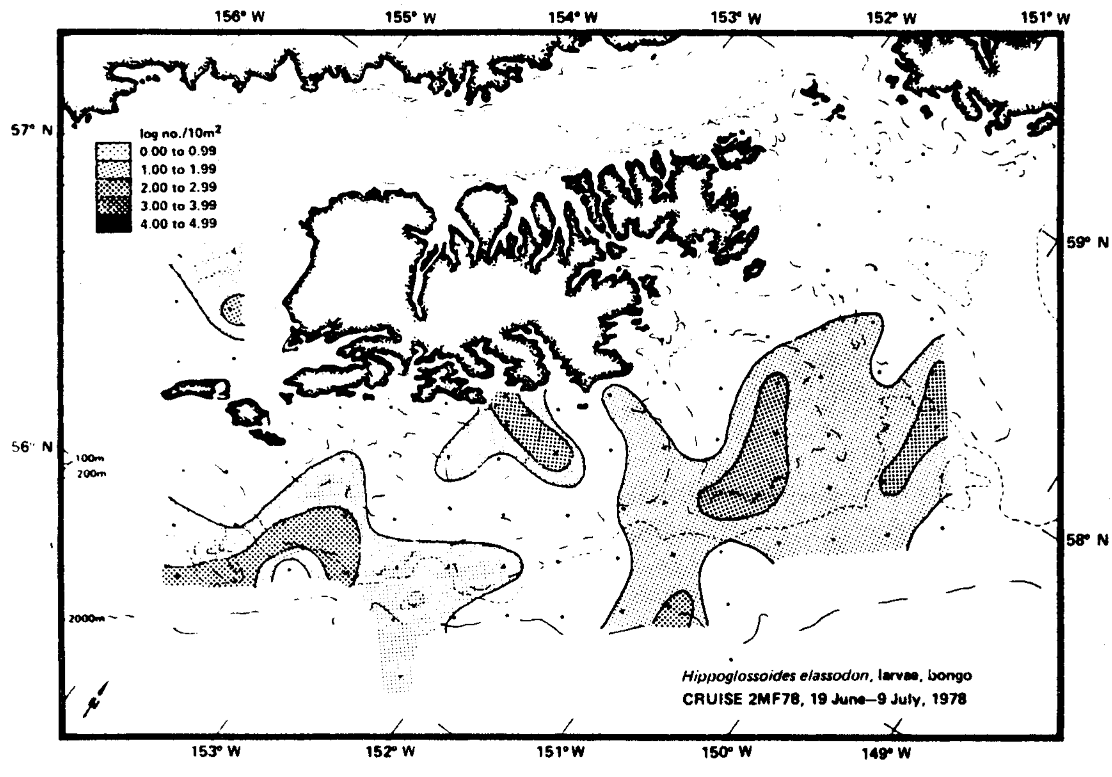


Figure 178.--Distribution and abundance of Hippoglossoides elassodon larvae in bongo tows from the summer 1978 OCSEAP plankton cruise.

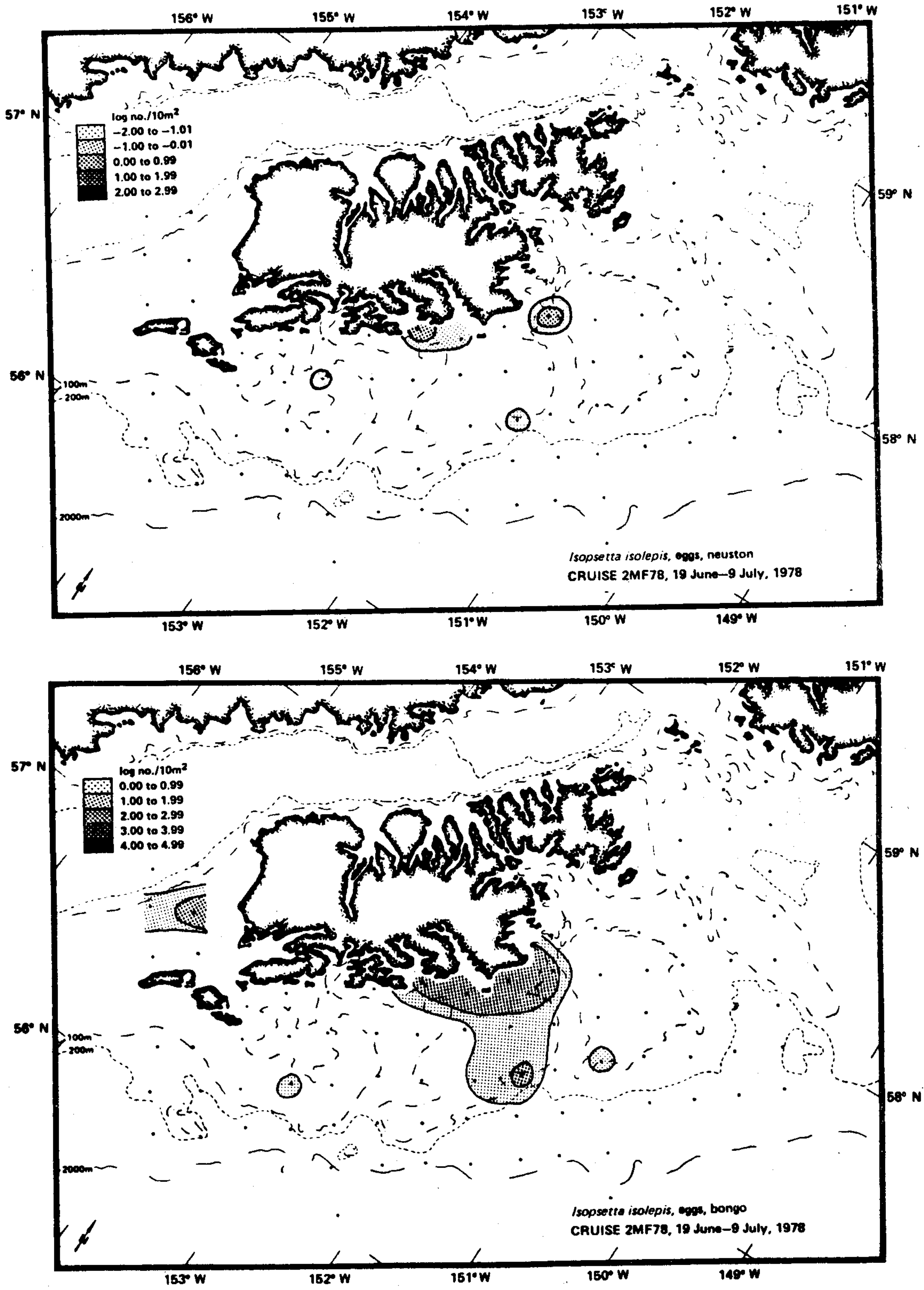


Figure 179.--Distribution and abundance of Isopsetta isolepis eggs in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.

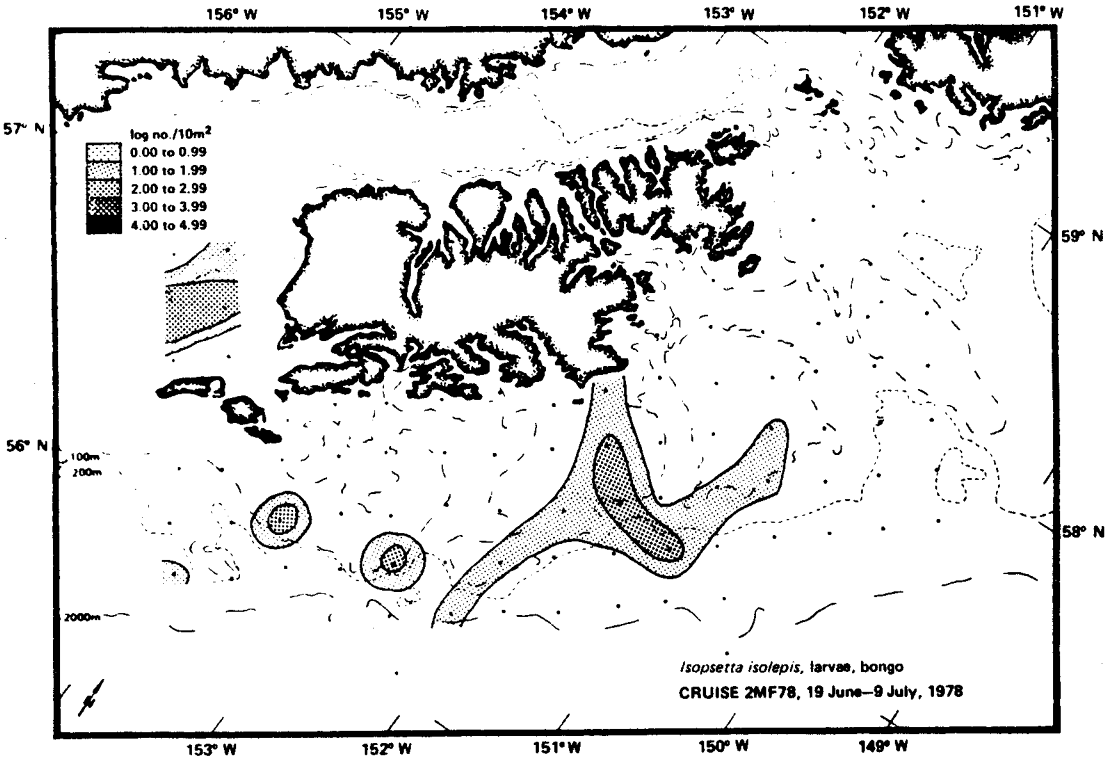


Figure 180.--Distribution and abundance of Isopsetta isolepis larvae in bongo tows from the summer 1978 OCSEAP plankton cruise.

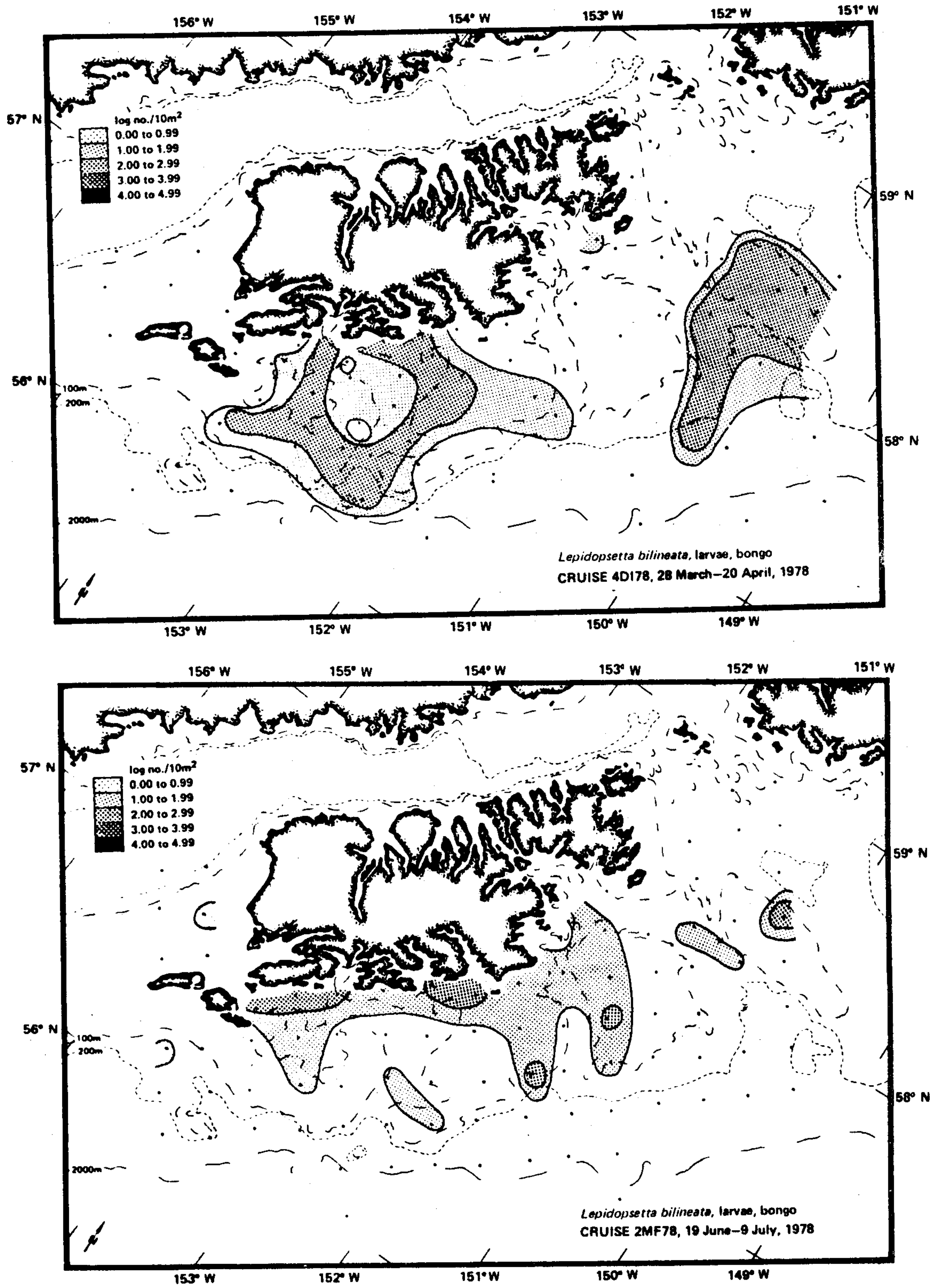
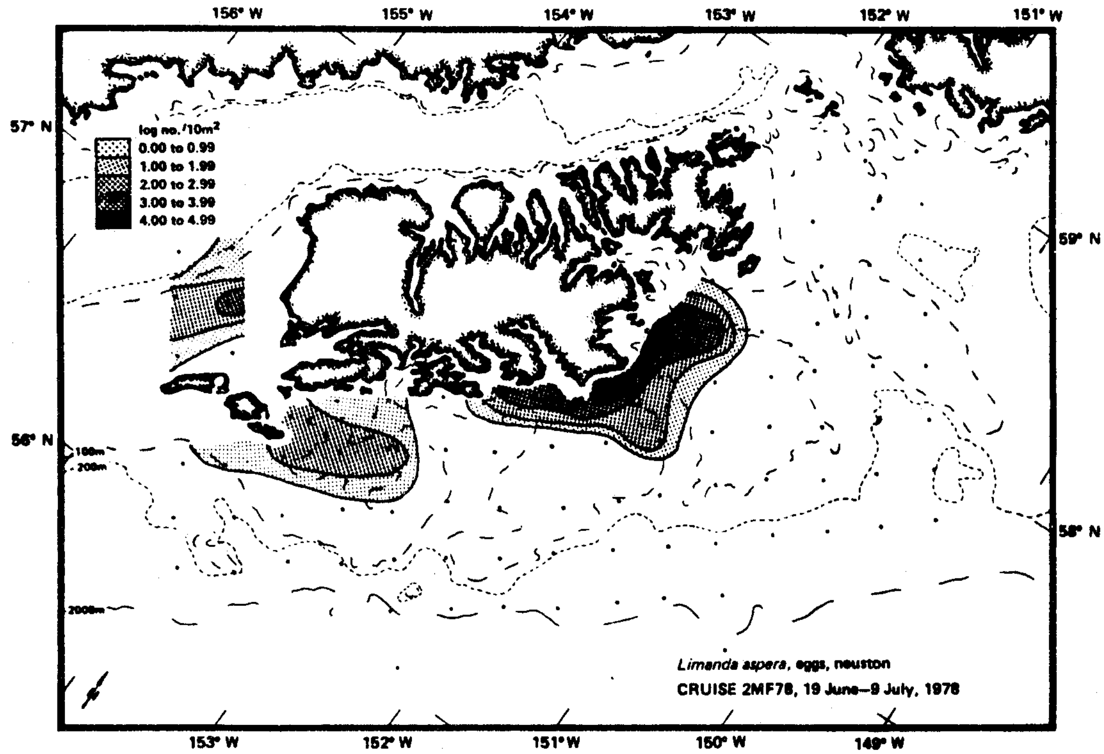


Figure 181.--Distribution and abundance of Lepidopsetta bilineata larvae in bongo tows from the spring (top) and summer (bottom) 1978 OCSEAP plankton cruises.



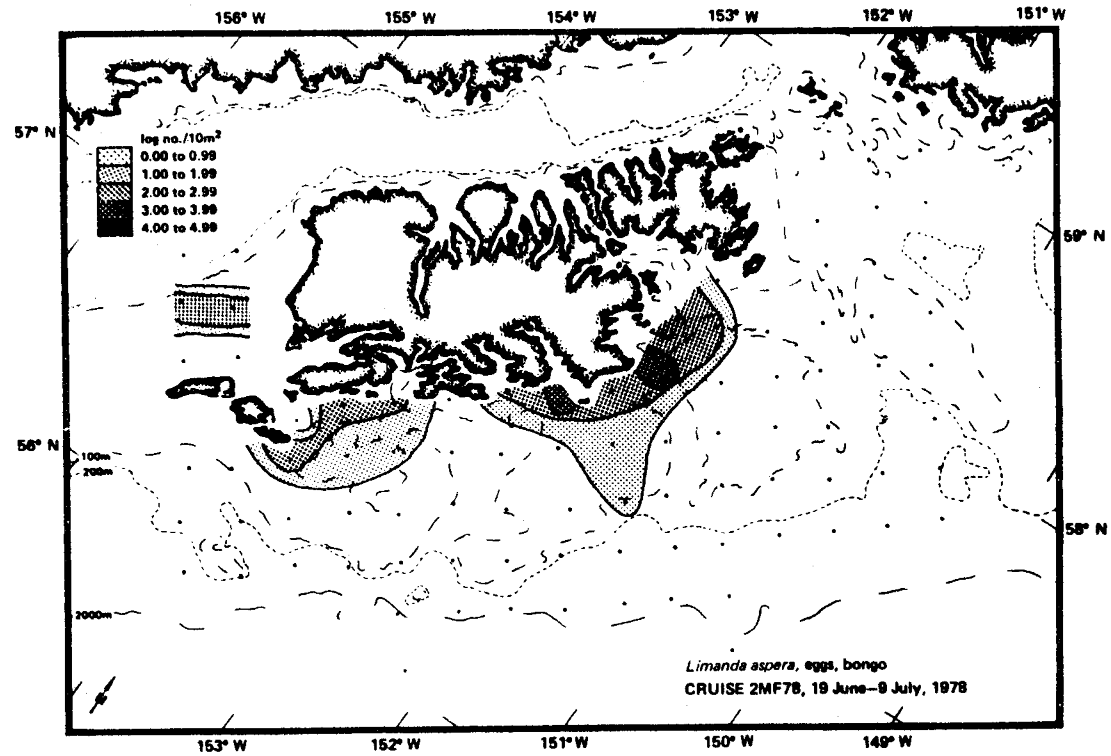


Figure 182.--Distribution and abundance of Limanda aspera eggs in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.

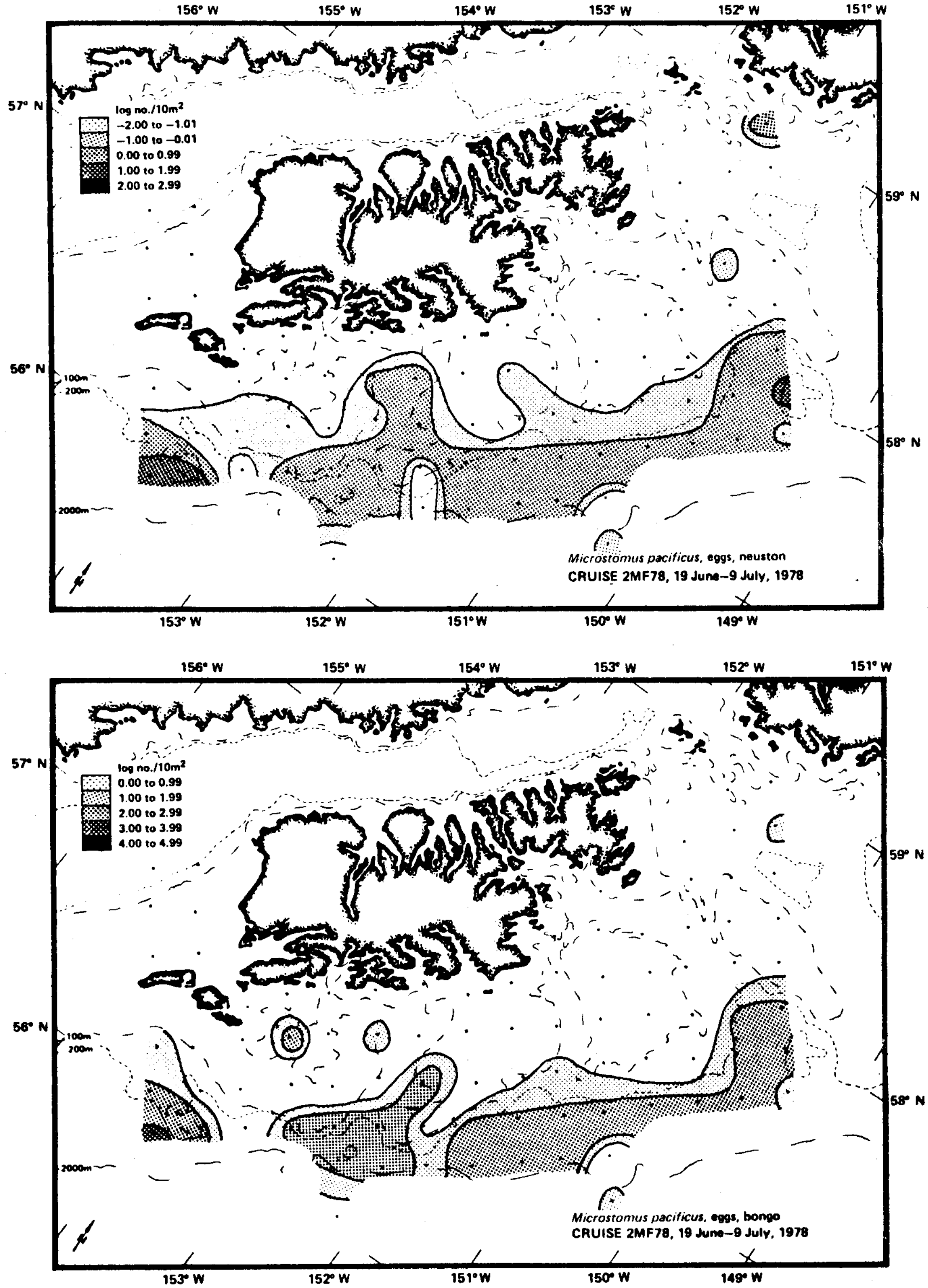
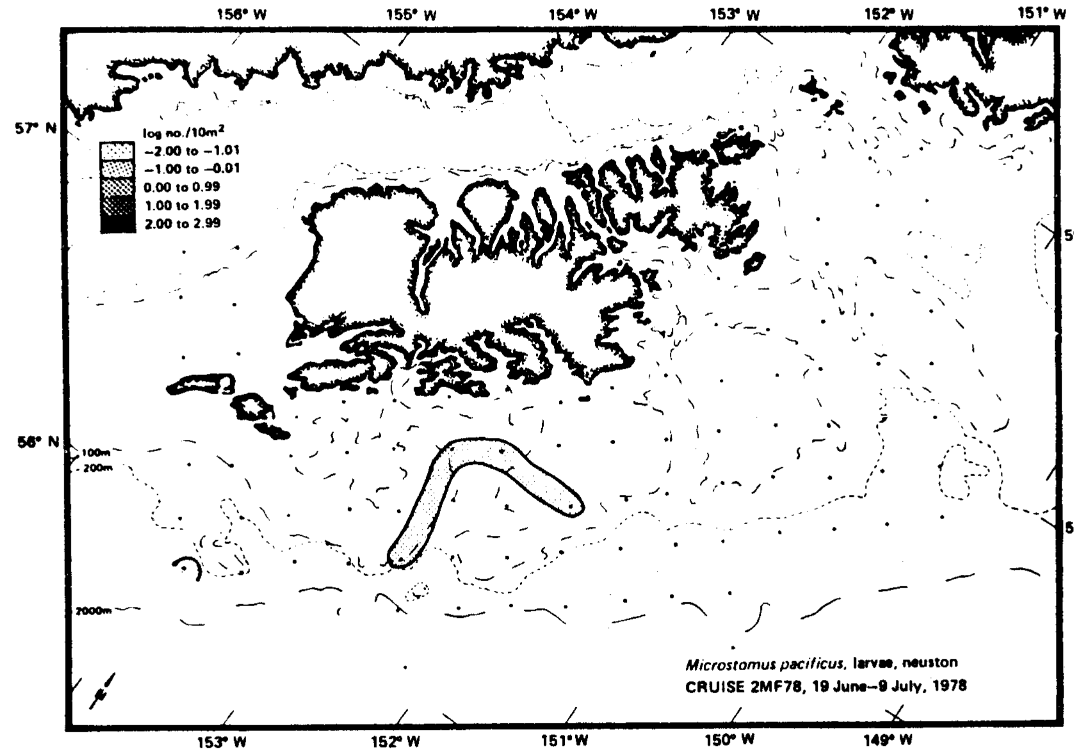


Figure 183.--Distribution and abundance of Microstomus pacificus eggs in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.



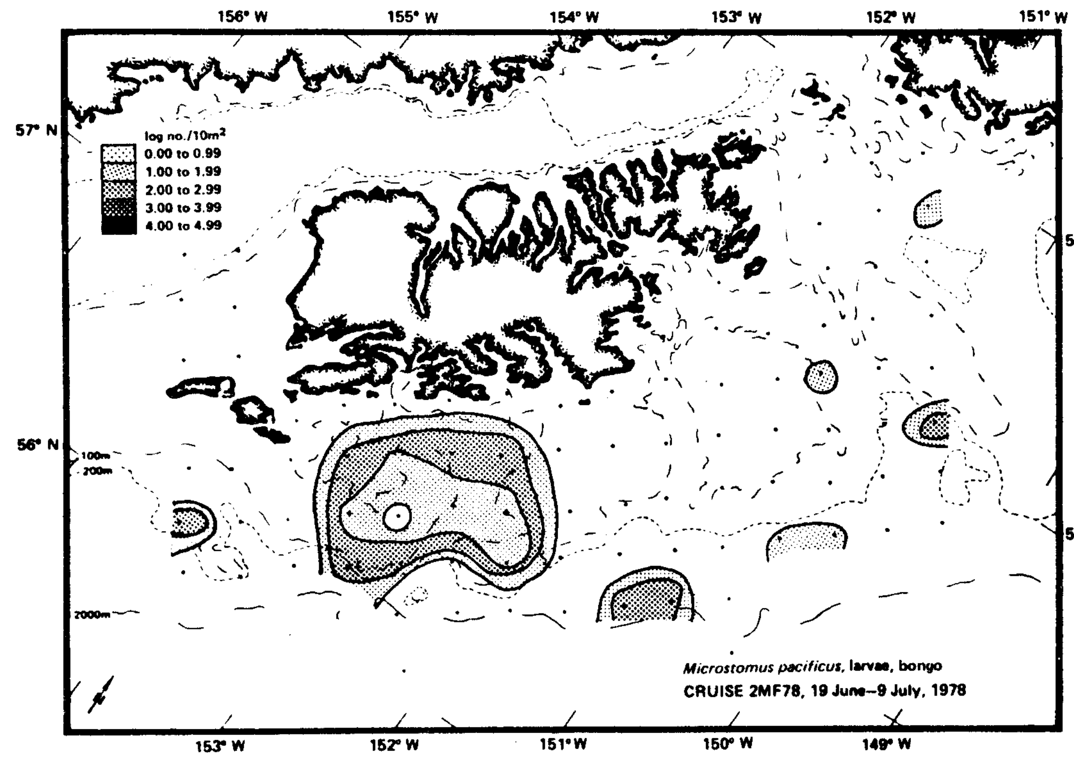


Figure 184.--Distribution and abundance of Microstomus pacificus larvae in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.

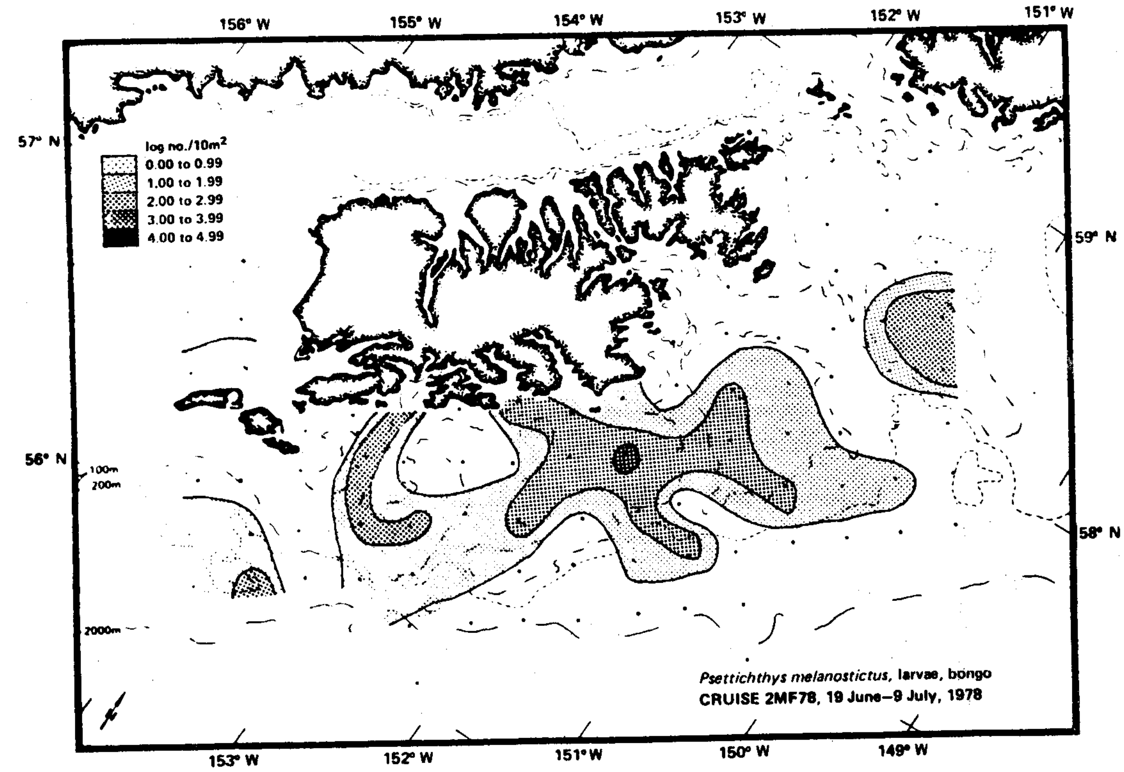
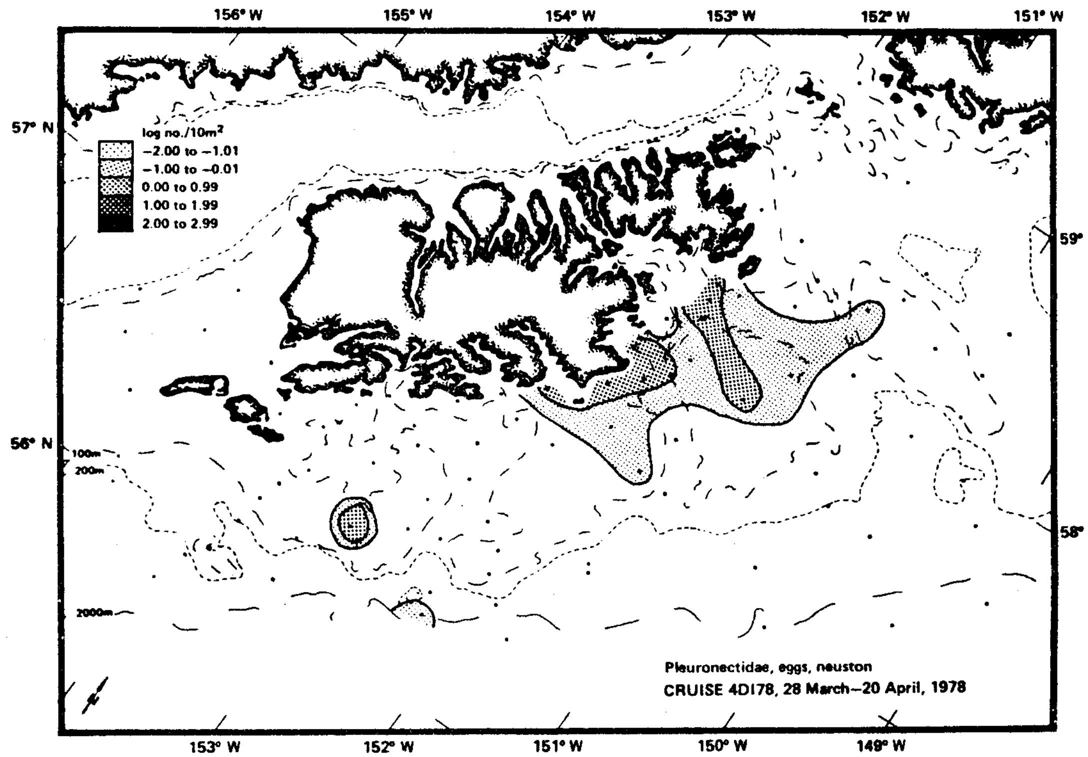


Figure 185.--Distribution and abundance of Psettichthys melanostictus larvae in bongo tows from the summer 1978 OCSEAP plankton cruise.



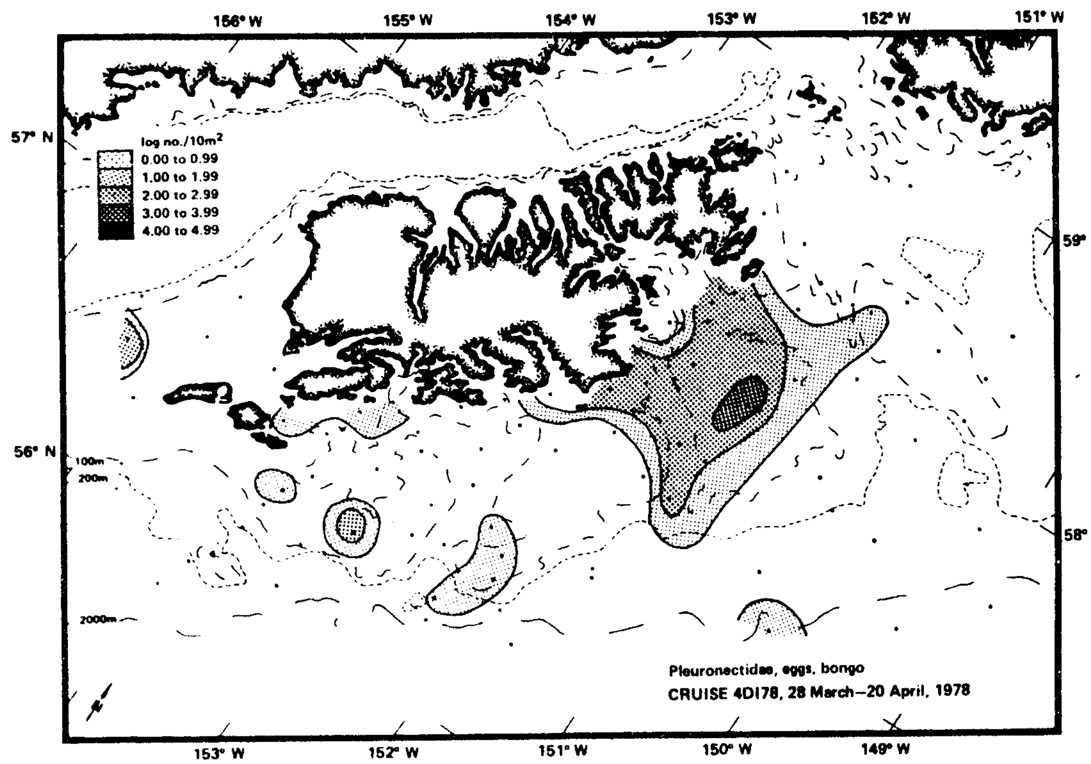


Figure 186.--Distribution and abundance of Pleuronectidae eggs in neuston (top) and bongo (bottom) tows from the spring 1978 OCSEAP plankton cruise.

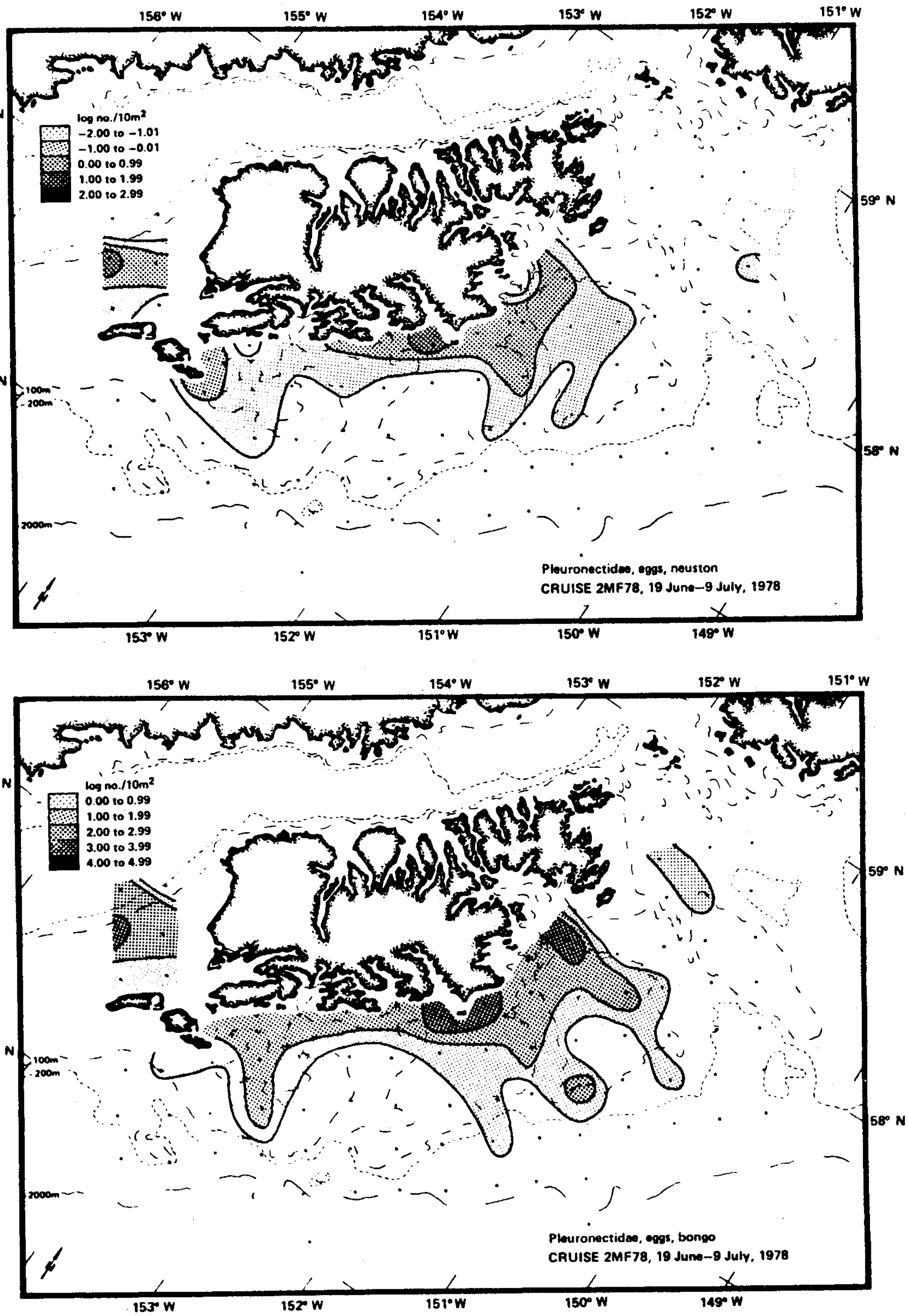


Figure 187.--Distribution and abundance of Pleuronectidae eggs in neuston (top) and bongo (bottom) tows from the summer 1978 OCSEAP plankton cruise.

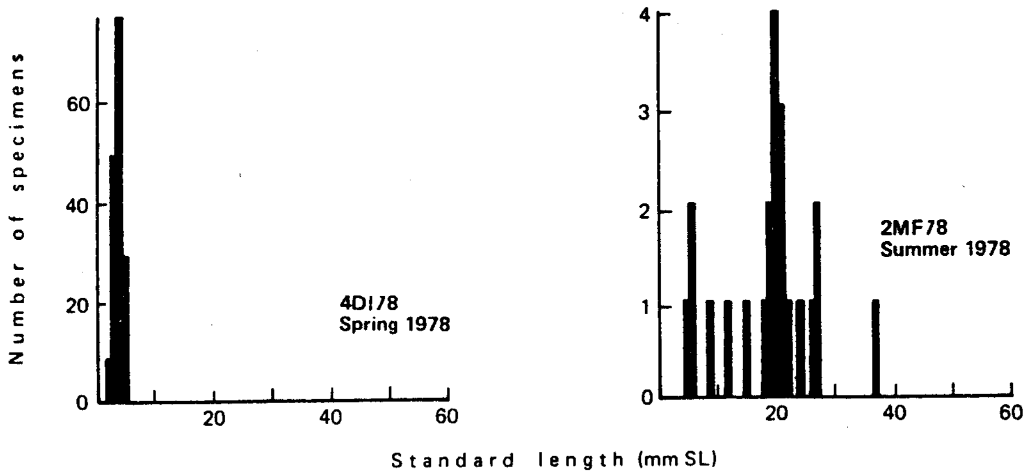


Figure 188.--Lengths of Theragra chalcogramma larvae collected in bongo net tows from the OCSEAP plankton cruises from spring and summer 1978.

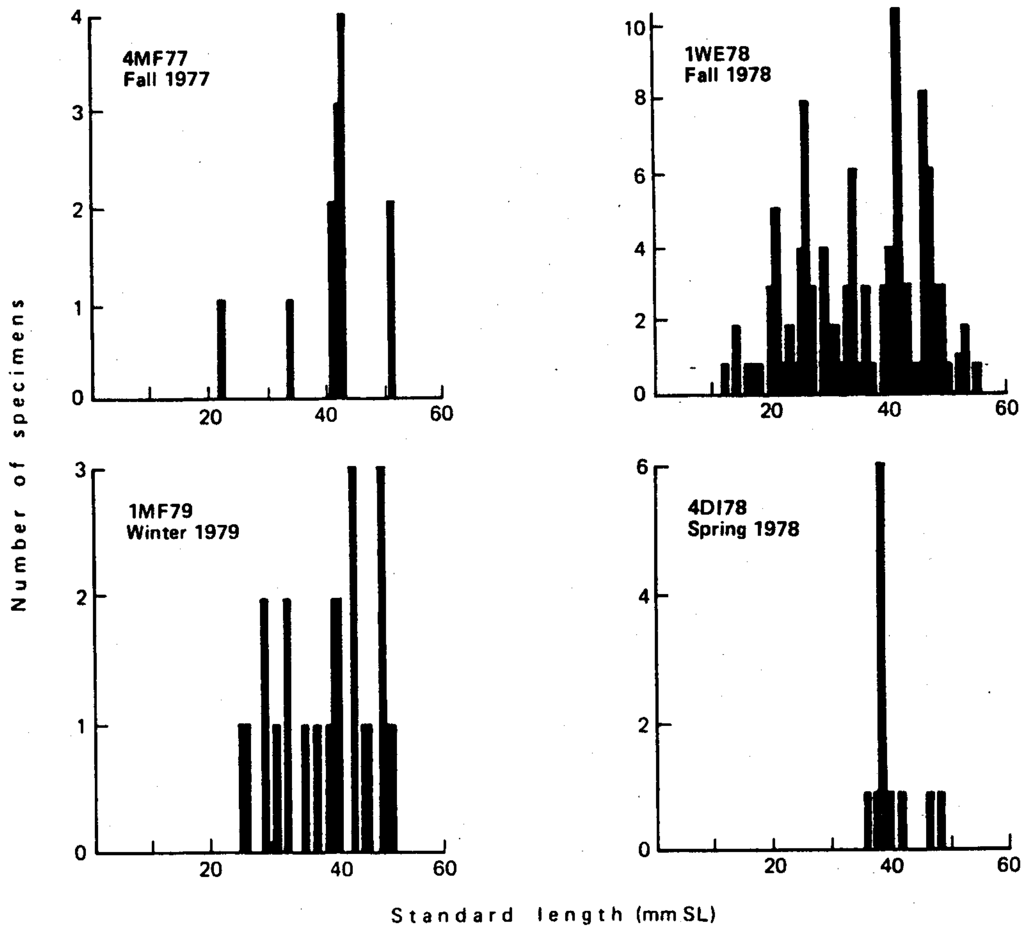


Figure 189.--Lengths of Mallotus villosus larvae collected in neuston net tows from the OCSEAP plankton cruises from fall 1977, fall 1978, winter 1979 and spring 1978.

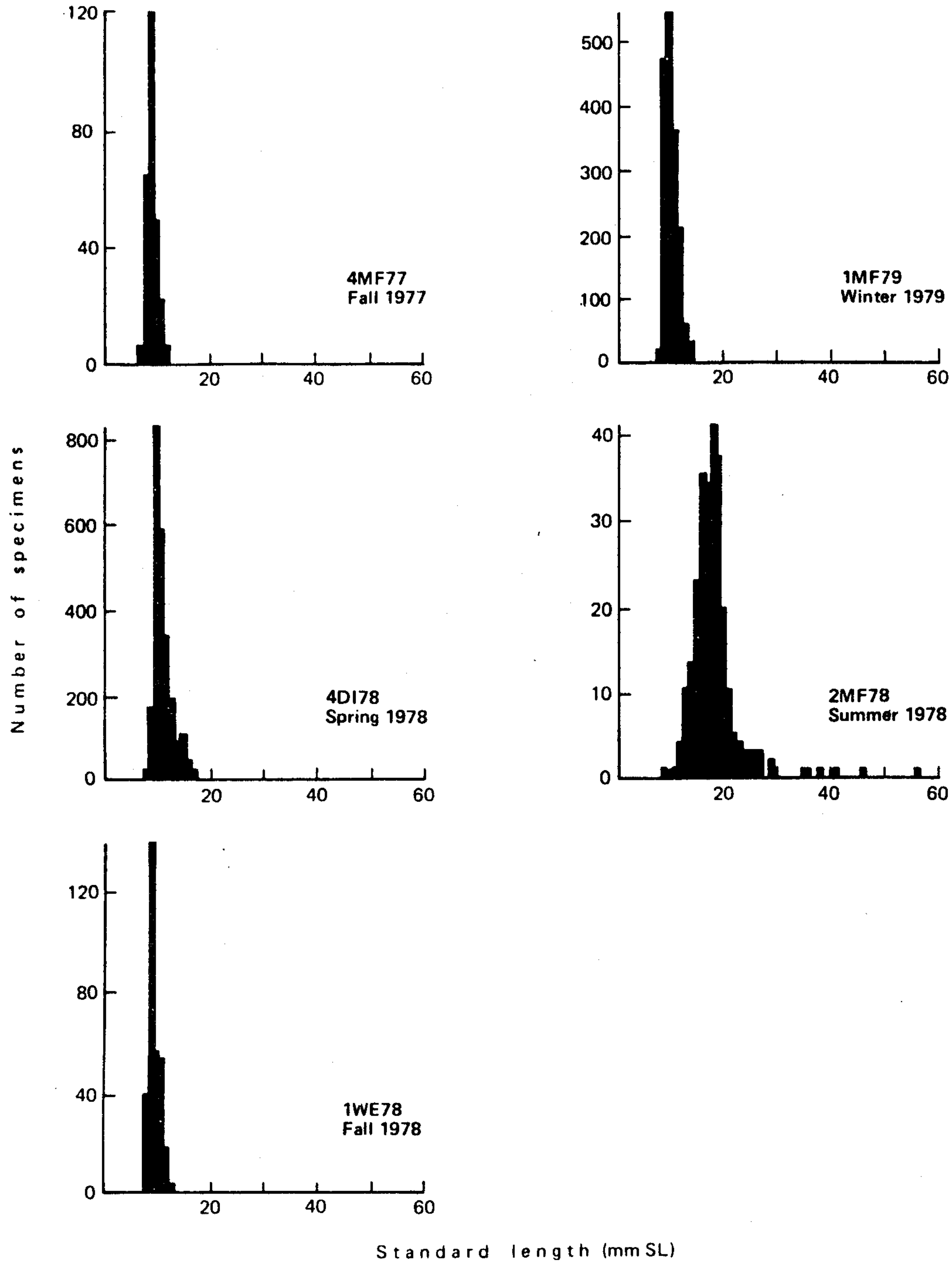


Figure 190.--Lengths of Hexagrammos decagrammus larvae collected in neuston net tows from the five OCSEAP plankton cruises.

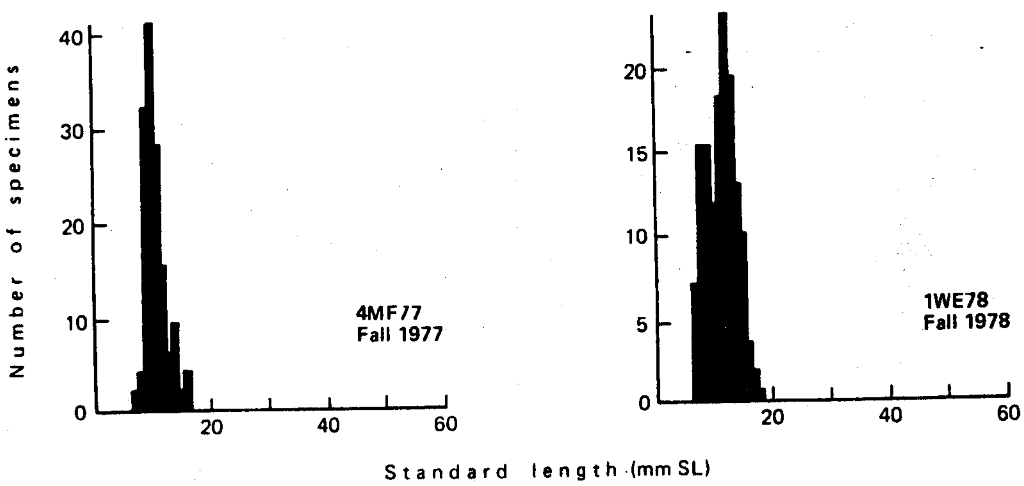


Figure 191.--Lengths of Hexagrammos lagocephalus larvae collected in neuston net tows from the OCSEAP plankton cruises from fall 1977 and fall 1978.

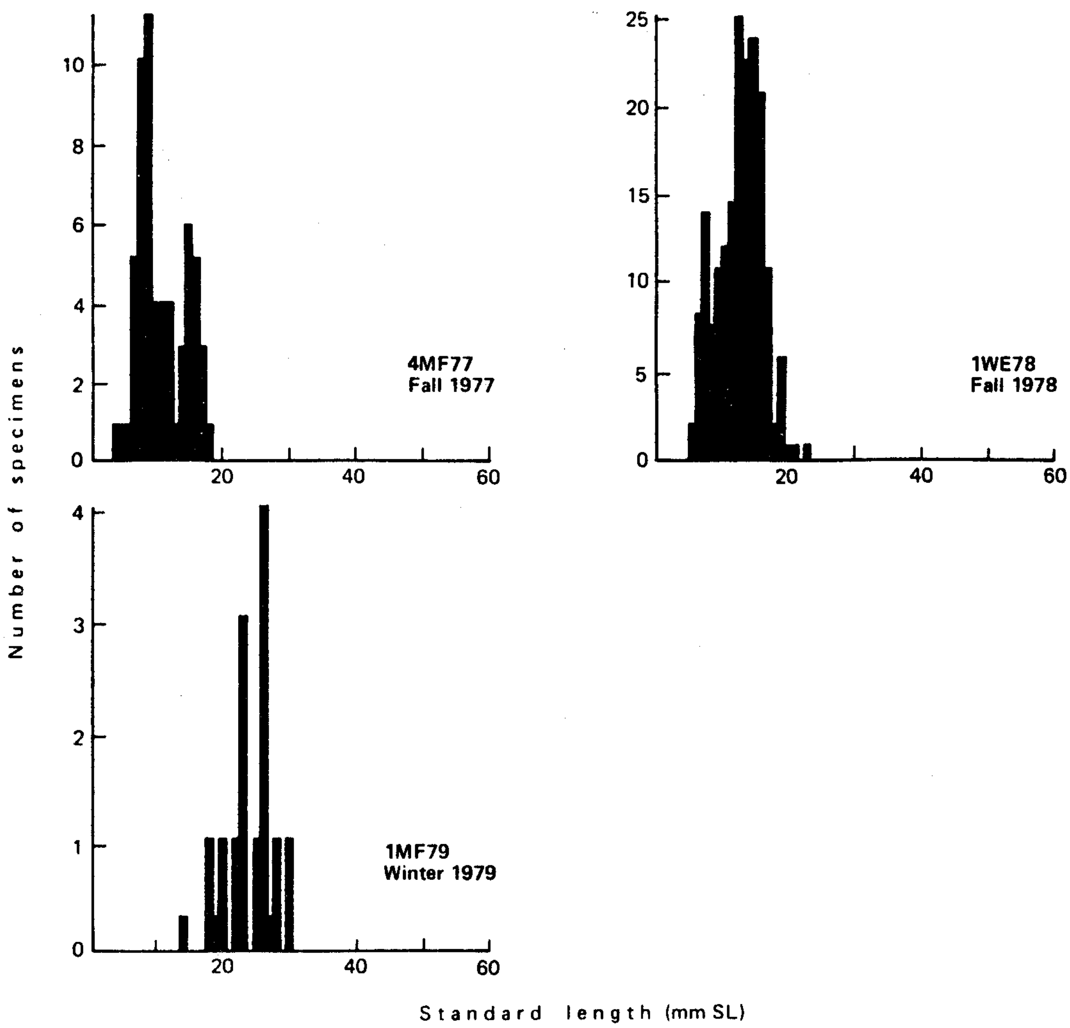


Figure 192.--Lengths of Hexagrammos octogrammus larvae collected in neuston net tows from the OCSEAP plankton cruises from fall 1977 and 1978 and winter 1979.

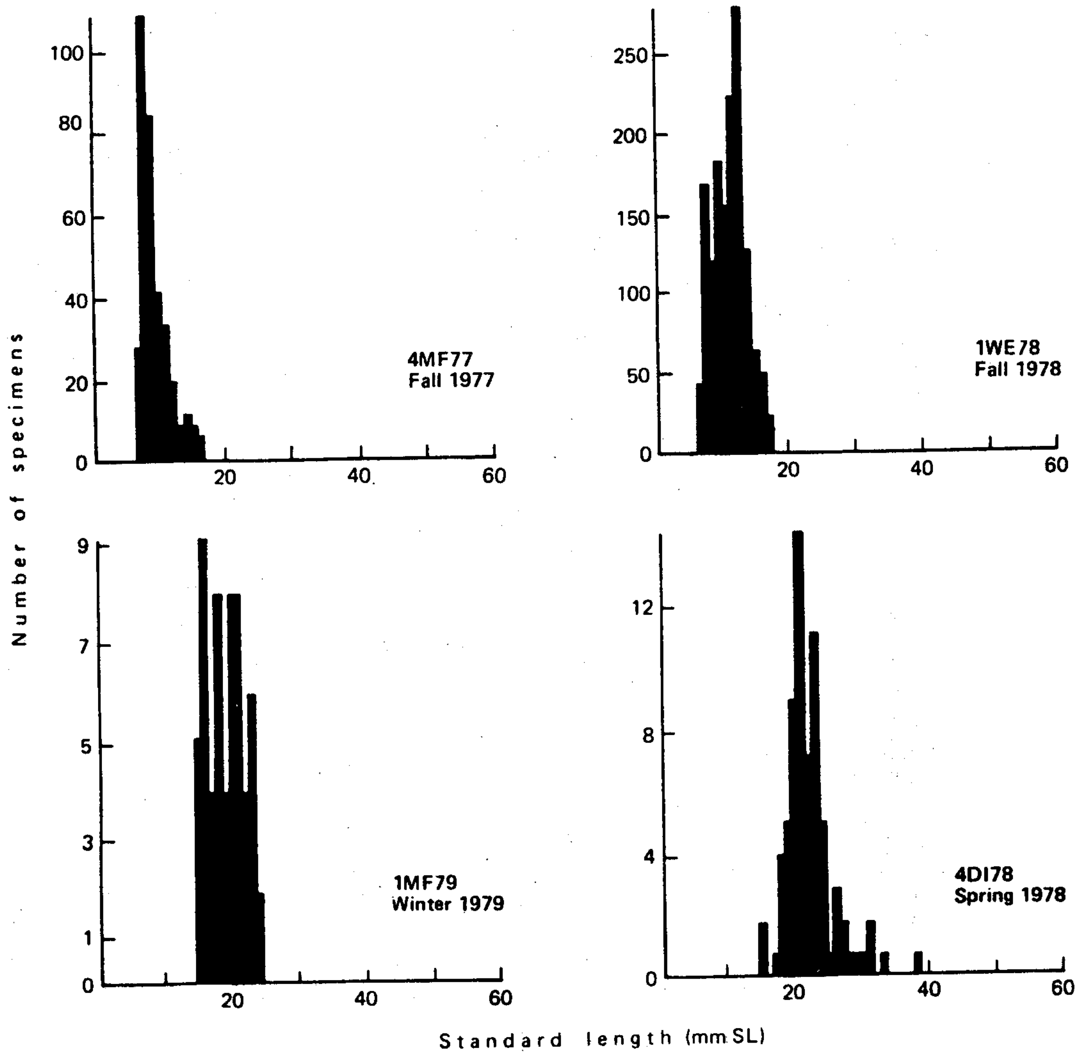


Figure 193.--Lengths of Hexagrammos stelleri larvae collected in neuston net tows from the OCSEAP plankton cruises from fall 1977 and 1978, winter 1979 and spring 1978.

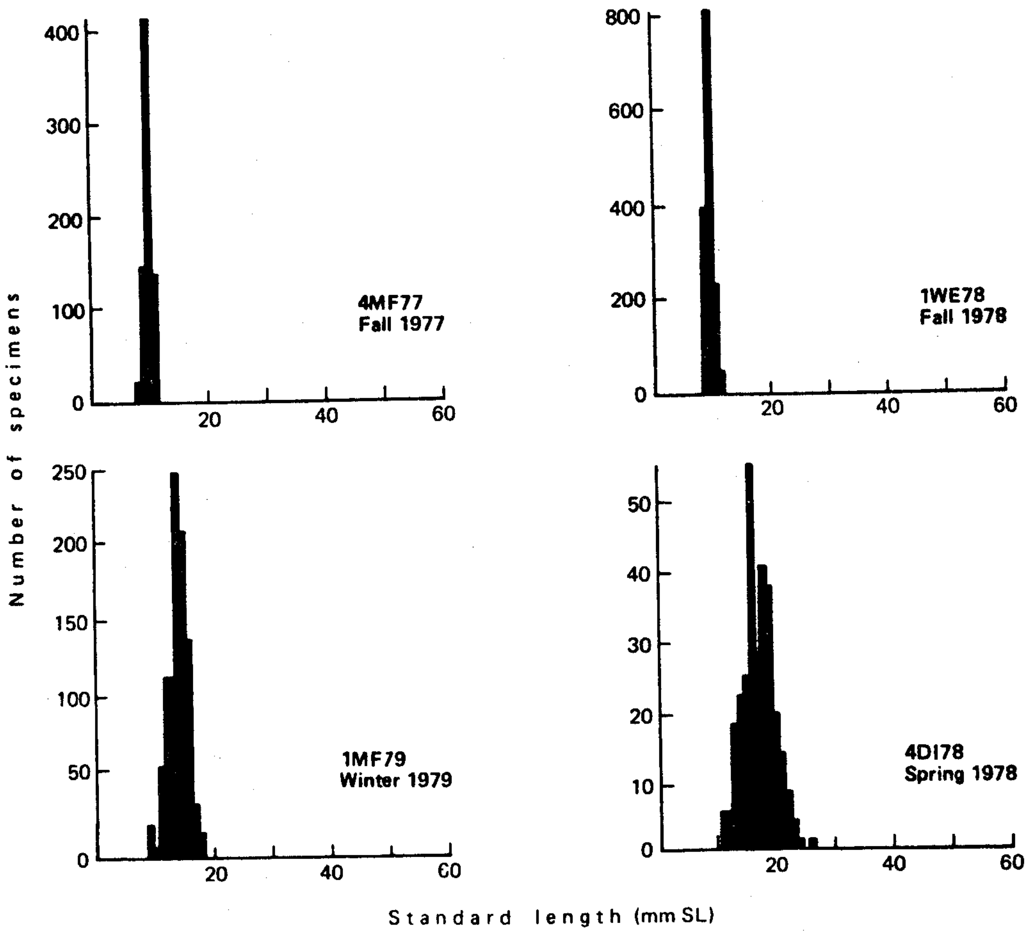


Figure 194.--Lengths of Pleurogrammus monopterygius larvae collected in neuston net tows from the OCSEAP plankton cruises from fall 1977, spring and fall 1978 and winter 1979.

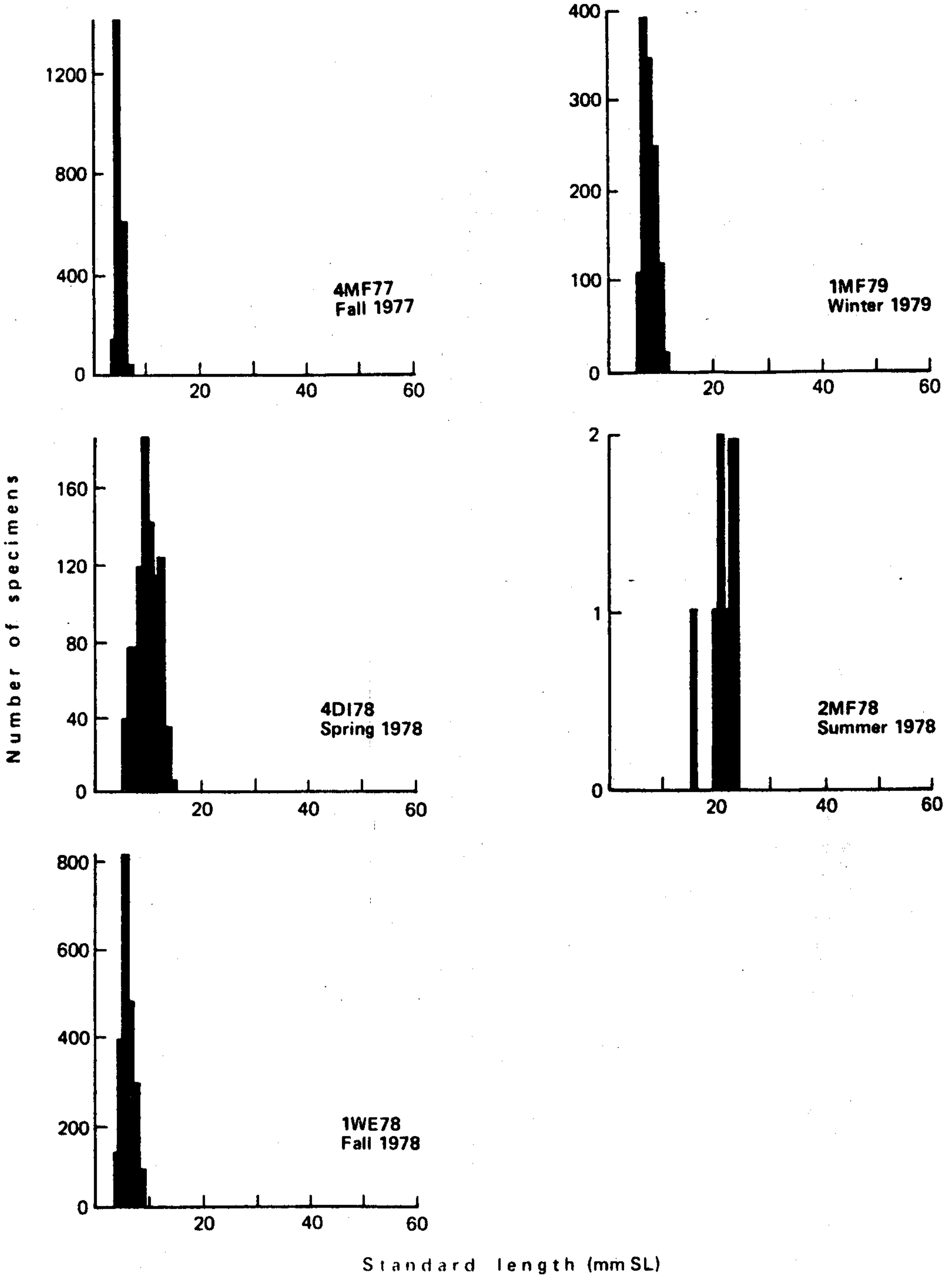


Figure 195.--Lengths of Hemilepidotus spp. larvae collected in neuston net tows from the five OCSEAP plankton cruises.

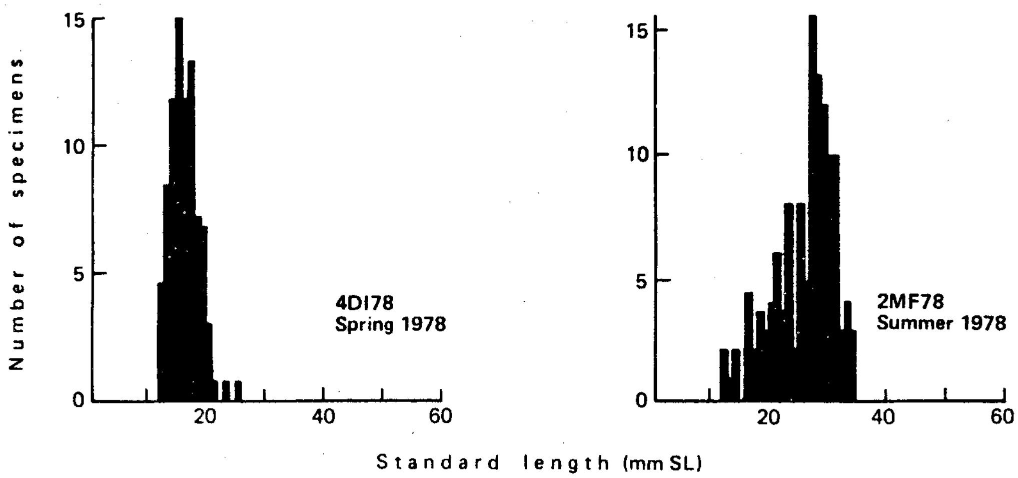


Figure 196.--Lengths of Lyconectes aleutensis larvae collected in neuston net tows from the OCSEAP plankton cruises in spring and summer 1978.

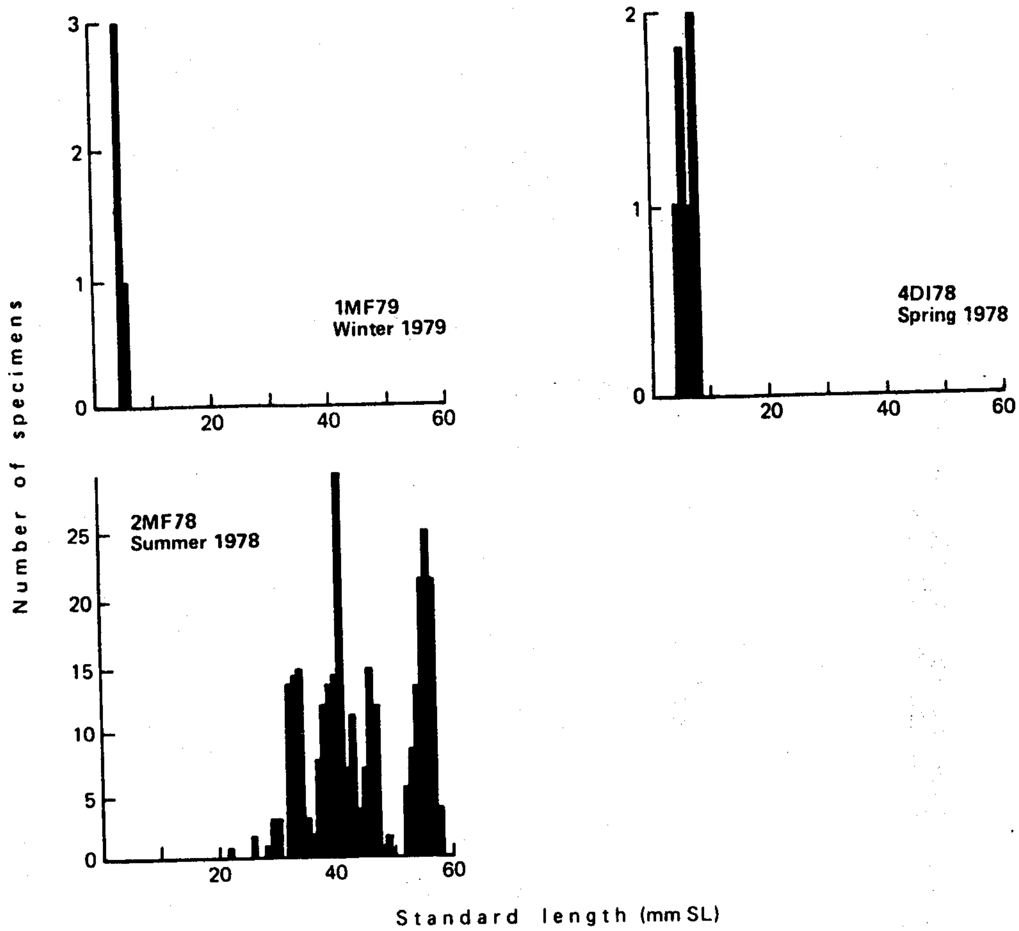


Figure 197.--Lengths of Ammodytes hexapterus larvae collected in bongo net tows (winter 1979 and spring 1978) and neuston net tows (summer 1978) from the OCSEAP plankton cruises.

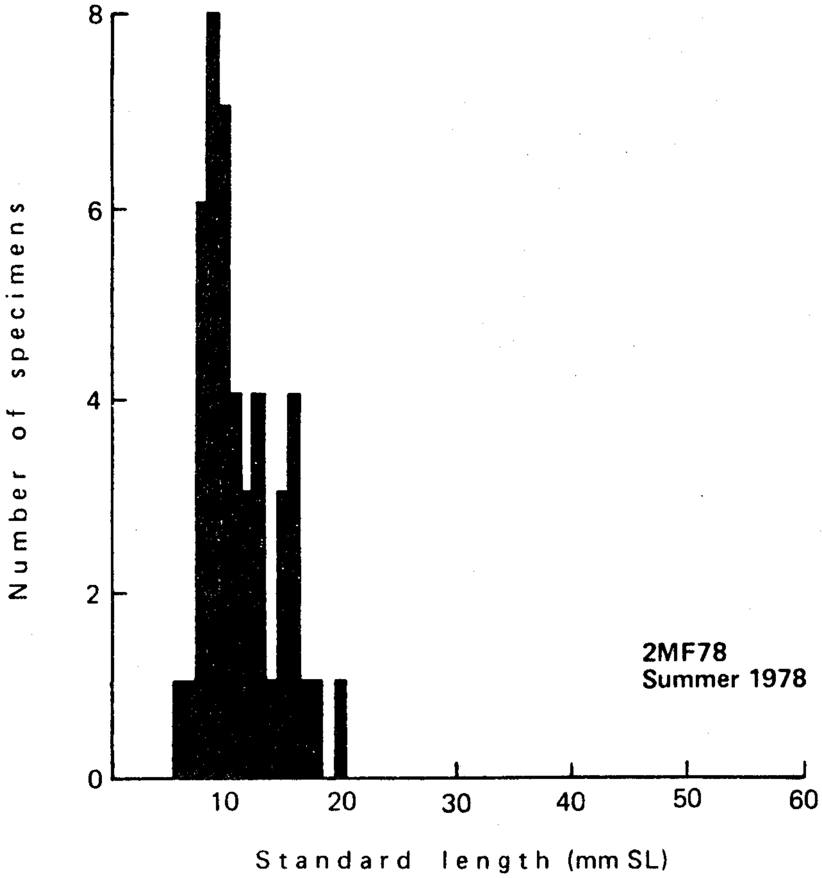


Figure 198.--Lengths of Glyptocephalus zachirus larvae collected in bongo net tows from the OCSEAP plankton cruise from summer 1978.

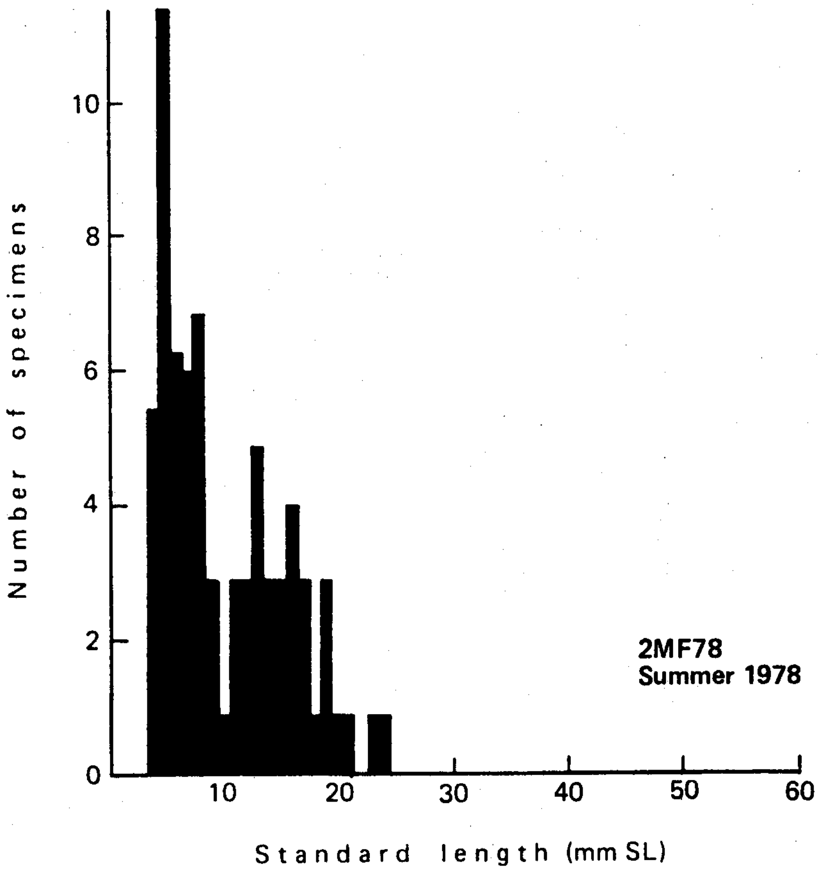


Figure 199.--Lengths of Hippoglossoides elassodon larvae collected in bongo net tows from the OCSEAP plankton cruise from summer 1978.

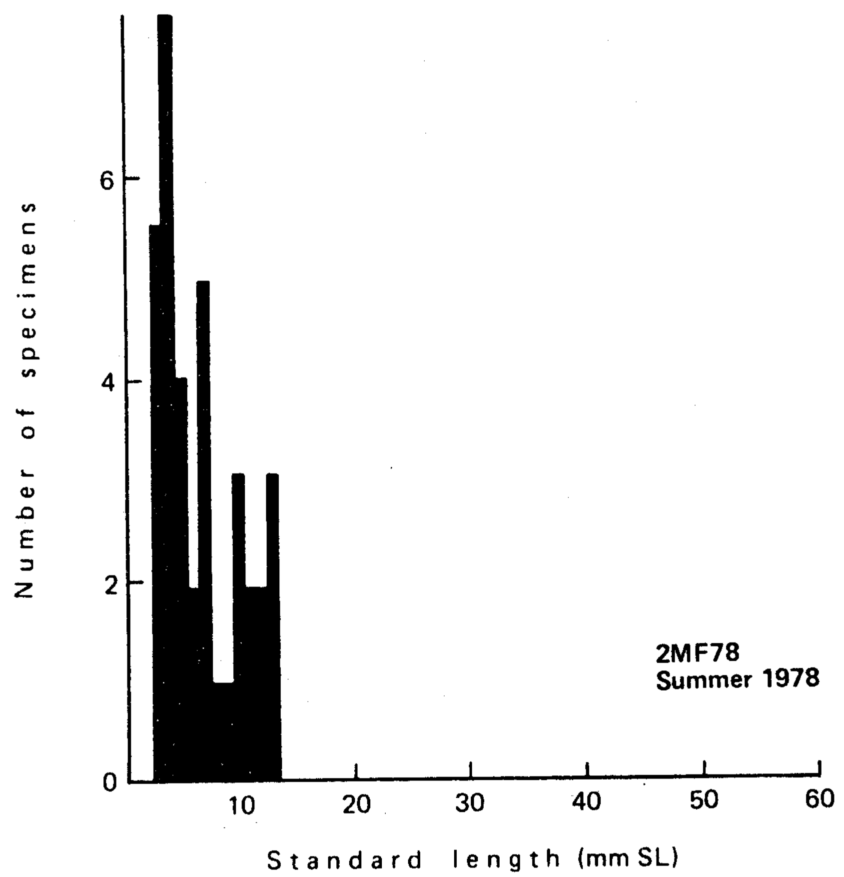


Figure 200.--Lengths of Isopsetta isolepis larvae collected in bongo net tows from the OCSEAP plankton cruise from summer 1978.

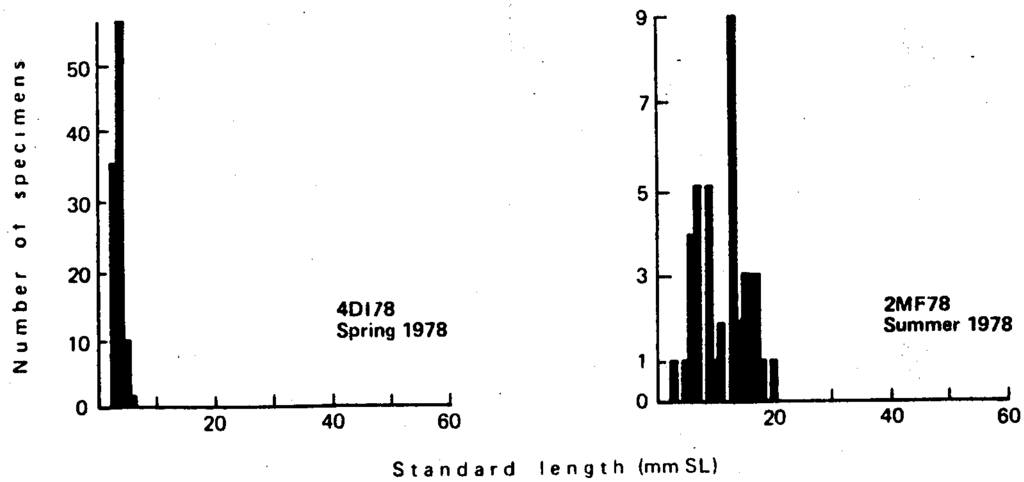


Figure 201.--Lengths of Lepidopsetta bilineata larvae collected in bongo net tows from the OCSEAP plankton cruises from spring and summer 1978.

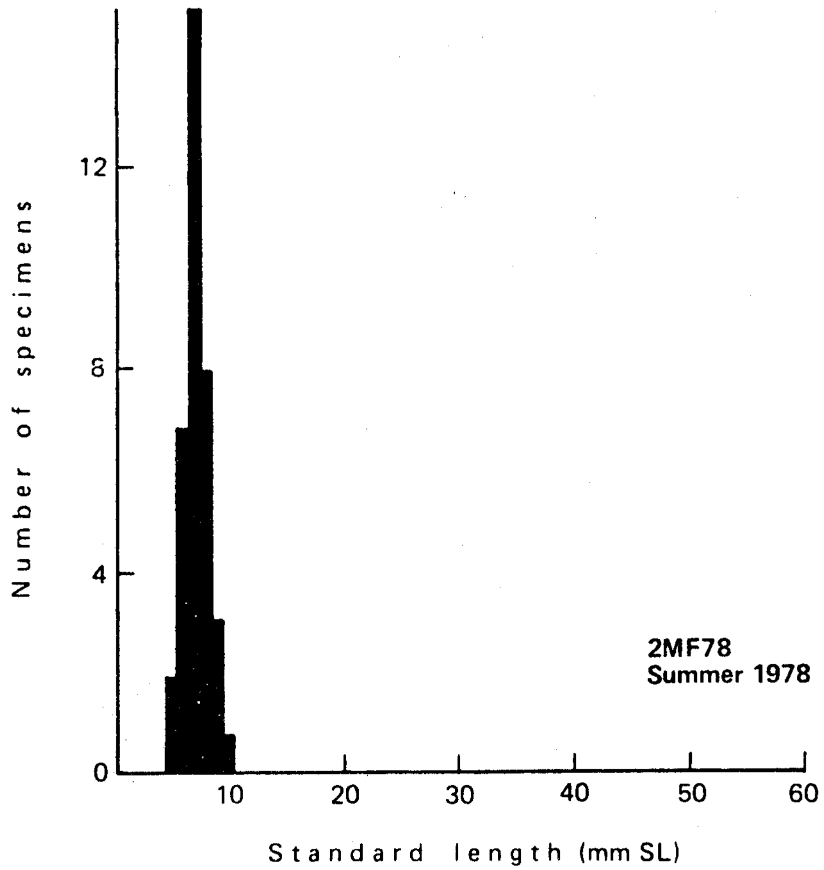


Figure 202.--Lengths of Microstomus pacificus larvae collected in bongo net tows from the OCSEAP plankton cruise from summer 1978.

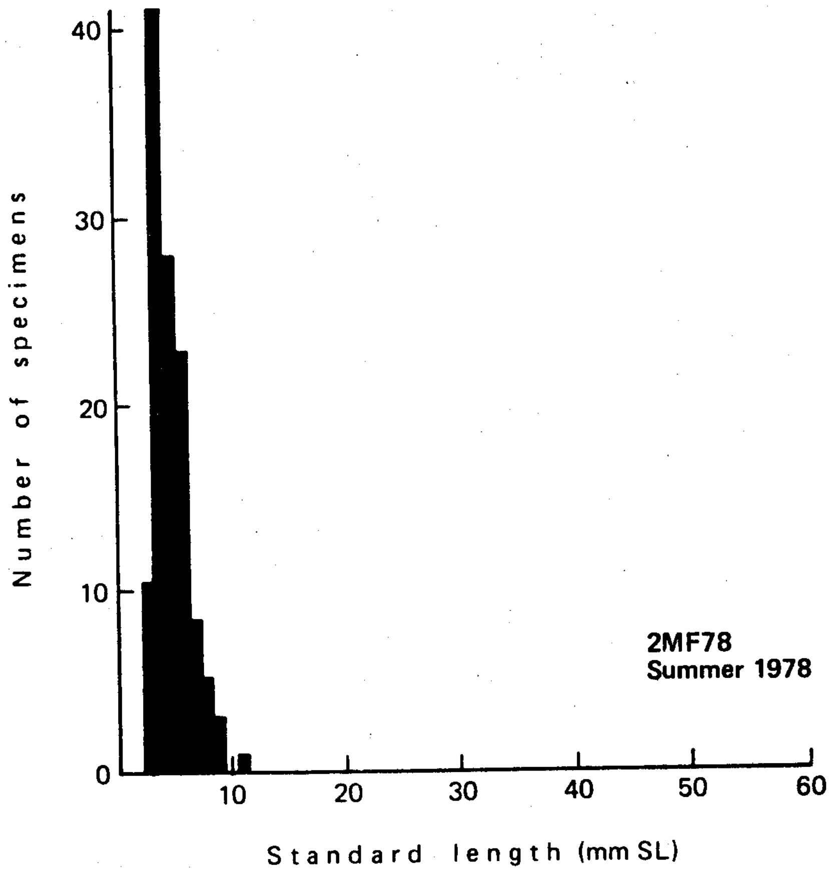


Figure 203.--Lengths of Psettichthys melanostictus larvae collected in bongo net tows from the OCSEAP plankton cruise from summer 1978.

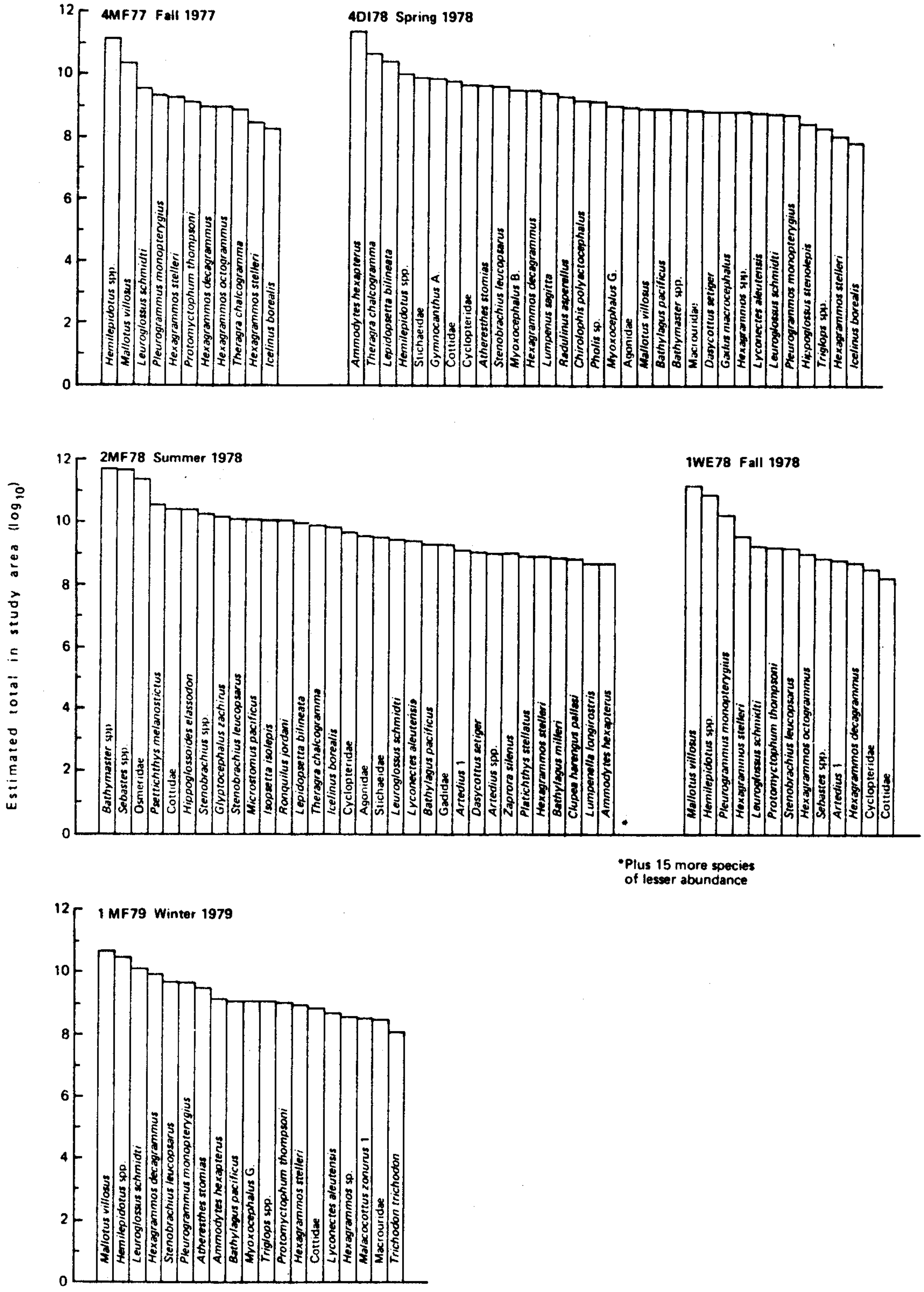


Figure 204.--Ranked abundance of common fish larvae in bongo catches from the five OCSEAP plankton cruises.

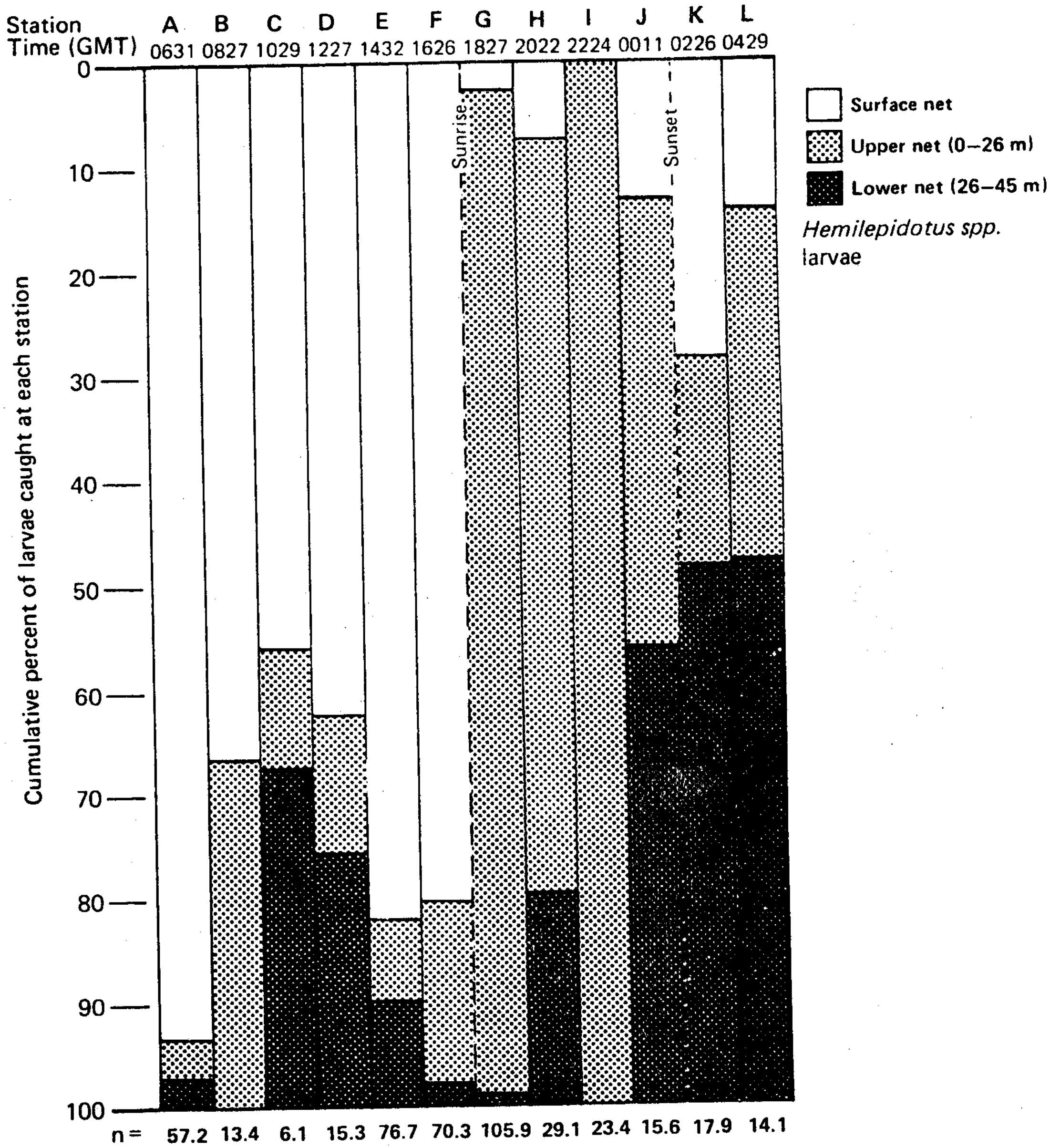


Figure 205.--Depth distribution with time of day of Hemilepidotus spp. larvae at stations D33A-L (Diel 1), fall 1977. n = numbers of larvae/100 m^3 caught in all nets at each station.

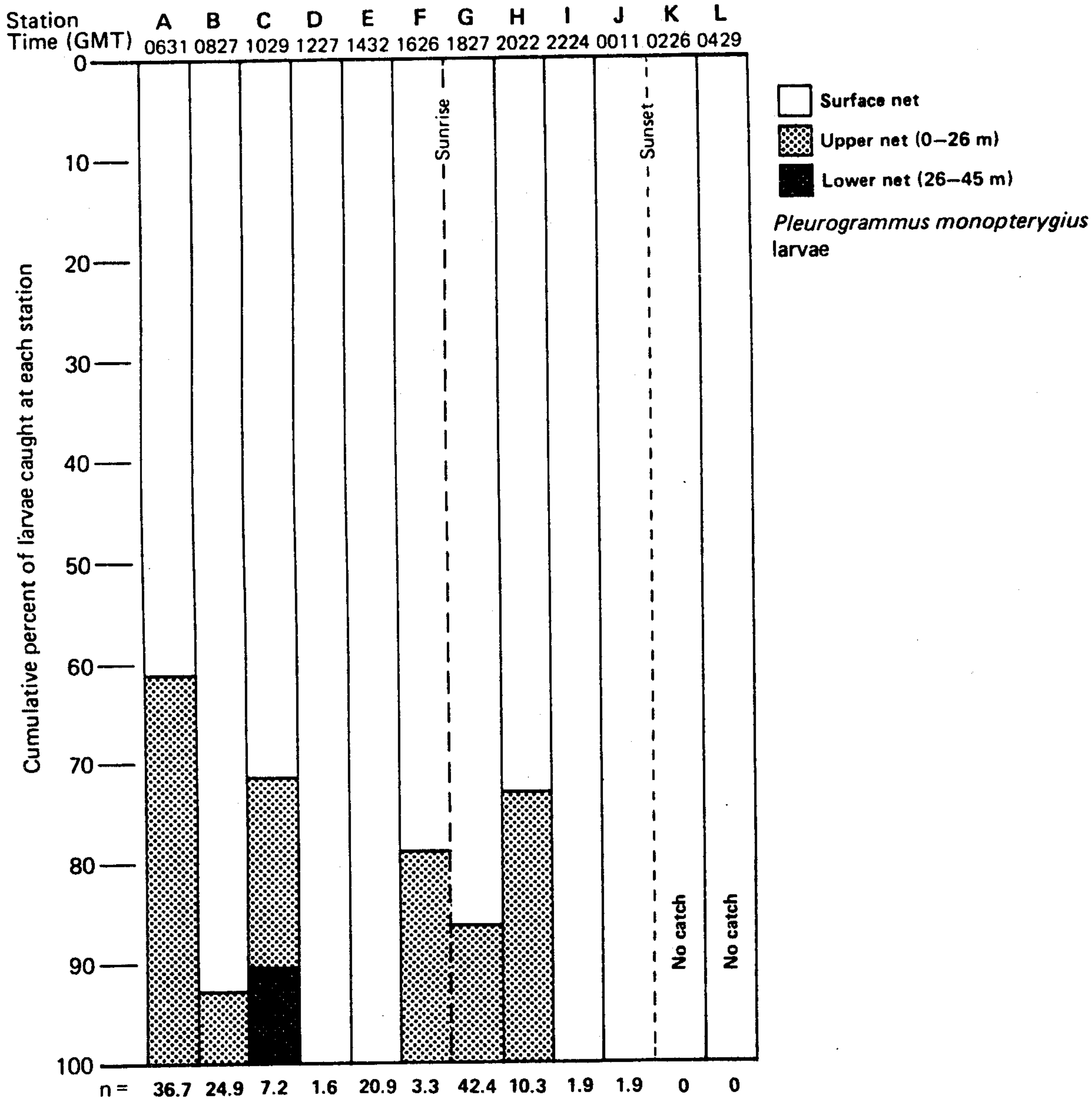


Figure 206.--Depth distribution with time of day of Pleurogrammus monopterygius larvae at stations D33A-L (Diel 1), fall 1977. n = numbers of larvae/100 m^3 caught in all nets at each station.

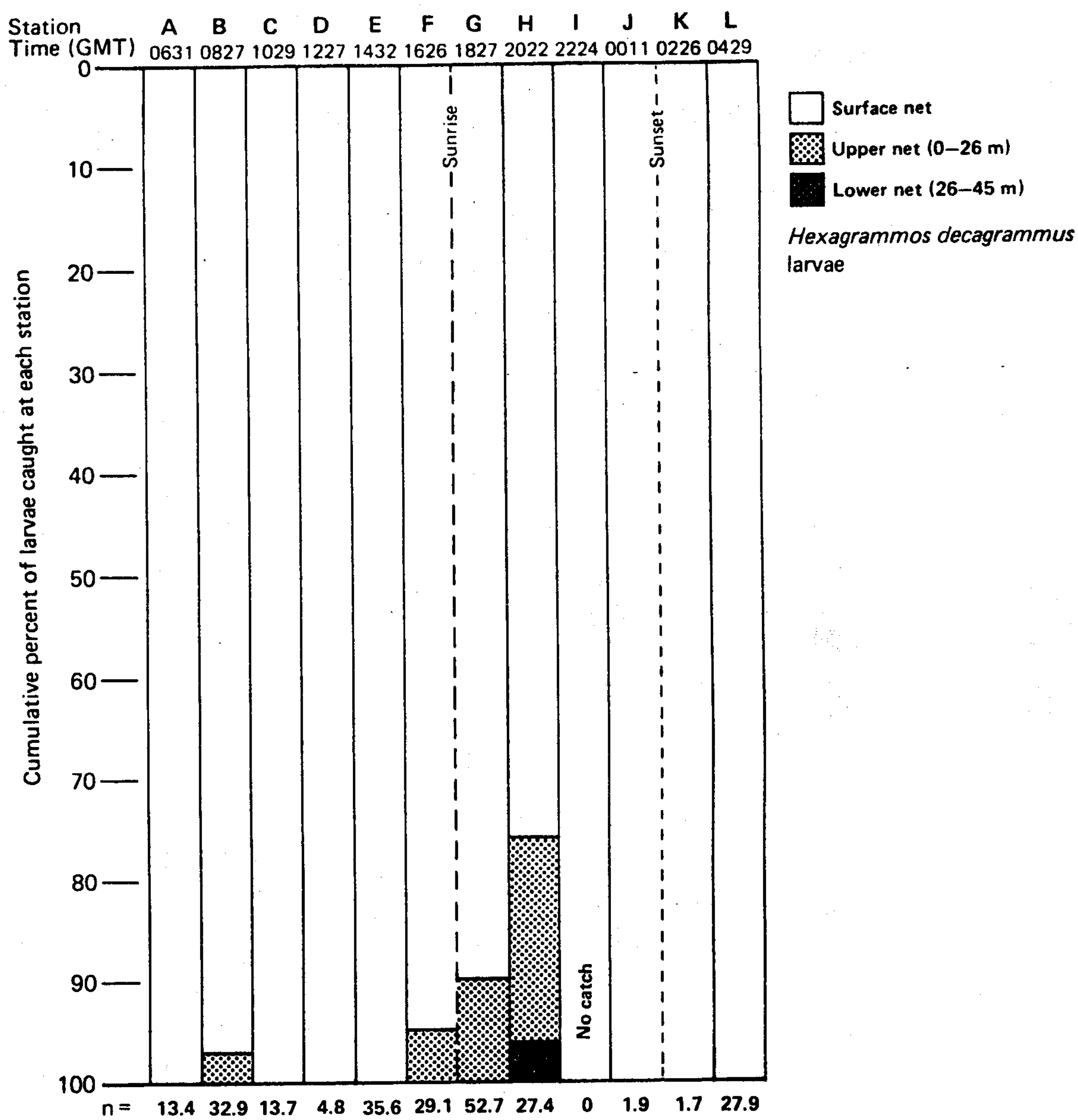


Figure 207.--Depth distribution with time of day of Hexagrammos decagrammus larvae at stations D33A-L (Diel 1), fall 1977. n = numbers of larvae/100 m^3 caught in all nets at each station.

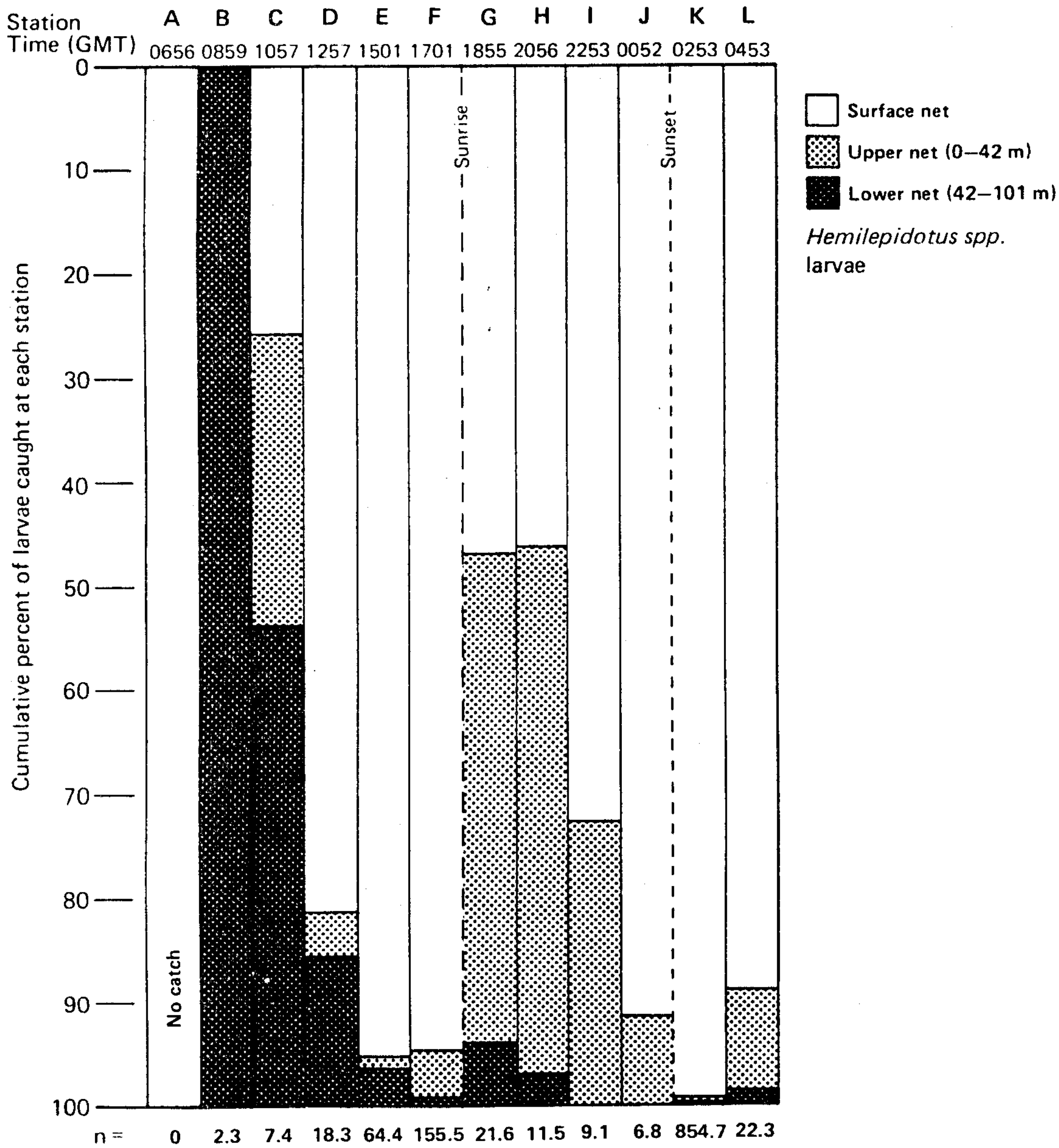


Figure 208.--Depth distribution with time of day of Hemilepidotus spp. larvae at stations D35A-L (Diel 2), fall 1977. n = numbers of larvae/ 100 m^3 caught in all nets at each station.

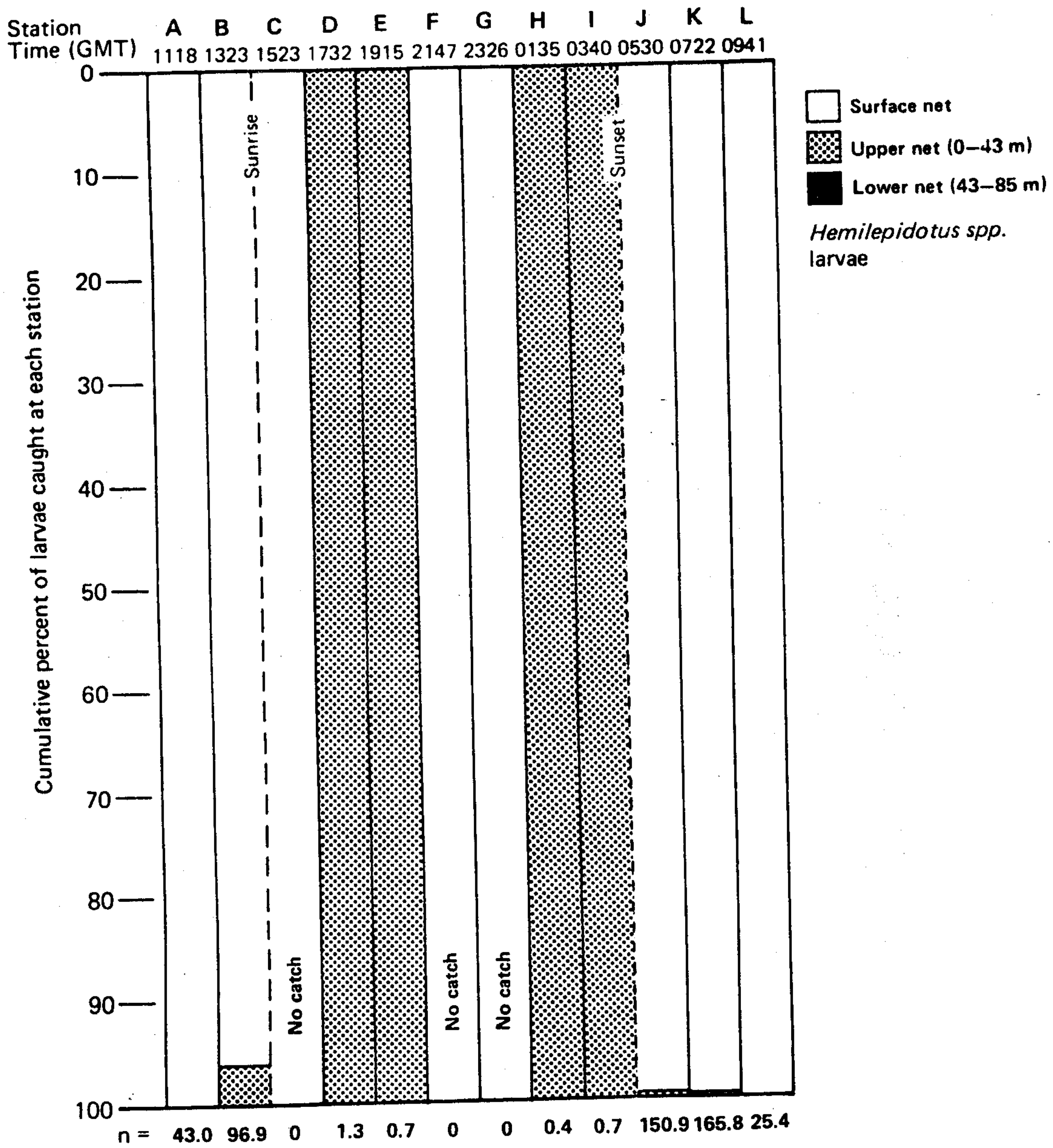


Figure 209.--Depth distribution with time of day of Hemilepidotus spp. larvae at stations D45A-L (Diel 3), spring 1978. n = numbers of larvae/ 100 m^3 caught in all nets at each station.

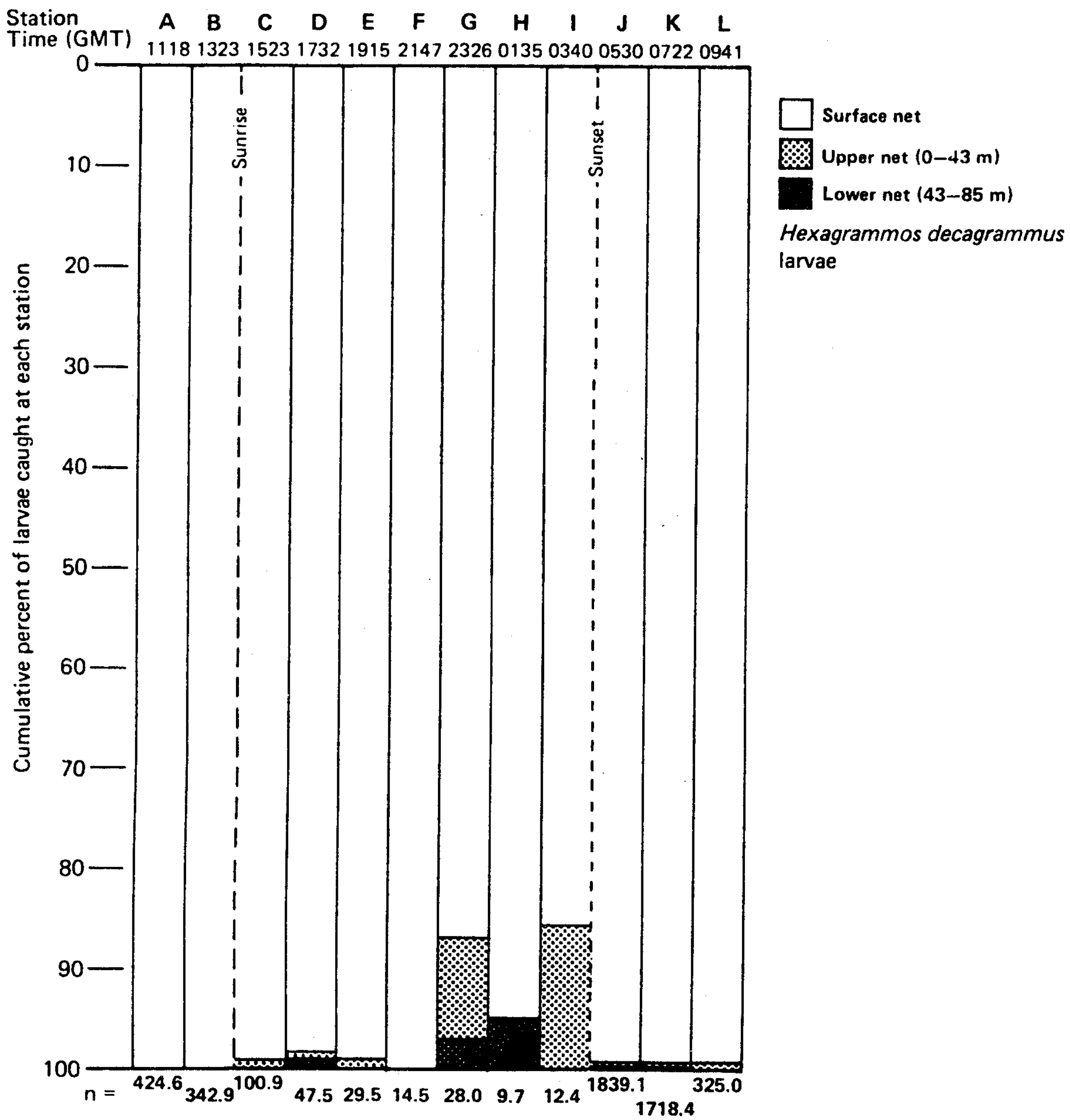


Figure 210.--Depth distribution with time of day of Hexagrammos decagrammus larvae at stations D45A-L (Diel 3), spring 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

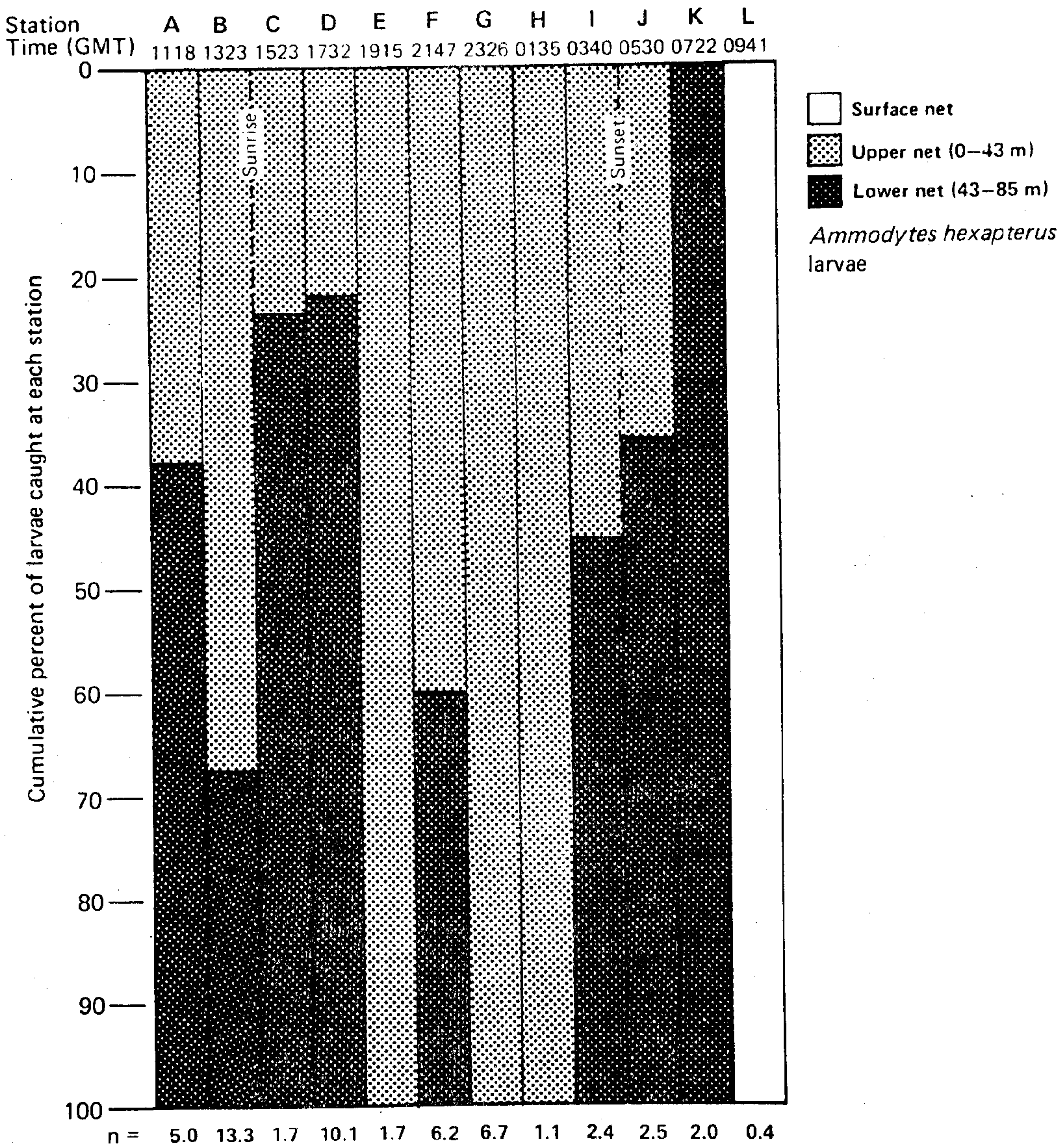


Figure 211.--Depth distribution with time of day of Ammodytes hexapterus larvae at stations D45A-L (Diel 3), spring 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

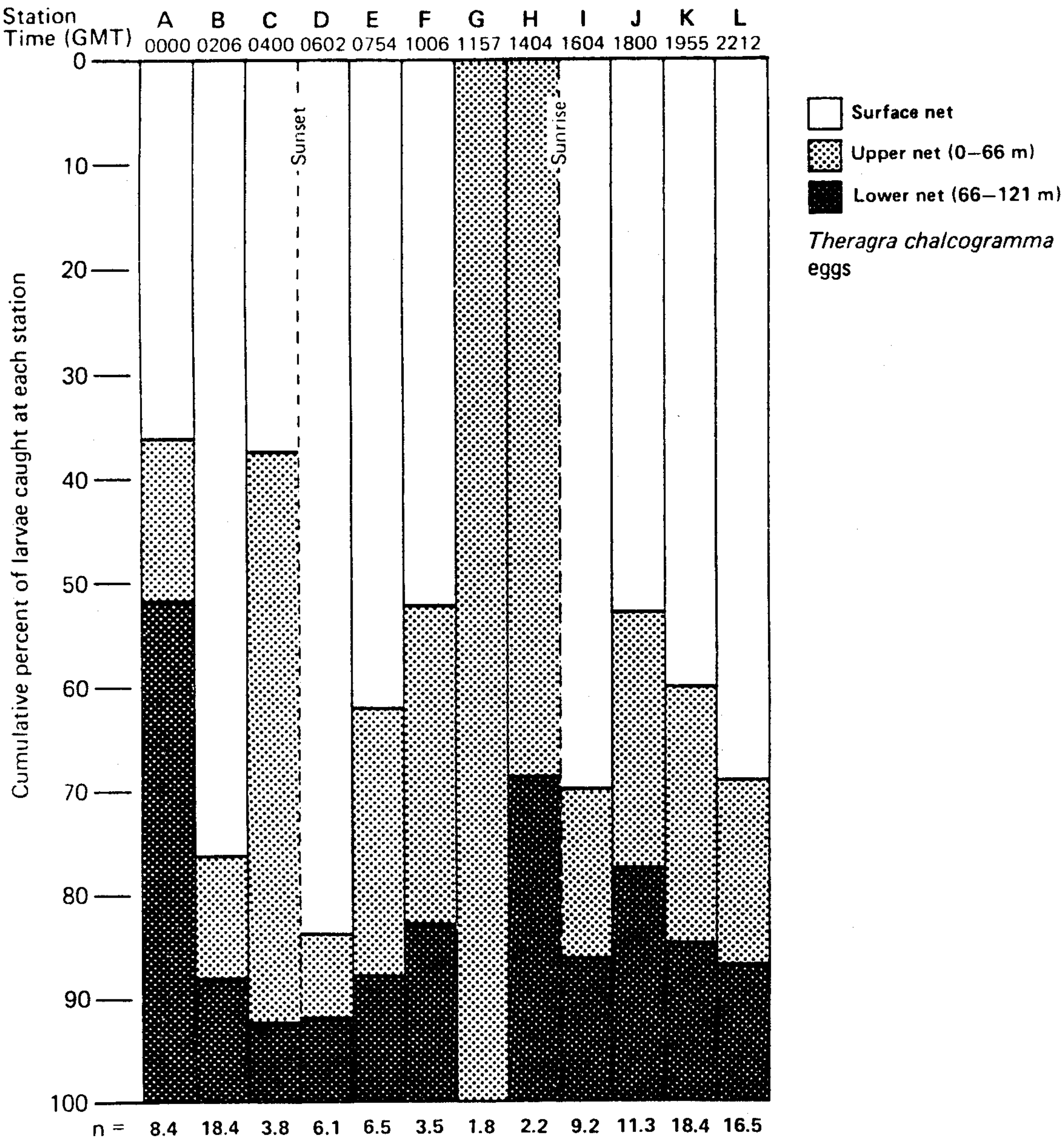


Figure 212.--Depth distribution with time of day of Theragra chalcogramma eggs at stations D63A-L (Diel 4), spring 1978. n = numbers of eggs/100 m^3 caught in all nets at each station.

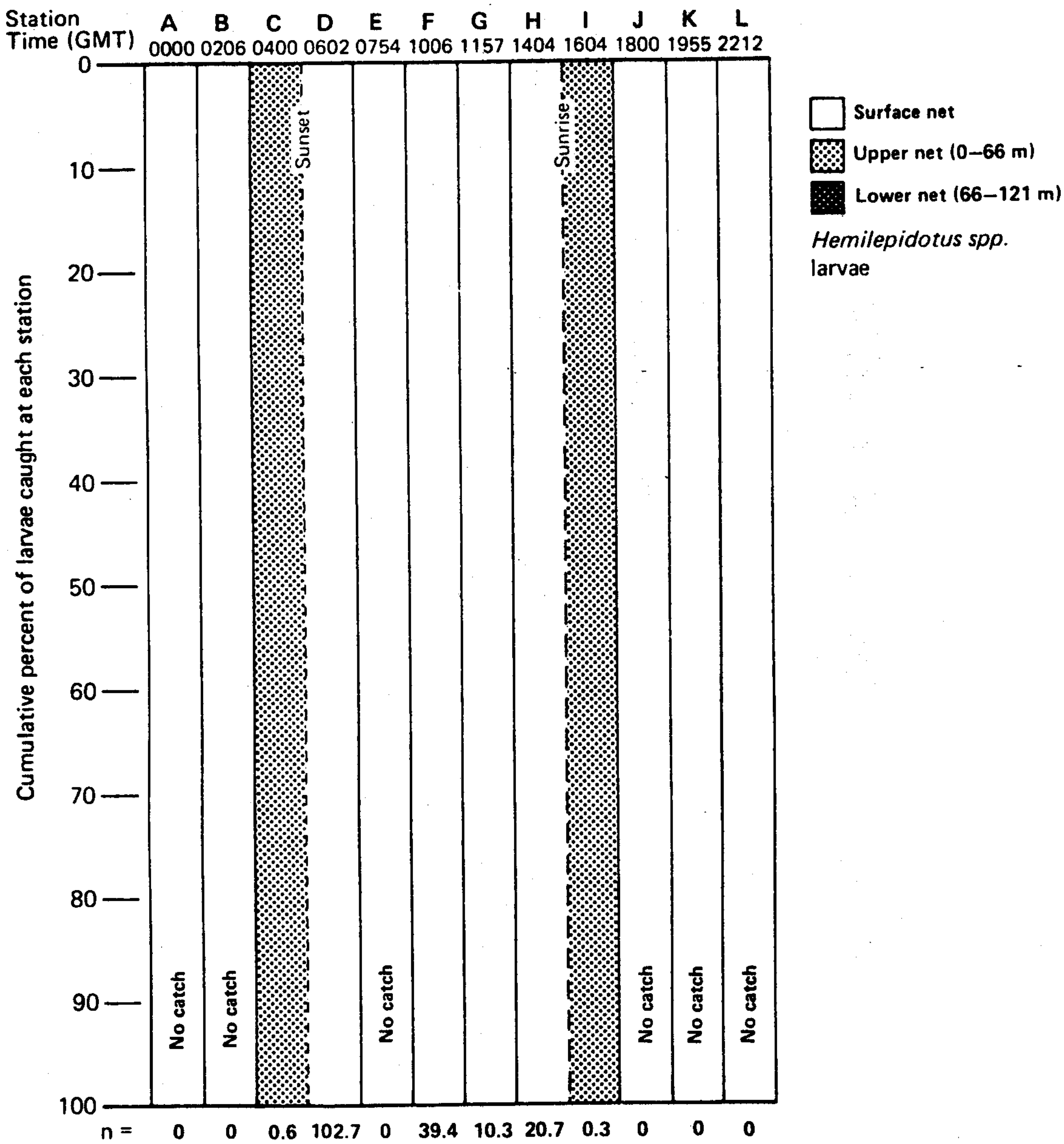


Figure 213.--Depth distribution with time of day of <u>Hemilepidotus</u> spp. larvae at stations D63A-L (Diel 4), spring 1978. n = numbers of larvae/ 100 m^3 caught in all nets at each station.

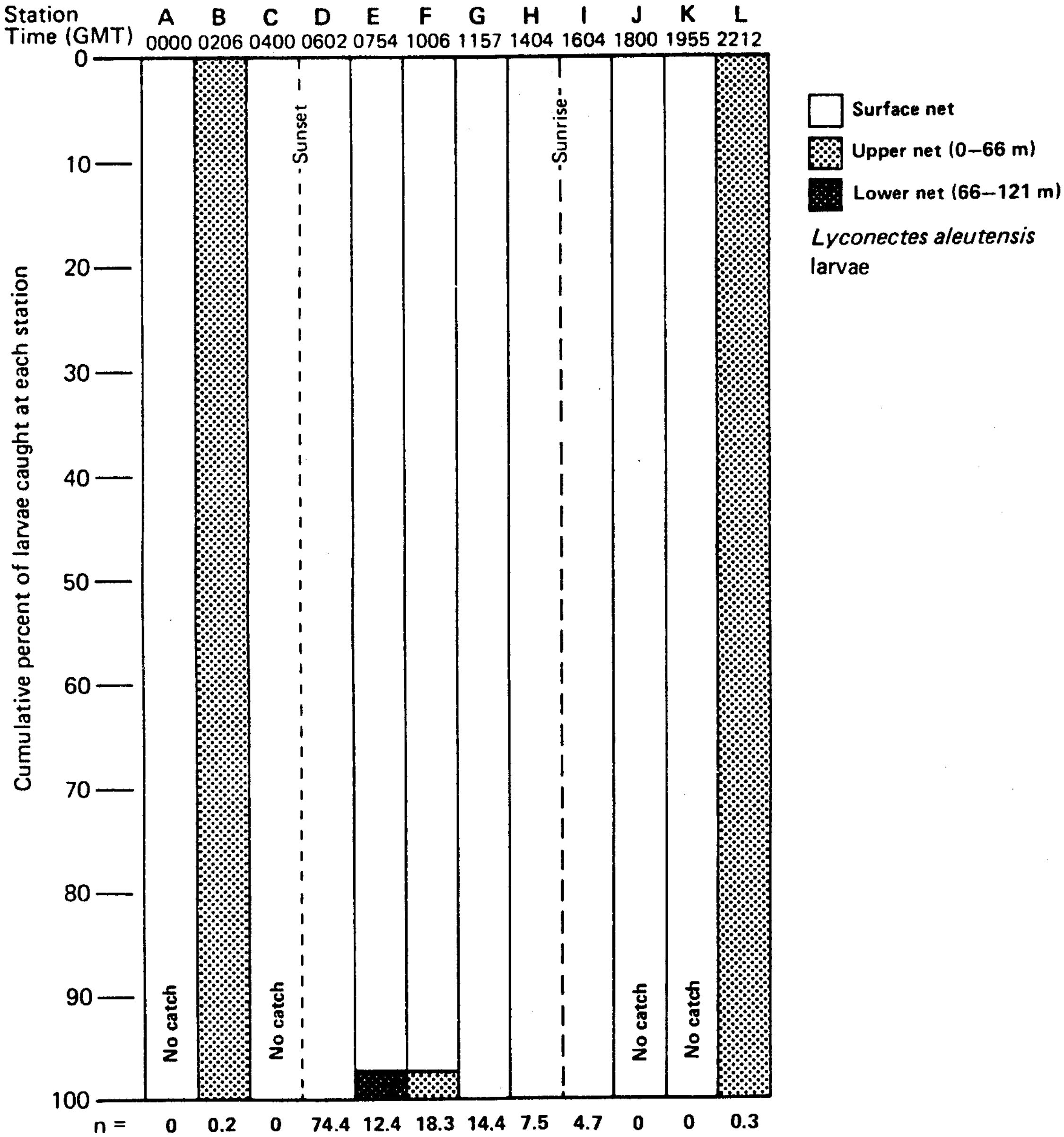


Figure 214.--Depth distribution with time of day of Lyconectes aleutensis larvae at stations D63A-L (Diel 4), spring 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

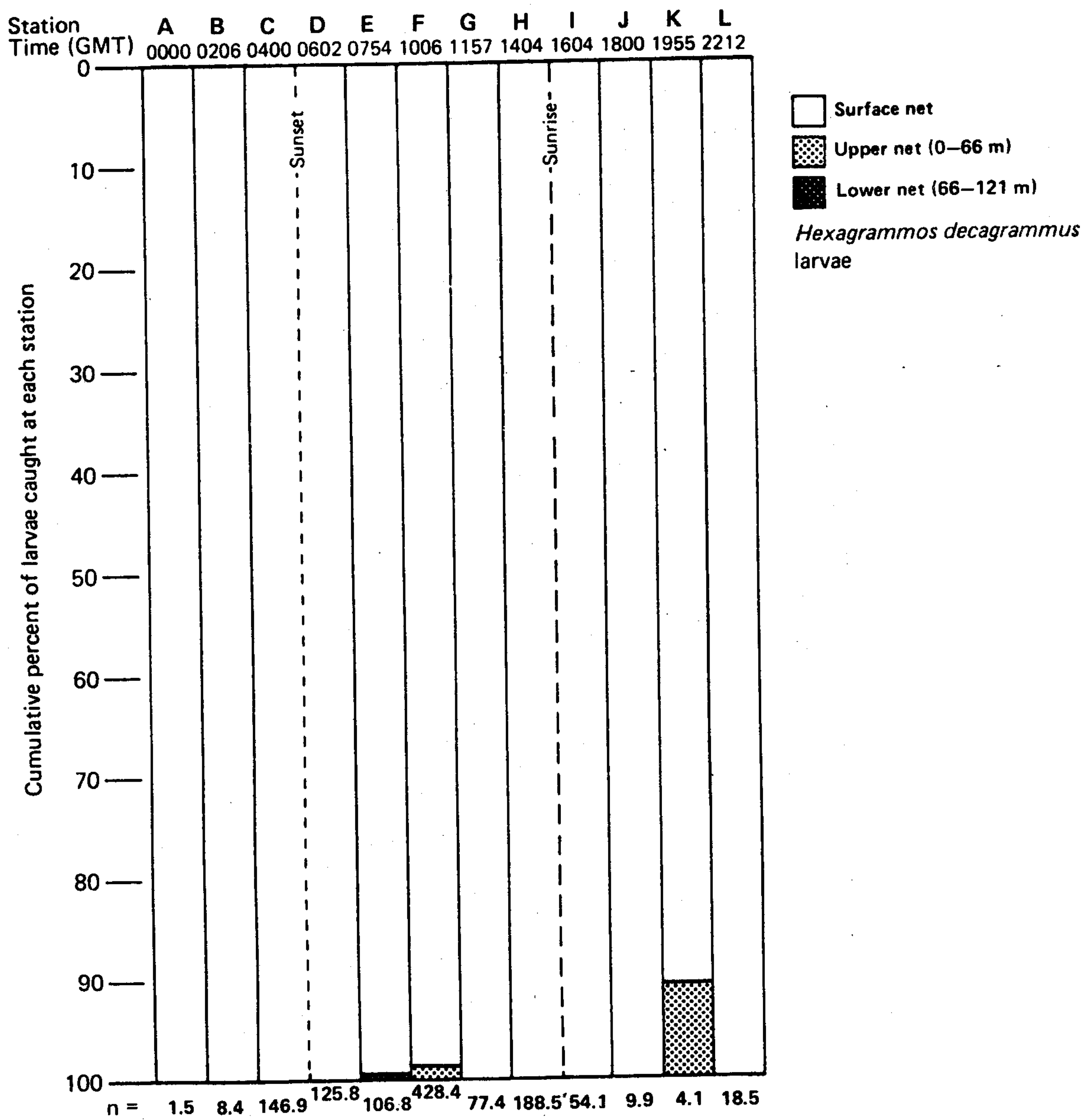


Figure 215.--Depth distribution with time of day of <u>Hexagrammos decagrammus</u> larvae at stations D63A-L (Diel 4), spring 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

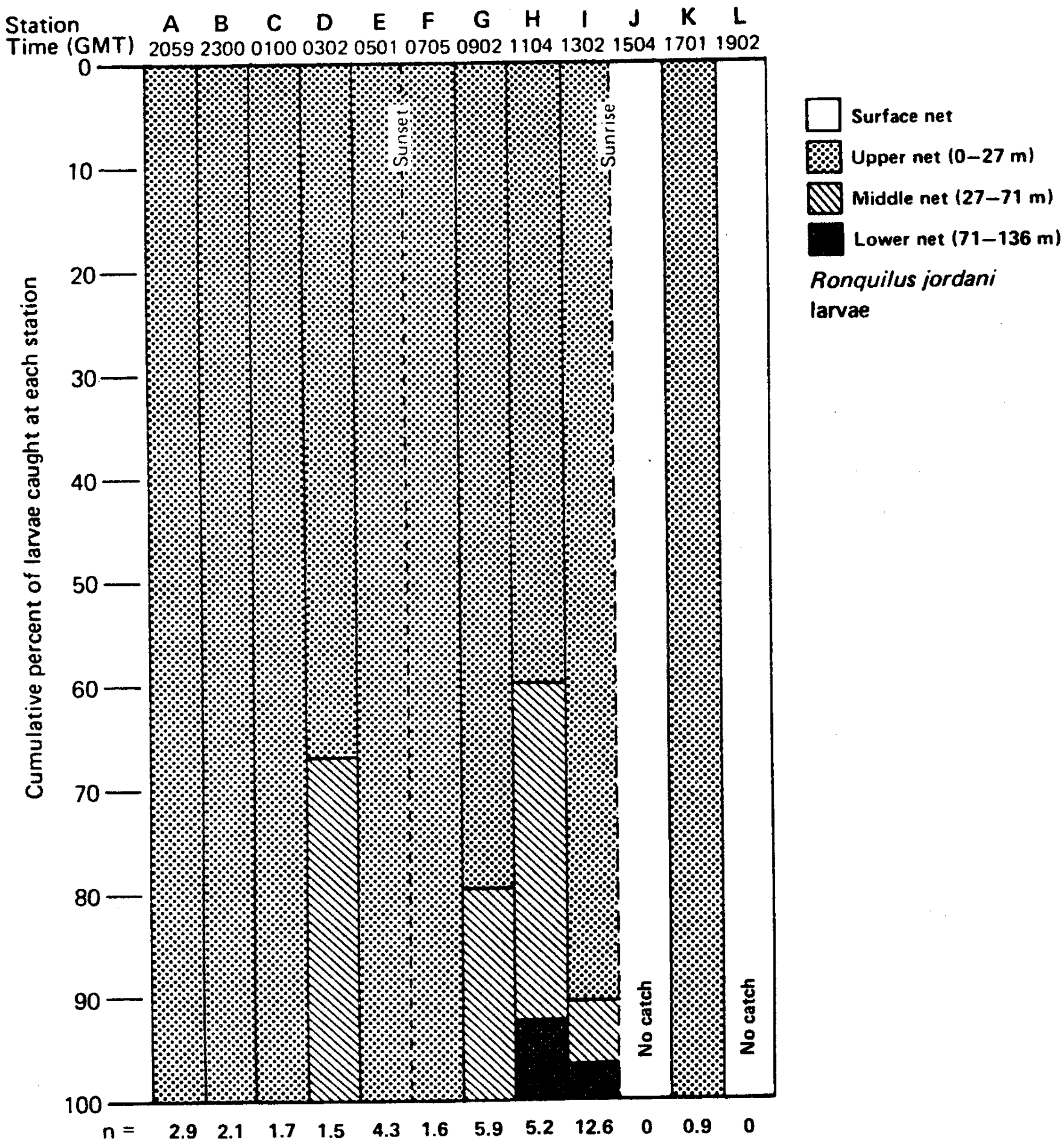


Figure 216.--Depth distribution with time of day of Ronquilus jordani larvae at stations D01A-L (Diel 5), summer 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

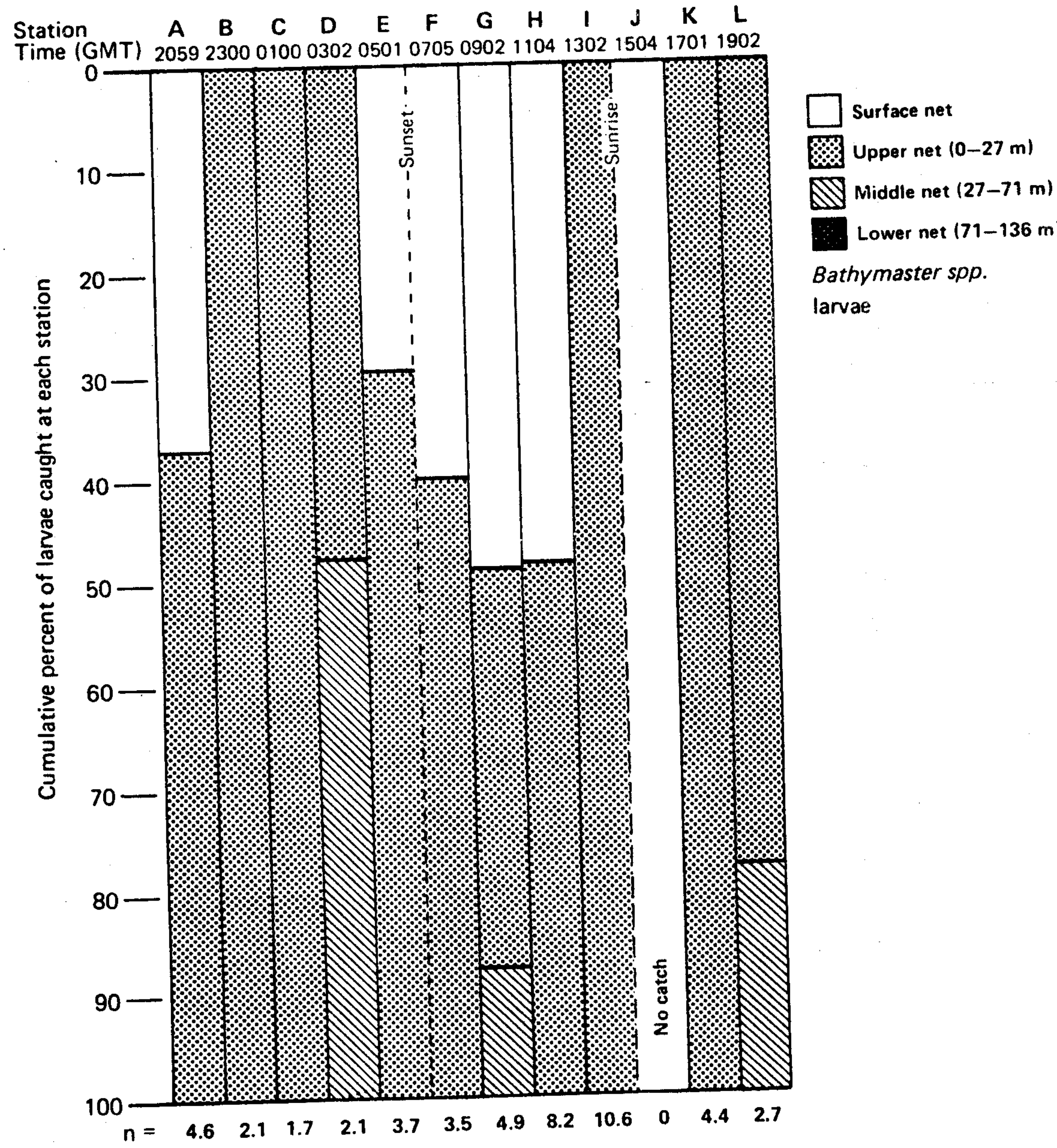


Figure 217.--Depth distribution with time of day of Bathymaster spp. larvae at stations D01A-L (Diel 5), summer 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

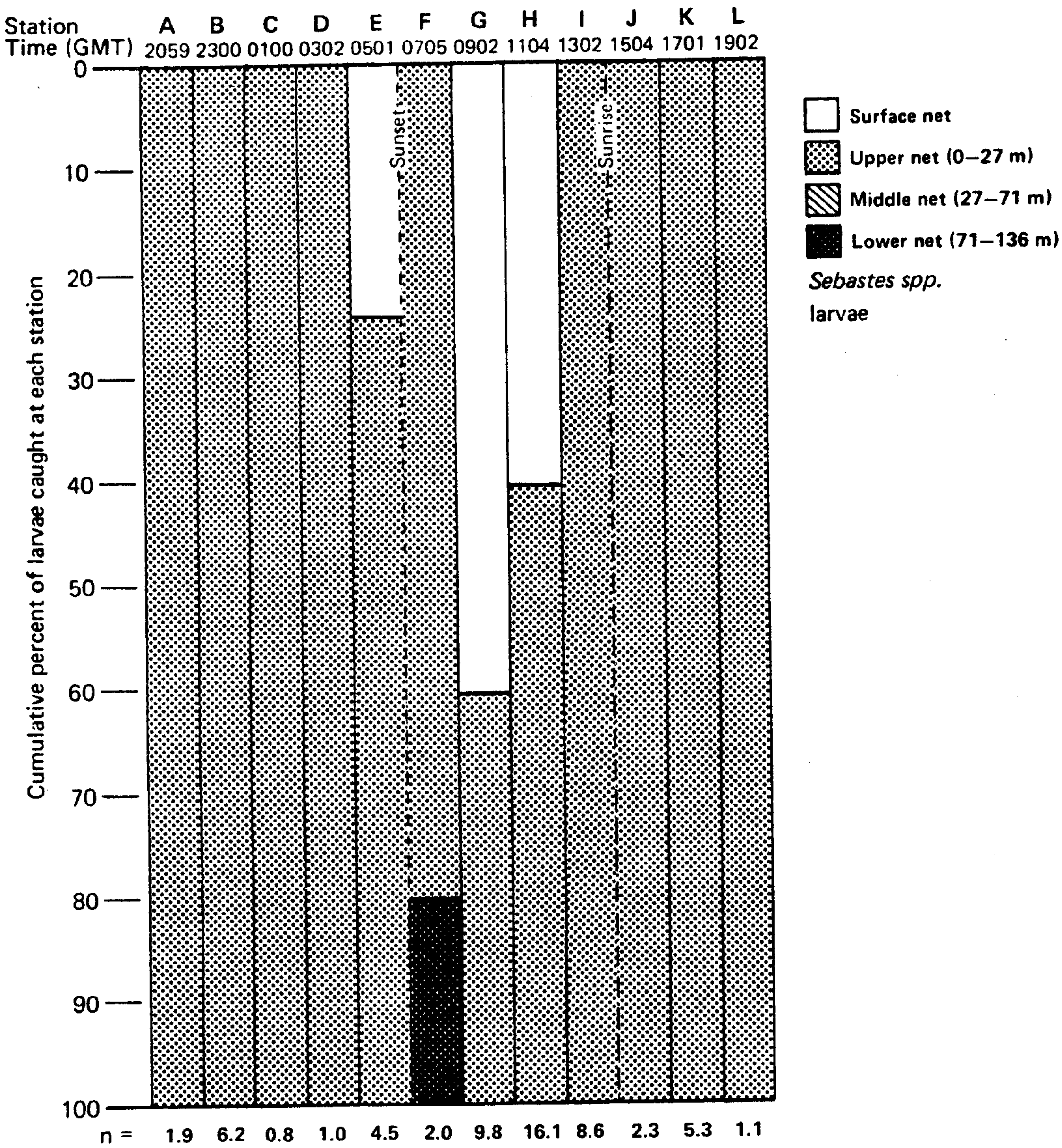


Figure 218.--Depth distribution with time of day of Sebastes spp. larvae at stations D01A-L (Diel 5), summer 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

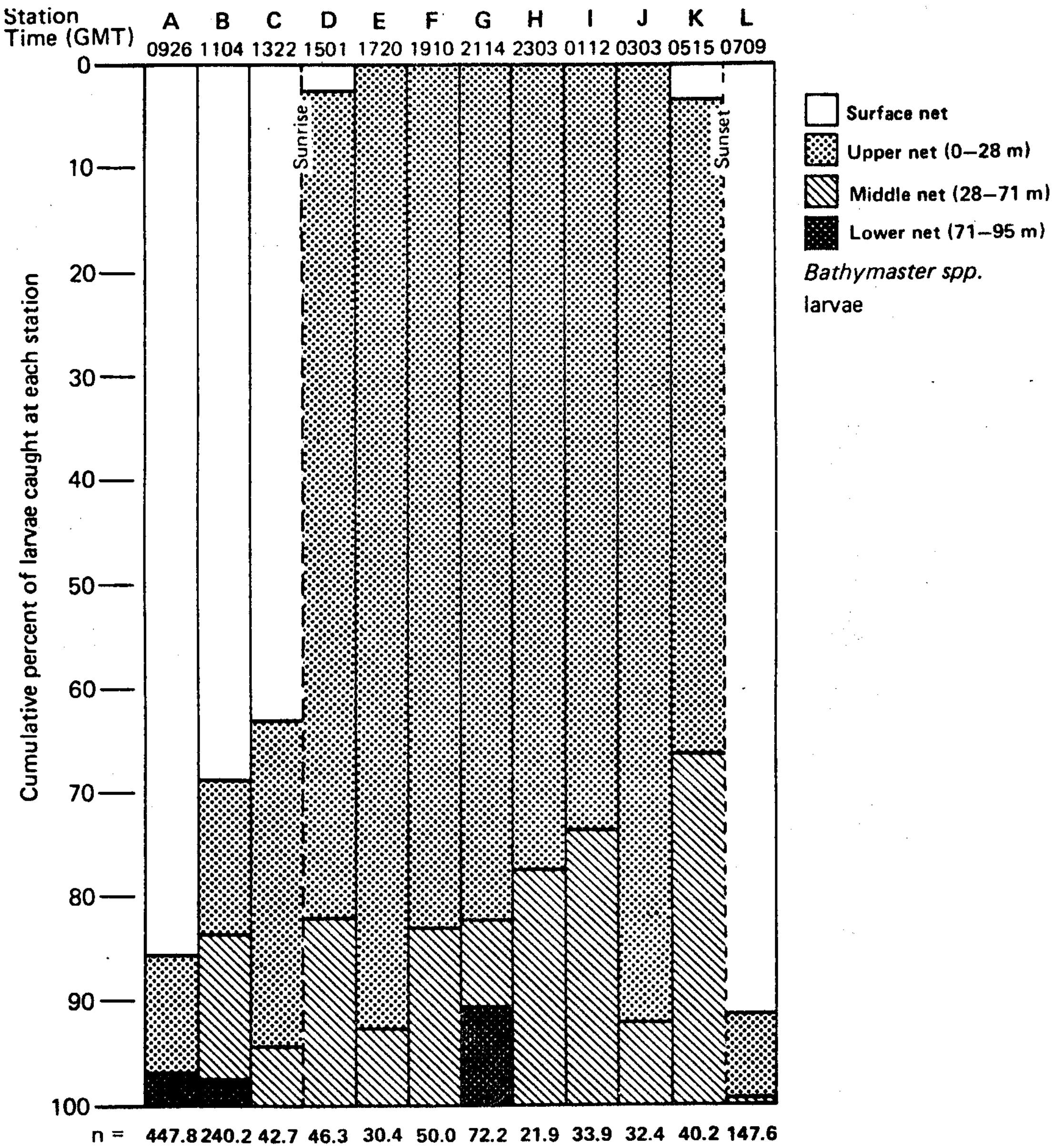


Figure 219.--Depth distribution with time of day of Bathymaster spp. larvae at stations D69A-L (Diel 6), summer 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

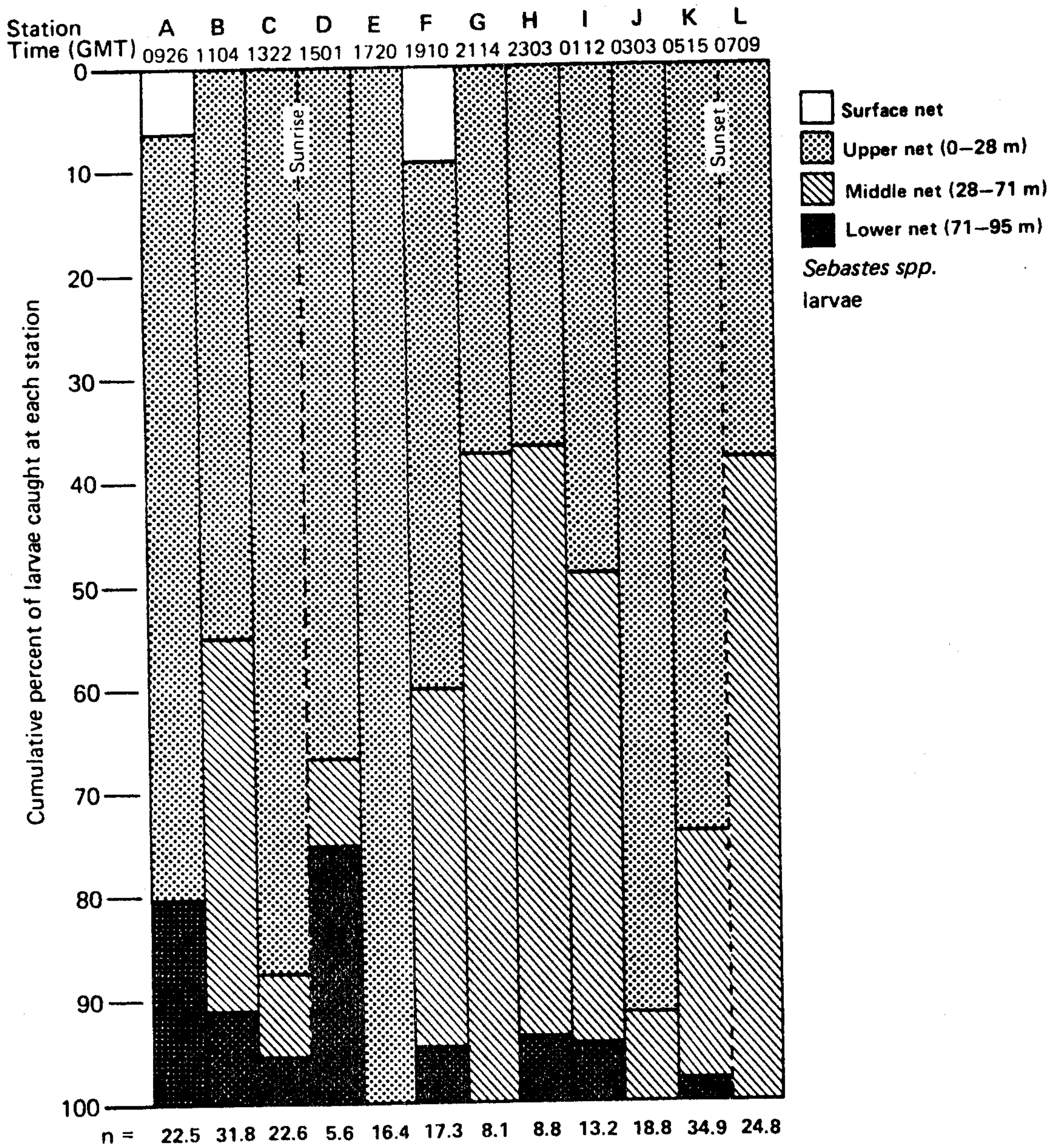


Figure 220.--Depth distribution with time of day of Sebastes spp. larvae at stations D69A-L (Diel 6), summer 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

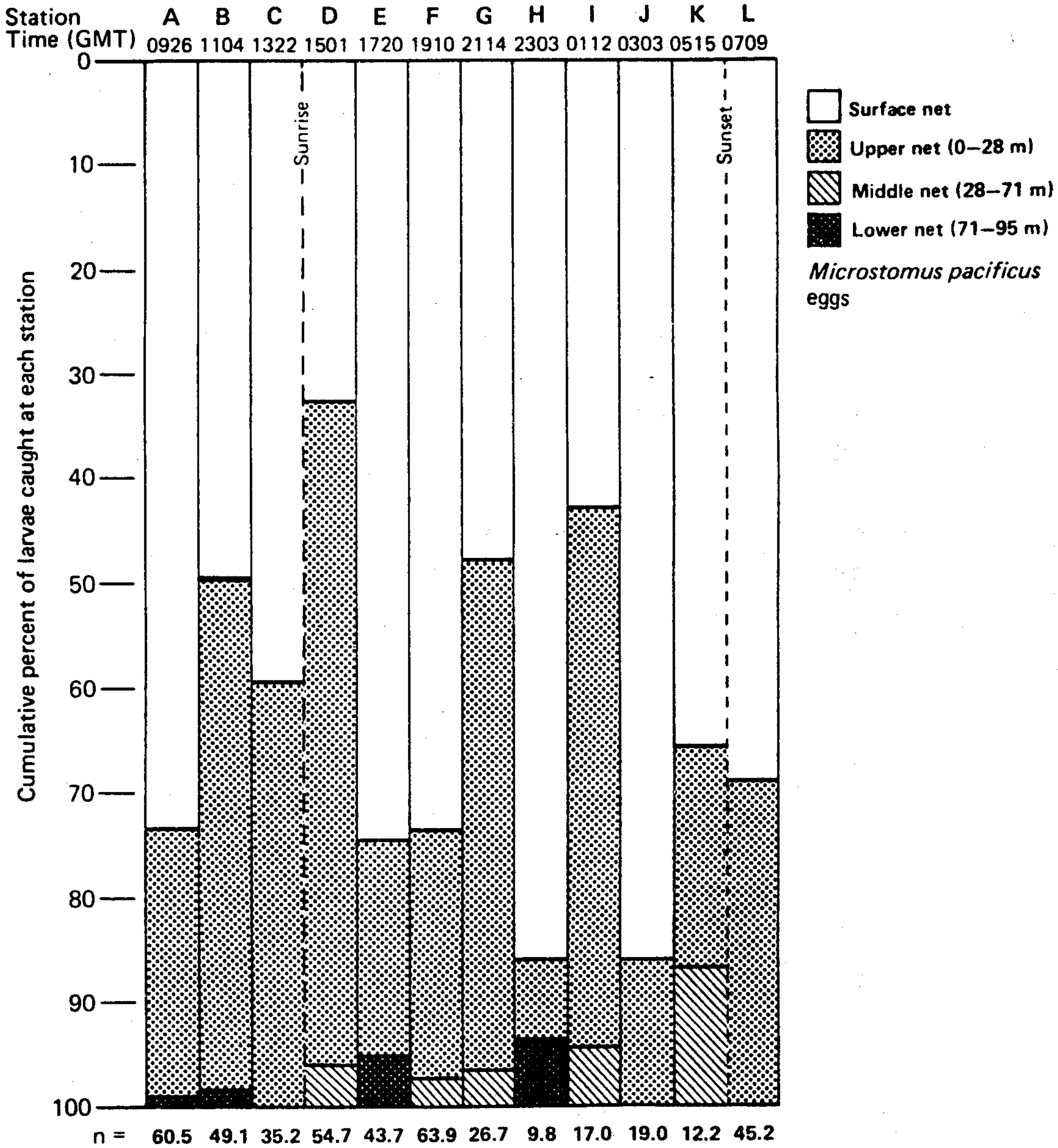


Figure 221.--Depth distribution with time of day of Microstomus pacificus eggs at stations D69A-L (Diel 6), summer 1978. n = numbers of eggs/100 m^3 caught in all nets at each station.

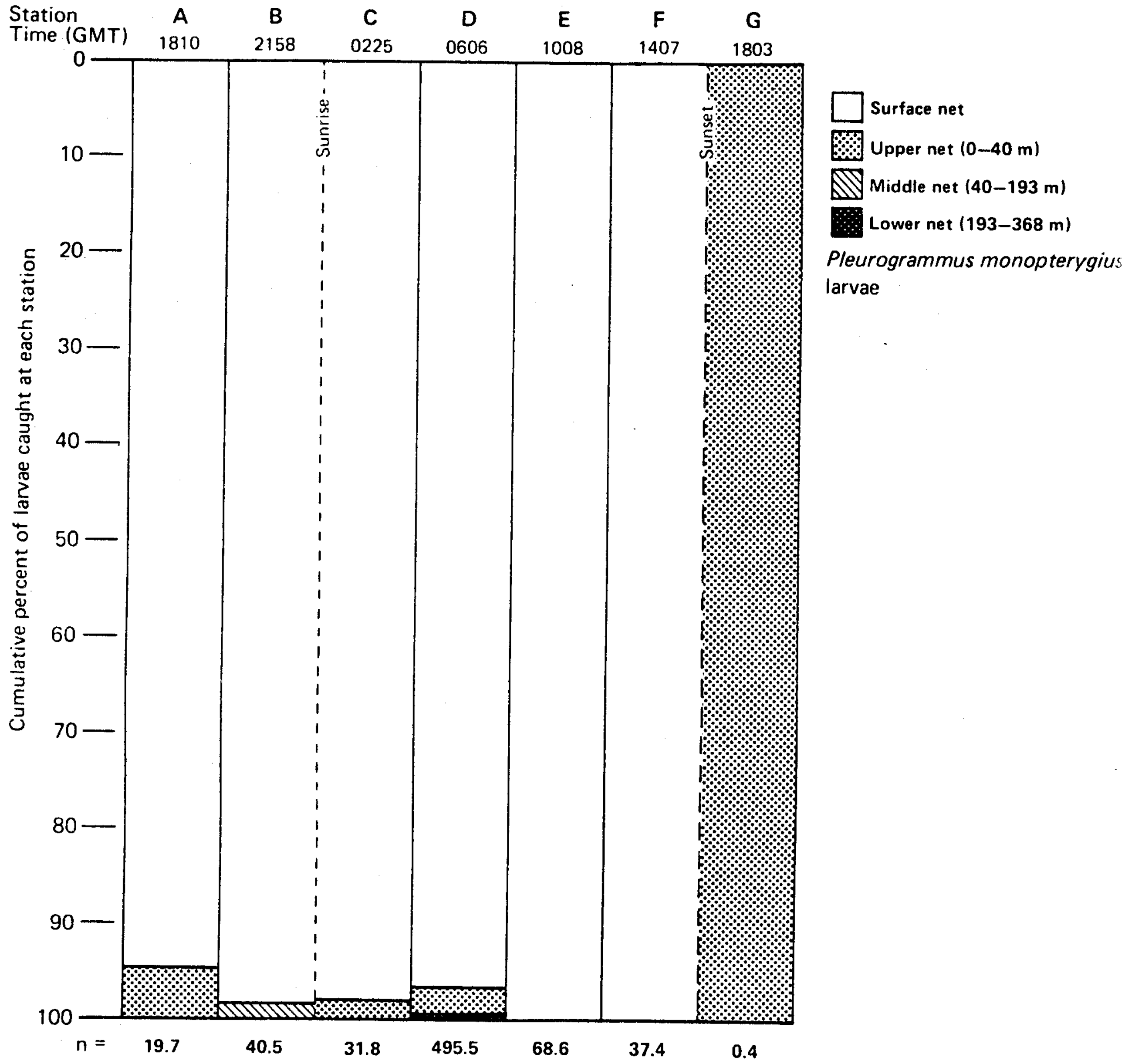


Figure 222.--Depth distribution with time of day of Pleurogrammus monopterygius larvae at stations D01A-G (Diel 7), fall 1978. n = numbers of larvae/100 m^3 caught in all nets at each station.

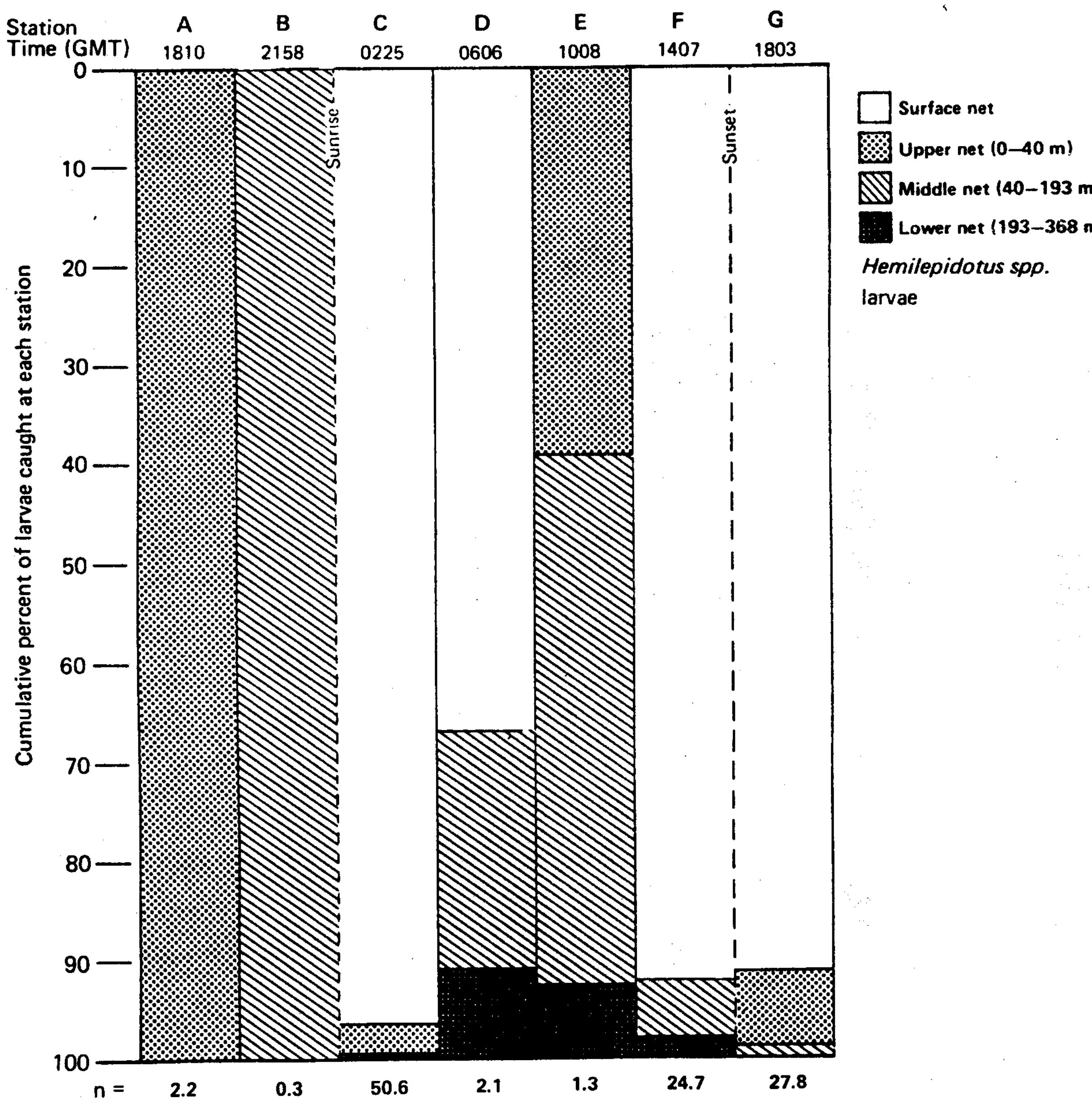


Figure 223.--Depth distribution with time of day of Hemilepidotus spp. larvae at stations D01A-G (Diel 7), fall 1978. n = numbers of larvae/ 100 m^3 caught in all nets at each station.

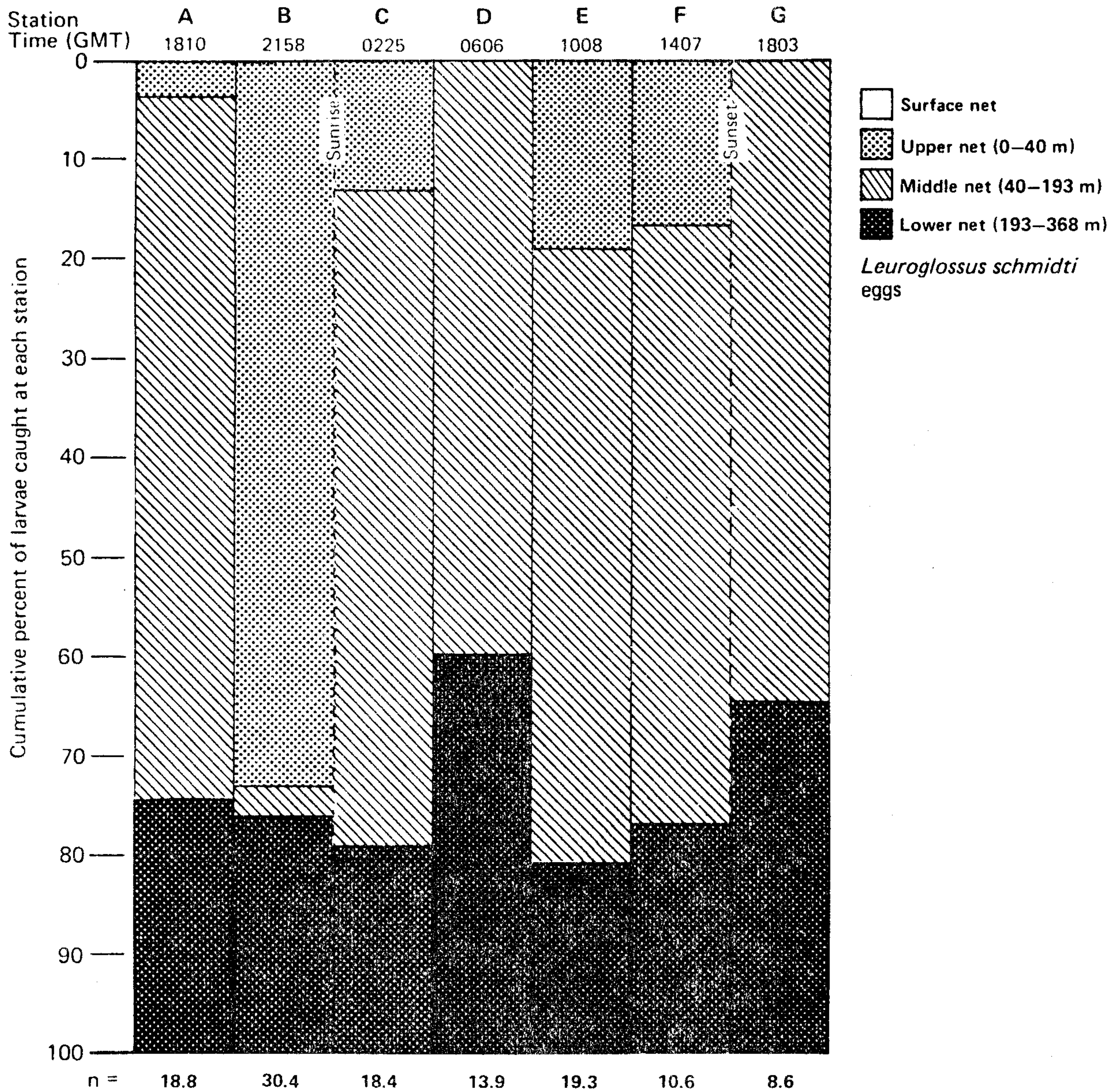


Figure 224.--Depth distribution with time of day of Leuroglossus schmidti eggs at stations D01A-G (Diel 7), fall 1978. n = numbers of eggs/100 m^3 caught in all nets at each station.

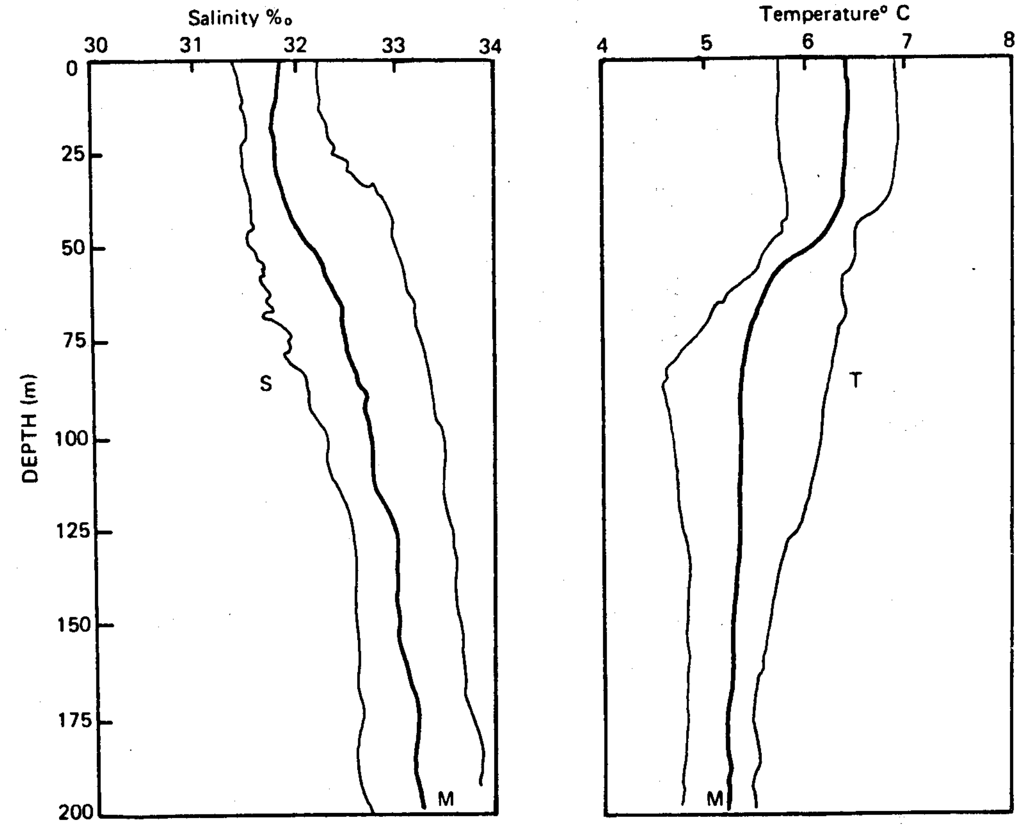


Figure 225.--Salinity (S) and temperature (T) profiles for stations D33A-L (Diel 1) and D35A-L (Diel 2), fall 1977. Bold lines represent average values (M) and fine lines represent the range during the 24 stations in these series.

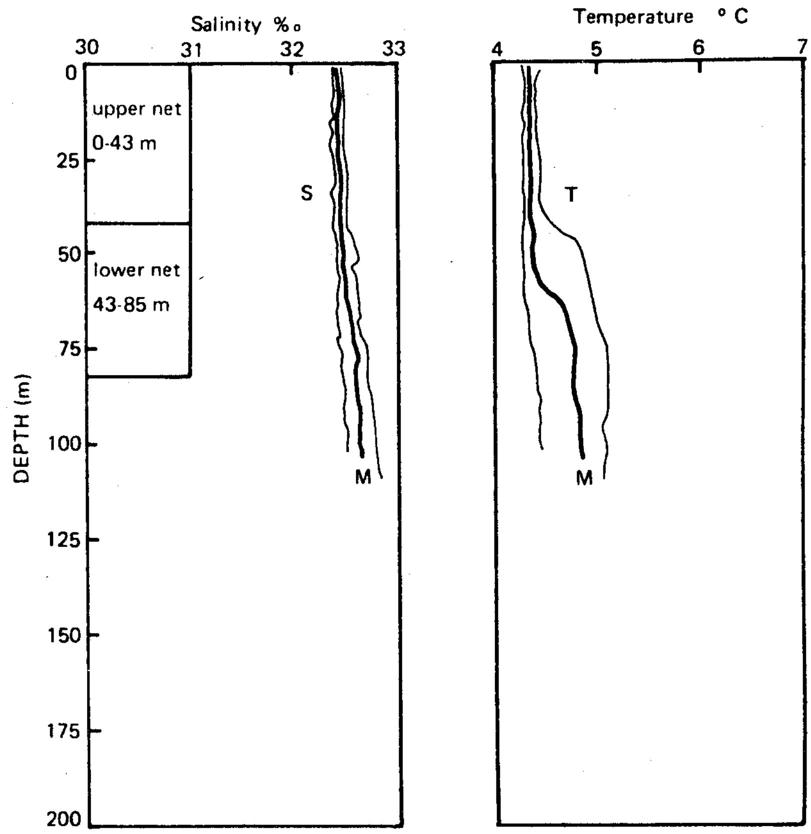


Figure 226.--Salinity (S) and temperature (T) profiles for stations D45A-L (Diel 3), spring 1978. Bold lines represent average values (M) and fine lines represent the range during the 12 stations in this series.

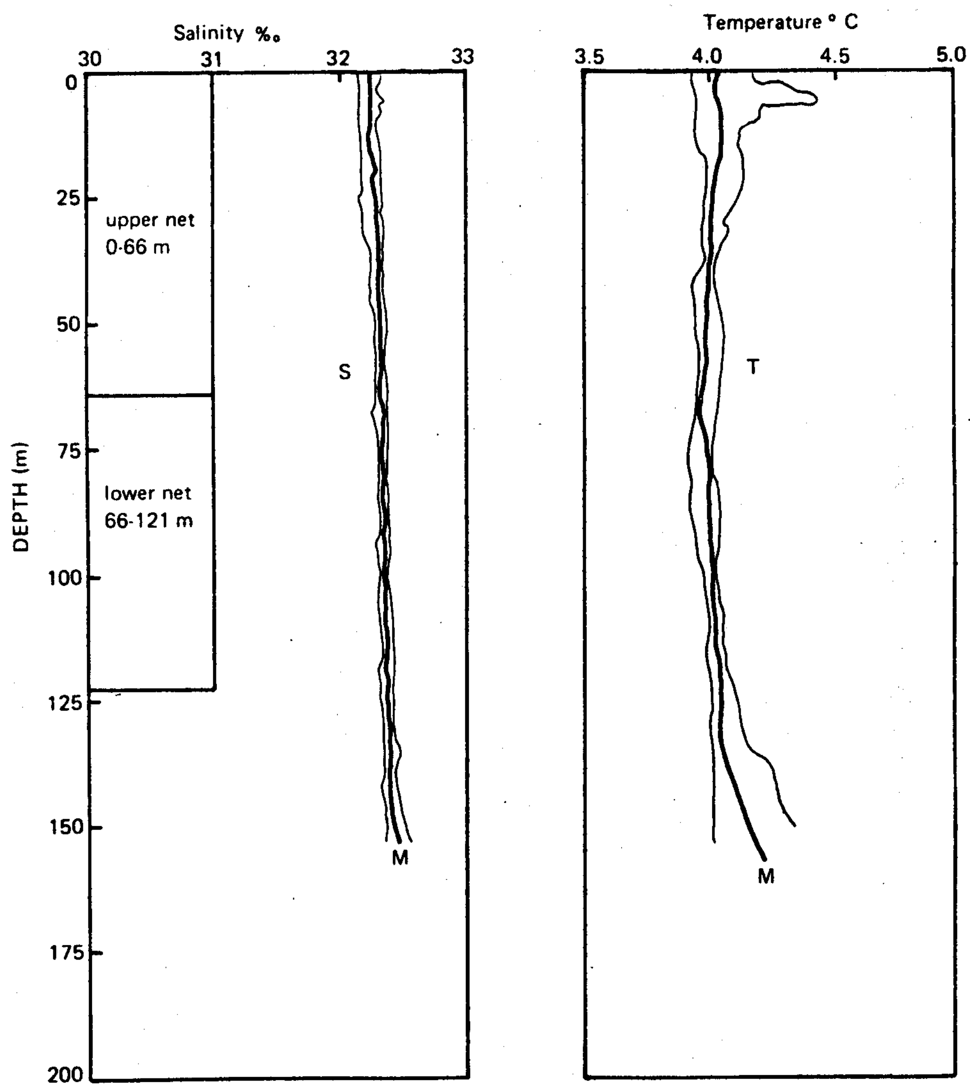


Figure 227.--Salinity (S) and temperature (T) profiles for stations D63A-L (Diel 4), spring 1978. Bold lines represent average values (M) and fine lines represent the range during the 12 stations in this series.

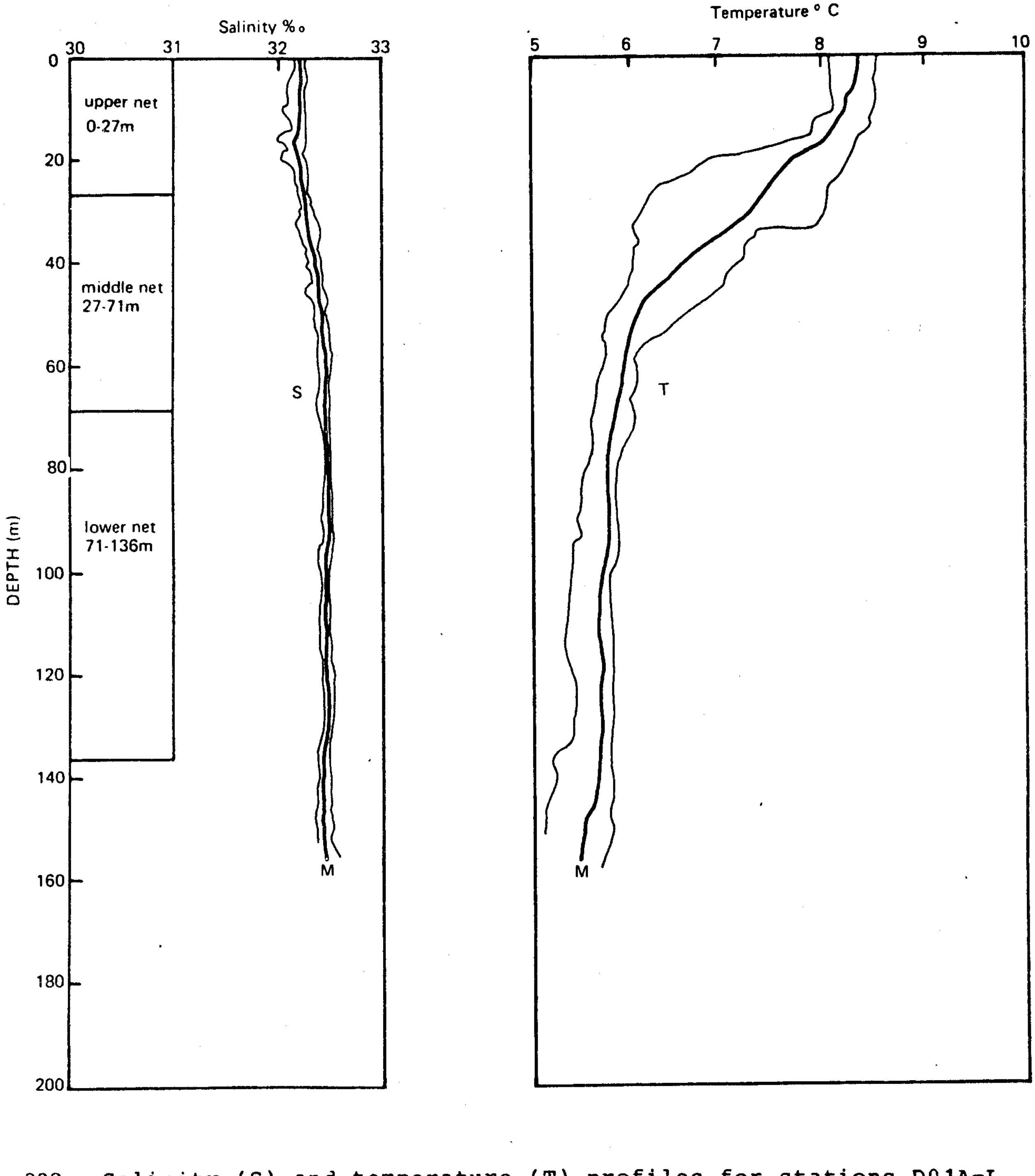


Figure 228.--Salinity (S) and temperature (T) profiles for stations D01A-L (Diel 5), summer 1978. Bold lines represent average values (M) and fine lines represent the range during the 12 stations in this series.

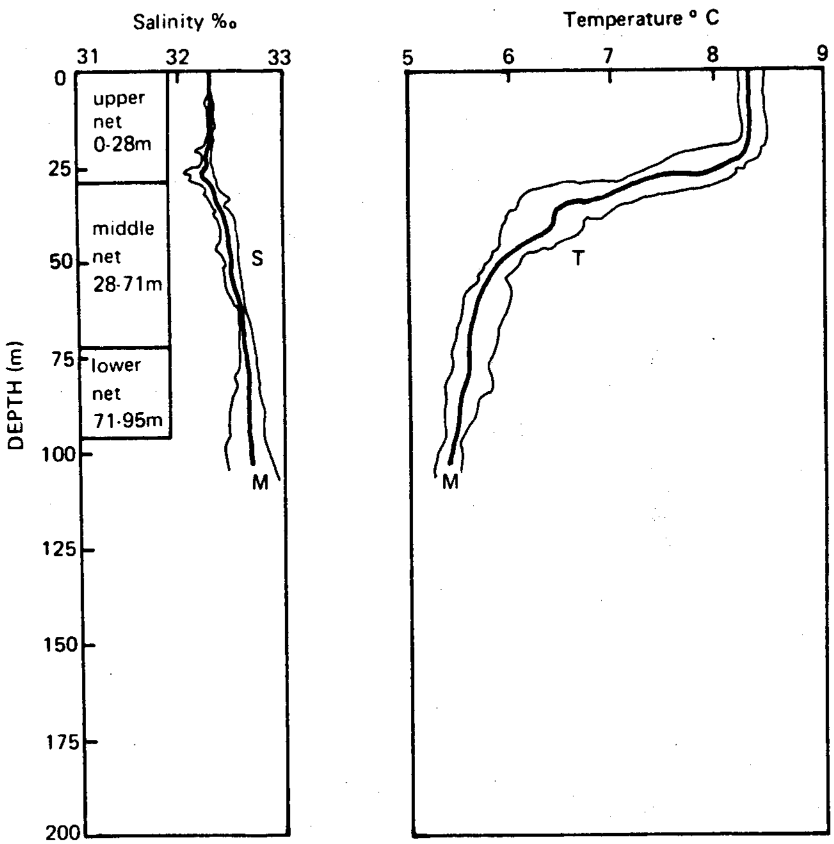


Figure 229.--Salinity (S) and temperature (T) profiles for stations D69A-L (Diel 6), summer 1978. Bold lines represent average values (M) and fine lines represent the range during the 12 stations in this series.

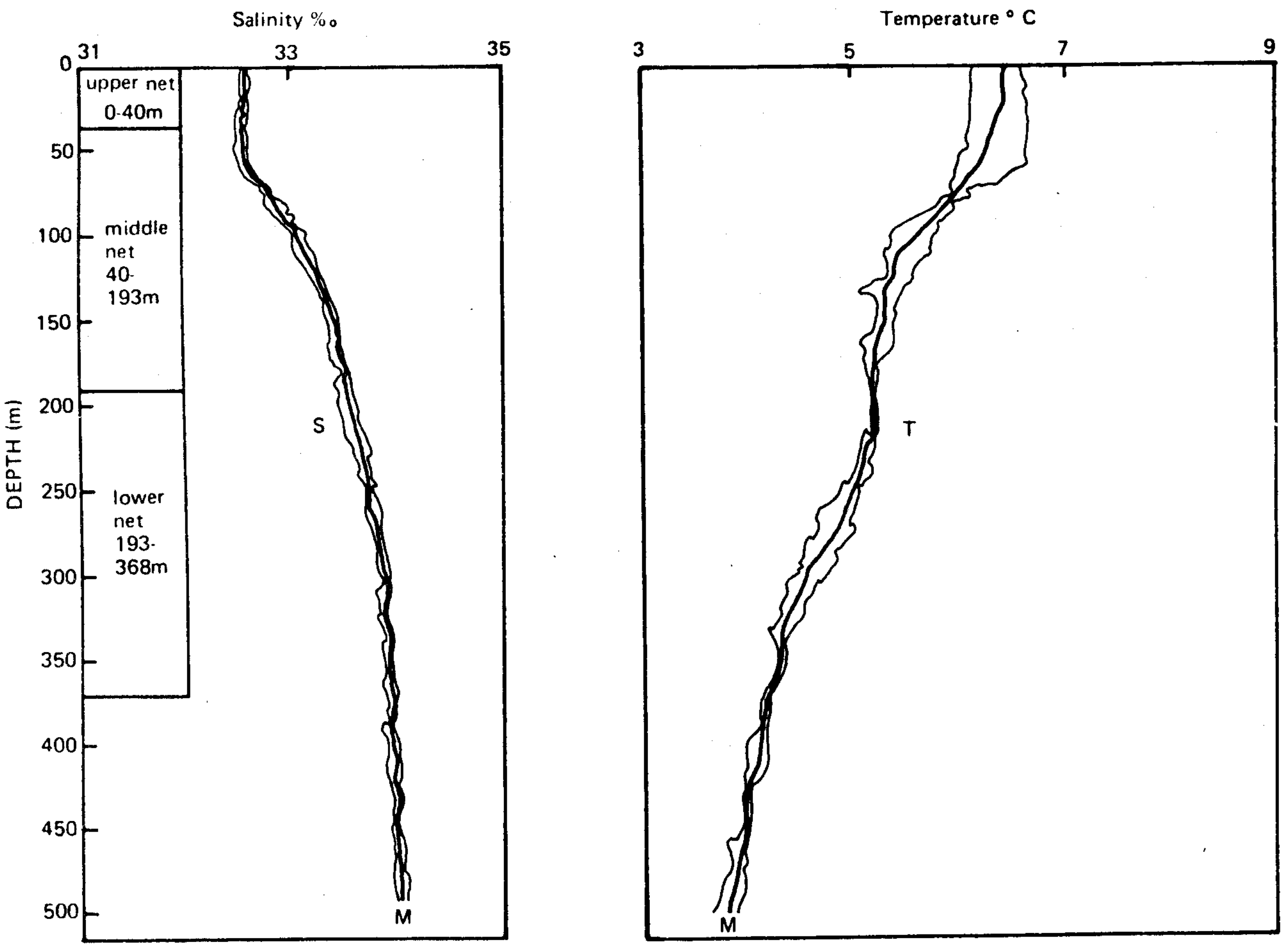


Figure 230.--Salinity (s) and temperature (T) profiles for stations D01A-G (Diel 7), fall 1978. Bold lines represent average values (M) and fine lines represent the range during the 7 stations in this series.

FINAL REPORT

Contract No.: R7120825
Research Unit: 551
Number of pages: 62

TAXONOMIC COMPOSITION, SEASONAL DISTRIBUTION, AND ABUNDANCE OF ICHTHYOPLANKTON IN THE NEARSHORE ZONE OF THE KODIAK ARCHIPELAGO, ALASKA

Co-Principal Investigators

Arthur W. Kendall, Jr. and Jean R. Dunn
with Ann C. Matarese
National Marine Fisheries Service
Northwest and Alaska Fisheries Center
Seattle, Washington 98112

and

Donald E. Rogers
with Kathryn J. Garrison
Fisheries Research Institute
College of Fisheries
University of Washington
Seattle, Washington 98195

TABLE OF CONTENTS

	Page
LIST OF TABLES	779
LIST OF FIGURES	780
INTRODUCTION	781
METHODS	781
RESULTS AND DISCUSSION	782
Analysis of Variance	782
Structure of Shelf Larval Fish Community	791
Relationship of Distribution of Young Stages	793
to Environmental Parameters	793
CONCLUSIONS	794
ACKNOWLEDGMENTS	794
LITERATURE CITED	796
TABLES	798
FIGURES	804
APPENDIX	808

LIST OF TABLES

Table 1. Number of occurrences and mean density (number/1000 m^3) of fish eggs and larvae collected in neuston tows during the five OCSEAP plankton cruises. (From Dunn et al. MS 1980)

Table 2. Total numbers ($\log_{10}$) of eggs and larvae of each taxon of fish estimated from catches in bongo tows during the five OCSEAP plankton cruises. (From Dunn et al. MS 1980)

Table 3. Number of positive hauls, percent occurrence (out of 289 hauls), and sum of the nos./1000 m^3 for larval fish and eggs caught by neuston 505μ net; numbers summed over all stations, cruises, and bays, Kodiak Archipelago, Alaska, 1978-1979. Listed by order of abundance as indicated by no./1000 m^3.

Table 4. Number of positive hauls, percent occurrence (out of 292 hauls), and sum of the nos./1000 m^3 and nos./10 m^2 for larval fish and eggs caught by bongo 505μ net; numbers summed over all stations, cruises, and bays, Kodiak Archipelago, Alaska, 1978-1979. Listed by order of abundance indicated by no./1000 m^3.

Table 5. Taxa dealt with in study of ichthyoplankton of Kodiak (larvae except as indicated).

Table 6. Summary of results of ANOVA on Kodiak Ichthyoplankton Survey.

LIST OF FIGURES

Figure 1. Subareas used for analysis of distribution of ichthyoplankton from the five OCSEAP offshore plankton surveys.

Figure 2. Station locations from OCSEAP plankton survey of bays of Kodiak.

Figure 3. Results of REGROUP of Kodiak ichthyoplankton study of offshore area. Analysis at affinity level of 0.4, run by cruise and gear. Boxes enclose taxa with affinities of ≥0.4. Lines connect taxa with affinities ≥0.4 that do not have affinities with all in the group (fractions indicate proportions of possible inter-group affinities found). Numbers of occurrences of the taxa are in parentheses after the name. Roman numerals are arbitrarily assigned group numbers.

Figure 4. Results of REGROUP of Kodiak ichthyplankton study of offshore area. Analysis at affinity level of 0.4, run with all cruises and gears combined. Notations as in Figure 3.

INTRODUCTION

This report summarizes the results of an ichthyoplankton survey conducted on the continental shelf and in four major bays of the Kodiak Archipelago. Results concerning the shelf survey alone were presented previously (Dunn et al., MS 1980) as were those concerning the bays alone (Rogers et al., MS 1979). The objectives of this survey were to determine the taxonomic, spatial and seasonal distribution of planktonic eggs and larvae of fish of the Kodiak area to help evaluate if, when, and where petroleum exploration and development could proceed to avoid impact to the fisheries resources of the area. Some understanding of the factors influencing the observed distributions was also sought.

The current state of knowledge of ichthyoplankton of the Kodiak area was reviewed in detail by Dunn et al. (MS 1980) and Rogers et al. (MS 1979). Briefly, insufficient work had previously been conducted to describe the ichthyoplankton community of the Kodiak area. Dunn et al. (MS 1980) list only six studies which even mentioned eggs and larvae of fish in the general vicinity of Kodiak Island.

METHODS

Details of field and laboratory procedures are given in Dunn et al. (MS 1980) and Rogers et al. (MS 1979). Gear and methods for the two studies were identical so the results obtained could be compared directly, without need for adjustments. Plankton was sampled at selected stations with Sameoto neuston nets and 60cm bongo nets equipped with 0.505mm mesh nets. Bongo net tows followed standard MARMAP procedures (Smith and Richardson, 1977). In the bays 26 stations were sampled on each of 12 cruises (five spring, five summer, one fall and one winter). Offshore about 90 stations were sampled on each of five cruises (one in each season except two in fall). Abundances of fish eggs and larvae were reported as numbers per 10 m^2 of sea surface. Larvae of selected species were measured to the nearest 0.1 mm SL using a scale on a microscope stage.

Planktonic early stages of over 110 taxa of fishes were collected in the survey. In the proposal for this study a list of possible species to be studied was given. However, upon examination of the bay and shelf bongo and neuston collections, it was found that some species listed in the proposal were too rare for more detailed study, while some species not listed in the proposal were quite abundant members of the ichthyoplankton community of the Kodiak area (Tables 1-4). From the total list of taxa collected, 30 were selected as being abundant enough in the bay or shelf collections to analyze their distribution using analysis of variance. For the analysis of variance we selected inshore taxa from the bongo catches that ranked in the 20 most abundant larval taxa. From the neuston catches, those larvae that ranked in the 10 most abundant taxa were analyzed. The three most abundant egg taxa from each gear type were also analyzed. For the analysis of variance of offshore taxa, those that were present in the bongo catches with an estimated total abundance in the survey area of $>10^{10}$ during at least one cruise and for the neuston catches those taxa that occurred at more than 35 stations on at least one cruise, were selected. The taxa dealt with in this report as well as those originally proposed for study are listed in Table 5.

To compare abundance of the selected taxa by season and location, data were subjected to analysis of variance (ANOVA) using BMD program 02V (Dixon, 1973). To homogenize the variances, since they were highly correlated with the means, the catches expressed as numbers per 10 m^2 of surface area were transformed to $\log_{10}(x+1)$. The factorial design for the bay study included 10 time periods (cruises) and 4 bays. Five stations within each bay were considered replicates (Fig. 2). Missing values were estimated by appropriate methods in Snedecor and Cochran (1971). The shelf survey area was subdivided into 16 adjacent areas of equal size (Fig. 1). Four stations within each of these areas were randomly chosen as data points, and considered replicates. Thus for the shelf area the factors were 5 time periods (cruises) and 16 areas. Values for missing data points were estimated from nearby data points (in time and place). The ANOVA was applied only to those cruises in which the considered taxon was collected.

The co-occurrence of larval fish in the shelf samples was investigated using REGROUP and a support program CONNEX (Fager, 1957). This program considers joint occurrences but does not deal with abundance. After trying several affinity levels, a level of 0.4 was chosen as demonstrating the most reasonable grouping of larval fish.

RESULTS AND DISCUSSION

Analysis of Variance

We found that the waters of the shelf and bays of the Kodiak area held a complex, diverse ichthyoplankton assemblage. Although several egg and larval types could not be identified to species, over 110 taxa were collected during this study. Among these, 30 taxa were considered abundant enough in shelf or bay samples, or both, to warrant further analysis. The following section details the results of analysis of variance performed on these taxa. These taxa and where significant differences were found with time or location are listed in Table 6. Where significant differences in abundance were found, they are discussed on a taxon by taxon basis in the following section. Mean catches by area, time and gear for the taxa discussed in the following section are given in the Appendix.

Osmeridae - smelts

Smelt larvae identified only to family level were caught year-round in the inshore bay area. They were collected in 8 out of 10 cruises but occurred in large numbers only during summer. In the offshore area smelt larvae were identified to species level when possible (when >30mm SL); smaller larvae which could be identified only to family level are reported only from the summer cruise. Larvae occurred in both neuston and bongo tows but were far more abundant in bongo tows for both the inshore and offshore areas. They occurred in over 20% of the bongo tows during the summer offshore cruise. Inshore, the highest cruise abundance for both bongo and neuston catches occurred during the 15-21 Aug cruise. During summer when larvae identified as osmerids were collected in the offshore area there was a large difference in abundance in bongo tows between the bays and the offshore area, over 170 times more larvae were caught inshore (21-29 Jul) than were caught offshore (19 Jun-9 Jul). Differences in abundance between bays occurred in mid June and late August when catches in Izhut Bay ranked highest. Larvae were more abundant at the shorewardmost stations especially near Izhut and Chiniak bays, and along the easternmost parts off Kodiak Island than at other offshore stations.

Mallotus villosus - capelin

Capelin larvae were identified only from the offshore cruises and in all seasons but summer when osmerid larvae which were too small for specific identification were abundant. Larvae were collected in both neuston and bongo tows but were much more abundant in bongo catches where they occurred in over 38% of the tows during three out of the four cruises in which they occurred. The highest abundance occurred during fall 1978 but larvae were also abundant in winter. Larvae were widespread but concentrated over the northeast part of Kodiak Island over Portlock and North Albatross banks.

Larvae enter the plankton in summer and remain there until the following spring. In fall their mean lengths in bongo tows were 22mm SL, in winter 40mm SL, and in spring 41mm SL. We did not catch larvae longer than 55mm SL.

Leuroglossus schmidti - Northern smoothtongue

Northern smoothtongue eggs and larvae were primarily collected in bongo tows in the offshore region only. Eggs occurred during every season but spring, and larvae occurred year-round. Eggs occurred primarily in fall when in 1977 they were found in 12.1% of the bongo tows and in 1978 in 28.4% of the bongo tows. The highest mean abundance of eggs occurred during the fall 1978 cruise. Larvae were found in greatest amounts during winter when they occurred in over 19% of the bongo tows. Eggs were found offshore near the shelf edge while larvae were slightly more widespread although also found well offshore. During summer, larvae occurred in more eastern areas over Stevenson Entrance.

Stenobrachius leucopsarus - Northern lampfish

Northern lampfish larvae were in small numbers year-round in offshore waters, but not at all in bays. Larvae were collected only in bongo tows where in summer they occurred in 27% of the tows. More larvae occurred during summer than during other seasons. About equal catches of larvae were made during spring and winter and the lowest catches were during fall. There were differences in abundance among offshore areas, as larvae were more abundant in the eastern portion of the study area and over Kiliuda Trough.

Theragra chalcogramma - Walleye pollock

Walleye pollock eggs were collected year-round in both neuston and bongo samples and in both offshore waters and in bays. Larvae were collected primarily in bongo tows in spring from both inshore and offshore areas. The highest cruise abundance for eggs and larvae in the inshore area occurred during the 21 Apr-1 May cruise. In the offshore area, the highest cruise abundance for both eggs and larvae was during the spring cruise. During spring cruises four times more eggs and larvae occurred in the bays than offshore.

The overall mean abundance of eggs in the inshore areas was greatest in Kaiugnak Bay and least in Izhut Bay. In the offshore areas, eggs occurred in greatest concentrations toward the southern end of Kodiak Island near Shelikof Strait and around the Kiliuda Trough - Horsehead Basin area. For walleye pollock larvae, the overall mean abundance was greatest in Chiniak Bay and least in Kaiugnak Bay. The highest concentration of larvae in the offshore areas was near Shelikof Strait.

Sebastes spp. - Rockfishes

Rockfish larvae were caught during summer and fall in offshore waters, and in late spring and summer in the bays. They were primarily collected in bongo samples, where they occurred in more than 50% of the tows in the offshore summer cruise. The highest mean abundance in the inshore area occurred during the 15-21 Aug cruise, and offshore it occurred during the summer cruise. Larvae were collected in greatest amounts in Izhut and Chiniak bays and to a lesser extent in Kiliuda and Kaiugnak bays. There were also differences in mean abundance among the offshore areas where larvae were most abundant off the easternmost portions of Kodiak Island over North Albatross and Portlock banks.

Hexagrammos decagrammus - Kelp greenling

Kelp greenling larvae were caught year-round in offshore waters, and in all seasons but summer in the bays. They were primarily found in neuston samples, where they occurred in more than 50% of the tows in three of the five offshore cruises. The highest cruise abundance in the inshore area occurred during the 21 Apr-1 May cruise, and offshore it occurred during the spring cruise, although they were nearly as abundant in winter. They were similar in abundance among the four bays, but among the offshore areas, they were most abundant in waters over the Horsehead Basin and Chiniak Trough areas. From the larval lengths it appears that kelp greenling enter the plankton in fall and winter and remain there until the following summer.

Hexagrammos lagocephalus - Rock greenling

Rock greenling larvae were caught in the neuston net in the two fall offshore cruises and they occurred throughout the summer and fall in neuston catches in the bays. Offshore they were most abundant off Izhut Bay and the abundances in bays and offshore in fall were comparable. Rock greenling probably spawn mainly in bays in the Kodiak area, therefore their seasonal appearance is earlier there than offshore. Larvae as small as 5.5mm were taken in bays during late summer, whereas in fall, larvae in both inshore and offshore areas averaged between 11-12mm.

Hexagrammos octogrammus - Masked greenling

Larvae of masked greenling were caught primarily in the neuston net, in summer and fall in the bays and in all cruises offshore except spring. They were most abundant in late summer-early fall in the bays and most abundant in fall offshore. They were uniform in abundance among the bays and offshore areas, however the abundances were rather low. In offshore waters the smallest larvae were taken in the fall, and the largest in the summer. In the bays, larvae during summer ranged from 4.5-10mm and during fall they ranged from 6.5-14.5mm.

Hexagrammos stelleri - Whitespotted greenling

Whitespotted greenling larvae occurred in all offshore cruises in both bongo and neuston tows and occurred in neuston tows in the bays in fall through early spring. In the bays they were most abundant in fall and winter, and offshore in fall. Offshore they were most abundant in the southern areas, whereas inshore they were most abundant in Izhut and Chiniak bays. In offshore waters the mean lengths increased from 10-12mm in fall through winter and spring to 51mm in summer. In bay areas, the smallest larvae (~5.0mm) also occurred in fall. During winter and spring larvae ranged from 8.0-30.5mm.

Pleurogrammus monopterygius - Atka mackerel

Atka mackerel larvae occurred primarily in offshore samples in both neuston and bongo tows in all seasons except summer. A few were caught in neuston tows in the bays in fall and winter. The areas of abundance offshore were near the edge of the shelf over Middle Albatross Bank. In bongo catches they were also abundant off Chiniak Bay. Mean lengths of Atka mackerel increased from about 10mm in fall to 14mm in winter, in both the inshore and offshore areas. By spring, 18mm larvae were caught in the offshore area only.

Cottidae - Sculpins

Thirty-eight species of marine sculpins are reported from the Kodiak Shelf area (Science Applications, Inc., MS 1977). They occur primarily in shallow water and several are abundant in the intertidal zone. The larvae of many of these can only be identified to genus and in some cases can only be "typed." Larval sculpins were numerically important in the bays of Kodiak Island and larvae of at least 25 species were collected. Most sculpins were collected in greatest abundance with the bongo net; however, catches of *Myoxocephalus* types A and B and *Hemilepidotus* spp. were relatively high in neuston samples. Other sculpins of relative numerical importance were Cottidae type L (believed to include species of *Artedius*, *Clinocottus*, and/or *Oligocottus*), Cottidae type I (possibly *Icelinus* and/or *Icelus* species), *Icelinus* spp. and *Gymnocanthus* spp.

In the offshore bongo tows, sculpins were analyzed as a group and were more abundant in summer than during other seasons. Areas of abundance shifted from cruise to cruise and probably reflected different areas and seasons of abundance for larvae of various species in this family.

Hemilepidotus spp. - Irish lords

Irish lord larvae were caught offshore in both bongo and neuston tows and occurred over a wide area. Four species in this genus are found in the Gulf of Alaska, and are not separated in our samples until they reach a large size (>12mm). They were caught in the neuston net from all the offshore cruises and in the bongo net from all but the summer cruise. A few were caught in neuston tows in the bays, during one spring cruise and during the fall and winter cruises. In both nets the maximum abundance offshore occurred during the fall 1977 cruise and they were also abundant in the fall 1978 cruise. In the bays the maximum abundance was in the fall also. Areas of abundance in the offshore cruises were just off Kiliuda Bay and near the edge of the shelf off Chiniak Trough.

Myoxocephalus Types

Three species of *Myoxocephalus* occur in the Northeast Pacific, *M. jaok*, plain sculpin, *M. polyacanthocephalus*, great sculpin, and *M. niger*, warthead sculpin (Howe and Richardson, MS 1978). We recognized larvae of two distinct types (called A and B) from samples taken in the bays. Type A resembled larval great sculpin described briefly by Blackburn (1973) from Skagit Bay, Washington, and adults are very abundant in Kodiak bays (Harris and Hartt, MS 1977). Identification to species for type B is not possible at present.

Larval *Myoxocephalus* types occurred primarily during spring and type B was more abundant than type A. Averaged over all times, there were no significant differences between bays for catches of both *Myoxocephalus* types.

Cyclopteridae - Lumpfishes and Snailfishes

Snailfish and lumpfish larvae were analyzed at the family level in the bay samples and occurred primarily in bongo catches. Larvae were found in all seasons except fall and the highest mean catch over all bays occurred in late April. The catches were uniform among bays.

Bathymasteridae - Ronquils

Ronquil larvae collected in bays were identified only to family whereas those collected offshore were identified as either members of the genus *Bathymaster*, searchers, or as *Ronquilus jordani*, northern ronquil. In the bays ronquil larvae were caught in both gear types in April through August and occurred in 46% of the bongo tows and 17% of the neuston tows. In bongo samples, larvae were most abundant in spring during late May and early June and most abundant in Izhut Bay. In neuston samples they were evenly abundant among bays and cruises.

Bathymaster spp. - Searchers

The genus *Bathymaster* contains three species of ronquils, *B. caeruleofaciatus*, *B. leurolepis*, and *B. signatus*, reported from the Gulf of Alaska. Information on the taxonomy and life history of members of this genus is limited and at present we are unable to distinguish larvae of the three species. Searcher larvae were caught in the offshore sampling area in all seasons, but were found in abundance only in the summer in bongo nets, where they occurred at 93% of the stations sampled. The variation of mean abundance with time (cruise) differed for both bongo and neuston catches, but areal catches were different only for bongo catches in the summer, when they were greater over Portlock and North Albatross banks than to the west.

Ronquilus jordani - Northern ronquil

Larvae of northern ronquil were caught only in the offshore sampling area in bongo nets in the summer, where they occurred at 24% of the stations. There was no difference in abundance among various areas sampled.

Lumpenus maculatus - Daubed shanny

Larvae of daubed shanny were collected in bongo nets in the inshore area from late March through early June 1978, where peak abundance occurred from Apr 10-17. This species was more abundant in Kaiugnak and Chiniak bays than in either Izhut or Kiliuda bays.

Lumpenus medius - Stout eelblenny

Larvae of stout eelblenny were taken in bongo nets in the inshore area in winter, spring and early summer. Peak abundance occurred in late March-early April, and the mean catch was highest in Kiliuda Bay and lowest in Izhut Bay.

Ammodytes hexapterus - Pacific sand lance

Larvae of Pacific sand lance occurred in the four bays in bongo nets primarily from early March through mid-June. In offshore waters, they were caught primarily in bongo nets in winter through summer. In the bays, abundance of sand lance larvae differed by time period, but no differences in abundance among bays was observed. Peak abundance occurred in late March-early May in the four bays. In the offshore sampling area the catches were largest in the spring when they were caught in nearly 68% of the tows. Mean catches were generally larger in the nearshore areas as opposed to offshore areas. From the length frequency distribution of the larvae it appears that sand lance enter the plankton in winter and remain there until the following summer in the offshore area, but dissappear from inshore plankton catches in late June.

Unidentified Pleuronectid Eggs

Unidentified flatfish eggs were caught in neuston and bongo nets in bays as well as offshore. The majority of these were early and middle stage eggs about 1 mm in diameter, and are most likely of four possible species: starry flounder (*Platichthys stellatus*), sand sole (*Psettichthys melanostictus*), English sole (*Parophrys vetulus*) or butter sole (*Isopsetta isolepis*).

In bays, unidentified flatfish eggs were collected in the neuston sampler from early March through mid-August. The largest catches occurred in late June and early July. Catches also differed among bays with larger mean catches in Kiliuda Bay than in the other bays. Catches of unidentified flatfish eggs in bongo nets in the bays were made from late March through late August. Differences were found in catches among bays and sampling periods. Maximum catches occurred in mid-July and early August, and the highest overall mean catch of eggs was in Kiliuda Bay. In the offshore area, unidentified flatfish eggs were collected in bongo and neuston nets in spring and summer primarily in the nearshore areas.

Glyptocephalus zachirus - Rex sole

Rex sole eggs and larvae were rarely found in inshore samples; however, they were caught in the summer in the offshore area in both neuston and bongo nets. Rex sole eggs occurred in bongo nets at 26% of the stations sampled and in neuston nets at 27% of the stations in the offshore area, but the mean catch was much larger in the bongo nets. Rex sole eggs were mainly over the slope area and abundance of eggs differed among areas. Rex sole larvae were taken primarily in bongo nets and they occurred at 32% of the stations sampled. Differences in abundance of larvae among areas were not detected, but larvae tended to occur primarily over slope waters.

Hippoglossoides elassodon - Flathead sole

Eggs and larvae of flathead sole were caught in bays and in the offshore sampling area in both bongo and neuston nets. In bays, flathead sole eggs were caught in neuston nets from late March through late August and in bongo nets from late March to early August. The largest catches in the neuston net occurred in mid-June, and the abundance of eggs in the neuston samples did not differ among bays. The largest catches of eggs in the bongo net occurred in late April to May 1, and the mean catch in Kaiugnak Bay was larger than in the other three bays. Flathead sole eggs in offshore areas occurred mainly in bongo nets (1% of the stations in winter, 11% in spring, and 29% of the stations in summer). Abundance of eggs differed among time periods (largest catches occurring in the summer) but not among areas.

Larvae of flathead sole were caught in bays primarily in bongo nets from from late April to early November. Differences in abundance of larvae occurred among sampling periods, with the largest catches in late May - early June. Catches of larvae did not vary significantly among bays. In the offshore area, larvae were caught only in the summer and mainly in bongo nets in which they occurred at 46% of the stations sampled.

Isopsetta isolepis - Butter sole

Butter sole eggs were not specifically identified from bay areas, but may be included in "unidentified" flatfish eggs from that area. In the offshore cruises, only late stage butter sole eggs were identified. They were caught primarily in bongo nets during spring and summer, and the largest mean catches were in the latter time period. In summer most eggs were caught over Middle Albatross Bank. Butter sole larvae, however, were found in bongo catches in the bays as well as in the offshore zone. In the bays, they were in greatest abundance in late July and mean catches were greatest in Kaiugnak Bay. In the offshore area, catches of larvae were made in summer only, when they were in 18% of the tows. Abundance of larvae among areas differed as they occurred primarily over the slope area and northwest of the Trinity Islands.

Lepidopsetta bilineta - Rock sole

Rock sole larvae were caught primarily in bongo nets in bays and in the offshore sampling area from late March through early August. In the bays the largest catches were in Chiniak and Kaiugnak bays. Differences occurred among sampling periods in the bays and the peak of abundance was in late April - early May. In the offshore area, rock sole larvae were caught in spring at 35% of the stations and summer at 27% of the stations, but differences were not found in mean catches between the two sampling periods. Larvae occurred primarily over the mid-shelf areas. Because rock sole spawn demersal eggs, they were not collected in our sampling gear.

Limanda aspera - Yellowfin sole

Yellowfin sole larvae were collected mainly in the bays from late July through late August. Differences in catches occurred among sampling periods, with a peak in early August. No yellowfin sole larvae were collected in Izhut Bay and mean catches were highest in Kaiugnak Bay. In the offshore area, yellowfin sole eggs were caught only in the summer in both the neuston and bongo nets. They were concentrated primarily nearshore.

Microstomus pacificus - Dover sole

Dover sole eggs and larvae were primarily in the bongo nets in the offshore sampling area. Eggs were caught in summer at 35% of the stations although a few eggs occurred in neuston nets in the spring. Differences in abundance of eggs in summer occurred among sampling areas; these eggs were usually between the 200m - 2000m contour. Larvae of dover sole were caught primarily in bongo nets and only in summer when they were collected at 20% of the stations sampled. Catches did not differ among areas.

Psettichthys melanostictus - Sand sole

Larvae of sand sole were caught in bays as well as in the offshore sampling area. Late stage eggs of sand sole were identified only from the offshore areas in the summer where they occurred at only 1% of the stations. Catches of larvae in bays occurred from late May through late August. The largest mean catches were in late July, whereas abundance did not differ among bays. In the offshore area, sand sole larvae were collected only in the summer when they were caught at 41% of the stations. Catches tended to be greater over Middle and North Albatross banks than in other areas.

Structure of Shelf Larval Fish Community

Since we caught over 110 taxa of larval fish in the plankton during the shelf cruises off Kodiak, an important question was which of these taxa co-occur, and thus may influence each others' survival through such factors as competition for food or predation. To determine which species co-occurred we used recurrent group analysis (using a computer program called REGROUP). This procedure has previously been used for a variety of community structure studies (Fager and Longhurst, 1968; Fager and McGowen, 1963; Kendall, 1975; Loeb, 1979; Venrick, 1971).

For the analysis of the shelf ichthyoplankton data, an affinity level of 0.4 was selected. The data were analyzed by each gear and cruise separately, and then with all data combined. Only groups in which at least one taxon occurred five or more times in a particular gear-cruise combination were included.

In the neuston tows from the fall cruises of both years (1977 and 1978) similar groups of species were present. These consisted of larvae of several species of hexagrammids and _Hemilepidotus_ spp. _Mallotus villosus_ and _Bathymaster_ spp. were associates of some of the group members in fall 1978. In the bongo catches no similar groups were found in 1977 but in 1978 a group composed of _Hemilepidotus_ spp. and _Bathymaster_ spp. was present.

In winter in neuston catches there was the same basic group (hexagrammids and _Hemilepidotus_ spp.) as in fall. In bongo catches in winter _Hemilepidotus_ spp. and _Hexagrammos decagrammus_ formed the only recurrent group.

In spring in the neuston catches a group similar to that found in fall and winter was present. It consisted of two species of _Hexagrammos_ and _Hemilepidotus_ spp. _Lyconectes aleutensis_ and _Pleurogrammus monopterygius_ were associates of some members of this group. A second group composed of _Ammodytes hexapterus_ and Stichaeidae was also present in the neuston catches. In the bongo catches in spring a group consisting of _Ammodytes hexapterus_ and _Lepidopsetta bilineata_ was found with _Hemilepidotus_ spp. and _Gymnocanthus_ A. as associates. A second group composed of Cyclopteridae and _Pholis_ spp. was present in bongo catches.

In summer the ichthyoplankton community was more complex than in other seasons as reflected by both the bongo and neuston catches. In neuston catches two groups were found with some association between the groups. Altogether eight species were grouped with each other in some way. The larger group consisted of _Bathymaster_ spp., _Lyconectes aleutensis_ and _Ammodytes hexapterus_. The other group included _Sebastes_ spp. and _Hemilepidotus_ spp. Associated with the larger group were _Hexagrammos decagrammus_, _Hemilepidotus hemilepidotus_, and _Myoxocephalus_ spp. In bongo catches in summer an even more complex community was evident when four groups were found and 13 species were grouped. _Lepidopsetta bilineata_ and _Radulinus asprellus_ formed a group not associated with any other taxa. The rest of the taxa and groups were associated with each other. The largest group was composed of _Bathymaster_ spp., _Sebastes_ spp., _Hippoglossoides elassodon_ and _Psettichthys melanostictus_. Several other taxa were associated with _Bathymaster_ spp. (e.g., _Stenobrachius leucopsarus_, Cottidae, and _Ronquilus jordani_). Two pleuronectids, _Microstomus pacificus_ and _Glyptocephalus zachirus_, which formed a recurrent group, were associated with _Bathymaster_ spp. and _Sebastes_ spp.

When REGROUP was applied to all collections together, regardless of cruise or gear (804 samples were used), two recurrent groups were recognized. One of these groups basically represented taxa found in neuston catches in fall, winter, and spring and the other represented taxa found in bongo catches mainly offshore in summer. Members of the neustonic group were three hexagrammids (Hexagrammos decagrammus, Hexagrammos stelleri, Pleurogrammus monopterygius) and Hemilepidotus spp. Two other species of Hexagrammos (H. lagocephalus and H. octogrammus) were associated with Hexagrammos stelleri and Mallotus villosus was associated with Hemilepidotus spp. The summer-subsurface group consisted of Sebastes spp., Bathymaster spp. and Hippoglossoides elassodon. Three pleuronectids were associated with members of this group: Glyptocephalus zachirus and Microstomus pacificus with Sebastes spp. and Psettichthys melanostictus with Bathymaster spp. and Hippoglossoides elassodon.

Relationship of Distribution of Young Stages to Environmental Parameters

It is of interest to determine the environmental parameters that influence the occurrence and abundance of early stages of fish. Studies that have used correlation techniques to investigate the abundance of eggs and larvae of fish in relation to such factors as water temperatures, salinity, depth and zooplankton abundance have found few significant relationships (e.g., Houde et al., MS 1979). This probably is due to at least two major characteristics of the distribution of these stages: 1) The distribution of young pelagic stages is to some extent the result of where their parents spawned them, or in the case of nesting species, where the nests were. This influences both the time and area of occurrence. 2) These stages start out completely passive - drifting with the currents - and become more capable of directing their movements with growth and development. Thus, in this study which was conducted within a relatively small area in regard to the overall distribution of the species we studied, and in an area of rather uniform hydrographic conditions, no strong correlations of egg and larval abundance with environmental parameters would be expected. For instance, although the hexagrammids probably nest in specific areas that could be characterized with regard to bottom depth and topography as well as hydrographic and biological conditions, by the time the larvae hatch and assume their neustonic habits, they will have drifted away from the nesting areas. Since the larvae remain in the neuston for several months, they may be found many kilometers from where the adults nested. Laboratory studies have shown that eggs and larvae of fish are tolerant of temperature and salinity conditions beyond the range of these conditions associated with their occurrence in the field (e.g., Alderdice and Forrester, 1968, 1971a, 1971b; Alderdice and Velsen, 1971). The temperature and salinity ranges on the shelf off Kodiak were quite narrow, and probably within the tolerance limits of all the taxa we encountered.

The distribution of several taxa taken in shelf collections was related to distance from shore. Larvae of some species that spawn nearshore or in bays were caught primarily in nearshore waters. These included smelt, sand lance, *Myoxocephalus* spp., walleye pollock, pricklebacks and yellowfin sole. Eggs and larvae of other species that are primarily oceanic in distribution - e.g. northern smoothtongue, northern lampfish, Atka mackerel, rex sole, dover sole, flathead sole, and rockfish - were taken offshore in waters with characteristics of the Alaska stream. Abundances of larvae were comparable between inshore and offshore study areas for several taxa including greenlings, ronquils, sand sole, butter sole, and rock sole.

CONCLUSIONS

The bays and shelf of the Kodiak area are used by a wide variety of fishes during their planktonic stages. We found no area or season that was not used by several species during these critical young stages. Most species in the area spawn demersal eggs, the notable exceptions being walleye pollock and all but one flatfish. Nearly all species, however, spend considerable time, up to several months, as larvae and prejuveniles in the plankton. During this time they disperse widely from the area where they were spawned, and at the end of this time, assume the habits of juveniles or adults.

These life history features make it difficult to provide general statements about the effects of environmental perturbations on year-class strength and recruitment of particular species. With the knowledge we now have, we could predict what the likely constituents of the ichthyoplankton community would be in a given area at a given time. The effects in the Kodiak area of chronic or catastrophic events associated with petroleum development on fish population as a result of impingement on their early stages cannot be predicted from present knowledge because 1) we do not know the relative importance of spawning in this area to recruitment of the species throughout their range and 2) we do not know the effects of various levels and types of pollutants on individual eggs and larvae of fish of the area.

ACKNOWLEDGMENTS

We thank several people from NWAFC, Seattle, for their help in preparation of this report: Jay Clark for computer-related tasks, Beverly Vinter and Bernie Goiney for laboratory assistance, Jim Peacock and his staff for drafting, Darlene Hoover and her staff for word processing, and Ethel Zweifel for printing and binding.

We give special thanks to the following FRI personnel: Mark Wangerin for running the analysis of variance programs, Colleen Clarke for measuring larval fish, and Ingrid Pearson for typing drafts of sections of the manuscript.

LITERATURE CITED

Alderdice, D.F., and C.R. Forrester.
1968. Some effects of salinity and temperature on early development and survival of the English sole (Parophrys vetulus). J. Fish. Res. Board Can. 25:495-521.
1971a. Effects of salinity, temperature, and dissolved oxygen on early development of the Pacific cod (Gadus macrocephalus). J. Fish. Res. Board Can. 28:883-902.
1971b. Effects of salinity and temperature on embryonic development of the petrale sole (Eopsetta jordani). J. Fish. Res. Board Can. 28:727-744.

Alderdice, D.F., and F.P.J. Velsen.
1971. Some effects of salinity and temperature on early development of Pacific herring (Clupea pallasi). J. Fish. Res. Board Can. 28:1545-1562.

Blackburn, J.E.
1973. A survey of abundance, distribution, and factors affecting distribution of ichthyoplankton in Skagit Bay. M.S. Thesis, Univ. Wash., Seattle, WA 98195, 136 p.

Dixon, W.J. (ed.).
1973. BMD Biomedical Computer Programs. Univ. Calif. Press, Berkeley, CA 94720, 773 p.

Dunn, J.R., A.W. Kendall, Jr., R.J. Wolotira, Jr., J.H. Bowerman, D.B. Dey, A.C. Matarese, and J.E. Munk.
MS 1980. Seasonal composition and food web relationships of marine organisms in the nearshore zone - including components of the ichthyoplankton, meroplankton, and holoplankton. Final Rep. OCSEAP RU551. Unpubl manuscr. xxvii + 393 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

Fager, E.W.
1957. Determination and analysis of recurrent groups. Ecology 38:586-595.

Fager, E.W., and J. McGowen.
1963. Zooplankton species groups in the North Pacific. Science 140:453-460.

Fager, E.W., and A.R. Longhurst.
1968. Recurrent group analysis of species assemblages of demersal fish in the Gulf of Guinea. J. Fish. Res. Board Can. 25:1405-1421.

Harris, C.K., and A.C. Hartt.
MS 1977. Assessment of pelagic and nearshore fish in three bays on the east and south coasts of Kodiak Island, Alaska. Final Rep. OCSEAP RU 485. Unpubl. manuscr. 190 p. Fish. Res. Inst., Univ. Wash., Seattle, WA 98195.

Houde, E.D., J.C. Leak, C.E. Dowd, S.A. Berkeley, and W.J. Richards.
MS 1979. Ichthyoplankton abundance and diversity in the eastern Gulf of Mexico. Rep. BLM No. AA550-CT7-28. Unpubl. manuscr. xxxii + 546 p. Rosenstiel School Mar. Atmos. Sci., Univ. Miami, Miami, FL 33149.

Howe, K.M., and S.L. Richardson.
MS 1978. Taxonomic review and meristic variation in marine sculpins (Osteichthys: Cottidae) of the Northeast Pacific Ocean. Final Rep., NOAA NMFS Contract no. 03-78-M02-120, January 1, 1978 to September 30, 1978. Unpubl. manuscr. 142 p. School of Oceanogr., Oregon State Univ., Corvallis, OR 97331.

Kendall, A.W., Jr.
1975. Patterns of larval fish distributions in the Middle Atlantic Bight, pp. 126-145, In: Manowitz, B. (ed.) Effects of energy related activities on the Atlantic continental shelf. Brookhaven National Laboratory, Upton, NY 11973.

Loeb, V.J.
1979. Larval fishes in the zooplankton community of the North Pacific Central gyre. Mar. Biol. 53:173-191.

Rogers, D.E., D.J. Rabin, B.J. Rogers, K. Garrison, and M. Wangerin.
MS 1979. Seasonal composition and food web relationships of marine organisms in the nearshore zone of Kodiak Island--including ichthyoplankton, meroplankton (shellfish), zooplankton, and fish. Final Rep. OCSEAP RU553. Unpubl. manuscr., 291 p. Fish. Res. Inst., Univ. Wash., Seattle, WA 98195.

Science Applications, Inc.
MS 1977. Environmental assessment of the Kodiak Shelf: A report based on NOAA/OCSEAP synthesis meeting. Unpubl. manuscr., 118 p. Science Applications, Inc., Boulder, CO 80302.

Smith, P.E., and S.L. Richardson.
1977. Standard techniques for pelagic fish egg and larva surveys. Food Agric. Organ. U.N., FAO Fish. Tech. Pap. 175, 100 p.

Snedecor, G.W., and W.G. Cochran.
1971. Statistical methods. 6th ed. Iowa State Univ. Press, Ames, IA 50010.

Venrick, E.L.
1971. Recurrent groups of diatom species in the North Pacific. Ecology 52:614-625.

	4MF77-Fall 1977		4DI78-Spring 1978		2MF78-Summer 1978		1WE78-Fall 1978		1MF79-Winter 1979	
eggs	occur-rences	mean density no./1000^3	occur-rences	mean density no./1000^3	occur-rences	mean density no./1000^3	occur-rences	mean density no./1000^3	occur-rences	mean density no./1000^3
Leuroglossus schmidti							2	19		
Theragra chalcogramma	14	25	23	415	3	14	1	14	1	21
Pleuronectidae			15	119	21	390				
Hippoglossoides elassodon			7	42	17	59				
Isopsetta isolepis			2	25	5	83				
Microstomus pacificus			1	22	38	245				
Platichthys stellatus			1	43	1	52				
Pleuronectes quadrituberculatus			2	18						
Glyptocephalus zachirus					29	47				
Limanda aspera					18	2155				
Psettichthys melanostictus					3	23				
larvae										
Osmeridae					2	2859	24	81	12	32
Mallotus villosus	10	48	6	49						
Bathylagus sp.					1	372				
Myctophidae	1	19	1	14						
Stenobrachius sp.					1	20				
Protomyctophum thompsoni	1	18								
Gadidae					2	92				
Theragra chalcogramma	3	21			3	23				
Sebastes spp.					15	59	1	17	1	15
Hexagrammidae	3	55	5	105			2	16	6	37
Hexagrammos sp.	13	33	8	51	3	73	8	39		
Hexagrammos decagrammus	56	142	75	659	62	66	31	154	74	382
Hexagrammos lagocephalus	40	79					39	88		
Hexagrammos octogrammus	39	37			5	25	39	84	11	21
Hexagrammos stelleri	71	110	33	42	5	59	71	348	29	34
Ophiodon elongatus					7	25				
Pleurogrammus monopterygius	37	413	28	208			36	739	42	348
Anoplopoma fimbria					13	22				
Cottidae			2	26	1	12				
Gymnocanthus sp.			1	36						
Gymnocanthus A			1	14						
Hemilepidotus spp.	60	998	32	581	5	29	52	773	51	409
Hemilepidotus hemilepidotus			2	22	15	37				
Hemilepidotus jordani					5	54				
Icelinus borealis					1	15				
Myoxocephalus sp.					13	50				
Myoxocephalus B.			1	35						
Myoxocephalus G.			1	28						
Cyclopteridae			1	76						
Aptocyclus ventricosus	3	21								
Bathymasteridae	2	28			1	13				
Bathymaster sp.			1	17	44	1946	17	34	5	17
Ronquilus jordani					3	15				
Stichaeidae			2	31	2	85				
Anoplarchus insignis					1	21				
Chirolophis polyactocephalus			5	92						
Stichaeus punctatus					3	15				
Lyconcetes aleutensis			15	108	30	74				
Pholis sp.					1	16				
Pholis laeta					1	19				
Zaprora silenus			2	153						
Ammodytes hexapterus			5	38	20	236				
Glyptocephalus zachirus					2	28				
Hippoglossoides elassodon					2	14				
Lepidopsetta bilineata			1	17	4	18				
Microstomus pacificus					5	20				
Psettichthys melanostictus					2	17				

Table 1. Number of occurrences and mean density (number/1000 m^3) of fish eggs and larvae collected in neuston tows during the five OCSEAP plankton cruises. (From Dunn et al. MS 1980)

taxon	4MF77 Fall 1977	4DI78 Spring 1978	2MF78 Summer 1978	1WE78 Fall 1978	1MF79 Winter 1979
eggs					
Bathylagidae					8.85
Leuroglossus schmidti	9.90		9.21	10.91	9.65
Theragra chalcogramma	9.60	12.10	8.54	8.76	9.86
Macrouridae	9.28		10.50	9.73	
Pleuronectidae		10.66	11.00		
Atheresthes stomias					9.47
Glyptocephalus zachirus			10.25		
Hippoglossoides elassodon		10.36	11.31		8.56
Isopsetta isolepis		8.47	9.97		
Limanda aspera			10.53		
Lyopsetta exilis			8.88		
Microstomus pacificus			10.80		
Platichthys stellatus		8.91	8.87		
Psettichthys melanostictus			8.27		
Unidentified	9.18	8.50	9.57	10.77	9.97
larvae					
Clupea harengus pallasi			8.87		
Osmeridae			11.35		
Mallotus villosus	10.34	9.01		11.25	10.67
Bathylagus milleri			8.91		
Bathylagus pacificus		8.98	9.30		9.07
Leuroglossus schmidti	9.49	8.82	9.42	9.38	10.10
Myctophidae			8.22		
Stenobrachius sp.			10.23		
Stenobrachius leucopsarus		9.67	10.12	9.29	9.75
Stenobrachius nannochir			8.62		
Protomyctophum crockeri			8.60		
Protomyctophum thompsoni	9.12		8.58	9.33	9.04
Gadidae			9.30		
Gadus macrocephalus		8.86	8.43		
Theragra chalcogramma	8.92	10.67	9.84		
Macrouridae		8.95	8.58		8.52
Sebastes sp.			11.73	8.97	
Hexagrammos sp.		8.86			8.58
Hexagrammos decagrammus	8.97	9.52	8.57	8.80	9.92
Hexagrammos lagocephalus	8.41				
Hexagrammos octogrammus	8.97			9.06	
Hexagrammos stelleri	9.28	8.12	8.92	9.63	8.94
Pleurogrammus monopterygius	9.36	8.80		10.38	9.63
Cottidae		9.86	10.37	8.23	8.85
Artedius sp.			9.07		
Artedius 1			9.16	8.94	
Artedius 2			8.10		
Clinocottus sp.			8.17		
Dasycottus setiger		8.91	9.10		
Gymnocanthus A		9.93			
Hemilepidotus spp.	11.16	10.06		11.01	10.49
Hemilepidotus hemilepidotus			8.22		
Icelinus borealis	8.29	7.89	9.81		
Malacocottus zonurus 1					8.55
Myoxocephalus sp.		8.34			
Myoxocephalus B.		9.54			
Myoxocephalus G.		9.06			9.07
Radulinus asperellus		9.35			
Triglops sp.		8.37			9.07
Agonidae		9.02	9.57		
Cyclopteridae		9.72	9.61	8.60	
Liparus florae			8.46		
Trichodon trichodon					8.02
Bathymaster sp.		8.97	11.74		
Ronquilus jordani			10.01		
Stichaeidae		9.95	9.54		
Chirolophis polyactocephalus		9.22			
Lumpenella longirostris			8.71		
Lumpenus sagitta		9.45			
Stichaeus punctatus			8.16		
Lyconectes aleutensis		8.85	9.41		8.71
Pholis sp.		9.21	8.46		
Zaprora silenus			9.06		
Ammodytes hexapterus		11.42	8.71		9.18
Pleuronectidae			8.17		
Atheresthes stomias		9.71			9.52
Glyptocephalus zachirus			10.18		
Hippoglossoides elassodon			10.37		
Isopsetta isolepis			10.05		
Lepidopsetta bilineata		10.41	9.98		
Microstomus pacificus			10.10		
Platichthys stellatus			8.93		
Psettichthys melanostictus			10.54		
Hippoglossus stenolepis		8.56	8.51		

Table 2. Total numbers ($\log_{10}$) of eggs and larvae of each taxon of fish estimated from catches in bongo tows during the five OCSEAP plankton cruises. (From Dunn et al. MS 1980)

	Taxa	Common name	Σ nos./1000 m^3	Occurrence No. of hauls	%
	Larvae				
1	Osmeridae	Smelts	77,179	67	23.2
2	Hexagrammos decagrammus	Kelp greenling	33,913	77	26.6
3	Hexagrammos stelleri	Whitespotted greenling	21,014	60	20.7
4	Bathymasteridae	Ronquils	6,955	49	16.9
5	Hexagrammos octogrammus	Masked greenling	4,768	28	9.7
6	Stichaeidae	Pricklebacks	4,032	2	.7
7	Hexagrammos lagocephalus	Rock greenling	2,122	16	5.5
8	Myoxocephalus type A		1,780	22	7.6
9	Myoxocephalus type B		1,551	18	6.2
10	Pleurogrammus monopterygius	Atka mackerel	1,170	6	2.1
11	Lyconectes aleutensis	Dwarf wrymouth	1,030	14	4.8
12	Hemilepidotus spp.		761	7	2.4
13	Ammodytes hexapterus	Pacific sand lance	694	15	5.2
14	Gasterosteus aculeatus	Threespine stickleback	676	10	3.5
15	Oncorhynchus gorbuscha	Pink salmon	641	4	1.4
16	Psettichthys melanostictus	Sand sole	496	5	1.7
17	Icelinus spp.		467	1	.3
18	Cottidae type L		416	6	2.1
19	Leptocottus armatus	Pacific staghorn sculpin	408	7	2.4
20	Scorpaenidae	Rockfishes	359	8	2.8
21	Lepidopsetta bilineata	Rock sole	242	5	1.7
22	Cottidae type I		140	3	1.0
23	Gadus macrocephalus	Pacific cod	129	1	.3
24	Cyclopteridae	Lumpfishes and snailfishes	127	6	2.1
25	Trichodon trichodon	Pacific sandfish	85	2	.7
26	Gadidae	Codfishes	72	3	1.0
27	Agonidae	Poachers	56	1	.3
28	Theragra chalcogramma	Walleye pollock	49	2	.3
29	Hemilepitodus jordani	Yellow Irish lord	48	1	.7
30	Hippoglossoides elassodon	Flathead sole	36	1	.3
31	Chirolophis spp.		34	3	1.0
32	Platichthys stellatus	Starry flounder	31	1	.3
33	Artedius type 1		28	1	.3
34	Isopsetta isolepis	Butter sole	24	1	.3
35	Radulinus asprellus	Slim sculpin	24	1	.3
36	Limanda aspera	Yellowfin sole	24	1	.3
	Eggs				
1	Pleuronectidae	Flatfishes	2,976,469	207	71.6
2	Hippoglossoides elassodon	Flathead sole	21,292	69	23.9
3	Theragra chalcogramma	Walleye pollock	10,585	39	13.5
4	Trichodon trichodon	Pacific sandfish	240	2	.7
5	Glyptocephalus zachirus	Rex sole	47	2	.7
6	Pleuronectes quadrituberculatus	Alaska plaice	24	1	.3

Table 3. Number of positive hauls, percent occurrence (out of 289 hauls), and sum of the nos./1000 m^3 for larval fish and eggs caught by neuston 505u net; numbers summed over all stations, cruises, and bays, Kodiak Archipelago, Alaska, 1978-1979. Listed by order of abundance as indicated by no./1000 m^3.

	Taxa	Common name	Σ no./1000 m^3	Σ no./10 m^2	Occurrence No. of hauls	Occurrence %
	Larvae					
1	Osmeridae	Smelts	530,621	284,150	171	58.6
2	*Ammodytes hexapterus*	Pacific sand lance	8,088	5,033	112	38.4
3	Bathymasteridae	Ronquils	4,377	3,272	135	46.2
4	*Lepidopsetta bilineata*	Rock sole	3,747	2,644	119	40.7
5	*Lumpenus medius*	Stout eelblenny	2,824	1,501	61	20.9
6	Cottidae type L		2,778	1,776	119	40.7
7	*Psettichthys melanostictus*	Sand sole	2,601	1,371	106	36.3
8	*Myoxocephalus* type B		1,563	1,360	51	17.5
9	Cottidae type I		1,394	1,322	98	33.6
10	*Icelinus* spp.		1,049	594	74	25.3
11	*Theragra chalcogramma*	Walleye pollock	970	804	40	13.7
12	*Lumpenus maculatus*	Daubed shanny	831	480	41	14.0
13	Scorpaenidae	Rockfishes	755	720	62	21.2
14	Cyclopteridae	Lumpfishes and snailfishes	752	520	81	27.7
15	*Isopsetta isolepis*	Butter sole	643	411	34	11.6
16	*Myoxocephalus* type A		534	391	51	17.5
17	Gadidae	Codfishes	445	383	38	13.0
18	*Anoplarchus* spp.		427	284	43	14.7
19	*Limanda aspera*	Yellowfin sole	420	195	33	11.3
20	*Gymnocanthus* spp.		404	339	38	13.0
21	*Hippoglossoides elassodon*	Flathead sole	404	317	50	17.1
22	*Lumpenus sagitta*	Snake prickleback	387	299	35	12.0
23	*Clinocottus* spp.		236	90	22	7.5
24	Agonidae	Poachers	231	233	32	11.0
25	*Lumpenella longirostris*	Longsnout prickleback	225	258	21	7.2
26	Stichaeidae	Pricklebacks	212	151	19	6.5
27	*Hemilepidotus* spp.		175	194	17	5.8
28	*Gadus macrocephalus*	Pacific cod	170	124	7	2.4
29	*Radulinus asprellus*	Slim sculpin	148	94	31	10.6
30	*Leptocottus armatus*	Pacific staghorn sculpin	128	60	26	8.9
31	*Artedius* type 2		88	28	9	3.1
32	*Artedius* type 1		84	78	12	4.1
33	*Lyconectes aleutensis*	Dwarf wrymouth	82	67	17	5.8
34	Pholidae	Gunnels	65	51	16	5.5
35	*Platichthys stellatus*	Starry flounder	65	41	9	3.1
36	Myctophidae	Lanternfishes	65	37	14	4.8
37	*Dasycottus setiger*	Spinyhead sculpin	58	54	11	3.8
38	*Hexagrammos decagrammus*	Kelp greenling	51	46	10	3.4
39	*Triglops* spp.		44	22	6	2.0
40	*Chirolophis* spp.		39	28	8	2.7
41	*Hexagrammos stelleri*	Whitespotted greenling	28	21	5	1.7
42	*Ptilichthys goodei*	Quillfish	24	30	4	1.4
43	*Malacocottus* sp.		15	19	5	1.7
44	*Hemilepidotus jordani*	Yellow Irish lord	14	16	4	1.4
45	*Enophrys* spp.		13	5	3	1.0
46	*Hemilepidotus hemilepidotus*	Red Irish lord	10	11	3	1.0
47	*Delolepis gigantea*	Giant wrymouth	7	5	2	.7
48	*Poroclinus rothrocki*	Whitebarred prickleback	8	3	1	.3
49	*Stichaeus punctatus*	Arctic shanny	8	3	2	.7
50	*Lycodes brevipes*	Shortfin eelpout	7	11	2	.7
51	*Microgadus proximus*	Pacific tomcod	7	8	2	.7
52	*Trichodon trichodon*	Sandfish	7	2	1	.3
53	*Glyptocephalus zachirus*	Rex sole	6	2	1	.3
54	*Pleurogrammus monopterygius*	Atka mackerel	5	7	2	.7
55	*Hippoglossus stenolepis*	Pacific halibut	5	2	1	.3
56	*Psychrolutes* ?		5	4	1	.3
57	*Cottus* spp.		3	1	1	.3
58	Cottidae type 2		3	1	1	.3
59	*Hexagrammos octogrammus*	Masked greenling	3	1	1	.3
60	*Ophiodon elongatus*	Lingcod	3	4	1	.3
61	Bathylagidae	Deepsea smelts	2	2	1	.3
	Eggs					
1	Pleuronectidae	Flatfishes	171,727	82,758	218	74.7
2	*Theragra chalcogramma*	Walleye pollock	2,342	2,127	73	25.0
3	*Hippoglossoides elassodon*	Flathead sole	1,973	927	49	16.8
4	*Glyptocephalus zachirus*	Rex sole	17	12	4	1.4
5	Osmeridae	Smelts	58	90	1	.3

Table 4. Number of positive hauls, percent occurrence (out of 292 hauls), and sum of the nos./1000 m^3 and nos./10 m^2 for larval fish and eggs caught by bongo 505u net; numbers summed over all stations, cruises, and bays, Kodiak Archipelago, Alaska, 1978-1979. Listed by order of abundance indicated by no./1000 m^3.

Taxon	Proposal	Inshore (FRI) B	Inshore (FRI) N	Offshore (NWAFC) B	Offshore (NWAFC) N	Primary catches of those taxa in proposal but not to be discussed in detail.
Clupea harengus pallasi	X					(offshore: 2 - summer - bongo)
Mallotus villosus	X			X		
Osmeridae		X	X	X		
Leuroglossus schmidti - eggs				X		
Leuroglossus schmidti - larvae				X		
Stenobrachius leucopsarus				X		
Gadus macrocephalus	X					(offshore: 3 - bongo - spring, 2 - bongo - summer; inshore: 17 - bongo - spring, 4 - neuston - spring)
Theragra chalcogramma - eggs		X	X	X		
Theragra chalcogramma - larvae	X	X		X		
Sebastes spp.	X	X		X		
Hexagrammos spp.	X					(identified to species)
Hexagrammos decagrammus			X		X	
Hexagrammos lagocephalus			X		X	
Hexagrammos octogrammus			X		X	
Hexagrammos stelleri	X		X		X	
Pleurogrammus monopterygius	X			X	X	
Ophiodon elongatus	X					(offshore: 10 at 7 sta. - neuston - summer; inshore: 3 - neuston - spring)
Anoplopoma fimbria	X					(offshore: 19 at 13 sta. - neuston - summer)
Cottidae				X		
Gymnocanthus spp.	X					(offshore: 47 at 17 sta. - bongo - spring; inshore: 106 at 38 sta. - bongo - spring)
Hemilepidotus spp.	X			X	X	
Myoxocephalus spp. (A,B)	X	X				
Trichodon trichodon	X					(offshore: 1 - bongo - winter; inshore: 1 - bongo - winter, 3 - neuston - winter)
Cyclopteridae		X				
Bathymasteridae		X	X			
Bathymaster spp.				X	X	
Ronquilus jordani				X		
Lumpenus maculatus	X	X				
Lumpenus medius		X				
Lyconectes aleutensis	X					(offshore: 87 at 15 sta. - neuston - spring, 125 at 30 sta. - neuston - summer; inshore: 292 at 22 sta. - neuston - summer)
Ammodytes hexapterus	X	X		X		
Pleuronectidae - eggs		X	X			
Atheresthes stomias	X					(offshore: 13 at 8 sta. - bongo - spring, 9 at 7 sta. - bongo - winter)
Glyptocephalus zachirus - eggs				X		
Glyptocephalus zachirus - larvae				X		
Hippoglossoides elassodon - eggs		X	X	X		
Hippoglossoides elassodon - larvae	X	X		X		
Isopsetta isolepis		X		X		
Lepidopsetta bilineata	X	X		X		
Limanda aspera	X	X				
Microstomus pacificus - eggs				X		
Microstomus pacificus - larvae				X		
Psettichthys melanostictus	X	X		X		

Table 5. Taxa dealt with in study of ichthyoplankton of Kodiak (larvae except as indicated).

		Inshore (bays)		significant 1/ differences			Offshore (shelf)		significant 1/ differences		
Taxon	net 2/	mean log (x+1)	variance log (x+1)	bays	cruises	inter-actions	mean log (x+1)	variance log (x+1)	areas	cruises	inter-actions
Mallotus villosus	B	- - - 3/					.42379	.26627	* *	* *	*
Osmeridae	B	1.09097	.25733	*	* *	*	.32140	.43262	*		
	N	.01995	.01165		*		- - - 3/				
Leuroglossus schmidti - eggs	B	-----					.23986	.39267	* *	* *	* *
Leuroglossus schmidti - larvae	B	-----					.09033	.05916	* *	* *	* *
Stenobrachius leucopsarus	B	-----					.09505	.07669	*	* *	
Theragra chalcogramma - eggs	B	.34088	.23193	*	* *		.10713	.12343	* *	* *	*
	N	.02178	.00445	* *	* *	* *	- - -				
Theragra chalcogramma - larvae	B	.19031	.01238	* *	* *	* *	.13435	.11739	*	* *	
Sebastes spp.	B	.18137	.09467	* *	* *	* *	.32293	.19730	* *	* *	* *
Hexagrammos decagrammus	N	.04340	.01249		* *	* *	.08299	.01662	* *	* *	* *
Hexagrammos lagocephalus	N	.00543	.00068		* *	* *	.02733	.00098	* *		
Hexagrammos octogrammus	N	.01027	.00238		* *		.00933	.00051		* *	
Hexagrammos stelleri	N	.03531	.00655	*	* *	* *	.03637	.00763	* *	* *	
Pleurogrammus monopterygius	B	-----					.07729	.07493	*		* *
	N	-----					.05960	.02409	* *		* *
Cottidae	B	- - -					.16208	.10511	* *	* *	* *
Hemilepidotus spp.	B	-----					.72297	.28342	* *	* *	
	N	-----					.07881	.03243	* *	* *	* *
Myoxocephalus spp. (A)	B	.16853	.08512		* *		-----				
(B)	B	.22846	.14792		* *	*	-----				
Cyclopteridae	B	.20753	.12889		* *		-----				
Bathymasteridae	B	.45177	.15386	*	* *	* *	- - -				
	N	.00574	.00039				- - -				
Bathymaster spp.	B	- - -					.89582	.19370	*	* *	*
	N	- - -					.05610	.03405		* *	*
Ronquilus jordani	B	- - -					.22046	.16811			
Lumpenus maculatus	B	.16531	.08925	* *	* *	* *	-----				
Lumpenus medius	B	.24485	.20905	* *	* *		-----				
Ammodytes hexapterus	B	.60740	.13558		*		.33105	.10624	* *	* *	* *
Pleuronectidae - eggs	B	1.27047	.30945	* *	* *	* *	- - -				
	N	.39427	.15537	* *	* *		- - -				
Glyptocephalus zachirus - eggs	B	-----					.27320	.16388	* *		
Glyptocephalus zachirus - larvae	B	-----					.34027	.21884			
Hippoglossoides elassodon - eggs	B	.13134	.06734	* *	* *	* *	.15022	.14860		* *	*
	N	.01645	.00289		* *		-----				
Hippoglossoides elassodon - larvae	B	.11105	.05948		* *		.48065	.27543			
Isopsetta isolepis	B	.06667	.03817	*	* *		.26606	.18301	*		
Lepidopsetta bilineata	B	.44067	.11125	* *	* *	* *	.33258	.19104	* *		* *
Limanda aspera	B	.06361	.03700	*	* *		-----				
Microstomus pacificus - eggs	B	-----					.50162	.30094	* *		
Microstomus pacificus - larvae	B	-----					.20559	.18283			
Psettichthys melanostictus	B	.27934	.11418		* *		.44850	.27264	* *		

1/ * p<0.05; * * p<0.01
2/ B = bongo; N = neuston
3/ - - - = taxon not identified in these samples; ----- = taxon not abundant enough for analysis.

Table 6. Summary of results of ANOVA on Kodiak Ichthyoplankton Survey.

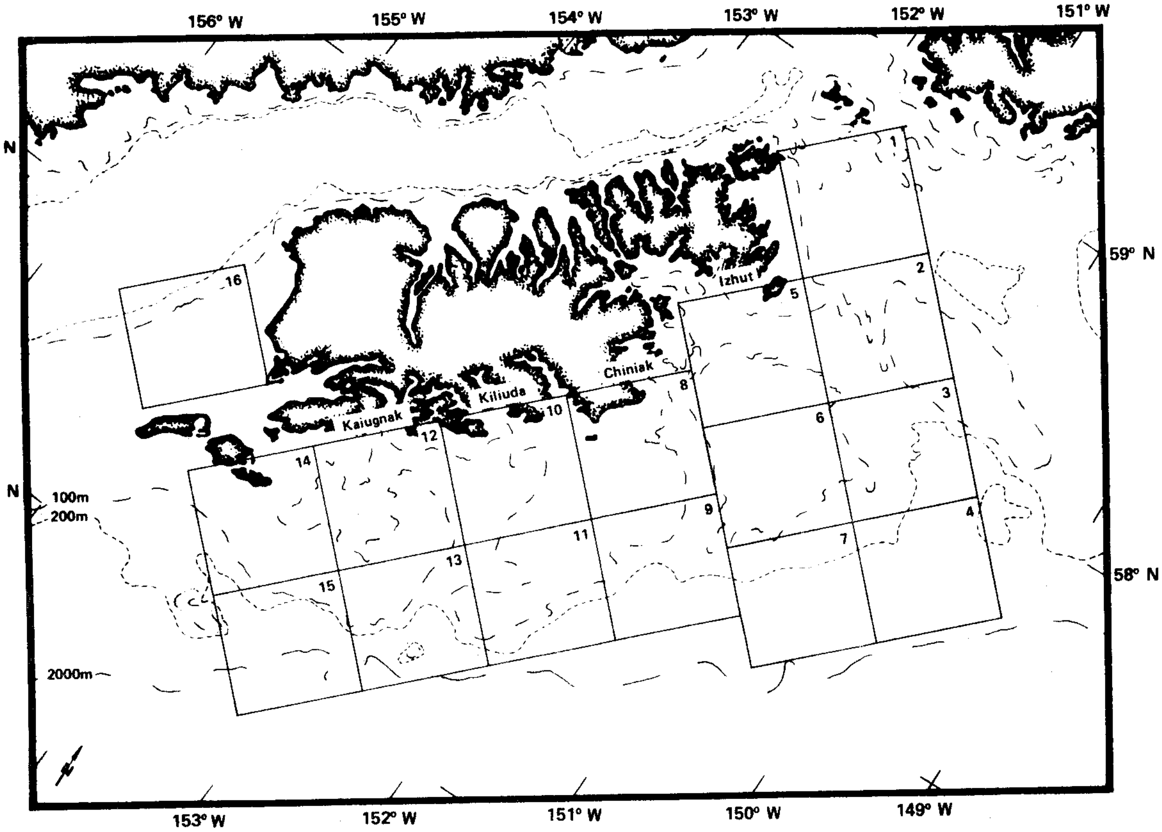


Figure 1. Subareas used for analysis of distribution of ichthyoplankton from the five OCSEAP offshore plankton surveys.

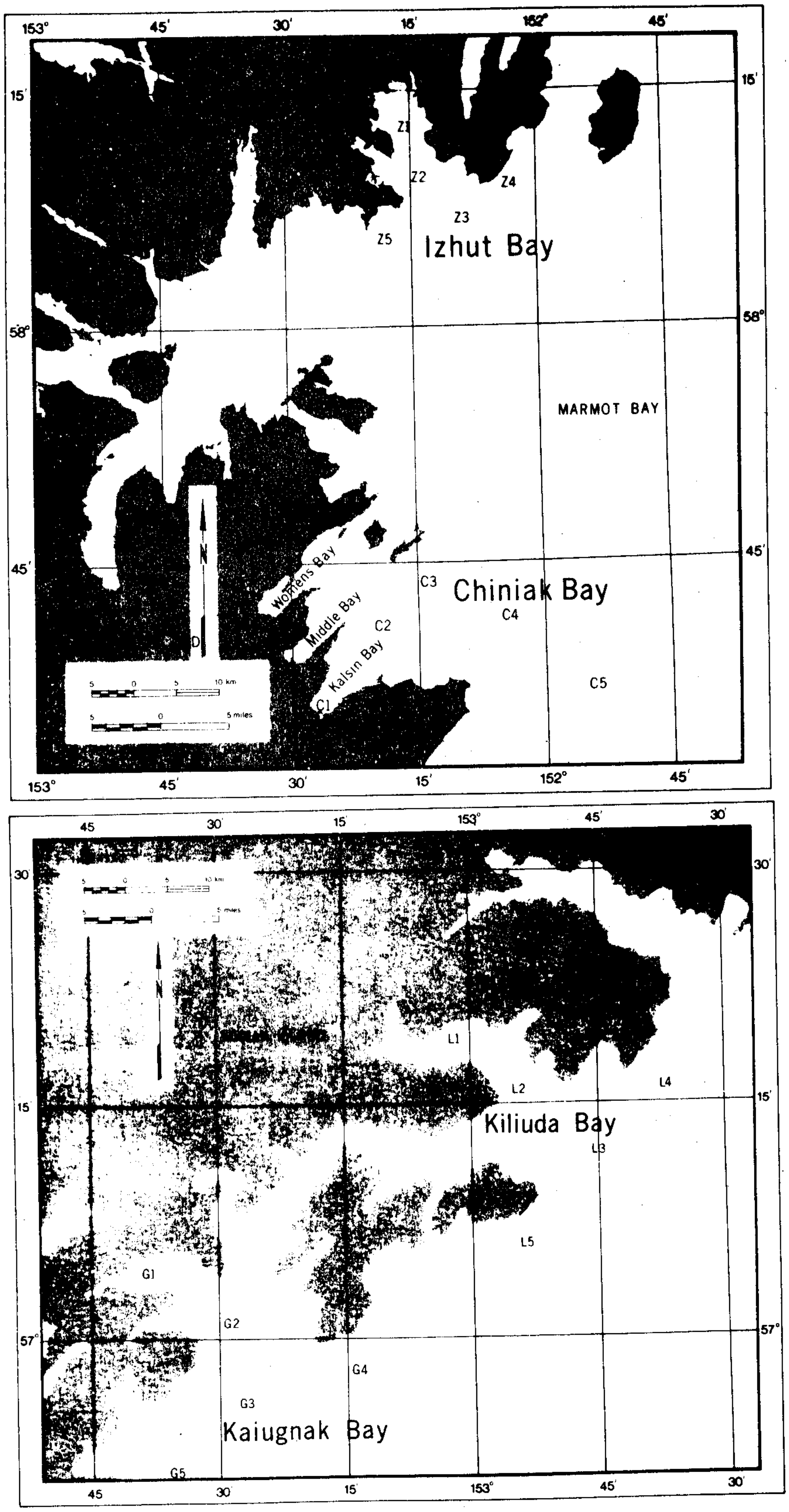


Figure 2. Station locations from OCSEAP plankton survey of bays of Kodiak.

KODIAK OFFSHORE ICHTHYOPLANKTON STUDY – RESULTS OF REGROUP (0.4 affinity level)

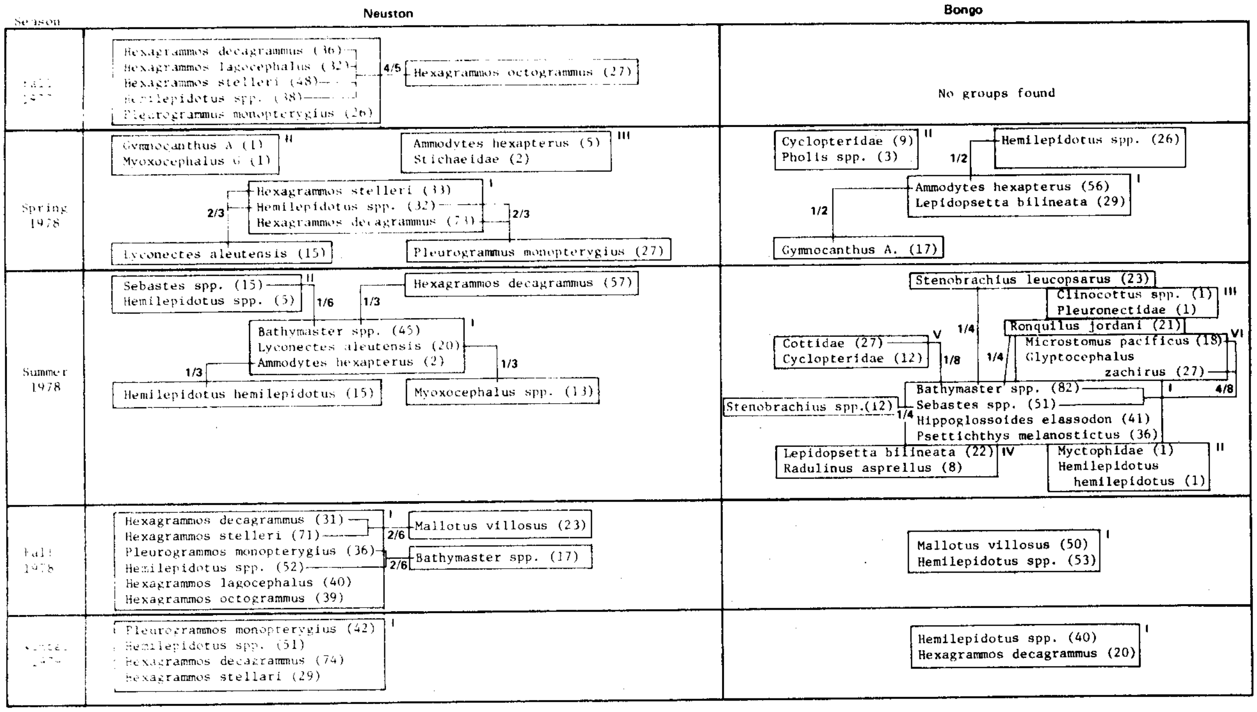


Figure 3. Results of REGROUP of Kodiak ichthyoplankton study of offshore area. Analysis at affinity level of 0.4, run by cruise and gear. Boxes enclose taxa with affinities of >0.4. Lines connect taxa with affinities >0.4 that do not have affinities with all in the group (fractions indicate proportions of possible inter-group affinities found). Numbers of occurrences of the taxa are in parentheses after the name. Roman numerals are arbitrarily assigned group numbers.

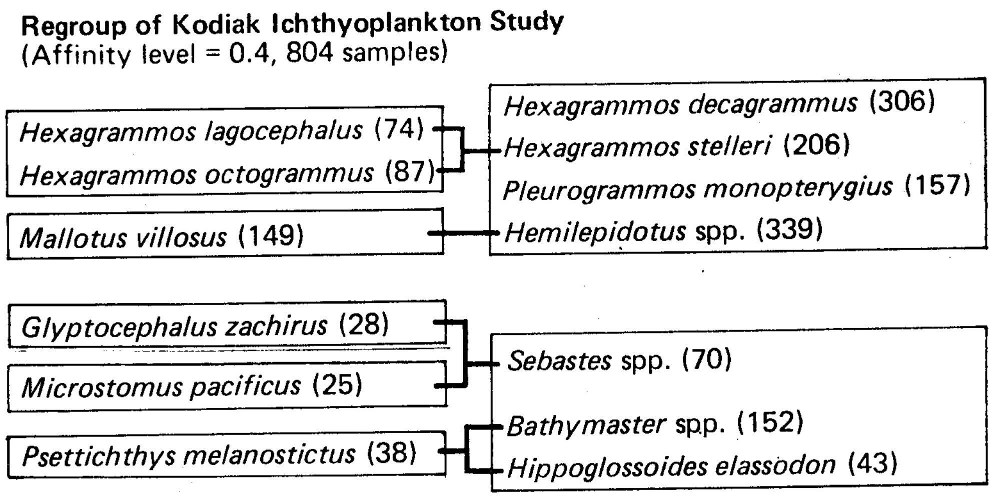


Figure 4. Results of REGROUP of Kodiak ichthyplankton study of offshore area. Analysis at affinity level of Ø.4, run with all cruises and gears combined. Notations as in Figure 3.

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Osmeridae Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov	___	___
Spring 1978	29 Mar-8 Apr	___	.1616			
	10-17 Apr	.0021	___	28 Mar-20 Apr	___	___
	21 Apr-1 May	___	___			
	31 May-6 Jun	___	.0718			
	14-24 Jun	.0693	12.29			
Summer 1978	21-29 Jul	.1843	170.3	19 Jun-9 Jul	___	1.096
	1-9 Aug	.0084	392.9			
	15-21 Aug	.2320	1348			
Fall 1978	3-13 Nov	.0041	13.51	25 Oct-17 Nov	___	___
Winter 1979	6-16 Mar	___	2.719	13 Feb-11 Mar	___	___

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Mallotus villosus Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		1.660
Spring 1978	29 Mar-8 Apr					
	10-17 Apr			28 Mar-20 Apr		.0291
	21 Apr-1 May					
	31 May-6 Jun					
	14-24 Jun					
Summer 1978	21-29 Jul			19 Jun-9 Jul		
	1-9 Aug					
	15-21 Aug					
Fall 1978	3-13 Nov			25 Oct-17 Nov		6.011
Winter 1979	6-16 Mar			13 Feb-11 Mar		1.653

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Leuroglossus schmidti Stage Eggs

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		1.367
Spring 1978	29 Mar-8 Apr					
	10-17 Apr			28 Mar-20 Apr		
	21 Apr-1 May					
	31 May-6 Jun					
	14-24 Jun					
Summer 1978	21-29 Jul			19 Jun-9 Jul		.1131
	1-9 Aug					
	15-21 Aug					
Fall 1978	3-13 Nov			25 Oct-17 Nov		1.783
Winter 1979	6-16 Mar			13 Feb-11 Mar		.2505

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Leuroglossus schmidti Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		.2500
Spring 1978	29 Mar-8 Apr					
	10-17 Apr			28 Mar-20 Apr		.0567
	21 Apr-1 May					
	31 May-6 Jun					
	14-24 Jun					
Summer 1978	21-29 Jul			19 Jun-9 Jul		.1832
	1-9 Aug					
	15-21 Aug					
Fall 1978	3-13 Nov			25 Oct-17 Nov		.1612
Winter 1979	6-16 Mar			13 Feb-11 Mar		.5589

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Stenobrachius leucopsarus Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		.0878
Spring 1978	29 Mar-8 Apr					
	10-17 Apr			28 Mar-20 Apr		.2134
	21 Apr-1 May					
	31 May-6 Jun					
	14-24 Jun					
Summer 1978	21-29 Jul			19 Jun-9 Jul		.7673
	1-9 Aug					
	15-21 Aug					
Fall 1978	3-13 Nov			25 Oct-17 Nov		.1186
Winter 1979	6-16 Mar			13 Feb-11 Mar		.1447

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Theragra chalcogramma Stage Eggs

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		.1911
Spring 1978	29 Mar-8 Apr	.2171	3.327			
	10-17 Apr	.2488	6.232	28 Mar-20 Apr		1.572
	21 Apr-1 May	.0625	8.295			
	31 May-6 Jun	.0019	1.174			
	14-24 Jun	.0107	.7315			
Summer 1978	21-29 Jul		.1487	19 Jun-9 Jul		.0325
	1-9 Aug	.0019				
	15-21 Aug		.0838			
Fall 1978	3-13 Nov	.0065	.5547	25 Oct-17 Nov		.0517
Winter 1979	6-16 Mar	.0015	.2097	13 Feb-11 Mar		.0320

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Theragra chalcogramma Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		.0213
Spring 1978	29 Mar-8 Apr		.4555			
	10-17 Apr		4.129	28 Mar-20 Apr		.6628
	21 Apr-1 May		7.586			
	31 May-6 Jun		.0937			
	14-24 Jun					
Summer 1978	21-29 Jul		.0353	19 Jun-9 Jul		.4896
	1-9 Aug					
	15-21 Aug					
Fall 1978	3-13 Nov			25 Oct-17 Nov		
Winter 1979	6-16 Mar		.1022	13 Feb-11 Mar		

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon *Sebastes* spp. Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		
Spring 1978	29 Mar-8 Apr					
	10-17 Apr			28 Mar-20 Apr		
	21 Apr-1 May					
	31 May-6 Jun		.4814			
	14-24 Jun		1.660			
Summer 1978	21-29 Jul		.6173	19 Jun-9 Jul		3.183
	1-9 Aug		2.088			
	15-21 Aug		2.308			
Fall 1978	3-13 Nov			25 Oct-17 Nov		.0577
Winter 1979	6-16 Mar			13 Feb-11 Mar		

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Hexagrammos decagrammus Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov	.0700	
Spring 1978	29 Mar-8 Apr	.1450				
	10-17 Apr	.1469		28 Mar-20 Apr	.5194	
	21 Apr-1 May	.6185				
	31 May-6 Jun	.1375				
	14-24 Jun	.0321				
Summer 1978	21-29 Jul			19 Jun-9 Jul	.0725	
	1-9 Aug					
	15-21 Aug					
Fall 1978	3-13 Nov	.0162		25 Oct-17 Nov	.0801	
Winter 1979	6-16 Mar	.0712		13 Feb-11 Mar	.3804	

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Hexagrammos lagocephalus Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov	.0650	
Spring 1978	29 Mar-8 Apr					
	10-17 Apr			28 Mar-20 Apr		
	21 Apr-1 May					
	31 May-6 Jun					
	14-24 Jun					
Summer 1978	21-29 Jul	.0042		19 Jun-9 Jul		
	1-9 Aug	.0043				
	15-21 Aug	.0687				
Fall 1978	3-13 Nov	.0513		25 Oct-17 Nov		
Winter 1979	6-16 Mar			13 Feb-11 Mar		

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon *Hexagrammos octogrammus* Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov	.0304	
Spring 1978	29 Mar-8 Apr					
	10-17 Apr			28 Mar-20 Apr		
	21 Apr-1 May					
	31 May-6 Jun					
	14-24 Jun					
Summer 1978	21-29 Jul	.0032		19 Jun-9 Jul	.0294	
	1-9 Aug	.0698				
	15-21 Aug	.1644				
Fall 1978	3-13 Nov	.1447		25 Oct-17 Nov	.0489	
Winter 1979	6-16 Mar			13 Feb-11 Mar	.0054	

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon *Hexagrammos stelleri* Stage Larvae

Season	Inshore Dates	Inshore Mean ($\#10m^2$) Neuston	Inshore Mean ($\#10m^2$) Bongo	Offshore Dates	Offshore Mean ($\#10m^2$) Neuston	Offshore Mean ($\#10m^2$) Bongo
Fall 1977				31 Oct-14 Nov	.1714	
Spring 1978	29 Mar-8 Apr	.0432				
	10-17 Apr	.0207		28 Mar-20 Apr	.0244	
	21 Apr-1 May	.0392				
	31 May-6 Jun					
	14-24 Jun					
Summer 1978	21-29 Jul			19 Jun-9 Jul	.0058	
	1-9 Aug					
	15-21 Aug					
Fall 1978	3-13 Nov	.8207		25 Oct-17 Nov	.2440	
Winter 1979	6-16 Mar	.1192		13 Feb-11 Mar	.0124	

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Pleurogrammus monopterygius Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov	.1687	.2475
Spring 1978	29 Mar-8 Apr					
	10-17 Apr			28 Mar-20 Apr	.0947	.0500
	21 Apr-1 May					
	31 May-6 Jun					
	14-24 Jun					
Summer 1978	21-29 Jul			19 Jun-9 Jul		
	1-9 Aug					
	15-21 Aug					
Fall 1978	3-13 Nov			25 Oct-17 Nov	.1809	.2281
Winter 1979	6-16 Mar			13 Feb-11 Mar	.1460	.2669

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Cottidae Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov	____	____
Spring 1978	29 Mar-8 Apr	____	____			
	10-17 Apr	____	____	28 Mar-20 Apr	____	.5968
	21 Apr-1 May	____	____			
	31 May-6 Jun	____	____			
	14-24 Jun	____	____			
Summer 1978	21-29 Jul	____	____	19 Jun-9 Jul	____	1.550
	1-9 Aug	____	____			
	15-21 Aug	____	____			
Fall 1978	3-13 Nov	____	____	25 Oct-17 Nov	____	.0270
Winter 1979	6-16 Mar	____	____	13 Feb-11 Mar	____	.0643

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon *Hemilepidotus* spp. Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov	.4131	17.81
Spring 1978	29 Mar-8 Apr					
	10-17 Apr			28 Mar-20 Apr	.1863	.7993
	21 Apr-1 May					
	31 May-6 Jun					
	14-24 Jun					
Summer 1978	21-29 Jul			19 Jun-9 Jul	.0030	
	1-9 Aug					
	15-21 Aug					
Fall 1978	3-13 Nov			25 Oct-17 Nov	.2292	7.805
Winter 1979	6-16 Mar			13 Feb-11 Mar	.1988	1.616

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Myoxocephalus Type A Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		
Spring 1978	29 Mar-8 Apr		2.881			
	10-17 Apr		1.364	28 Mar-20 Apr		
	21 Apr-1 May		2.587			
	31 May-6 Jun		.0718			
	14-24 Jun					
Summer 1978	21-29 Jul			19 Jun-9 Jul		
	1-9 Aug					
	15-21 Aug					
Fall 1978	3-13 Nov			25 Oct-17 Nov		
Winter 1979	6-16 Mar		.3741	13 Feb-11 Mar		

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Myoxocephalus Type B Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		
Spring 1978	29 Mar-8 Apr		2.600			
	10-17 Apr		2.845	28 Mar-20 Apr		
	21 Apr-1 May		7.662			
	31 May-6 Jun		.4180			
	14-24 Jun		.0565			
Summer 1978	21-29 Jul			19 Jun-9 Jul		
	1-9 Aug					
	15-21 Aug					
Fall 1978	3-13 Nov			25 Oct-17 Nov		
Winter 1979	6-16 Mar		.0718	13 Feb-11 Mar		

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Cyclopteridae Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		
Spring 1978	29 Mar-8 Apr		.3343			
	10-17 Apr		.6938	28 Mar-20 Apr		
	21 Apr-1 May		1.943			
	31 May-6 Jun		1.309			
	14-24 Jun		.3847			
Summer 1978	21-29 Jul		1.232	19 Jun-9 Jul		
	1-9 Aug		.5986			
	15-21 Aug		.4623			
Fall 1978	3-13 Nov			25 Oct-17 Nov		
Winter 1979	6-16 Mar		.0718	13 Feb-11 Mar		

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Bathymasteridae Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		
Spring 1978	29 Mar-8 Apr					
	10-17 Apr			28 Mar-20 Apr		
	21 Apr-1 May	.0260	.6596			
	31 May-6 Jun	.0042	22.43			
	14-24 Jun	.0292	8.765			
Summer 1978	21-29 Jul	.0349	2.878	19 Jun-9 Jul		
	1-9 Aug	.0213	6.070			
	15-21 Aug	.0184	2.164			
Fall 1978	3-13 Nov			25 Oct-17 Nov		
Winter 1979	6-16 Mar			13 Feb-11 Mar		

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon *Bathymaster* spp. Stage Larvae

Season	Inshore			Offshore		
	Dates	Mean (#10m^2)		Dates	Mean (#10m^2)	
		Neuston	Bongo		Neuston	Bongo
Fall 1977				31 Oct-14 Nov	.0034	___
Spring 1978	29 Mar-8 Apr	___	___			
	10-17 Apr	___	___	28 Mar-20 Apr	___	.0473
	21 Apr-1 May	___	___			
	31 May-6 Jun	___	___			
	14-24 Jun	___	___			
Summer 1978	21-29 Jul	___	___	19 Jun-9 Jul	.6531	58.10
	1-9 Aug	___	___			
	15-21 Aug	___	___			
Fall 1978	3-13 Nov	___	___	25 Oct-17 Nov	.0093	___
Winter 1979	6-16 Mar	___	___	13 Feb-11 Mar	.0014	___

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Ronquilus jordani Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov	___	___
Spring 1978	29 Mar-8 Apr	___	___			
	10-17 Apr	___	___	28 Mar-20 Apr	___	___
	21 Apr-1 May	___	___			
	31 May-6 Jun	___	___			
	14-24 Jun	___	___			
Summer 1978	21-29 Jul	___	___	19 Jun-9 Jul	___	.6614
	1-9 Aug	___	___			
	15-21 Aug	___	___			
Fall 1978	3-13 Nov	___	___	25 Oct-17 Nov	___	___
Winter 1979	6-16 Mar	___	___	13 Feb-11 Mar	___	___

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Lumpenus maculatus Stage Larvae

Season	Inshore Dates	Inshore Mean ($\#10m^2$) Neuston	Inshore Mean ($\#10m^2$) Bongo	Offshore Dates	Offshore Mean ($\#10m^2$) Neuston	Offshore Mean ($\#10m^2$) Bongo
Fall 1977				31 Oct-14 Nov		
Spring 1978	29 Mar-8 Apr		1.525			
	10-17 Apr		3.261	28 Mar-20 Apr		
	21 Apr-1 May		2.291			
	31 May-6 Jun		.1854			
	14-24 Jun					
Summer 1978	21-29 Jul			19 Jun-9 Jul		
	1-9 Aug					
	15-21 Aug					
Fall 1978	3-13 Nov			25 Oct-17 Nov		
Winter 1979	6-16 Mar			13 Feb-11 Mar		

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Lumpenus medius Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		
Spring 1978	29 Mar-8 Apr		3.114			
	10-17 Apr		2.954	28 Mar-20 Apr		
	21 Apr-1 May		2.475			
	31 May-6 Jun		.4497			
	14-24 Jun		.6904			
Summer 1978	21-29 Jul		.1487	19 Jun-9 Jul		
	1-9 Aug					
	15-21 Aug					
Fall 1978	3-13 Nov			25 Oct-17 Nov		
Winter 1979	6-16 Mar		.7653	13 Feb-11 Mar		

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Ammodytes hexapterus Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		
Spring 1978	29 Mar-8 Apr		54.33			
	10-17 Apr		23.92	28 Mar-20 Apr		7.939
	21 Apr-1 May		21.02			
	31 May-6 Jun		.6974			
	14-24 Jun		.1722			
Summer 1978	21-29 Jul			19 Jun-9 Jul		.0680
	1-9 Aug					
	15-21 Aug					
Fall 1978	3-13 Nov			25 Oct-17 Nov		
Winter 1979	6-16 Mar		18.63	13 Feb-11 Mar		.0312

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Pleuronectidae Stage Eggs

Season	Inshore Dates	Inshore Mean ($\#10m^2$) Neuston	Inshore Mean ($\#10m^2$) Bongo	Offshore Dates	Offshore Mean ($\#10m^2$) Neuston	Offshore Mean ($\#10m^2$) Bongo
Fall 1977				31 Oct-14 Nov		
Spring 1978	29 Mar-8 Apr	.1765	3.579			
	10-17 Apr	.5223	9.331	28 Mar-20 Apr		
	21 Apr-1 May	.3134	11.73			
	31 May-6 Jun	.3219	29.31			
	14-24 Jun	3.656	97.40			
Summer 1978	21-29 Jul	10.40	175.2	19 Jun-9 Jul		
	1-9 Aug	9.487	181.6			
	15-21 Aug	3.968	86.64			
Fall 1978	3-13 Nov			25 Oct-17 Nov		
Winter 1979	6-16 Mar	.0190		13 Feb-11 Mar		

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Glyptocephalus zachirus Stage Eggs

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		
Spring 1978	29 Mar-8 Apr					
	10-17 Apr			28 Mar-20 Apr		
	21 Apr-1 May					
	31 May-6 Jun					
	14-24 Jun					
Summer 1978	21-29 Jul			19 Jun-9 Jul		.8759
	1-9 Aug					
	15-21 Aug					
Fall 1978	3-13 Nov			25 Oct-17 Nov		
Winter 1979	6-16 Mar			13 Feb-11 Mar		

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Glyptochephalus zachirus Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		
Spring 1978	29 Mar-8 Apr					
	10-17 Apr			28 Mar-20 Apr		
	21 Apr-1 May					
	31 May-6 Jun					
	14-24 Jun					
Summer 1978	21-29 Jul			19 Jun-9 Jul		1.189
	1-9 Aug					
	15-21 Aug					
Fall 1978	3-13 Nov			25 Oct-17 Nov		
Winter 1979	6-16 Mar			13 Feb-11 Mar		

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon *Hippoglossoides elassodon* Stage Eggs

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		
Spring 1978	29 Mar-8 Apr	.0028	.0718			
	10-17 Apr	.0077	.3721	28 Mar-20 Apr		.4389
	21 Apr-1 May	.0959	3.351			
	31 May-6 Jun	.0303	.2638			
	14-24 Jun	.1845	.4497			
Summer 1978	21-29 Jul	.0307	.3476	19 Jun-9 Jul		.9027
	1-9 Aug	.0403	.3027			
	15-21 Aug	.0078				
Fall 1978	3-13 Nov			25 Oct-17 Nov		
Winter 1979	6-16 Mar			13 Feb-11 Mar		.0310

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Hippoglossoides elassodon Stage Larvae

Season	Inshore			Offshore		
	Dates	Mean (#10m^2)		Dates	Mean (#10m^2)	
		Neuston	Bongo		Neuston	Bongo
Fall 1977				31 Oct-14 Nov		
Spring 1978	29 Mar-8 Apr					
	10-17 Apr			28 Mar-20 Apr		
	21 Apr-1 May		.0565			
	31 May-6 Jun		1.521			
	14-24 Jun		.2821			
Summer 1978	21-29 Jul		.8710	19 Jun-9 Jul		2.025
	1-9 Aug		.5118			
	15-21 Aug		.2638			
Fall 1978	3-13 Nov		.0565	25 Oct-17 Nov		
Winter 1979	6-16 Mar			13 Feb-11 Mar		

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Isopsetta isolepis Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		
Spring 1978	29 Mar-8 Apr					
	10-17 Apr			28 Mar-20 Apr		
	21 Apr-1 May					
	31 May-6 Jun					
	14-24 Jun		.0565			
Summer 1978	21-29 Jul		1.525	19 Jun-9 Jul		.8453
	1-9 Aug		.6056			
	15-21 Aug		.0838			
Fall 1978	3-13 Nov			25 Oct-17 Nov		
Winter 1979	6-16 Mar			13 Feb-11 Mar		

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Lepidopsetta bilineata Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		
Spring 1978	29 Mar-8 Apr		1.396			
	10-17 Apr		5.048	28 Mar-20 Apr		1.524
	21 Apr-1 May		33.88			
	31 May-6 Jun		8.627			
	14-24 Jun		2.627			
Summer 1978	21-29 Jul		.2950	19 Jun-9 Jul		.8328
	1-9 Aug		.1161			
	15-21 Aug					
Fall 1978	3-13 Nov			25 Oct-17 Nov		
Winter 1979	6-16 Mar			13 Feb-11 Mar		

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Limanda aspera Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		
Spring 1978	29 Mar-8 Apr					
	10-17 Apr			28 Mar-20 Apr		
	21 Apr-1 May					
	31 May-6 Jun					
	14-24 Jun					
Summer 1978	21-29 Jul		.3300	19 Jun-9 Jul		
	1-9 Aug		.8669			
	15-21 Aug		.7424			
Fall 1978	3-13 Nov			25 Oct-17 Nov		
Winter 1979	6-16 Mar			13 Feb-11 Mar		

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Microstomus pacificus Stage Eggs

	Inshore			Offshore		
Season	Dates	Mean ($\#10m^2$)		Dates	Mean ($\#10m^2$)	
		Neuston	Bongo		Neuston	Bongo
Fall 1977				31 Oct-14 Nov		
Spring 1978	29 Mar-8 Apr					
	10-17 Apr			28 Mar-20 Apr		
	21 Apr-1 May					
	31 May-6 Jun					
	14-24 Jun					
Summer 1978	21-29 Jul			19 Jun-9 Jul		2.174
	1-9 Aug					
	15-21 Aug					
Fall 1978	3-13 Nov			25 Oct-17 Nov		
Winter 1979	6-16 Mar			13 Feb-11 Mar		

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Microstomus pacificus Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		
Spring 1978	29 Mar-8 Apr					
	10-17 Apr			28 Mar-20 Apr		
	21 Apr-1 May					
	31 May-6 Jun					
	14-24 Jun					
Summer 1978	21-29 Jul			19 Jun-9 Jul		.6054
	1-9 Aug					
	15-21 Aug					
Fall 1978	3-13 Nov			25 Oct-17 Nov		
Winter 1979	6-16 Mar			13 Feb-11 Mar		

APPENDIX I

Comparison of Inshore and Offshore Sampling Areas

Taxon Psettichthys melanostictus Stage Larvae

Season	Inshore Dates	Inshore Mean (#10m^2) Neuston	Inshore Mean (#10m^2) Bongo	Offshore Dates	Offshore Mean (#10m^2) Neuston	Offshore Mean (#10m^2) Bongo
Fall 1977				31 Oct-14 Nov		
Spring 1978	29 Mar-8 Apr					
	10-17 Apr			28 Mar-20 Apr		
	21 Apr-1 May					
	31 May-6 Jun		1.105			
	14-24 Jun		1.673			
Summer 1978	21-29 Jul		4.433	19 Jun-9 Jul		1.809
	1-9 Aug		3.956			
	15-21 Aug		3.084			
Fall 1978	3-13 Nov			25 Oct-17 Nov		
Winter 1979	6-16 Mar			13 Feb-11 Mar		