

PAPER

International Council for the  
Exploration of the Sea



ICES CM 1995/L:15  
Biological Oceanography  
Committee

ZOOPLANKTON INVESTIGATIONS OFF WEST GREENLAND, 1956-1984

by

S.A. Pedersen and E.L.B. Smidt  
Greenland Institute of Natural Resources  
(former: Greenland Fisheries Research Institute),  
Tagensvej 135, 1.tv., DK-2200 Copenhagen N, Denmark

Abstract

The available data on the density and composition of zooplankton obtained in offshore plankton surveys carried out annually during 1956-1984, except in 1965 and 1967, in June-July off West Greenland by the Danish Institute of Fisheries and Marine Research and the Greenland Fisheries Research Institute have been analysed. The average densities have been calculated and inter-annual changes in the densities and of the most important species investigated. There was a decreasing trend in both the CPUEs of plankton volume and selected species e.g. the copepod, *Calanus finmarchicus*, as well as a positive associations to sea temperature measurements from the late 1950s and early 1960s to the 1970s. These trends may be indicative for a decrease in the zooplankton productivity and changes in the ecosystem food-web structure in the same time period. A very weak positive association between the mean number of cod (*Gadus morhua*) larvae caught and the mean sea temperatures were found. The failure of the 1982 year-class and the inability to relate the catches of cod larvae to subsequent recruitment were the main reasons that put the end to the zooplankton time-series from off West Greenland in 1985.

## Introduction

In the present century there have been major changes in the abundance of commercially important fish species in West Greenland waters. Historically, Atlantic cod (*Gadus morhua*) has been the most important commercial fish species in Greenland waters, with annual international landings peaking at levels between 400,000 and 500,000 tons in the early 1960s (Fig. 1). In the late 1960s the annual landings showed a drastic decline. After 1970, the recruitment to the West Greenland cod stock has shown large variations and all important year-classes in West Greenland waters have been of Icelandic origin (Buch *et al.* 1994, Hovgård and Wieland in press). After 1990 the Atlantic cod has been very sparse in West Greenland waters (Anon. 1994). In the 1980s and 1990s the northern shrimp (*Pandalus borealis*) has been the far most important fishery resource at West Greenland with annual landing peaking at 87,000 tons in 1992 (Anon. 1995). The low productivity of the West Greenland cod stock is assumed to be due mainly to decreased and unfavourable water temperature conditions for spawning, egg/larvae survival and to changes in the whole ecosystem productivity (food-web structure) (Hermann *et al.* 1965, Pedersen 1994).

In the North Atlantic analogous biological seasons occur at different times of the year in different parts of the same aquatory, as if they moved together with the water of warm currents and this phenomenon often determines the direction of the feeding migrations of pelagic fishes (Pavshtiks 1968, 1972). Davis Strait resembles the other northern regions of the Atlantic in many ways in its complex circulation, clearly defined frontal zones, and other hydrological factors (Pavshtiks l.c.). Seasonal and inter-annual variability in the hydrographical conditions and fauna of the upper ocean layer along West Greenland is – governed mainly by inflow of water from other parts of the North Atlantic (Pavshtiks l.c., Lee 1968, Buch 1984, 1990, 1993). The surface layer (0–150 m) of the West Greenland Current is dominated by cold, relatively fresh Polar Water carried to the area by the East Greenland Current, while the underlying layer (150–800 m) consists totally of water originating from the warm, salty Irminger Current (Fig. 2). Mixing and heat diffusion between the two layers are important factors for the temperature conditions which among other things are dependent on the flow intensity. Years with a strong East Greenland Current will tend to show up as cold ones and vice versa. A description of annual and inter-annual variation in the ice conditions is given in Buch (1990).

The most recent general publication on zooplankton in West Greenland waters, including a protracted list of references is by Smidt (1979). Smidt (l.c.) presents results of zooplankton sampling in inshore and coastal waters throughout the years 1950–66, mainly in the Nuuk (Godthåb) district.

From 1956 to 1984 a series of offshore plankton surveys were carried out annually, except in 1965 and 1967, in June–July off West Greenland by the Danish Institute of Fisheries and Marine Research and the Greenland Fisheries Research Institute. Some of the main aims of these surveys and zooplankton collections were: 1) to collect and possibly quantify fish egg and larvae, especially of Atlantic cod, in order to get information on the strength of the new year-classes, 2) to evaluate the amount of zooplankton and quality (species composition) as food for the recruiting year-classes of fish, 3) to identify indicator species for different hydrographical conditions in the area, 4) to compare variations in the zooplankton by year and

possibly to identify trends over the years in the species composition and productivity. The zooplankton data (invertebrates and fish eggs and larvae) have recently been compiled in a database together with sea temperature and salinity measurements. The purpose of the present paper is to give a description of the information in the zooplankton database and to present results from analyses of the zooplankton data (species composition, occurrence, abundance indices) for variations, trends and associations with e.g. temperature. Of special interest is the long-term variations or trend between the period before 1970 (1956–1970, relatively warm period) and after 1970 (1970–1984, relatively cold period).

## Materials and methods

### Methods of sampling

By far most of the zooplankton, 1956–1984, was collected on stations along three transects [hydrographic areas/sections, (S1, S2 and S3)] off West Greenland in June–July in conjunction with collections of hydrography data from standard depths (Fig. 2–5). Zooplankton and sea water temperature data from these transects have been analyzed for annual variations.

Sampling was carried out with the R/V "Adolf Jensen" and "DANA". The zooplankton sampling gear used was a 2 m (diameter) stramin-ring-net with 1 mm mesh size. The towing speed was about 1.5 to 2.0 knots during the whole tow duration of about 30 min. During the years two different hauling procedures were employed. Before 1963, all hauls were horizontally, stratified with two nets on the same wire in three times 10 min. and with wire lengths 200, 150, 125 and 100, 50, 25 m for the two nets, respectively.

In 1963 (the NORWESTLANT survey), all hauls were made obliquely with only one net hauled from about 50 m depth to the surface at 1.5 knots, wire length 225–0 m, duration about 30 min.

In 1964 and 1966, stratified hauls with two nets were again made, but in all the following years, 1967–1984, hauls with only one net were made obliquely as in 1963.

### Analysis of samples

In order to make the zooplankton samples comparable haul by haul, between years, and hence by hauling method (stratified vs. oblique hauls) all figures in the present paper are calculated to 30 min. hauls. The figures from the two nets in the stratified hauls (before 1963 and in 1964 and 1966) have been averaged. Because of some extra hauling time a conversion factor of roughly 0.75 is used for the stratified hauls before 1963 and roughly 0.85 for hauls in the years 1964 and 1966. Only data from hauls with a maximum wire length less than 251 m have been included in the present paper.

Calibration experiments performed in 1984 with flowmeter attached to the opening of the 2 m stramin net showed that a haul duration of 30 min. at towing speed 2 knots equals a filtered volume of water of about 6125 m<sup>3</sup> (Hovgård and Wieland in press).

The method used for sorting and counting was first to pick out and count the larger animals

from the total sample before taking an aliquot subsample to identify and count the smaller and more numerous animals. The plankton volume in ml is the displacement volume measured at sea exclusive salps and scyphomedusae, adjusted to 30 min. haul. All other zooplankton data presented in this paper are expressed in numbers per 30 min. haul.

The zooplankton groups and species selected and analyzed in the paper are listed in Table 1. Very small animals are not caught by the 1 mm mesh size in the ring net used, and many small development stages and small species are therefore not included in the species list Table 1. For more complete lists of species including also small development stages and species see Jørgensen *et al.* (1978a,b) and Smidt (1979). In some years not all samples were sorted for invertebrates, although sorted for fish eggs and larvae and in 1965 and 1967 there were no sampling at all (Table 2).

#### Analysis of variance and associations

The zooplankton CPUE data (volume and numbers per 30 min. haul) showed non-normality and were, therefore, analyzed for variations (effects of sampling section and year) using rank tests. Kruskal-Wallis tests and two-way ANOVAs on ranked data were performed (Anon. 1985, NPAR1WAY, RANK and GLM procedures).

The sea temperature and salinity at the sampling stations were calculated as simple means of temperature and salinity measurements in the range 10–50 m (normally the standard depths 10, 25, and 50 m or 10, 20, 30, and 50 m). Effects of sampling locations and year on the mean temperature and salinity were analyzed by a two-way ANOVA. The number of temperature, salinity and zooplankton observations (sampled stations with data) by section and year are given in Table 2.

Associations between temperature, salinity and logarithmic transformed CPUE-values of zooplankton [ $\ln(\text{volume and animal numbers per 30 min. haul}) + 1$ ] were investigated by Persons product-moment correlations (Anon. 1985).

## Results

#### Distribution of the zooplankton CPUEs (Fig. 5–27)

The zooplankton CPUE-values, June–July 1956–1984, show not surprisingly large distributional variations, however, some general trends are apparent. Comparing the "white" and "red" form of *Aglantha digitale* it appears that the "white" form becomes less abundant in the northern survey area around Disko Island whereas the "red" form is found only in the northern and westernmost samples (Fig. 7 and Fig. 8). The copepods *Calanus finmarchicus* and *C. hyperboreus* show alike distribution and the largest quantities are taken at the westernmost stations and in the Disko Bay (Fig. 9 and Fig. 10). *Euchaeta* (*Pareuchaeta*) *norvegica* is most abundant at the western and southern haul stations (Fig. 11). Comparisons of the distributions of *Limacina* (*Spiratella*) *helicina* and *Limacina* (*Spiratella*) *retroversa* show a clear trend of the former being more northerly distributed than the latter (Fig. 15 and Fig. 16). *Clione limacina* shows no clear distributional trends (Fig. 17). Shrimp larvae are caught on most of the sampling locations with a trend of the largest catches being taken in the Disko bay (Fig. 19). Crab larvae are most abundant in hauls near the coast and in the

Disko Bay (Fig. 20). Larvae of Atlantic cod, Greenland halibut, long rough dab, and catfishes have been caught in highest numbers in hauls from section S1, S2 and S3 (Fig. 21, Fig. 22, Fig. 26 and Fig. 27). The highest CPUE-values of redfish larvae have been observed on the southern and southwesternmost haul stations (Fig. 23). Highest CPUE-values of sandeel larvae have been observed over the so-called fishing banks closest to the shore and in the Disko Bay (Fig. 24). Capelin larvae have been taken mainly in inshore hauls in the Godthåbsfjord area and just south of Disko island (Fig. 25).

#### Analysis of variance and associations

##### Mean sea temperature (MTEMP) and salinity (MSAL):

The MTEMP and MSAL shows large inter-annual fluctuations (Fig. 28a,b). A two-way ANOVA with section and year as class variables showed a significant effect of year on MTEMP ( $F=10.64$ ,  $p<0.01$ ), but no significant effect of sampling section ( $F=2.37$ ,  $p=0.10$ ). A two-way ANOVA with section and year as class variables showed a significant effects of both year and section on MSAL ( $F=39.26$ ,  $p<0.01$  and  $F=14.95$ ,  $p<0.01$ , respectively). Section 1 generally had the highest mean salinity followed by section 2 and 3. MTEMP showed the highest association with MSAL ( $r=0.46$ ,  $p<0.01$ ,  $n=540$ ) followed by log. transformed CPUEs of the "white" form *Aglantha digitale* ( $r=0.32$ ,  $p<0.01$ ,  $n=186$ ). MSAL showed the highest association with MTEMP ( $r=0.46$ ,  $p<0.01$ ,  $n=540$ ) followed by log. transformed CPUEs of *Gonatus fabricii* ( $r=0.28$ ,  $p<0.01$ ,  $n=306$ ), and Euphausiacea ( $r=0.27$ ,  $p<0.01$ ,  $n=312$ ).

##### Plankton volume (PLVOL):

A two-way ANOVA on the ranked PLVOL data with section and year as class variables showed a significant effect of year ( $F=6.98$ ,  $p<0.01$ ), and section ( $F=21.58$ ,  $p<0.01$ ) (Fig. 30). The log. transformed PLVOL showed positive but weak associations to MTEMP ( $r=0.29$ ,  $p<0.01$ ,  $n=446$ ) with a trend of higher PLVOL in the late 1950s and early 1960s with mean temperatures above 2° C. compared to the 1970s and 1980s with more fluctuating mean temperatures (Fig. 30). The log. transformed PLVOL showed the highest associations with log. transformed CPUEs of *Aglantha digitale* ( $r=0.84$ ,  $p<0.01$ ,  $n=315$ ), *Limacina* sp. ( $r=0.52$ ,  $p<0.01$ ,  $n=314$ ), *Gonatus fabricii* ( $r=0.51$ ,  $p<0.01$ ,  $n=306$ ), euphausiids ( $r=0.50$ ,  $p<0.01$ ,  $n=314$ ), ctenophores ( $r=0.49$ ,  $p<0.01$ ,  $n=262$ ), *Calanus hyperboreus* ( $r=0.47$ ,  $p<0.01$ ,  $n=271$ ) and negative associations with sandeel larvae ( $r=-0.26$ ,  $p<0.01$ ,  $n=532$ ) and crab larvae ( $r=-0.19$ ,  $p<0.01$ ,  $n=315$ ).

##### *Aglantha digitale* (HAGLA="white" form and RAGLA="red" form):

A two-way ANOVA with section and year as class variables showed a significant effect of year on the ranked HAGLA data ( $F=10.07$ ,  $p<0.01$ ), but not on the ranked RAGLA data ( $F=1.35$ ,  $p=0.17$ ) (Fig. 29). For both ranked HAGLA and RAGLA data the sampling section had a significant effect ( $F=10.29$ ,  $p<0.01$  and  $F=19.30$ ,  $p<0.01$ , respectively). Log. transformed HAGLA was positively associated with MTEMP ( $r=0.32$ ,  $p<0.01$ ,  $n=186$ ), whereas log. RAGLA was negatively associated with MTEMP ( $r=-0.26$ ,  $p<0.01$ ,  $n=186$ ). The latter shows that RAGLA is a cold water indicator.

##### *Calanus finmarchicus* (includes also *C. glacialis*) (CALFI):

A two-way ANOVA on the ranked CALFI data with section and year as class variables showed a significant effect of section ( $F=12.27$ ,  $p<0.01$ ) and year ( $F=7.11$ ,  $p<0.01$ ) (Fig. 31 and Fig. 32). Log. CALFI showed the highest association with log. transformed CPUEs of

*Chaetognatha* ( $r=0.81$ ,  $p<0.01$ ,  $n=272$ ), *Calanus hyperboreus* ( $r=0.73$ ,  $p<0.01$ ,  $n=273$ ), *Euchaeta* (*Pareuchaeta*) *norwegica* ( $r=0.68$ ,  $p<0.01$ ,  $n=268$ ), and Euphausiacea ( $r=0.67$ ,  $p<0.01$ ,  $n=272$ ), but no significant association with MTEMP ( $r=-0.00$ ,  $p=0.96$ ,  $n=230$ ).

*Calanus hyperboreus* (CALHY):

A two-way ANOVA on the ranked CALHY data with section and year as class variables showed a significant effect of section ( $F=8.44$ ,  $p<0.01$ ) and year ( $F=9.73$ ,  $p<0.01$ ) (Fig. 31 and Fig. 32). Log. CALHY showed the highest association with log. transformed CPUEs of *Calanus finmarchicus* ( $r=0.73$ ,  $p<0.01$ ,  $n=273$ ), Euphausiacea ( $r=0.69$ ,  $p<0.01$ ,  $n=272$ ), and *Euchaeta* (*Pareuchaeta*) *norwegica* ( $r=0.67$ ,  $p<0.01$ ,  $n=272$ ), but no significant association with MTEMP ( $r=-0.01$ ,  $p=0.94$ ,  $n=230$ ).

*Euchaeta* (*Pareuchaeta*) *norwegica* (EUCH):

A two-way ANOVA on the ranked EUCH data with section and year as class variables showed a significant effect of section ( $F=5.39$ ,  $p<0.01$ ) and year ( $F=6.07$ ,  $p<0.01$ ) (Fig. 32). Log. EUCH showed the highest association with log. transformed CPUEs of *Chaetognatha* ( $r=0.68$ ,  $p<0.01$ ,  $n=277$ ), *Calanus finmarchicus* ( $r=0.68$ ,  $p<0.01$ ,  $n=268$ ), and Euphausiacea ( $r=0.60$ ,  $p<0.01$ ,  $n=276$ ), but no significant association with MTEMP ( $r=-0.01$ ,  $p=0.82$ ,  $n=269$ ).

Hyperiidæ (HYPER):

A two-way ANOVA on the ranked HYPER data with section and year as class variables showed a significant effect of year ( $F=2.21$ ,  $p<0.002$ ), but not of section ( $F=3.10$ ,  $p=0.05$ ) (Fig. 32). Log. HYPER showed the highest association with log. transformed CPUEs of *Euchaeta* (*Pareuchaeta*) *norwegica* ( $r=0.57$ ,  $p<0.01$ ,  $n=276$ ), but no significant association with MTEMP ( $r=-0.09$ ,  $p=0.12$ ,  $n=269$ ).

Euphausiacea (EUPH):

A two-way ANOVA on the ranked EUPH data with section and year as class variables showed a significant effect of section ( $F=9.28$ ,  $p<0.01$ ) and year ( $F=6.68$ ,  $p=0.01$ ) (Fig. 32). Log. EUPH showed the highest association with log. transformed CPUEs of *Calanus hyperboreus* ( $r=0.69$ ,  $p<0.01$ ,  $n=272$ ), and *Calanus finmarchicus* ( $r=0.67$ ,  $p<0.01$ ,  $n=272$ ). Log. EUPH showed a weak positive association with MTEMP ( $r=0.22$ ,  $p<0.01$ ,  $n=268$ ).

*Chaetognatha* (CHAE):

A two-way ANOVA on the ranked CHAE data with section and year as class variables showed a significant effect of section ( $F=7.36$ ,  $p<0.01$ ) and year ( $F=4.41$ ,  $p=0.01$ ) (Fig. 32). Log. CHAE showed the highest association with log. transformed CPUEs of *Calanus finmarchicus* ( $r=0.81$ ,  $p<0.01$ ,  $n=272$ ), *Euchaeta* (*Pareuchaeta*) *norwegica* ( $r=0.68$ ,  $p<0.01$ ,  $n=277$ ), *Calanus hyperboreus* ( $r=0.67$ ,  $p<0.01$ ,  $n=272$ ), and Euphausiacea ( $r=0.62$ ,  $p<0.01$ ,  $n=315$ ), but no significant association with MTEMP ( $r=-0.01$ ,  $p=0.86$ ,  $n=269$ ).

*Limacina* (*Spiratella*) *helicina* (LIMH):

A two-way ANOVA on the ranked LIMH data with section and year as class variables showed a significant effect of section ( $F=17.76$ ,  $p<0.01$ ) and year ( $F=6.93$ ,  $p<0.01$ ) (Fig. 33). Log. LIMH showed the highest association with log. transformed CPUEs of *Limacina* (*Spiratella*) *retroversa* ( $r=0.63$ ,  $p<0.01$ ,  $n=304$ ), *Calanus hyperboreus* ( $r=0.59$ ,  $p<0.01$ ,  $n=264$ ), and Hyperiidæ ( $r=0.52$ ,  $p<0.01$ ,  $n=305$ ), but no significant association with MTEMP ( $r=-0.06$ ,

$p=0.35$ ,  $n=258$ ).

*Limacina (Spiratella) retroversa* (LIMR):

A two-way ANOVA on the ranked LIMR data with section and year as class variables showed a significant effect of section ( $F=26.17$ ,  $p<0.01$ ) and year ( $F=7.22$ ,  $p=0.01$ ) (Fig. 33). Log. LIMR showed the highest association with log. transformed CPUEs of *Limacina (Spiratella) helicina* ( $r=0.63$ ,  $p<0.01$ ,  $n=304$ ), Greenland halibut larvae (*Reinhardtius hippoglossoides*) ( $r=0.60$ ,  $p<0.01$ ,  $n=304$ ), juvenile squids (*Gonatus fabricii*) ( $r=0.60$ ,  $p<0.01$ ,  $n=294$ ), "white" form *Aglantha digitale* ( $r=0.52$ ,  $p<0.01$ ,  $n=204$ ), and depth to bottom ( $r=0.54$ ,  $p<0.01$ ,  $n=303$ ). Log. LIMR showed a weak positive association with MTEMP ( $r=0.15$ ,  $p=0.02$ ,  $n=257$ ).

*Clione limacina* (CLIO):

A two-way ANOVA on the ranked CLIO data with section and year as class variables showed a significant effect of year ( $F=6.57$ ,  $p<0.01$ ) but not of section ( $F=0.91$ ,  $p=0.40$ ) (Fig. 33). Log. CLIO showed the highest association with log. transformed CPUEs of *Limacina (Spiratella) retroversa* ( $r=0.50$ ,  $p<0.01$ ,  $n=304$ ), and *Limacina (Spiratella) helicina* ( $r=0.49$ ,  $p<0.01$ ,  $n=305$ ), but no significant association with MTEMP ( $r=0.09$ ,  $p=0.16$ ,  $n=269$ ).

*Gonatus fabricii* juv. (GONA):

A two-way ANOVA on the ranked GONA data with section and year as class variables showed a significant effect of section ( $F=10.00$ ,  $p<0.01$ ) and year ( $F=5.42$ ,  $p<0.01$ ) (Fig. 33). Log. GONA showed the highest association with log. transformed CPUEs of *Limacina (Spiratella) retroversa* ( $r=0.60$ ,  $p<0.01$ ,  $n=294$ ), Greenland halibut larvae (*Reinhardtius hippoglossoides*) ( $r=0.56$ ,  $p<0.01$ ,  $n=308$ ), and depth to bottom ( $r=0.53$ ,  $p<0.01$ ,  $n=307$ ). Log. GONA showed a weak positive association with MTEMP ( $r=0.25$ ,  $p=0.01$ ,  $n=260$ ).

Shrimp (*Pandalus* sp.), mainly *Pandalus borealis* (SHR):

A two-way ANOVA on the ranked SHR data with section and year as class variables showed a significant effect of section ( $F=3.59$ ,  $p=0.03$ ) and year ( $F=3.88$ ,  $p<0.01$ ) (Fig. 33). Log. SHR showed the highest association with log. transformed CPUEs of *Calanus finmarchicus* ( $r=0.39$ ,  $p<0.01$ ,  $n=264$ ), *Calanus hyperboreus* ( $r=0.38$ ,  $p<0.01$ ,  $n=264$ ), and Euphausiacea ( $r=0.37$ ,  $p<0.01$ ,  $n=307$ ), but no significant association with MTEMP ( $r=0.00$ ,  $p=0.96$ ,  $n=262$ ).

Crab (Zoea stage). Brachyura: *Hyas* sp. and *Chionoecetes* sp. (CRAB):

A two-way ANOVA on the ranked CRAB data with section and year as class variables showed a significant effect of section ( $F=23.61$ ,  $p<0.01$ ) and year ( $F=5.05$ ,  $p<0.01$ ) (Fig. 33). Log. CRAB showed the highest association with log. transformed CPUEs of sandeel larvae (*Ammodytes* sp.) ( $r=0.45$ ,  $p<0.01$ ,  $n=317$ ), "white" form *Aglantha digitale* ( $r=-0.29$ ,  $p<0.01$ ,  $n=209$ ), and depth to bottom ( $r=-0.24$ ,  $p<0.01$ ,  $n=316$ ). Log. CRAB showed no significant association with MTEMP ( $r=-0.01$ ,  $p=0.82$ ,  $n=269$ ).

Fish larvae:

*Gadus morhua* (COD):

A two-way ANOVA on the ranked COD data with section and year as class variables showed a significant effect of section ( $F=12.49$ ,  $p<0.01$ ), and year ( $F=5.07$ ,  $p<0.01$ ) (Fig. 34 and Fig.

35). Log. COD showed the highest association with log. transformed CPUEs of long rough dab larvae (*Hippoglossiodes platessoides*) ( $r=0.37$ ,  $p<0.01$ ,  $n=540$ ), "white" form *Aglantha digitale* ( $r=0.37$ ,  $p<0.01$ ,  $n=209$ ), redfish larvae (*Sebastes* sp.) ( $r=0.31$ ,  $p<0.01$ ,  $n=540$ ), Greenland halibut larvae (*Reinhardtius hippoglossoides*) ( $r=0.30$ ,  $p<0.01$ ,  $n=540$ ), *Calanus finmarchicus* ( $r=0.26$ ,  $p<0.01$ ,  $n=273$ ), and *Calanus hyperboreus* ( $r=0.24$ ,  $p<0.01$ ,  $n=273$ ). Log. COD showed a weak positive association with MTEMP ( $r=0.20$ ,  $p=0.01$ ,  $n=452$ ).

*Reinhardtius hippoglossoides* (GHL):

A two-way ANOVA on the ranked GHL data with section and year as class variables showed a significant effect of section ( $F=30.31$ ,  $p<0.01$ ), and year ( $F=2.5$ ,  $p<0.01$ ) (Fig. 35). Log. GHL showed the highest association with log. transformed CPUEs of *Limacina (Spiratella) retroversa* ( $r=0.60$ ,  $p<0.01$ ,  $n=304$ ), juvenile squids (*Gonatus fabricii*) ( $r=0.56$ ,  $p<0.01$ ,  $n=308$ ), "white" form *Aglantha digitale* ( $r=0.52$ ,  $p<0.01$ ,  $n=209$ ), long rough dab larvae (*Hippoglossiodes platessoides*) ( $r=0.51$ ,  $p<0.01$ ,  $n=540$ ), plankton volume ( $r=0.46$ ,  $p<0.01$ ,  $n=533$ ), *Limacina (Spiratella) helicina* ( $r=0.43$ ,  $p<0.01$ ,  $n=305$ ), catfish larvae (*Anarhichas* sp.) ( $r=0.39$ ,  $p<0.01$ ,  $n=540$ ), and depth to bottom ( $r=0.36$ ,  $p<0.01$ ,  $n=538$ ). Log. GHL showed a weak positive association with MTEMP ( $r=0.13$ ,  $p=0.006$ ,  $n=452$ ).

*Sebastes* sp. (RED):

A two-way ANOVA on the ranked RED data with section and year as class variables showed a significant effect of section ( $F=3.51$ ,  $p=0.03$ ), and year ( $F=5.16$ ,  $p<0.01$ ) (Fig. 35). Log. RED showed the highest association with log. transformed CPUEs of cod larvae (*Gadus morhua*) ( $r=0.31$ ,  $p<0.01$ ,  $n=540$ ), *Calanus finmarchicus* ( $r=0.30$ ,  $p<0.01$ ,  $n=273$ ), Euphausiacea ( $r=0.29$ ,  $p<0.01$ ,  $n=316$ ), *Limacina (Spiratella) retroversa* ( $r=0.27$ ,  $p<0.01$ ,  $n=304$ ), *Euchaeta (Pareuchaeta) norvegica* ( $r=0.25$ ,  $p<0.01$ ,  $n=277$ ). Log. RED showed no significant association with MTEMP ( $r=0.06$ ,  $p=0.21$ ,  $n=452$ ).

*Ammodytes* sp. (SAND):

A two-way ANOVA on the ranked SAND data with section and year as class variables showed a significant effect of section ( $F=25.44$ ,  $p<0.01$ ), and year ( $F=8.84$ ,  $p<0.01$ ) (Fig. 35). Log. SAND showed the highest association with log. transformed CPUEs of Crab (*Zoea* stage) ( $r=0.45$ ,  $p<0.01$ ,  $n=317$ ), depth to bottom ( $r=-0.35$ ,  $p<0.01$ ,  $n=538$ ), "white" form *Aglantha digitale* ( $r=-0.30$ ,  $p<0.01$ ,  $n=209$ ), juvenile squids (*Gonatus fabricii*) ( $r=-0.29$ ,  $p<0.01$ ,  $n=308$ ). Log. SAND showed a weak negative association with MTEMP ( $r=-0.16$ ,  $p=0.0006$ ,  $n=452$ ).

*Hippoglossiodes platessoides* (PLA):

A two-way ANOVA on the ranked PLA data with section and year as class variables showed a significant effect of section ( $F=48.74$ ,  $p<0.01$ ), and year ( $F=4.33$ ,  $p<0.01$ ) (Fig. 35). Log. PLA showed the highest association with log. transformed CPUEs of Greenland halibut larvae (*Reinhardtius hippoglossoides*) ( $r=0.51$ ,  $p<0.01$ ,  $n=540$ ), juvenile squids (*Gonatus fabricii*) ( $r=0.39$ ,  $p<0.01$ ,  $n=308$ ), "white" form *Aglantha digitale* ( $r=0.39$ ,  $p<0.01$ ,  $n=209$ ), plankton volume ( $r=0.37$ ,  $p<0.01$ ,  $n=533$ ), and cod larvae (*Gadus morhua*) ( $r=0.37$ ,  $p<0.01$ ,  $n=540$ ). Log. PLA showed a weak positive association with MTEMP ( $r=0.15$ ,  $p=0.002$ ,  $n=452$ ).

*Anarhichas* sp. (CATF):

A two-way ANOVA on the ranked CATF data with section and year as class variables showed a significant effect of section ( $F=12.64$ ,  $p<0.01$ ), and year ( $F=2.62$ ,  $p<0.01$ ) (Fig. 35).



Log. CATF showed the highest association with log. transformed CPUEs of *Limacina* (*Spiratella*) *retroversa* ( $r=0.40$ ,  $p<0.01$ ,  $n=304$ ), Greenland halibut larvae (*Reinhardtius* *hippoglossoides*) ( $r=0.39$ ,  $p<0.01$ ,  $n=540$ ), juvenile squids (*Gonatus* *fabricii*) ( $r=0.38$ ,  $p<0.01$ ,  $n=308$ ), and *Limacina* (*Spiratella*) *helicina* ( $r=0.35$ ,  $p<0.01$ ,  $n=305$ ), but no significant association with MTEMP ( $r=0.08$ ,  $p=0.08$ ,  $n=452$ ).

## Discussion

### General remarks on the sampling

There is large seasonal and inter-annual variability in the abundance and patchiness formation of zooplankton off West Greenland and this may cause difficulties in the interpretation of the results of the data comparisons between years. However, by taking the same stations on a particular section at approximately the same time each year and calculating the average density for that section one should get a measure of each year's conditions and the most marked changes taking place (Astthórsson *et al.* 1983). This has not completely been fulfilled during the West Greenland zooplankton surveys. Before 1968 the stations sampled were situated further offshore in section S2 and S3 as compared to the stations after 1968 (Fig. 4a,b – only some selected years are presented). This may cause difficulties in the interpretation of the results of the data comparisons between sampling years for some of the species with high CPUEs far offshore e.g. *Calanus finmarchicus* and *C. hyperboreus* (Fig. 9 and Fig. 10), but not for others e.g. northern shrimp and Greenland halibut (Fig. 19 and Fig. 22).

### Trends in species composition and productivity

There was a decreasing trend in both the CPUEs of plankton volume and copepods as well as a positive association to sea temperature measurements from the late 1950s and early 1960s to the 1970s (Fig. 30 and Fig. 31). These trends may be indicative for a decrease in zooplankton productivity and changes in the ecosystem food-web structure in the same time period. Similar decreasing trend in CPUEs of plankton volume and especially *Calanus finmarchicus* have also been observed in northern Icelandic waters in spring from the early 1960s to 1970 (Astthórsson *et al.* 1983, Stefansson and Jakobsson 1989). According to Astthórsson *et al.* (l.c.) a reduced influx of Atlantic water to the areas north of Iceland probably delayed the onset of the spring primary production and thus the zooplankton production. The same may have happened off West Greenland during approximately the same time period.

### Warm and cold water indicators

Boreal species (*Calanus finmarchicus*, *Euchaeta* (*Pareuchaeta*) *norwegica*, *Limacina retroversa*) and Arctic forms (*Calanus hyperboreus*, *C. glacialis*, *Metridia longa*, *Limacina helicina*) occur in the Davis Strait zooplankton during the greater part of the year (Pavshtiks 1968, 1972). Arctic forms enter the Davis Strait with the cold Baffin Land Current (Labrador Current), and with the East Greenland Current (Fig. 2). The boreal species occur throughout the strait together with the cold water forms from the Arctic; they overwinter in the deep part of the strait (Pavshtiks l.c.). In the data presented in this paper no reliable discrimination between *C. finmarchicus* and *C. glacialis* have been made, therefore, the *C. finmarchicus* data

may include an unknown number of *C. glacialis*. According to Pavshikov (l.c.) *C. finmarchicus* and *C. glacialis* form the bulk of the Davis Strait zooplankton during the greater part of the year and it is assumed that several populations of *Calanus* exist and spawn in this area. However, the most abundant *C. finmarchicus* population is brought into the Davis Strait with the Irminger Current (Atlantic water) during spring (Pavshikov l.c.). Spawning of *C. finmarchicus* takes place from May to July both in the Atlantic water of the Irminger current and in the West Greenland coastal waters whereas *C. glacialis* is associated with cold water in the Baffin Land Current and spawns in the coastal waters of Canada (Pavshikov l.c.). Therefore, the *C. finmarchicus* data in this paper from section S1-S3 are assumed to include only a relatively small number of *C. glacialis*.

The "white" form of *Aglantha* occurs almost everywhere in the Davis Strait, but in decreasing numbers the colder the water, and it is replaced by the "red" form in arctic waters (Bainbridge and Corlett 1968). According to Smidt (1979) *Limacina (Spiratella) retroversa* is a warm-water species found only off southern West Greenland whereas *Limacina (Spiratella) helicina* is a cold water species found further to the north and with similar distribution as another cold water species *Clione limacina*. These findings were also indicated by the present study and data analysis.

#### Monitoring year-class strength of fishes from larval surveys

The year-class strength (given at number at age 3) of Atlantic cod off West Greenland has been found to be positively correlated with the mean water temperature (surface to 45 m over Fylla Bank in June) during the larval phase (Hermann *et al.* 1965, Hansen and Buch 1986). Hansen and Buch (l.c.) also found year-class strength to be positively correlated with larval abundance (mean number of cod larvae caught per 30 min. stramin net haul). However, they conclude that although temperature and larval abundance off West Greenland provide some information on the size of cod year-classes better estimates of recruitment may be obtained from young fish surveys. In the present study we found a very weak positive association between the mean number of cod larvae caught and the mean sea temperature (Fig. 34). The sea temperature, the drift of larvae by surface currents, and the stability of the water masses (hydrographic fronts) are important oceanographic factors affecting recruitment to fish and shellfish stocks in West Greenland waters as in waters elsewhere (Horsted *et al.* 1978, Buch *et al.* 1994, Stein and Lloret 1994, Tande *et al.* 1994, Rassmussen and Tande 1995, Munk *et al.* in press, Sinclair and Page 1995).

Recruitment success for fish and shellfish larvae depend on mainly two (controlling) biological processes – predation and food availability (the right food in sufficient amount at the right time). An assessment of the possible intensity of predation on fish larvae is difficult since little is known of the relative importance of the various carnivorous species as predators of young fish (Bainbridge and Corlett 1968). Coelenterates, especially *Aglantha*, together with ctenophores, chaetognaths, and siphonophores are serious predators of fish larvae (Fraser 1961). Among other forms known to be voracious feeders on a wide variety of zooplankton are the hyperiid amphipods, adult *Meganyctiphanes*, *Euchaeta*, *Tomopteris*, and small cephalopods (Bainbridge and Corlett l.c.). An other common carnivorous species in the North Atlantic is *Clione* but this gastropod may be a selective feeder in *Spiratella* (Bainbridge and Corlett 1968, after Bigelow 1924). The latter phenomenon is also indicated in the present study by high associations between *Clione limacina* and both *Limacina (Spiratella) retroversa*

and *Limacina (Spiratella) helicina*. The fish larvae show both associations with potential food species and predator species e.g. Greenland halibut larvae showed positive associations with *Limacina (Spiratella) retroversa*, small squids (*Gonatus fabricii*), "white" form *Aglantha digitale*, long rough dab larvae (*Hippoglossoides platessoides*), and *Limacina (Spiratella) helicina*. Cod, redfish, Greenland halibut and long rough dab larvae showed relatively high associations with *Calanus finmarchicus* and this prey species may be of crucial importance for the larvae survival (Bainbridge and McKay 1968). However, there is a need to establish whether inter-annual variability in fish stock recruitment depends directly upon variations of *Calanus* productivity (Miller 1995). High associations between predators and their prey may not be expected to show up as high correlation coefficients of CPUE survey data, especially not in cases where the predators very effectively are grazing their prey. Similarly, the correlation coefficients of sea temperature, salinity and zooplankton CPUE data can be difficult to interpret because the data are integrated over e.g. hydrographical fronts and patchy zooplankton distributions.

Attempts to monitor the strength of new year-classes of fish and shellfish already in the larval phase are known from many areas, however, with moderate success due to the many and highly fluctuating variables (Cushing 1990, Ådlandsvik and Sundby 1994, Sundby *et al.* 1994, Sinclair and Page 1995). According to Sinclair and Page (1995) there is a need for increased consensus by the scientific community on which of the competing hypotheses on population regulation best capture the critical mechanisms. Prediction of the impacts of climate change are dependent upon which hypothesis or hypotheses best capture the realistic dynamics for a given population and time (Sinclair and Page *l.c.*).

In 1982, the relatively high mean number of cod larvae caught in the stramin net hauls on the West Greenland sampling sections S1-S3 indicated a good prospect for a large cod recruitment, however, the 1982 year-class became poor. It has been assumed that the failure of the 1982 year-class mainly was caused by the extremely low winter temperatures in West Greenland during 1982-1984 (Buch 1990). The failure of the 1982 year-class and the inability to relate the catches of cod larvae to subsequent recruitment were the main reasons that put the end to the time-series and zooplankton collections off West Greenland in 1985.

We hope the present paper will stimulate and add direction to future studies on pelagic ecology, and critical recruitment mechanisms for fish and shellfish stocks in West Greenland marine waters.

#### Acknowledgement

A large part of the work compiling the zooplankton database was made by E.L.B. Smidt and H. Hovgård. Thanks to the ICES Secretariat and J.R. Nielsen (Danish Fisheries Research Institute) for help with the hydrographical data. Thanks also to S.Aa. Horsted for a critical review of an earlier draft of this paper.

## References

- Anon. 1985. SAS User's Guide: Basics/Statistics Version 5. Edition. SAS Institute Inc., Raleigh, North Carolina 1985.
- Anon. 1994. Report of the North-western Working Group. ICES C.M. 1994/Assess:19.
- Anon. 1995. NAFO Scientific Council Reports 1994. 234 pp.
- Astthórsson, O.S., Hallgrímsson, I. and Jónsson, G.S. 1983. Variations in zooplankton densities in Icelandic waters in spring during the years 1961-1982. Rit Fiskideildar 7,2:73-113.
- Bainbridge, V and Corlett, J. 1968. The zooplankton of the NORWESTLANT surveys. Spec. Publ. Int. Comm. Northwest Atl. Fish. 7 (I):101-122.
- Bainbridge, V. and McKay, B.J. 1968. The feeding of cod and redfish larvae. Spec. Publ. Int. Comm. Northwest Atl. Fish. 7 (I):187-217.
- Bigelow, H.B. 1924. Plankton of the offshore waters of the Gulf of Maine. Bull. Bur. Fish., Wash., 40(Pt. 2), 509 p.
- Buch, E. 1984. Variations in temperature and salinity of West Greenland waters, 1970-82. NAFO Sci. Coun. Studies, 7: 39-43.
- Buch, E. 1990. A monograph on the physical environment of Greenland waters. Greenland Fisheries Research Institute, 405 pp.
- Buch, E. 1993. The North Atlantic watercomponent of the West Greenland current. ICES CM 1993/C:20.
- Buch, E., Horsted, S.Aa. and Hovgård, H. 1994. Fluctuations in the occurrence of cod in Greenland waters and their possible causes.-ICES mar. Sci. Symp., 198:158-174.
- Fraser, J.H. 1961. The oceanic and bathypelagic plankton of the Northeast Atlantic. Mar. Res. Scot., 4: 40 p.
- Hansen, H. and Buch, E. 1986. Prediction of year-class strength of Atlantic cod (*Gadus morhua*) off West Greenland. NAFO Sci. Coun. Studies, 10: 7-11.
- Hermann, F, Hansen, P.M. and Horsted, S.A. 1965. The effect of temperature and currents on the distribution and survival of cod larvae at West Greenland. -Spec. Publ. int. Comm. Northw. Atl. Fish. 6: 389-395.
- Horsted, S.A. 1994. A review with some proposals for amendments of the catch statistics for the cod fisheries in Greenland waters since 1911. NAFO SCR Document No. 38, serial No. N2407. 33 pp.
- Horsted, S.A., Johansen, P. and Smidt, E. 1978. On the possible drift of shrimp larvae in the Davis Strait. ICNAF(NAFO) Res. Doc. 78/XI/93, Serial No. 5309. 13 pp.
- Hovgård, H. and Wieland, K. in press. Spawning and larval drift of cod (*Gadus morhua*) in Greenland waters. J. Northw. Atl. Fish. Sci.
- Jørgensen, K.F., Jensen, K., Andersen, O.N. and Hansen, L.M. 1978a. A survey of zooplankton in the upper 100 m at drilling site Ikermiut I (66°56'N, 56°35'W) from July 20 to September 8, 1977. Report for Chevron Petroleum Company of Greenland by BIOKON Aps.
- Jørgensen, K.F., Jensen, K., Andersen, O.N. and Petersen, G.P. 1978b. A survey of zooplankton in the upper 100 m at drilling site Nukik I & II (65°38'N, 54°46'W) from August 2 to 29, 1977. Report for Mobil Exploration Greenland by BIOKON Aps.
- Lee, A.J. 1968. NORWESTLANT Surveys: Physical Oceanography. Spec. Publ. Int.

- Comm. Northwest Atl. Fish. 7 (I):31-54.
- Miller, C. 1995. TransAtlantic studies of *Calanus* (TASC) working group.  
U.S. GLOBEC NEWS No. 8 -- March 1995.
- Munk, P., Larsson, P.O., Danielsen, D., and Moksness, E. in press. Larval and juvenile cod (*Gadus morhua*) concentrated in the highly productive areas of a shelf break front. Mar. Ecol. Prog. Ser.
- Pavshtiks, E.A. 1968. The influence of currents upon seasonal fluctuations in the plankton of the Davis Strait. Sarsia 34: 383-392.
- Pavshtiks, E.A. 1972. Biological seasons in the zooplankton of Davis Strait. Akad. Nauk. SSSR, Zool. Inst., Explor. Mar. Fauna. 12(20). Israel Prog. Sci. Transl., Jerusalem 1975: 200-247.
- Pedersen, S.A. 1994. Multispecies interactions on the offshore West Greenland shrimp grounds. ICES C.M. 1994/P:2.
- Rasmussen, T. and Tande, K. 1995. Temperature-dependent development, growth and mortality in larvae of the deep-water prawn *Pandalus borealis* reared in the laboratory. Mar. Ecol. Prog. Ser. Vol. 118:149-157.
- Sinclair, M. and Page, F. 1995. Cod fishery collapses and North Atlantic GLOBEC.  
U.S. GLOBEC NEWS No. 8 -- March 1995.
- Smidt, E.L.B. 1979. Annual cycles of primary production and of zooplankton at Southwest Greenland. Meddelelser om Grønland, Bioscience No. 1. 53 pp.
- Stefánsson, U. and Jakobsson, J. 1989. Oceanographical variations in the Iceland Sea and their impact on biological conditions - a brief review. In Proceedings of the sixth conference of the comité arctique international 13-15 May 1985, 427-455.  
Edited by Louis Rey and Vera Alexander. E.J. Brill. Leiden, New York, København, Köln.
- Stein, M. and Llort, J. 1994. Stability of water masses - impact on cod recruitment off West Greenland? NAFO SCR Doc. 94/67, Serial No. N2445. 13 pp
- Sundby, S., Ellertsen, B. and Fossum, P. 1994. Encounter rates between first-feeding cod larvae and their prey during moderate to strong turbulent mixing.-ICES mar. Sci.Symp., 198:398-405.
- Tande, K.S., Rasmussen, T., and Pedersen, G. 1994. Thermal Increase Enhancement: a possible link between recruitment and climate in high latitude environments.-ICES mar. Sci. Symp., 198:502-509.
- Ålandsvik, B. and Sundby, S. 1994. Modelling the transport of cod larvae from the Lofoten area.-ICES mar. Sci. Symp., 198:379-392.

Table 1. List of species in the West Greenland zooplankton samples. X - indicate selected group or species included in the database, abbreviations given in brackets.

---

X Ctenophora (CTEN):

*Beroe cucumis*  
*Mertensia ovum*

Hydromedusae :

- X *Aglantha digitale* (HAGLA="white" form and RAGLA="red" form)(red individuals are cold water indicators)  
*Sarsia tubulosa*  
*Sarsia princeps*  
*Euphysa* sp.  
*Bougainvillia superciliaris*  
*Ratkea ocopunctata*  
*Catablema vesicarium*  
*Catablema multicirrata*  
*Halitholus cirratus*  
*Laodicea undulata*  
*Staurophora mertensi*  
*Ptychogena lactea*  
*Halopsis ocellata*  
*Oblia* sp.  
*Aeginopsis laurentii*

Scyphomedusae: (Discarded, not incl. in plankton volume)

*Aurelia aurita*  
*Aurelia limbata*  
*Cyanea capillata*  
*Periphylla periphylla*

Siphonophora :

*Physophora hydrostatica*  
*Dimophyes arctica*

Polychaeta :

*Tomopteris* spp.  
*Autolytus* sp.

Ostracoda :

*Concoecia elegans*  
*Concoecia obtusata*

---

Table 1. continued.

---

X Copepoda (COP):

- X *Calanus hyperboreus* (cold water indicator)(CALHY)
- X *Calanus finmarchicus* (include also *C. glacialis*)(CALFI)
- X *Euchaeta* (*Pareuchaeta*) *norwegica*(EUCH)
- Other species in total copepoda:
  - Pleuromamma robusta*
  - Eucalanus elongatus*
  - Rhincalanus nastutus*
  - Euchirella rostrata*
  - Centropages* sp.
  - Metridia longa*
  - Heterorhabdus norwegicus*

X Hyperiidæ (HYPER):

- Parathemisto abyssorum*
- Parathemisto gadicaudi*
- Parathemisto libellula*
- Hyperoche medusarum*
- Hyperia galba*
- Hyperia medusarum*

Gammaridea :

*Gammarus wilkitaki* and others

X Euphausiacea (EUPH):

- Thysanoessa longicaudata*
- Thysanoessa inermis*
- Thysanoessa raschii*
- Meganyctiphanes norwegica*

Mysidacea :

*Boreomysis nobilis*

Pteropoda :

- X *Limacina* (*Spiratella*) *retroversa* (LIMR)
- X *Limacina* (*Spiratella*) *helicina* (cold water indicator)(LIMH)
- X *Clione limacina* (CLIO)

X Chaetognatha (CHAE):

- Eukrohnia hamata*
  - Sagitta elegans*
  - Sagitta maxima*
-

Table 1. continued.

---

Copelata :*Oikopleura* spp.  
*Fritillaria borealis*

Pelagic bottom invertebrate larvae: Only bigger larvae were taken with the stramin net. Smaller larvae were taken with microplankton and Hensen nets.

Decapod crustacean larvae:

- X Shrimp (*Pandalus* sp.), mainly *Pandalus borealis* (SHR).  
Other shrimp larvae: *Spirontocaris* sp., *Sabinea septemcarinata*,  
and *Pontophilus norvegicus*.
- X Crab (Zoea stage). Brachyura: *Hyas* sp. and *Chionoecetes* sp.  
(CRAB)

Gastropoda :*Velutina velutina*Cephalopoda :

- X *Gonatus fabricii* juv. (GONA)

Fish egg and larvae:

- X *Gadus morhua* (COD)
- X *Anarhichas* sp. (CATF)
- X *Sebastes* sp. (RED)
- X *Reinhardtius hippoglossoides* (GHL)
- X *Ammodytes* sp. (SAND)
- X *Hippoglossoides platessoides* (PLA)
- X *Mallotus villosus* (CAP)
-



Table 2. The number (station sampled) of temperature and zooplankton observations by section and year.

	MTEMP			MSAL			PLVOL			HAGLA			RAGLA			CALFI			CALHY		
	Section			Section			Section			Section			Section			Section			Section		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
YEAR																					
56	3	4	7	3	4	7	3	5	8	3	5	5	3	5	5	3	5	5	3	5	5
57	4	4	6	4	4	6	5	5	7	2	4	2	2	4	2	2	4	3	2	4	3
58	4	5	7	4	5	7	4	7	8	2	3	4	2	3	4	2	3	4	2	3	4
59	5	5	7	5	5	6	5	5	9												
60			2				2	2	2												
61	6	7	5	6	7	5	6	7	6	6	7	6	6	7	6	6	7	6	6	7	6
62	1		3				3	1													
63	6	20	21	6	20	21	12	33	33							12	26	15	12	26	15
64	5	7	10	5	7	10	6	9	11	6	8	8	6	8	8	6	9	8	6	9	8
66	5	7	7	5	7	7	7	10	8	6	9	8	6	9	8	7	9	8	7	9	8
68	4	5	8	4	5	8	6	7	9												
69	6	8	6	6	8	6	6	8	6												
70	5	5	15	5	5	15	6	7	16			4			4			12			12
71	8	8	14	8	8	14	8	9	14			4			4			10			10
72	6	4	8	6	4	8	7	7	10	7	6	5	7	6	5	7	7	10	7	7	10
73	5	5	5	5	5	5	5	5	5			1			1			4			4
74	5	5	5	5	5	5	7	6	5			4			4			3			3
75	6	6	4	6	6	4	6	6	4									4			4
76	6	6	5	6	6	5	6	6	5			5			5	1		5	1		5
77	4	6	4	4	6	4	4	6	5								4	4		4	4
78	6	6	5	5	5	5	6	6	5	5	6	5	5	6	5	6	6	5	6	6	5
79	7	6	6				7	6	6	7	6	6	7	6	6	7	6	5	7	6	5
80	3	4	5	3	4	5	5	5	5	5	5	5	5	5	5			5			
81	5	4	5	5	4	5	5	5	5	5	5	5	5	5	5			5			
82	2	5	4	2	5	4	2	5	5	2	5	5	2	5	5			5			5
83	3	4		3	4		4	4		2	1		2	1		4	4		4	4	
84	5	3	4	5	3	4	5	5	4												

(CONTINUED)

Table 2. continued.

	EUCH			HYPER			EUPH			CHAE			LIMR			LIMH			CLIO		
	Section			Section			Section			Section			Section			Section			Section		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
YEAR																					
56	3	5	2	3	5	5	3	5	5	3	5	5	3	5	5	3	5	5	3	5	5
57	2	4	3	2	4	3	2	4	3	2	4	3	2	4	3	2	4	3	2	4	3
58	2	3	4	2	3	4	2	3	4	2	3	4	2	3	3	2	3	4	2	3	4
59																					
60																					
61	6	7	5	6	7	6	6	7	6	6	7	6	5	7	6	5	7	6	6	7	6
62																					
63	12	26	15	12	26	15	12	26	15	12	26	15	12	26	15	12	26	15	12	26	15
64	6	9	8	6	9	8	6	9	8	6	9	8	6	9	8	6	9	8	6	9	8
66	7	8	8	7	9	8	7	8	8	7	9	8	7	9	8	7	9	8	7	9	8
68																					
69																					
70			14			14			14			14			14			14			14
71			10			10			10			10			10			10			10
72	7	7	10	7	7	10	7	7	10	7	7	10	7	7	10	7	7	10	7	7	10
73			5			5			5			5			5			5			5
74			5			5			5			5			5			5			5
75			5			5			5			5			3			3			5
76	1		5	1		5	1		5	1		5	1		2	1		2	1		5
77		4	4	3	5	5	3	5	5	3	5	5	2	3	2	2	3	2	3	5	5
78	6	6	5	6	6	5	6	6	5	6	6	5	6	6	5	6	6	5	6	6	5
79	7	6	5	7	6	5	7	6	5	7	6	5	7	6	5	7	6	5	7	6	5
80				5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
81				5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
82	2	5	5	2	5	5	2	5	5	2	5	5	2	5	5	2	5	5	2	5	5
83	4	4		4	4		4	4		4	4		4	4		4	4		4	4	
84																					

(CONTINUED)

Table 2. continued.

[illegible]

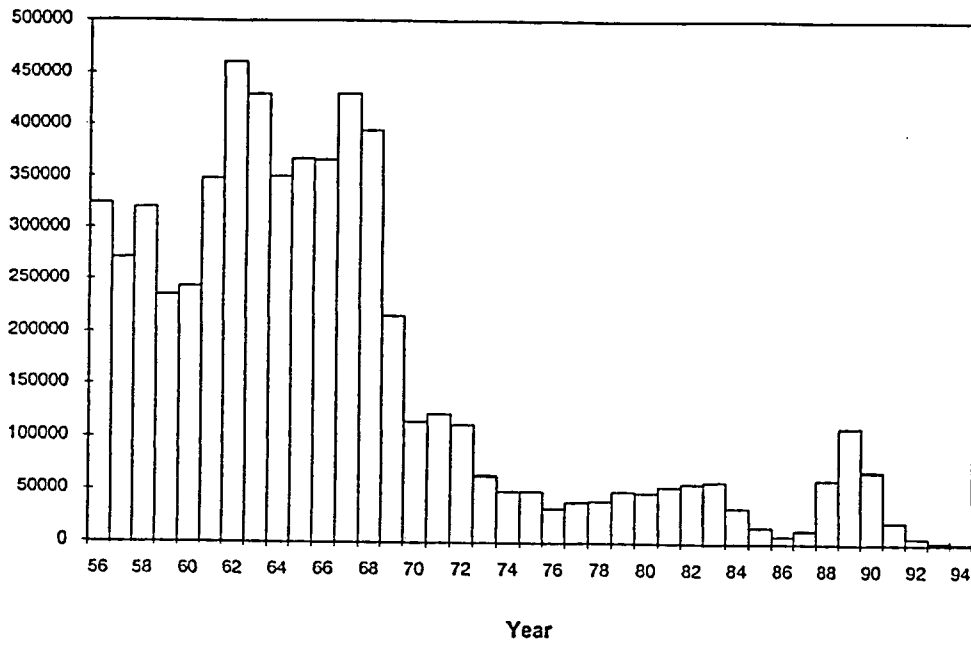


Fig. 1. Nominal catch in tons of Atlantic cod in Subarea 1, 1956-1994 (Data from Horsted 1994).



Fig. 2. The currents around Greenland, and the locations of the three hydrographic sections off West Greenland (From Buch 1984) (simplified after Kiierich 1939, Hermann and Thomsen 1946).

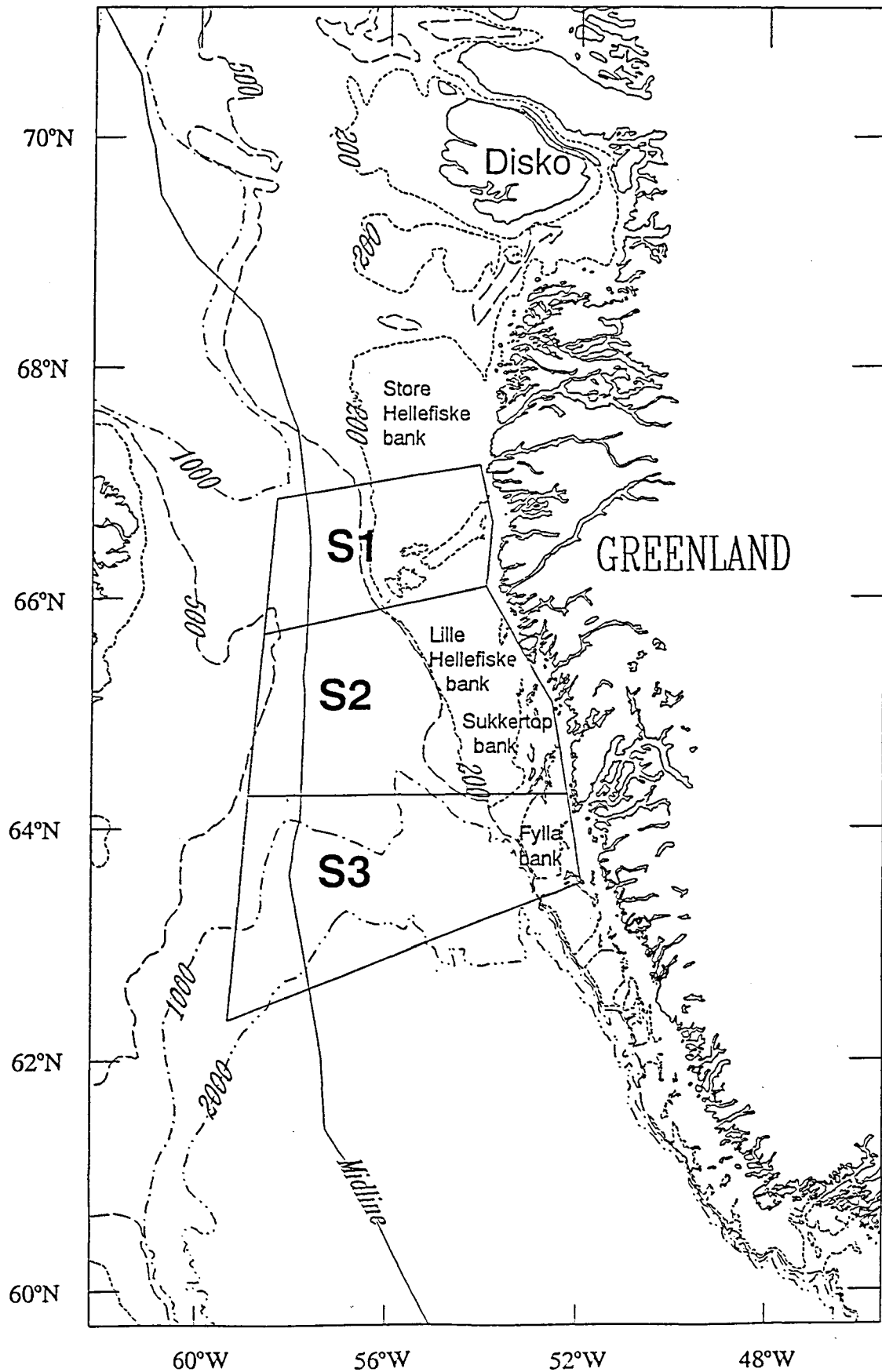


Fig. 3. Map showing the major physiographic features (depths in m) off West Greenland and locations of the three sections S1, S2 and S3.

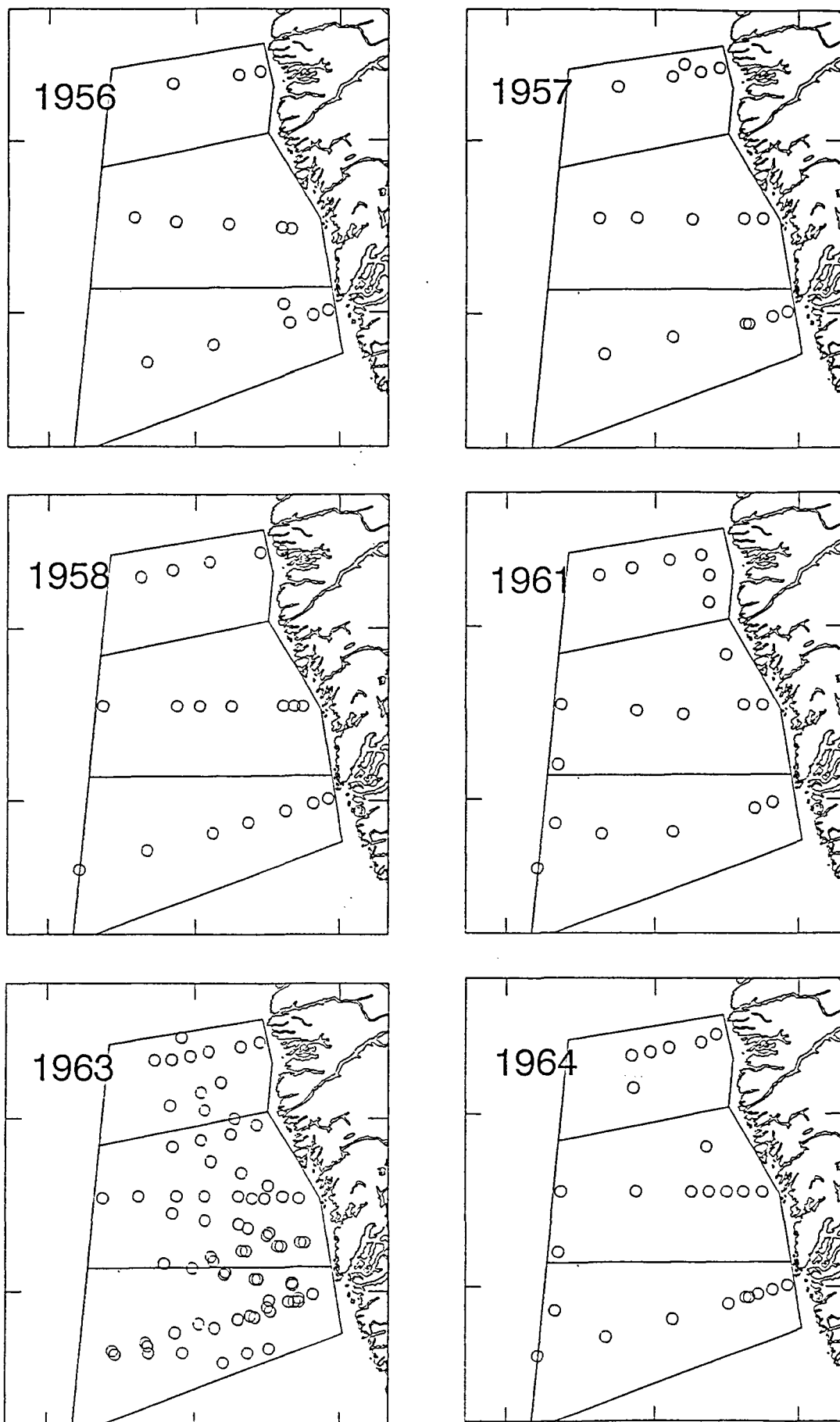


Fig. 4a. Sampling position of hydrography and zooplankton data in June-July by section and year.

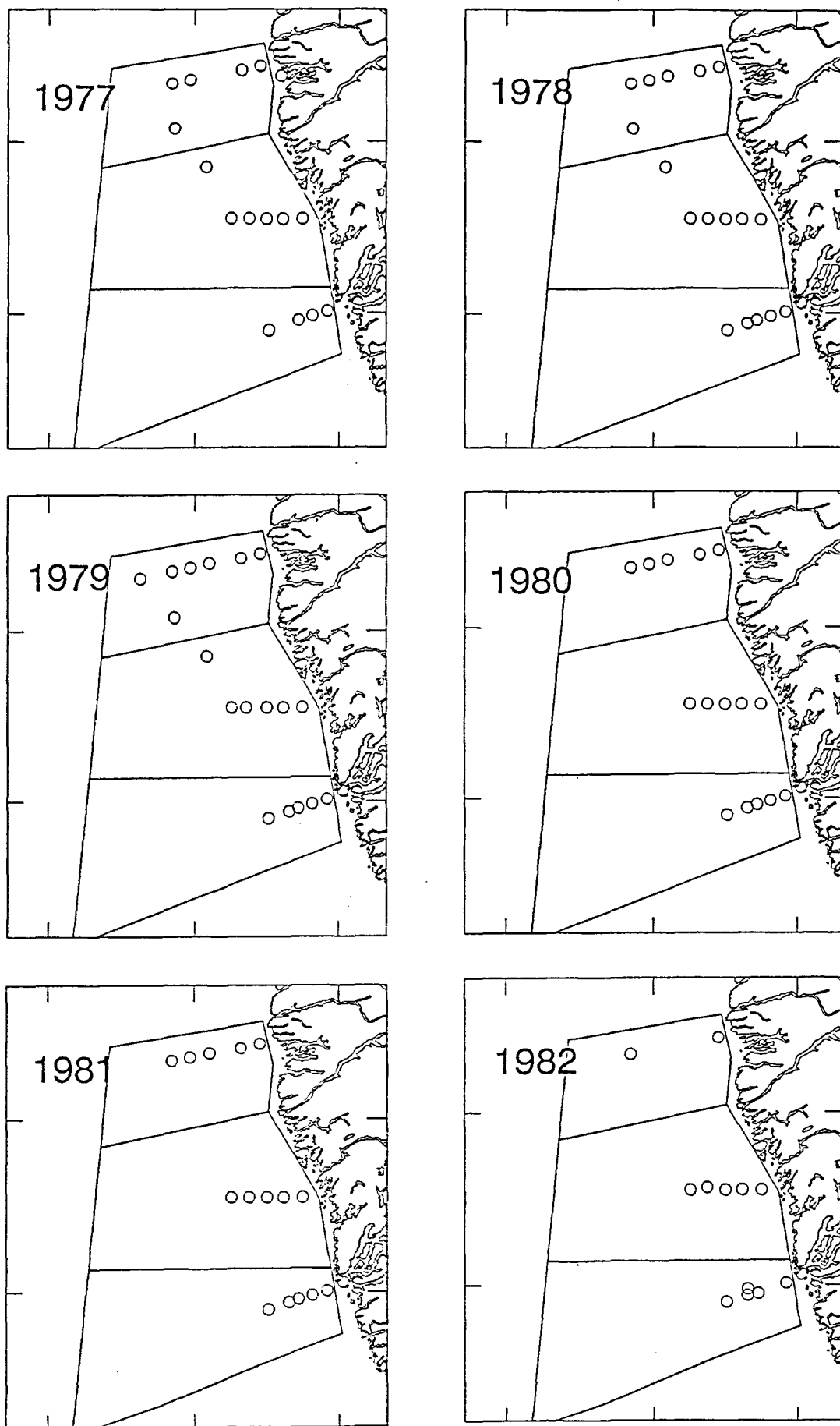


Fig. 4b. Sampling position of hydrography and zooplankton data in June-July by section and year.

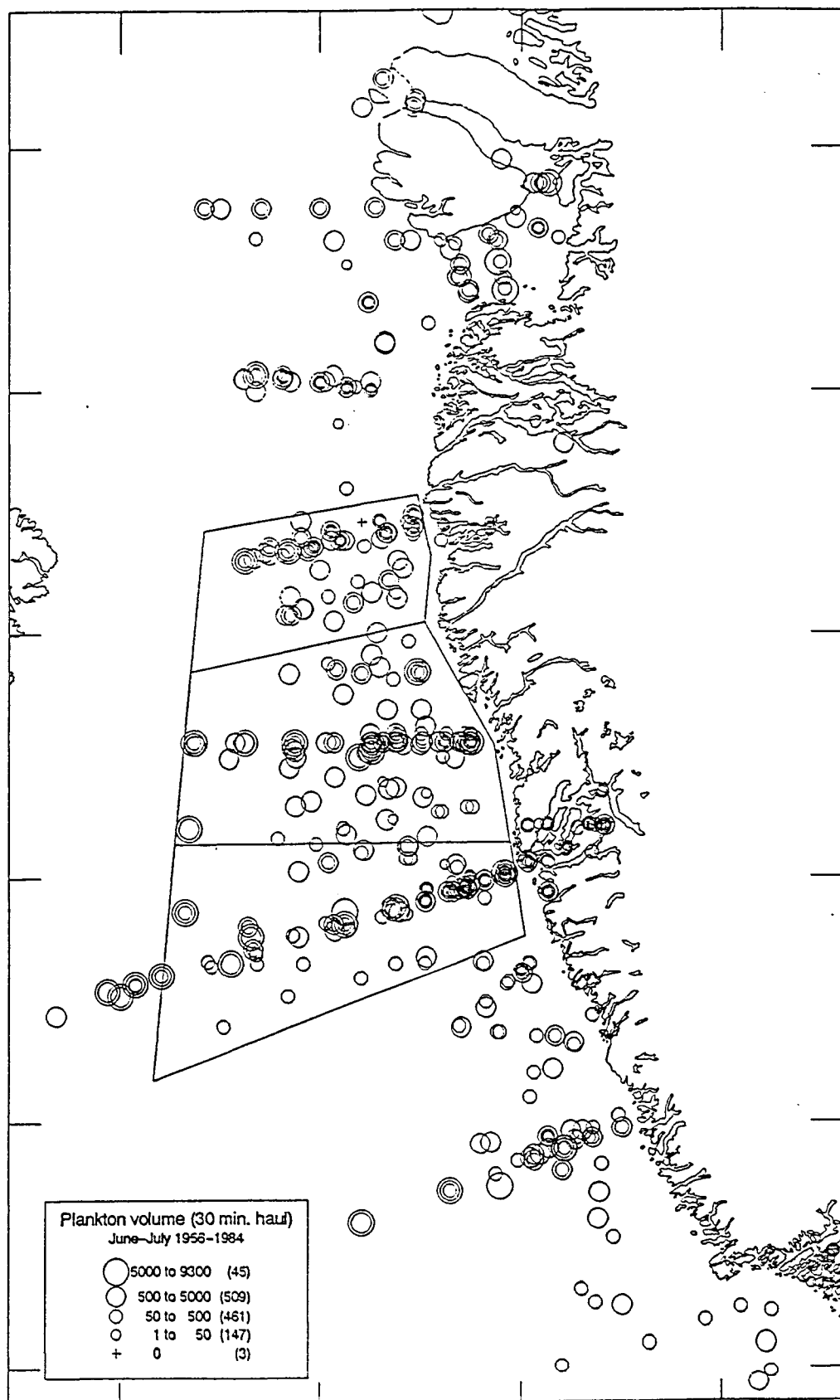


Fig. 5. Plankton volume in ml per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.



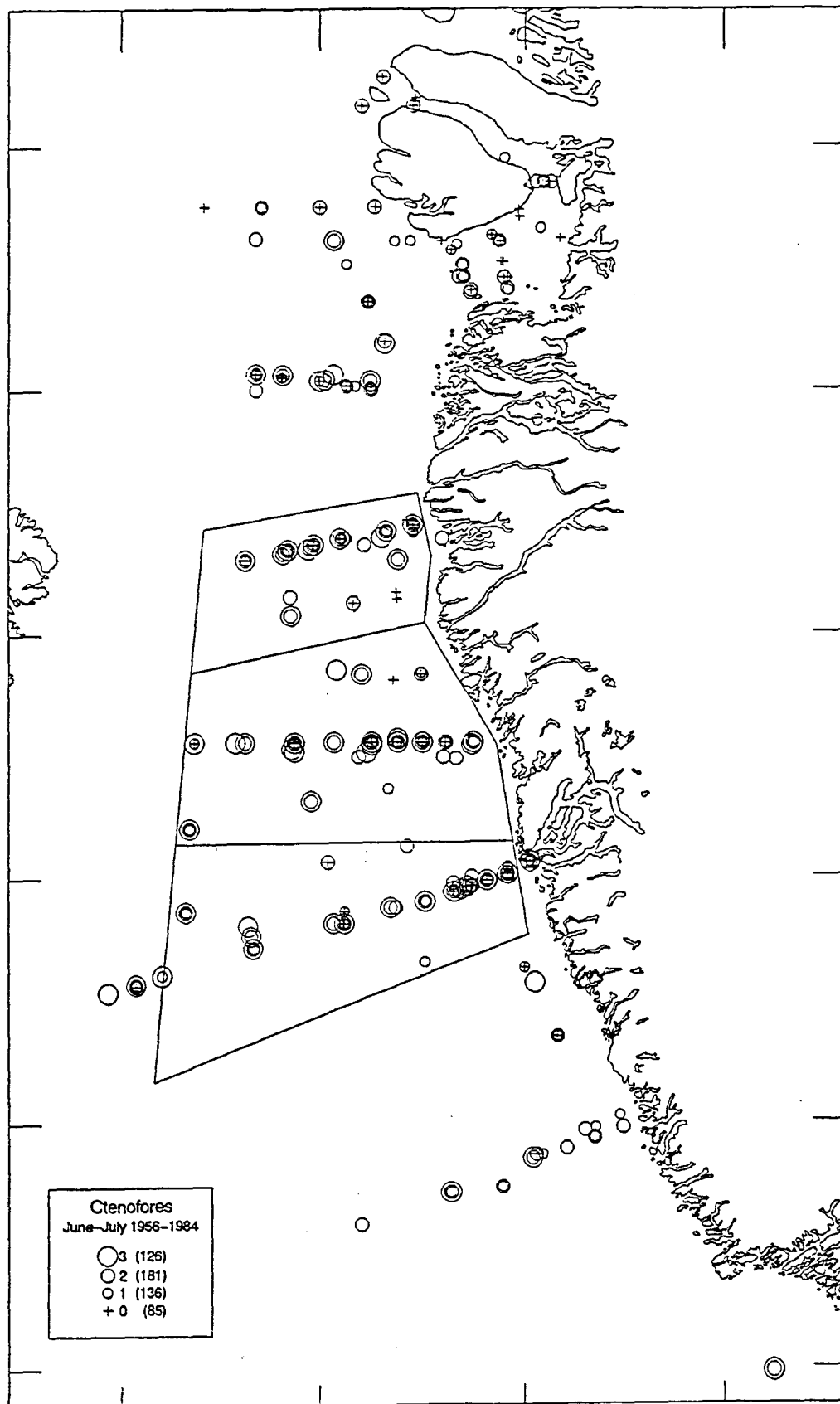


Fig. 6. Number of Ctenophores per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.

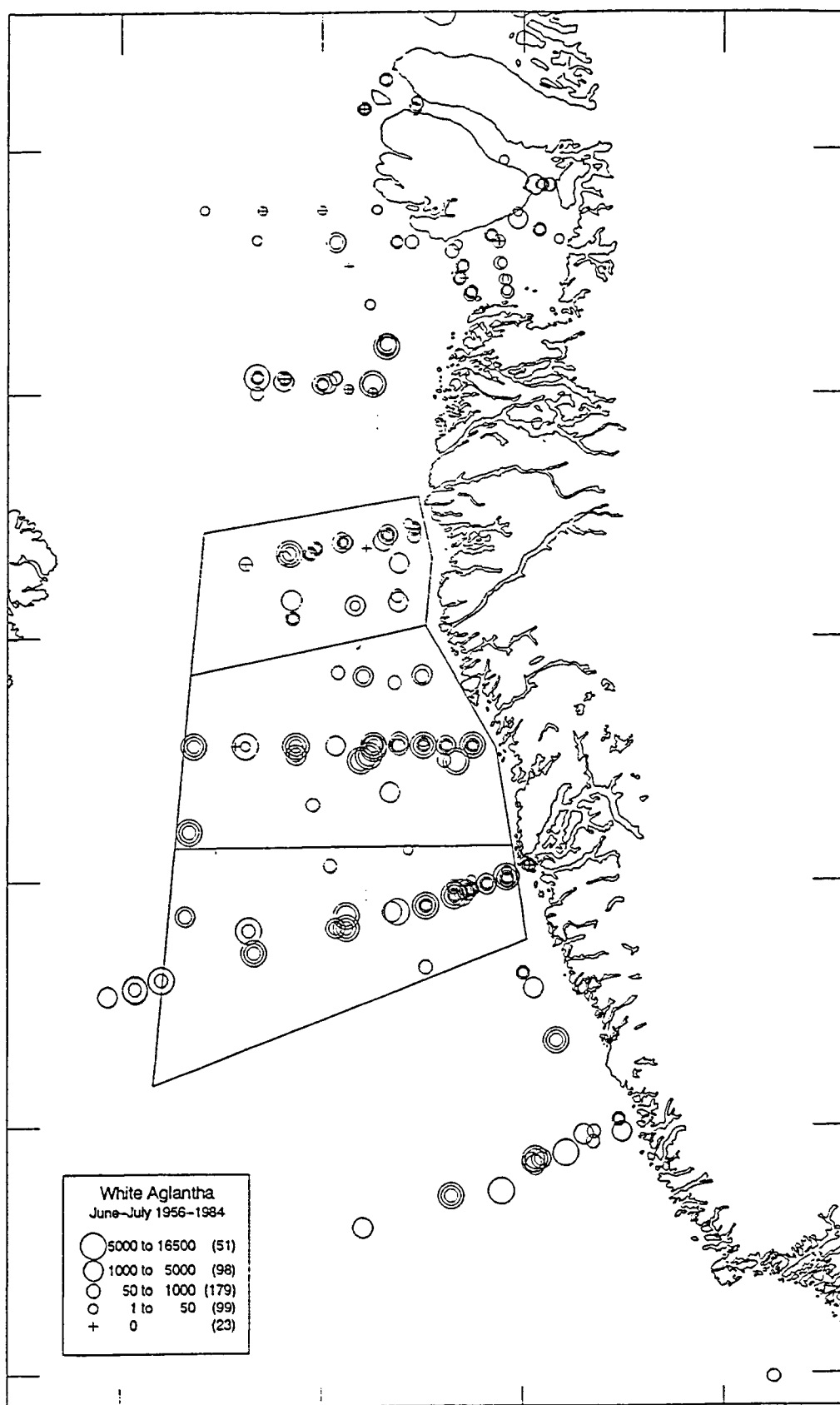


Fig. 7. Number of white *Aglantha digitale* per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets. Only stations sorted for red and white individuals are presented.

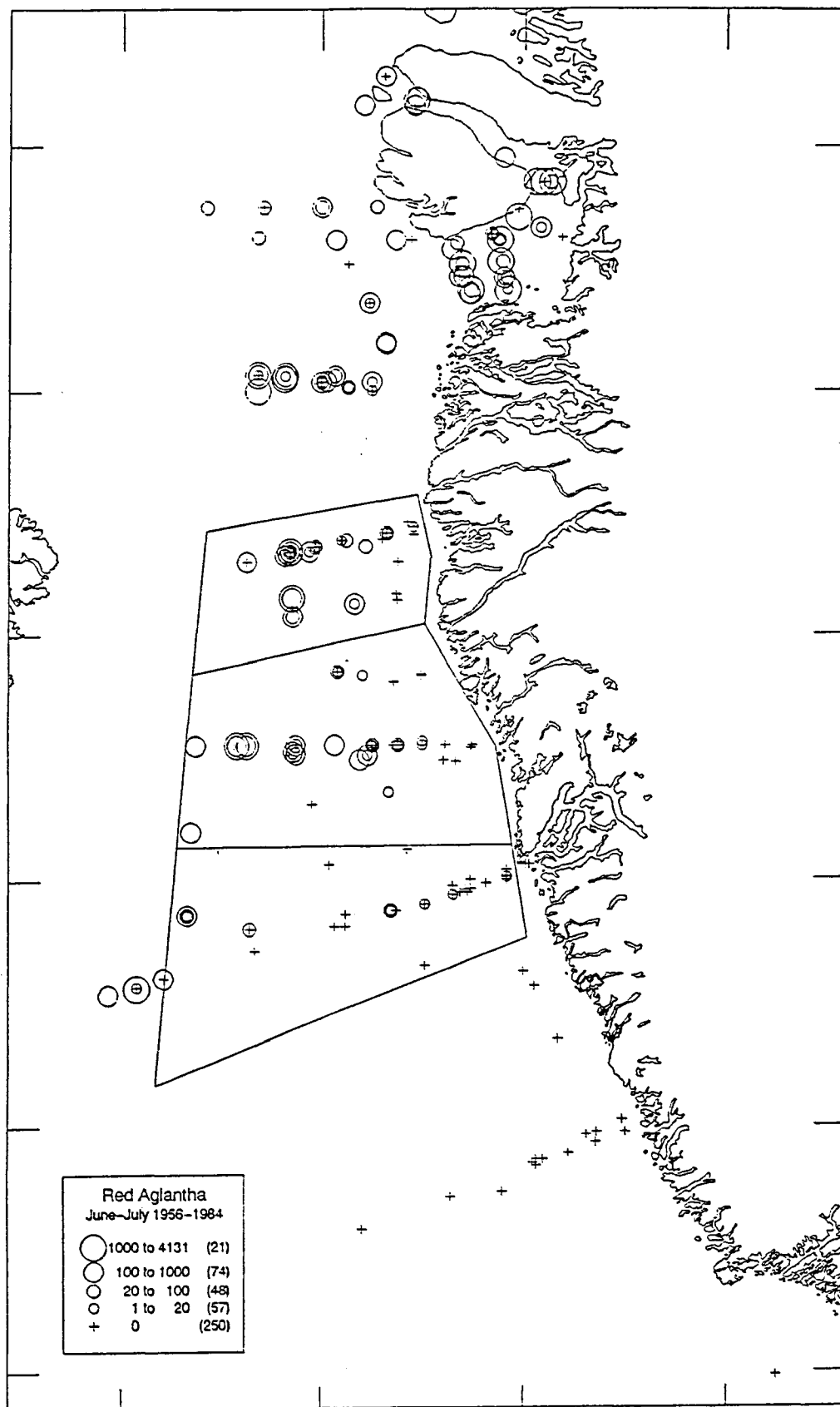


Fig. 8. Number of red *Aglantha digitale* per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets. Only stations sorted for red and white individuals are presented.

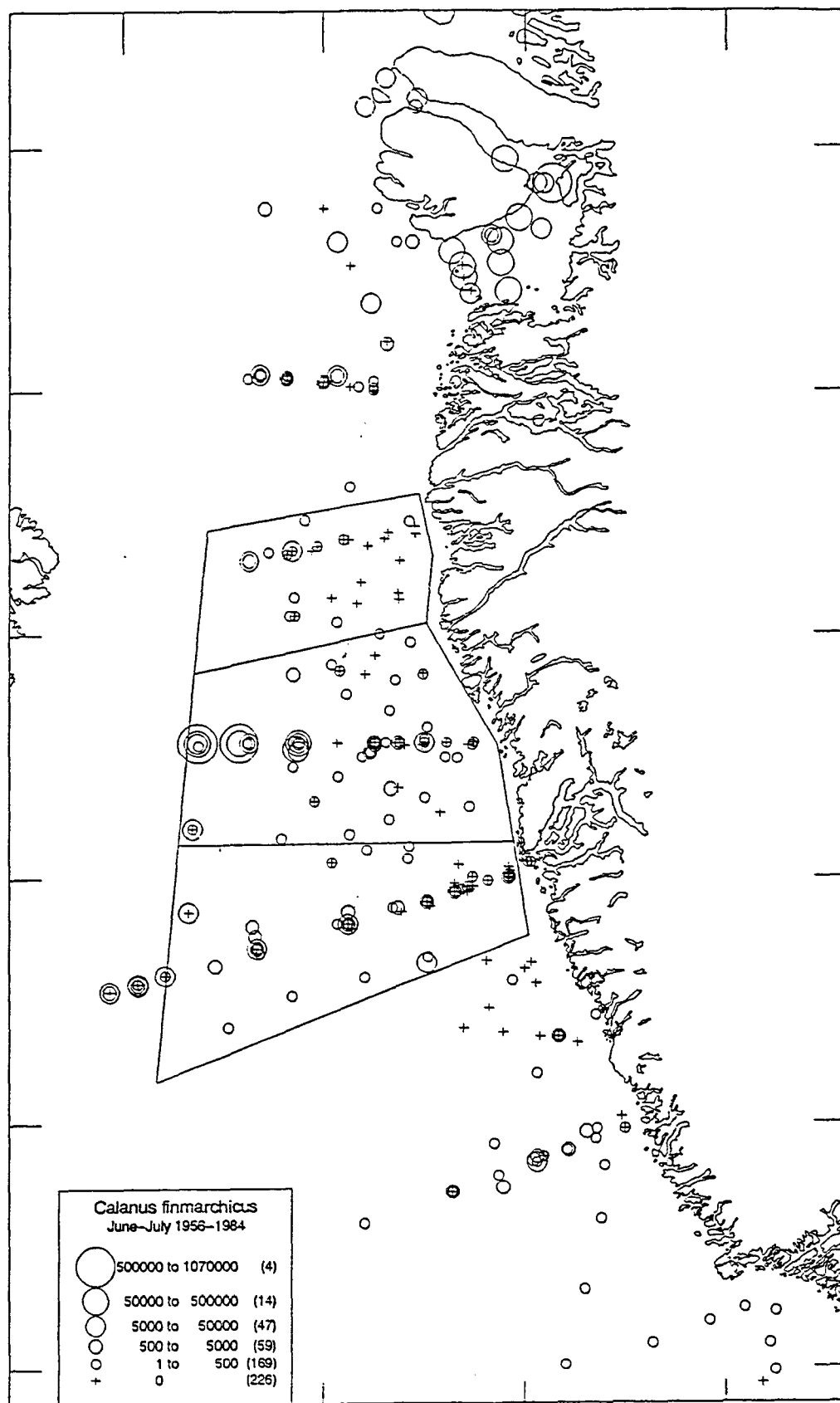


Fig. 9. Number of *Calanus finmarchicus* (*C. glacialis*) per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.

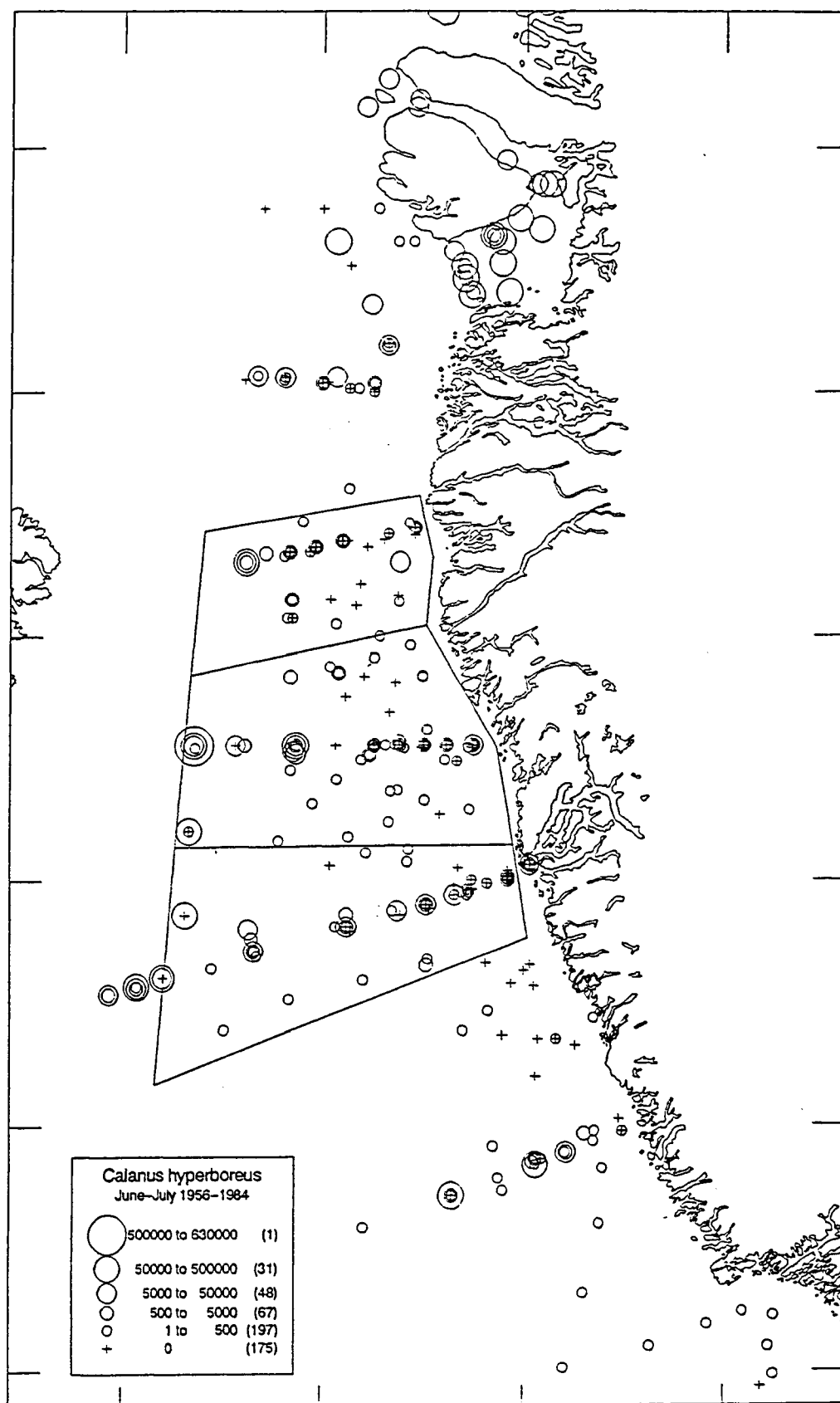


Fig. 10. Number of *Calanus hyperboreus* per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.

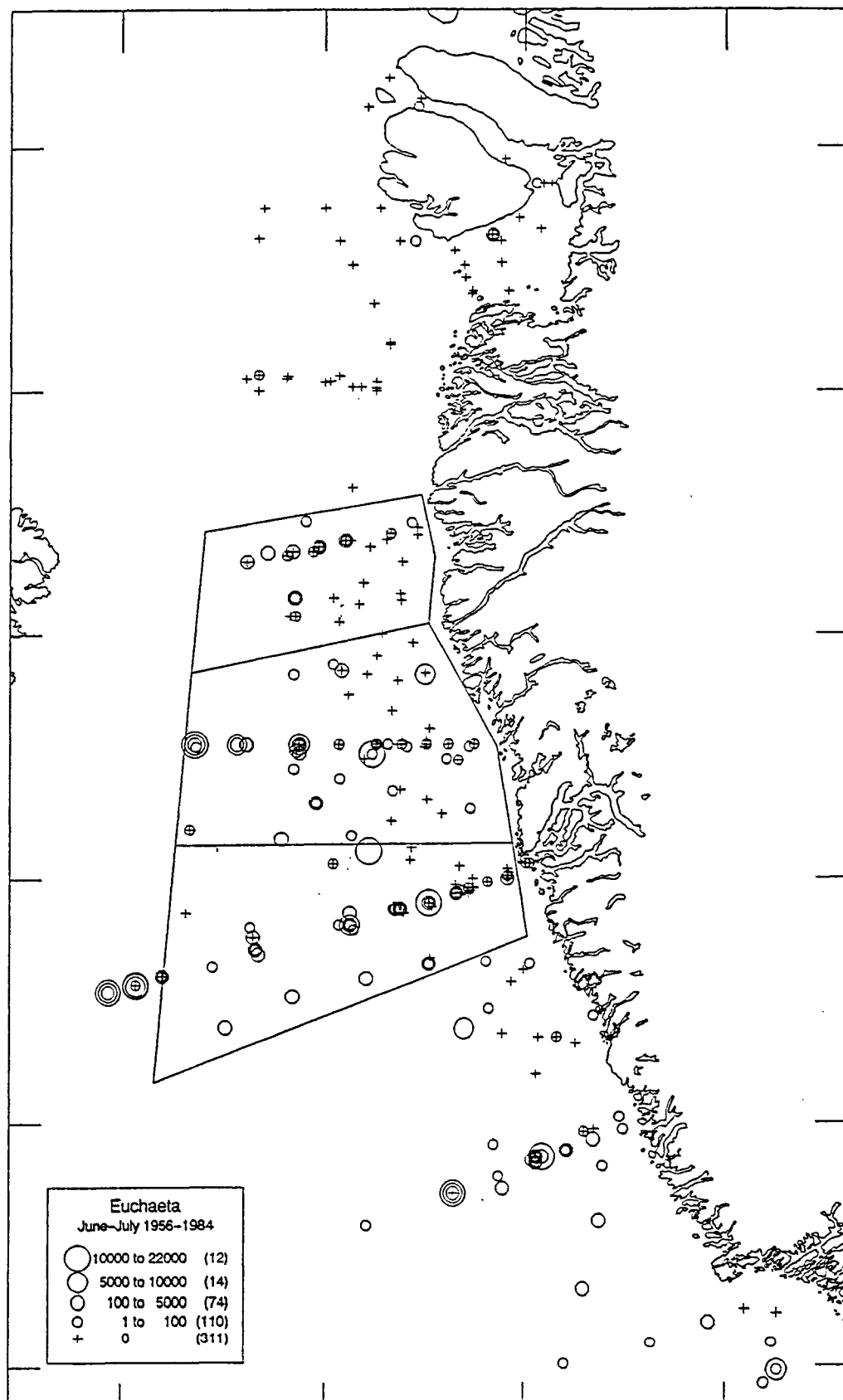


Fig. 11. Number of *Euchaeta* (*Pareuchaeta*) *norvegica* per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.

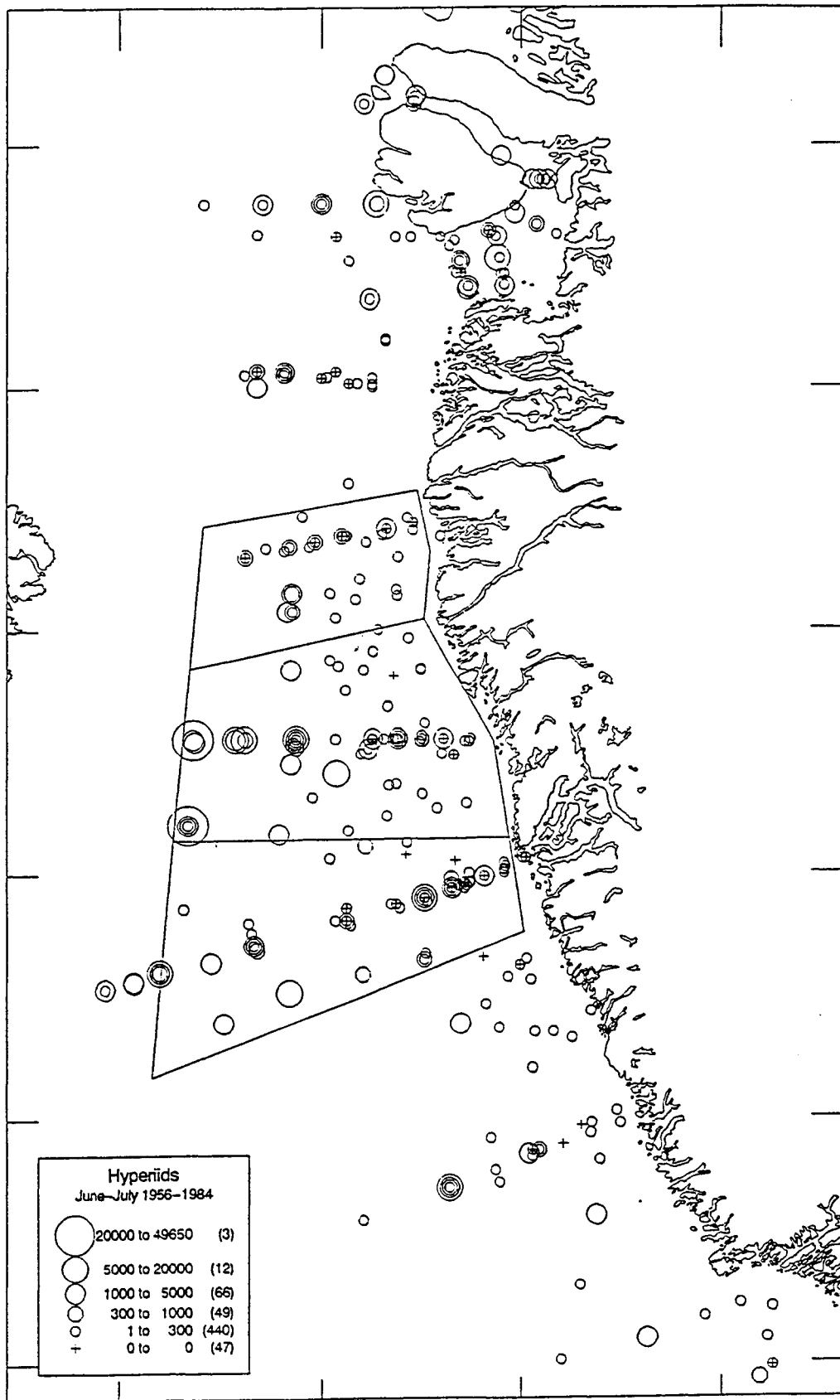


Fig. 12. Number of hyperiids per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.

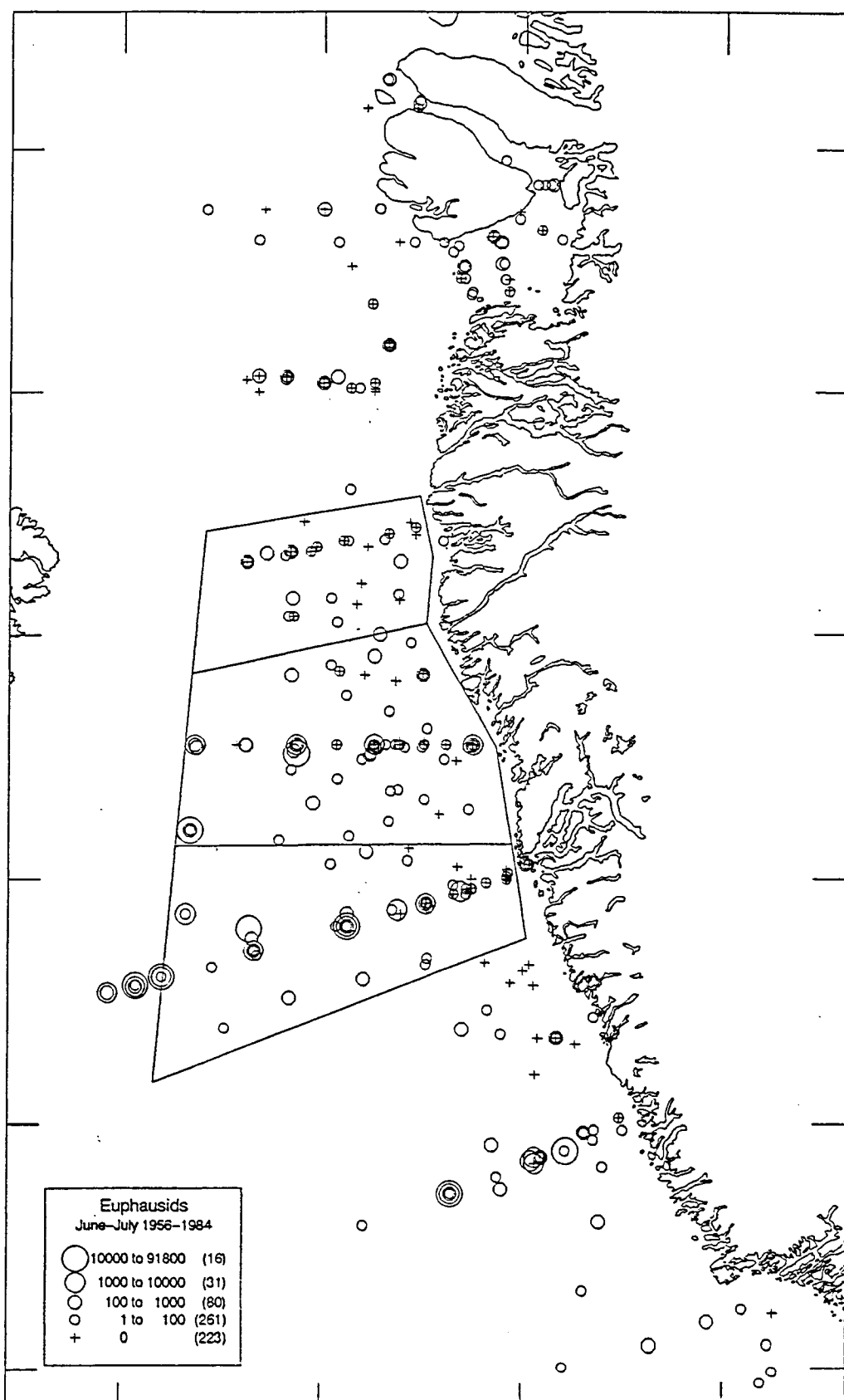


Fig. 13. Number of euphausiids per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.



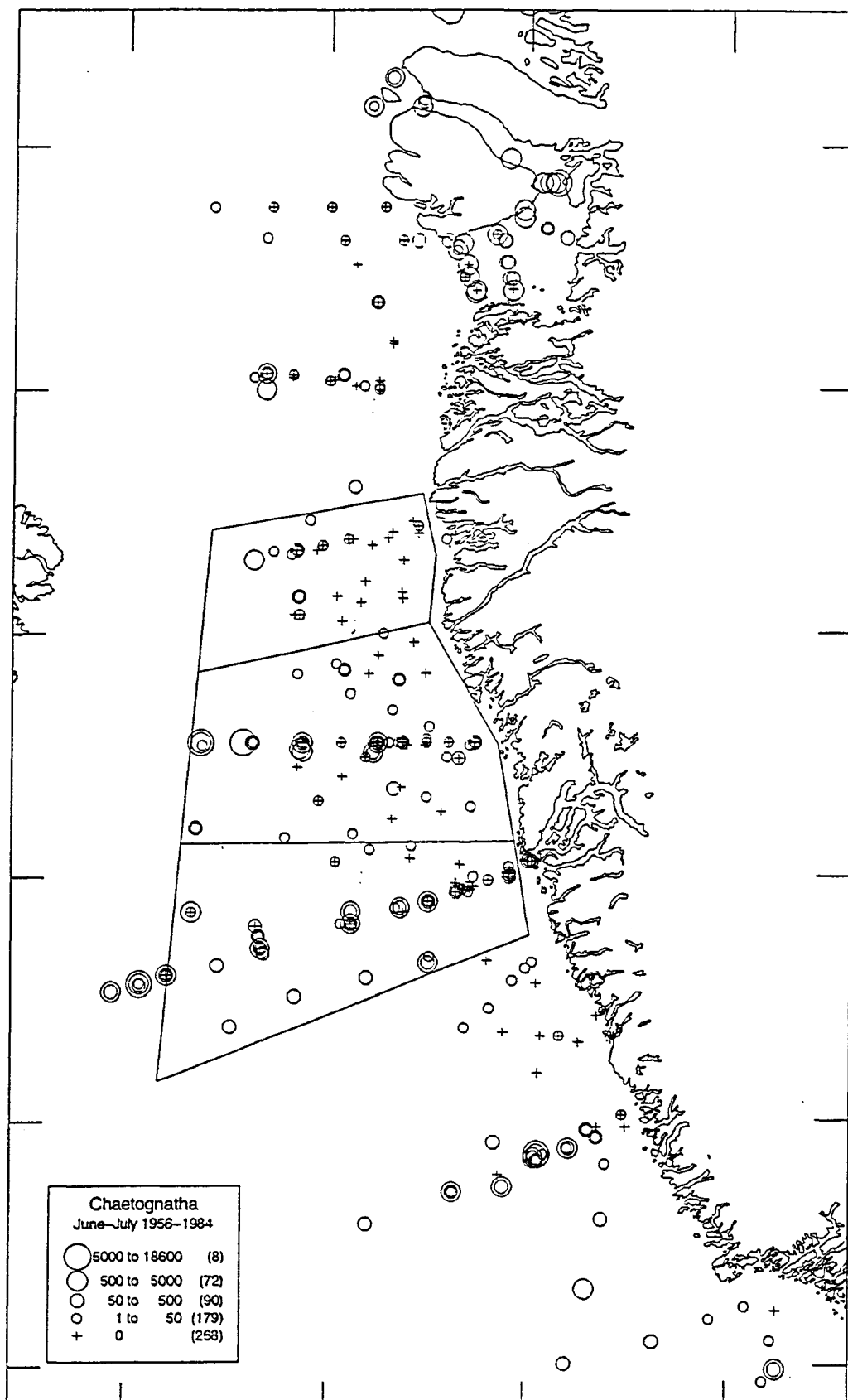


Fig. 14. Number of Chaetognatha per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.

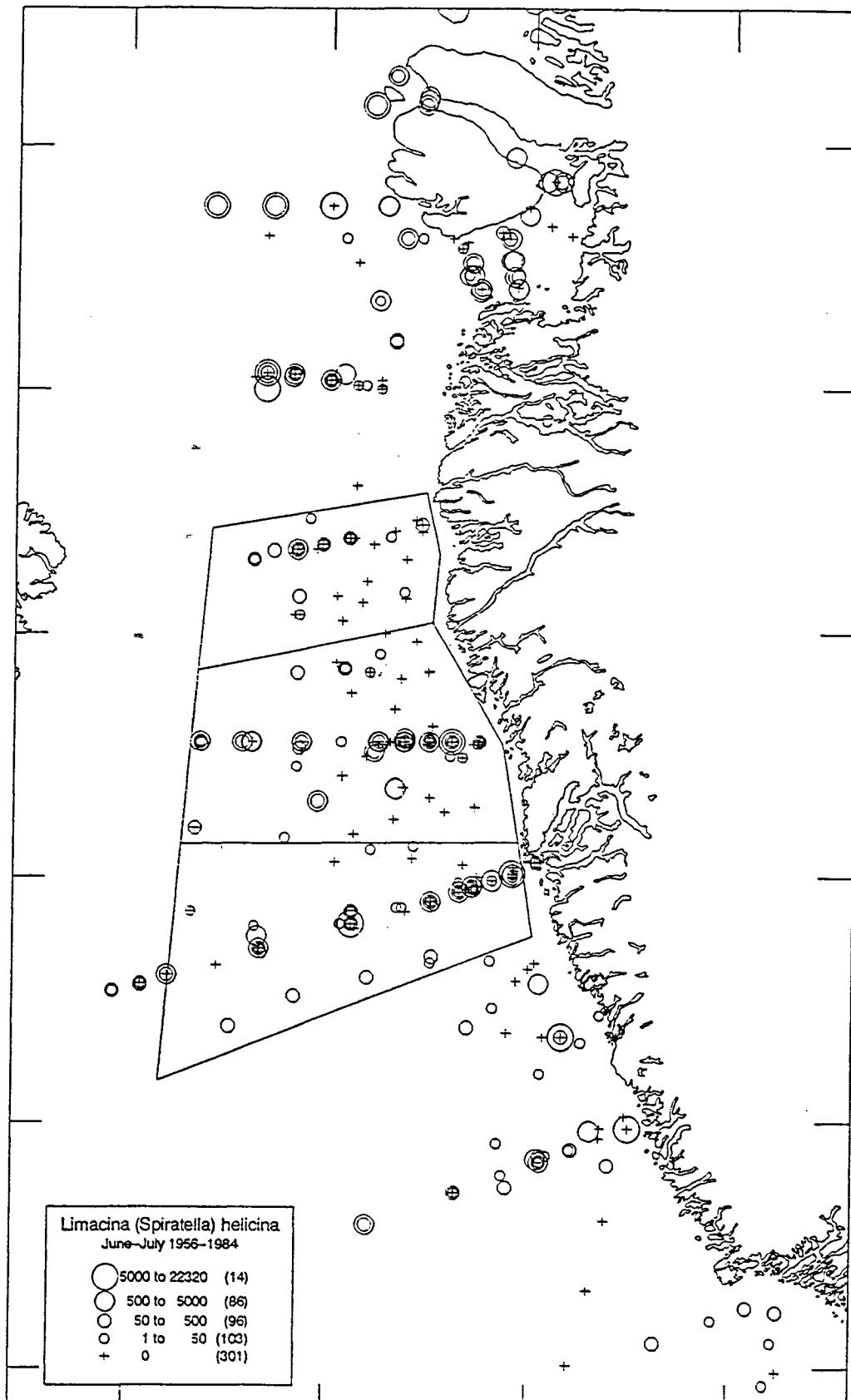


Fig. 15. Number of *Limacina (Spiratella) helicina* per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.

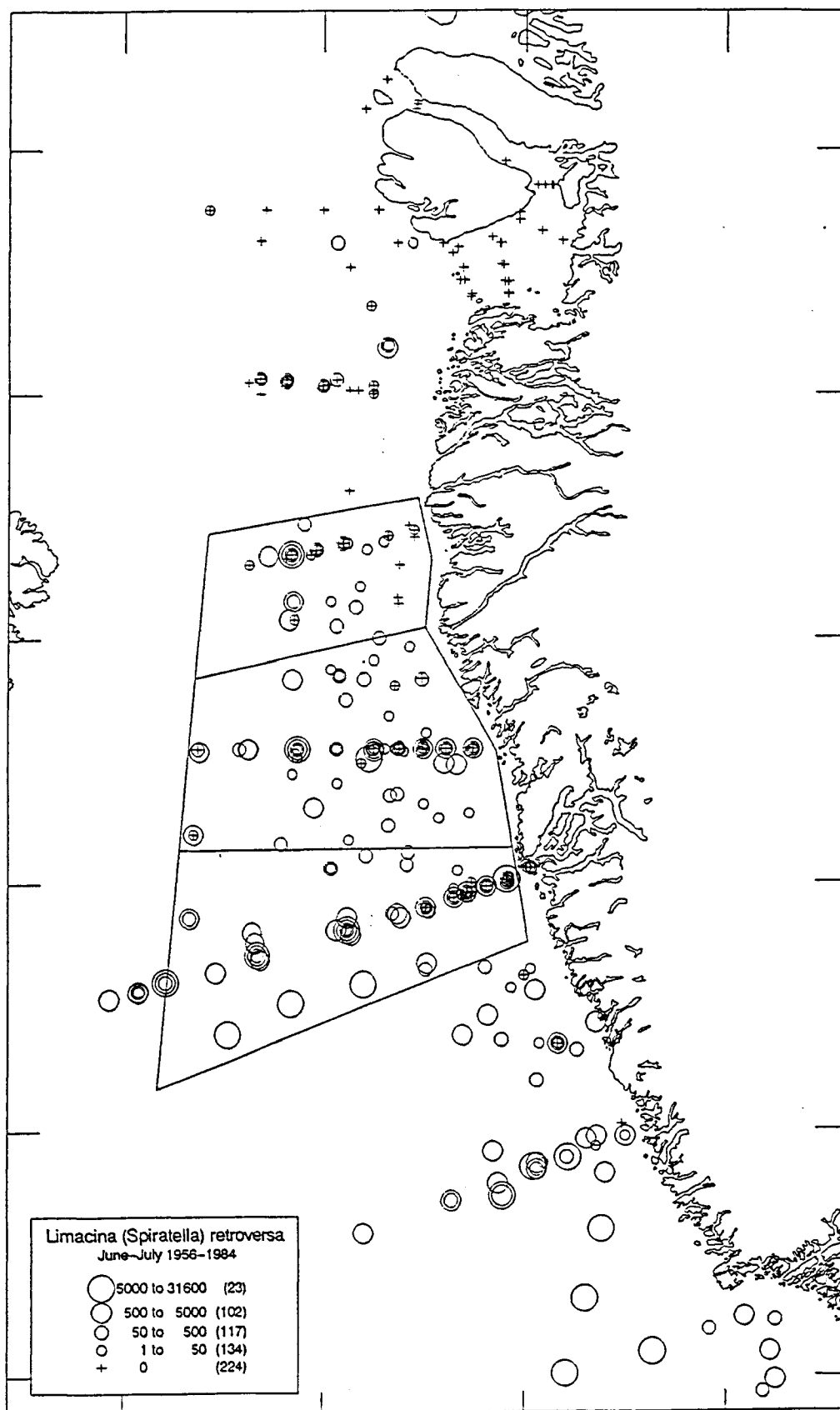


Fig. 16. Number of *Limacina (Spiratella) retroversa* per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.

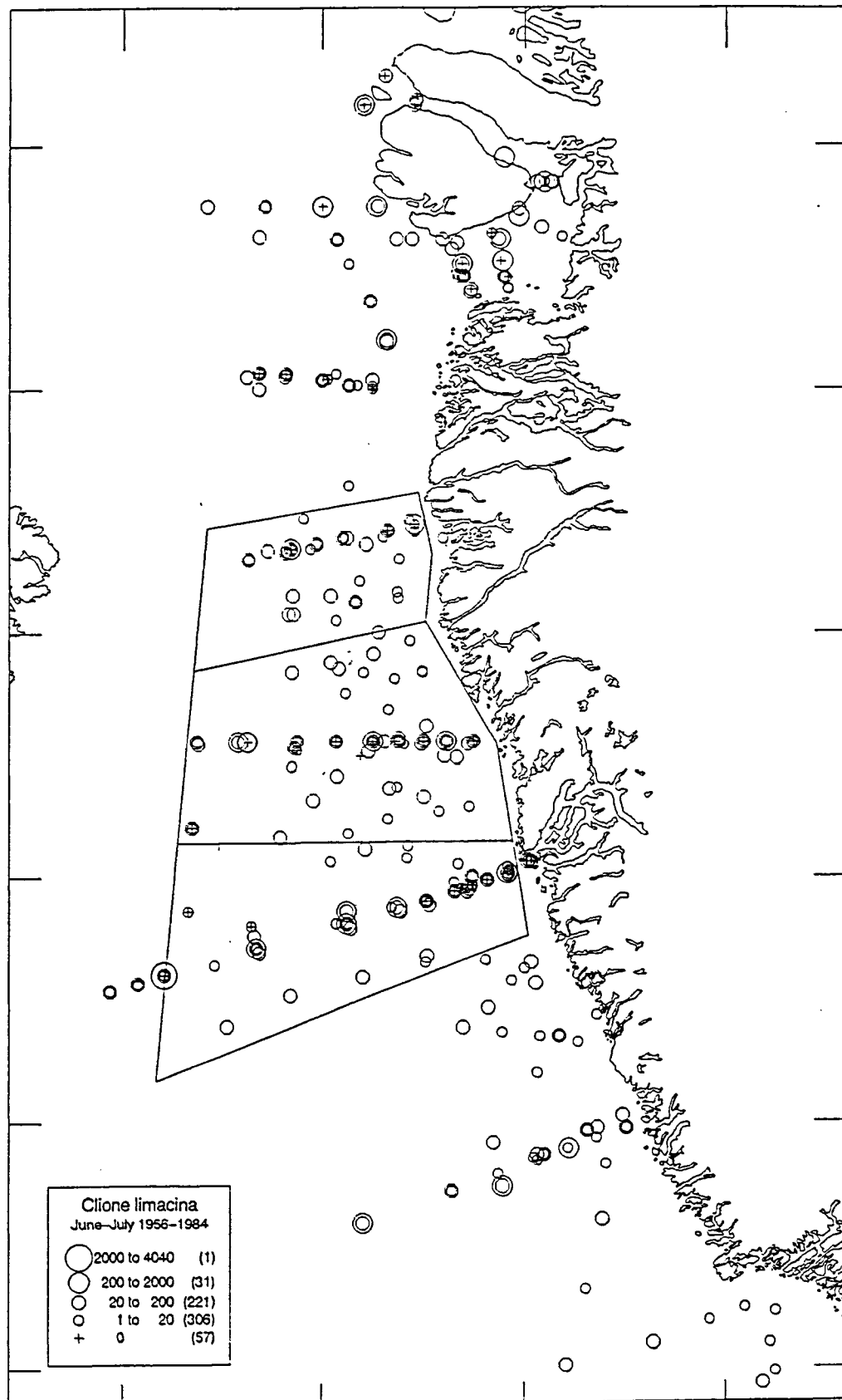


Fig. 17. Number of *Clione limacina* per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.

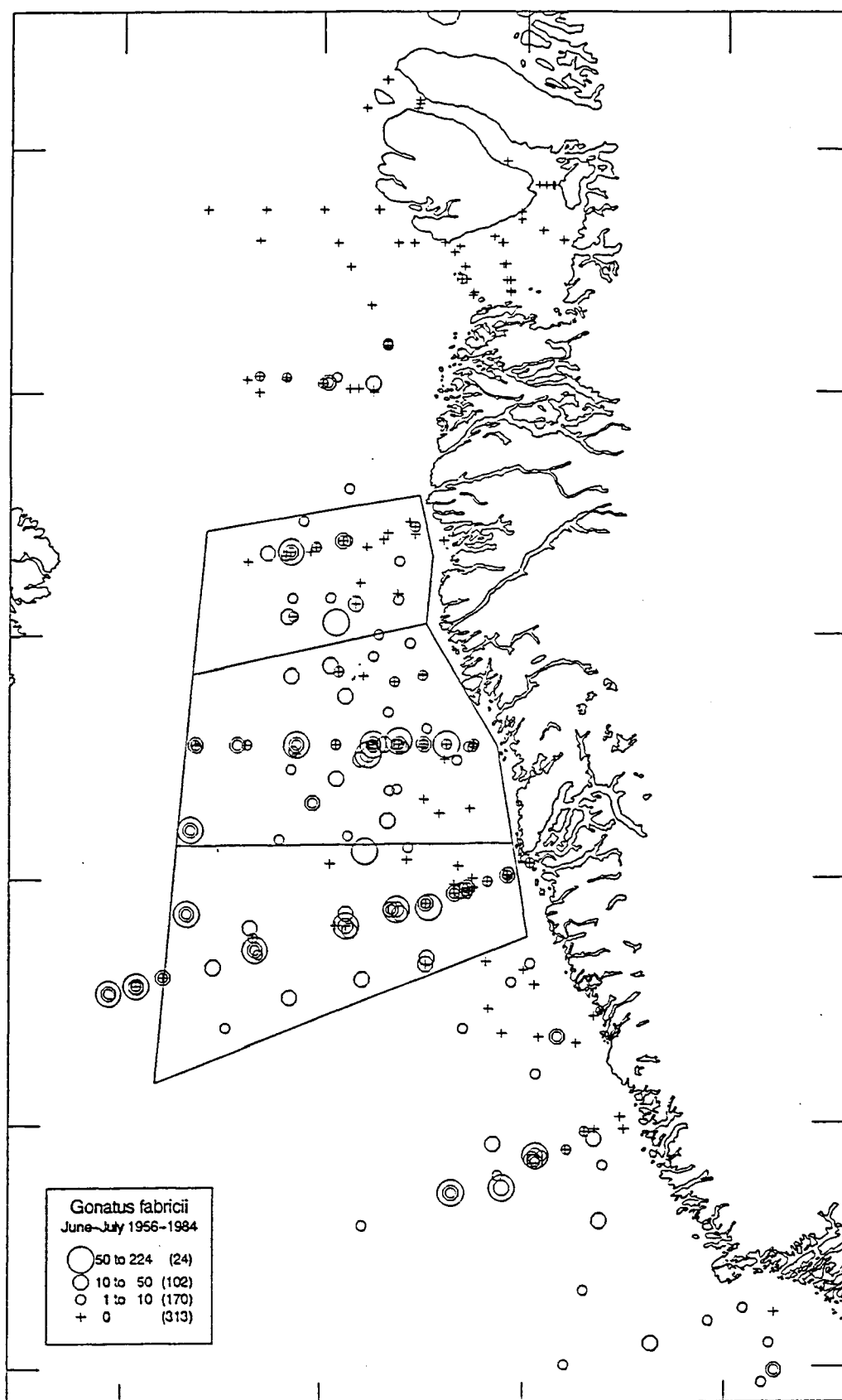


Fig. 18. Number of juvenile *Gonatus fabricii* per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.

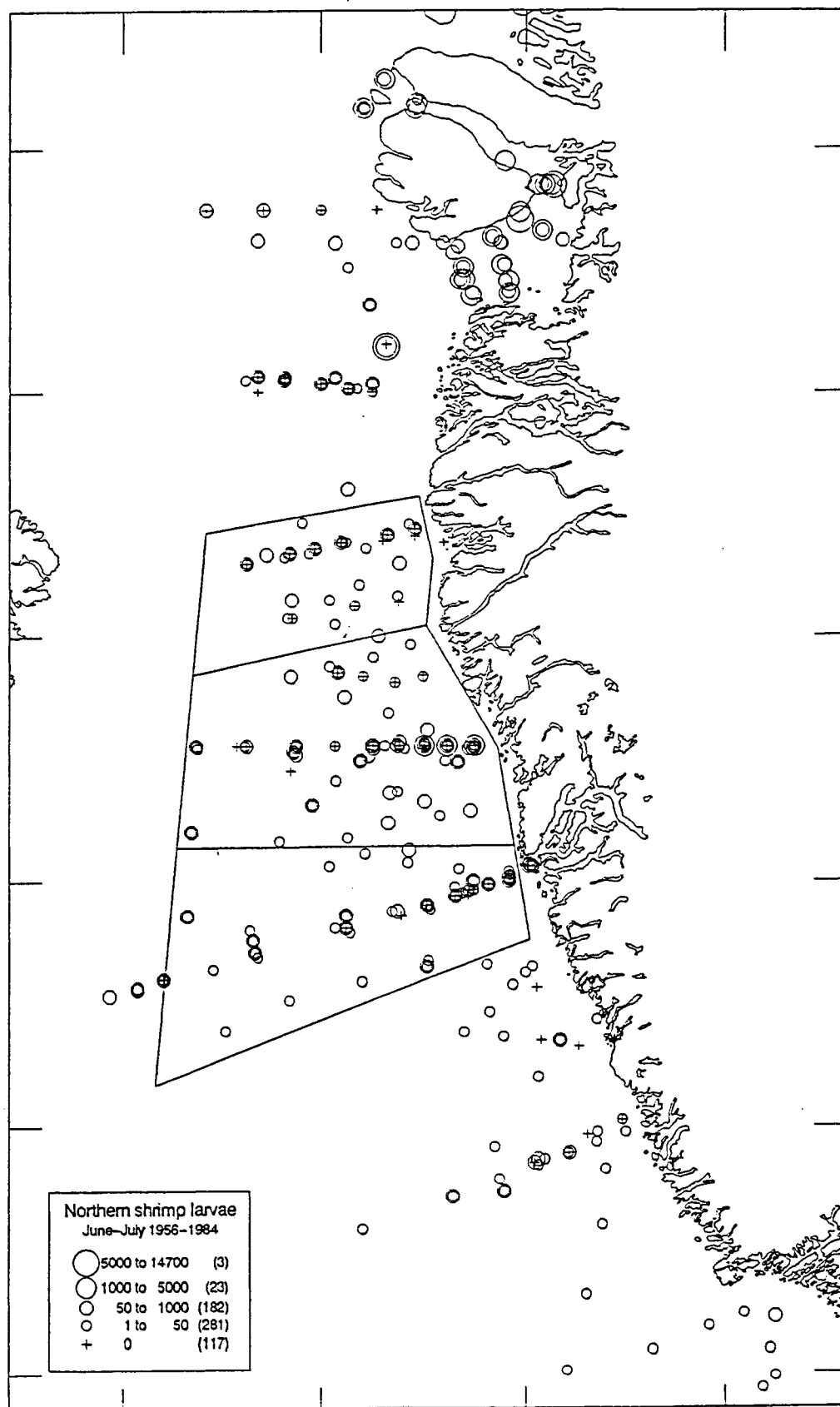


Fig. 19. Number of shrimp larvae (mainly Northern shrimp) per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.

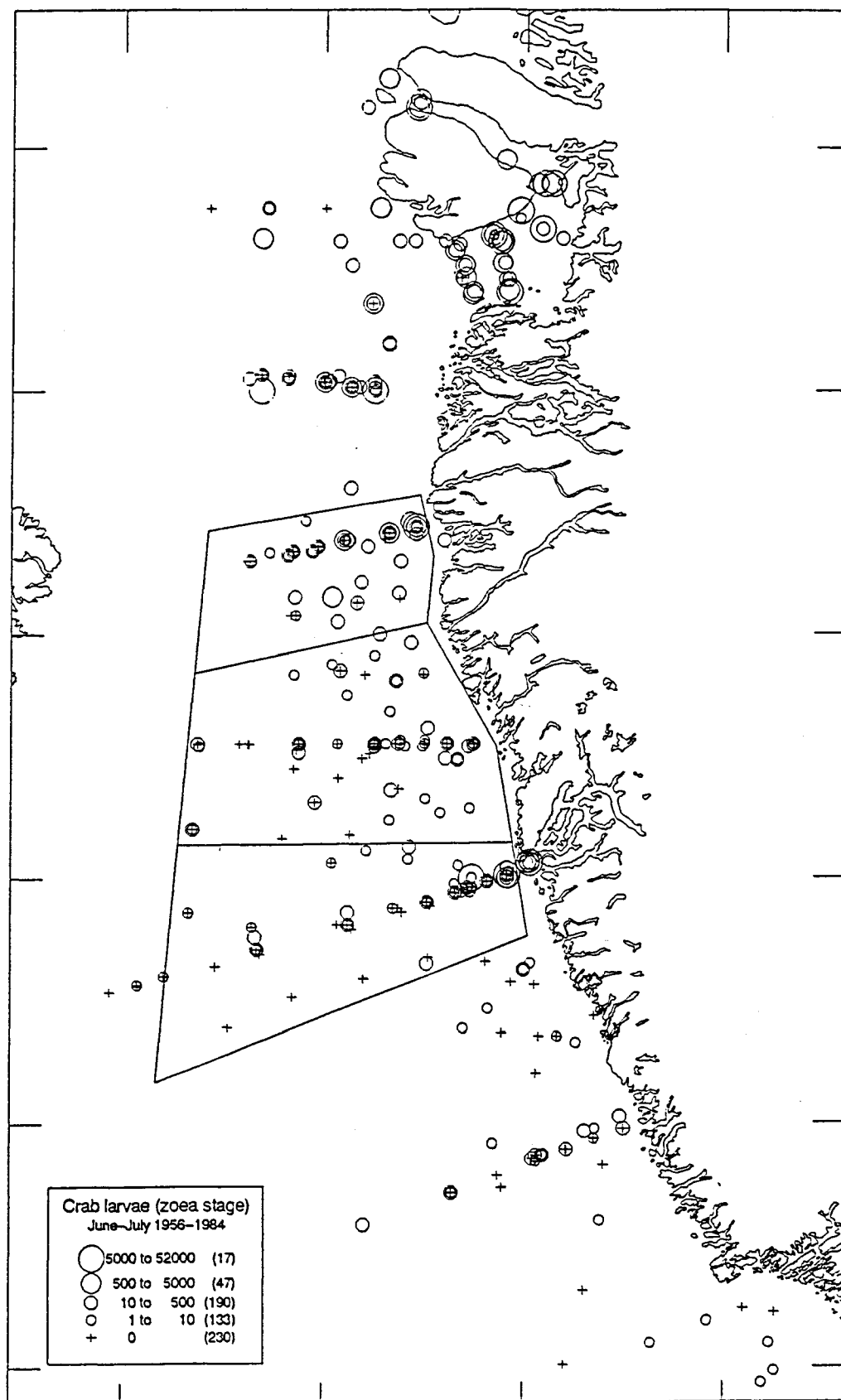


Fig. 20. Number of crab larvae per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.

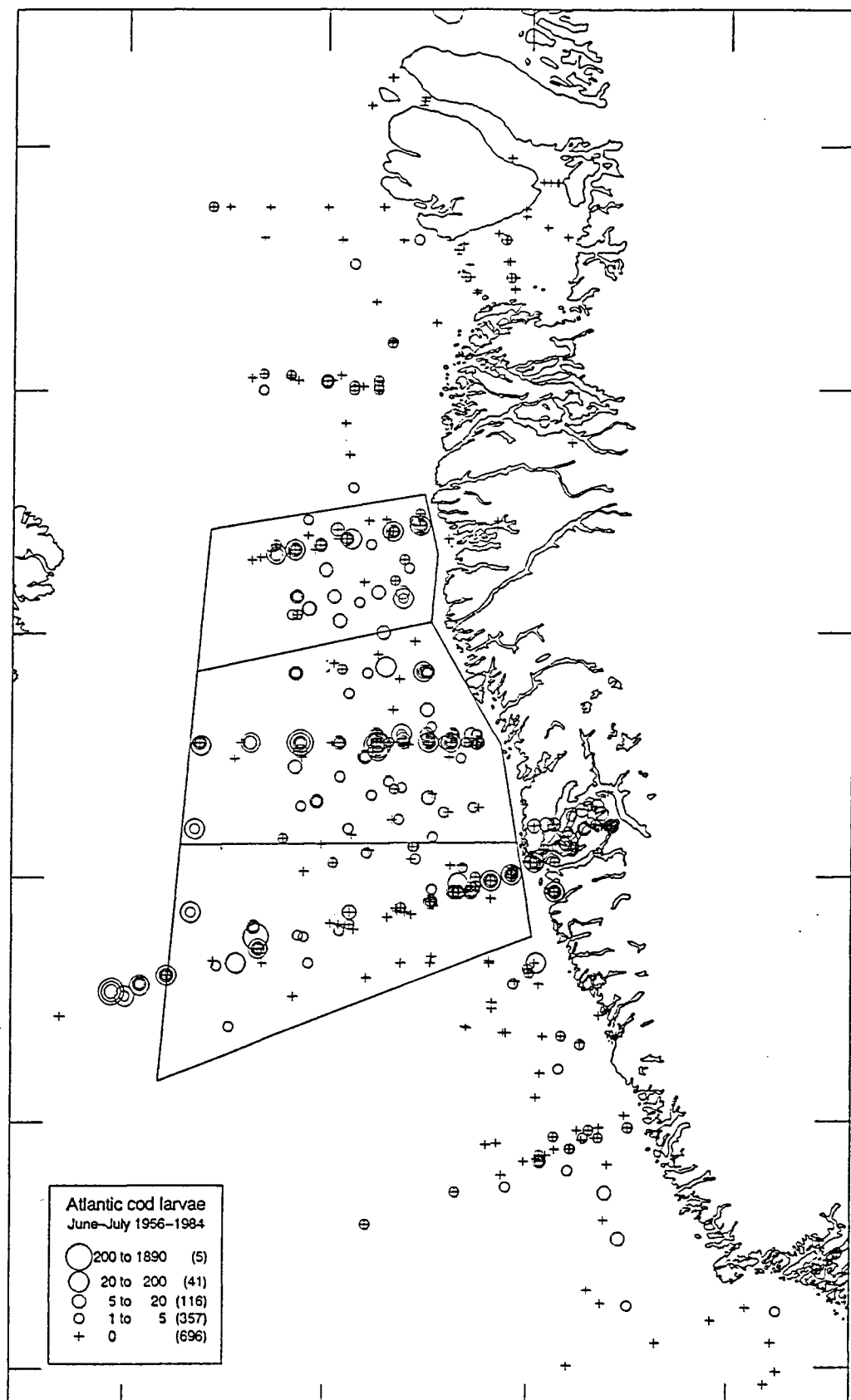


Fig. 21. Number of Atlantic cod larvae per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.



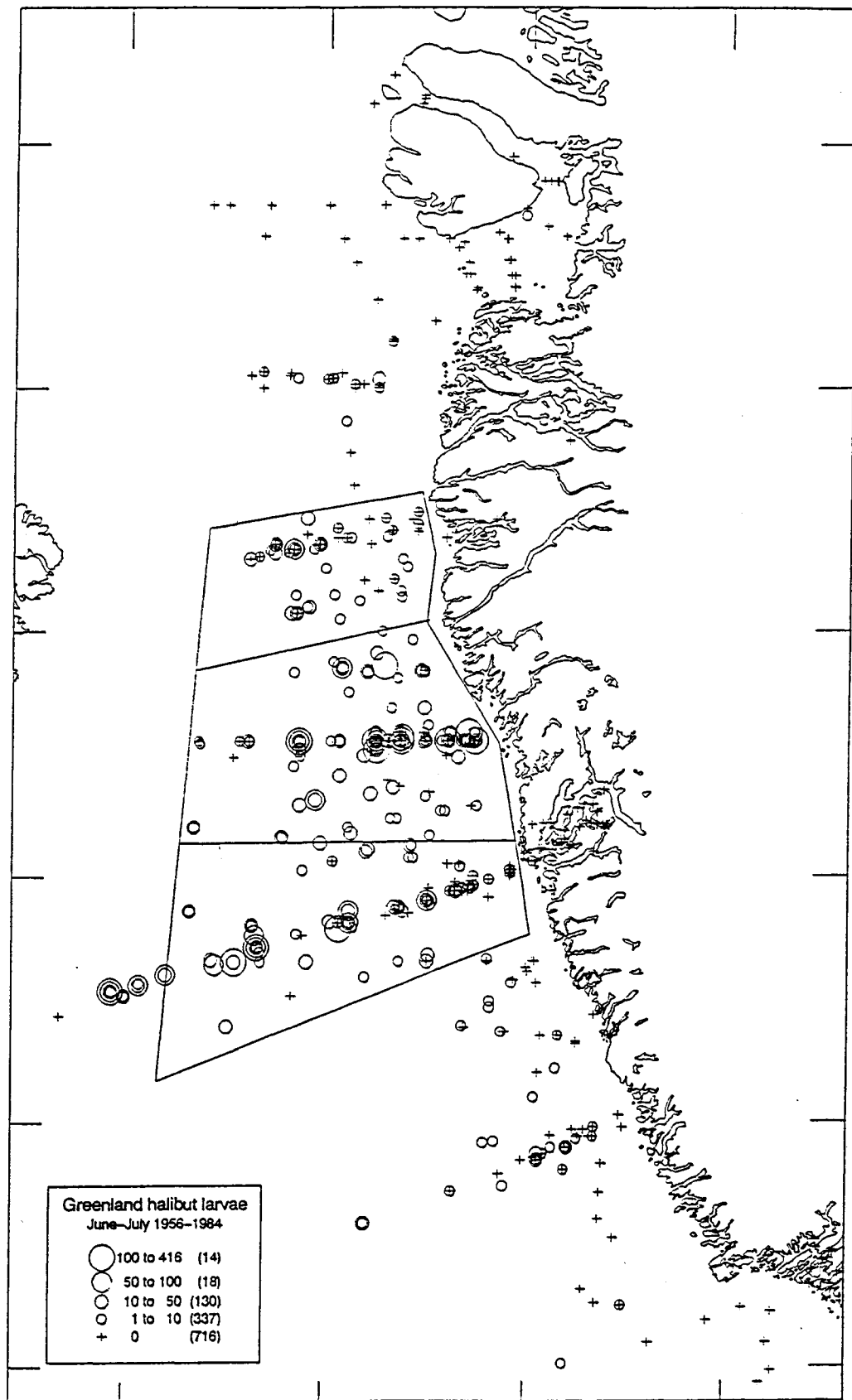


Fig. 22. Number of Greenland halibut larvae per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.

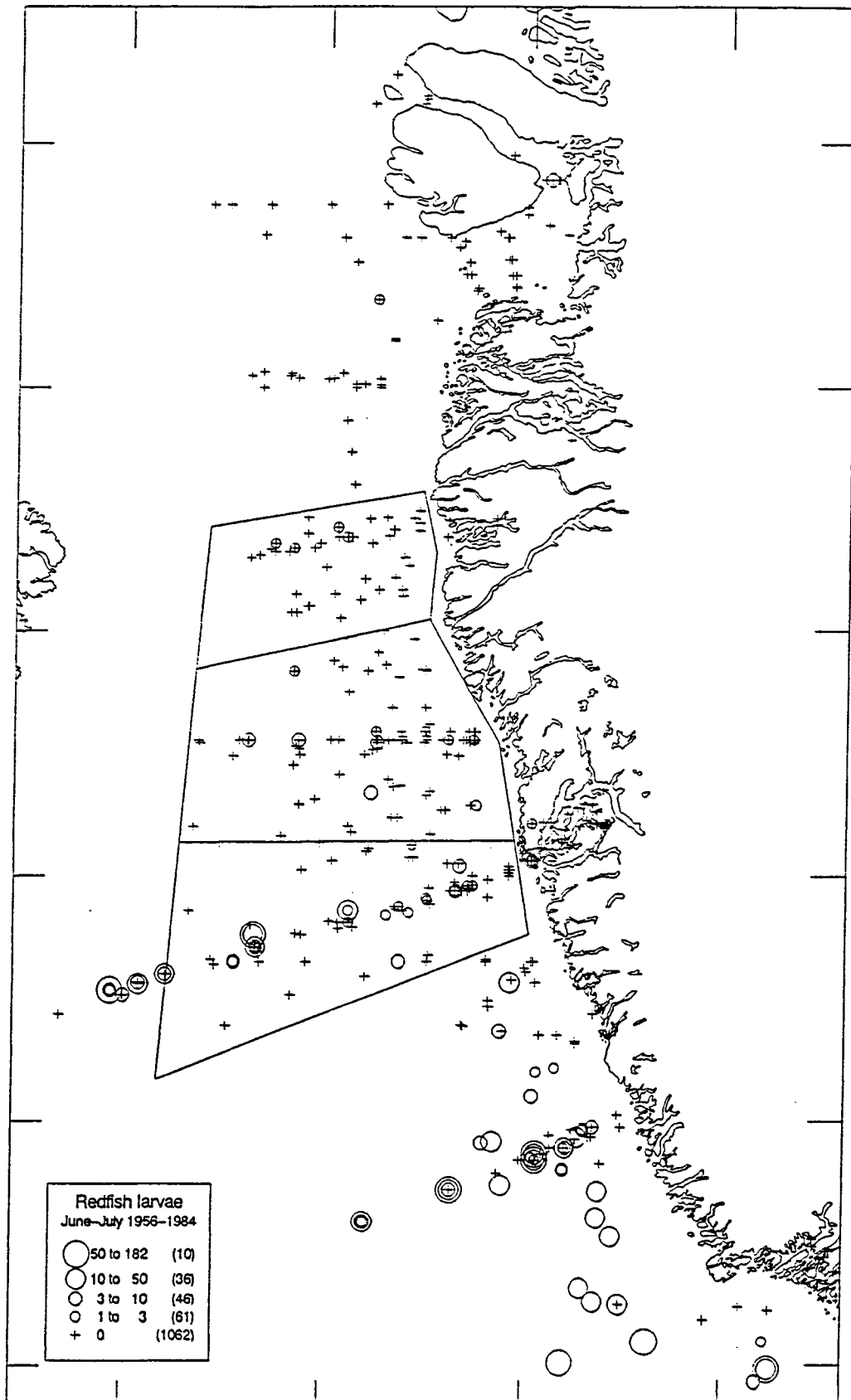


Fig. 23. Number of redfish larvae (*Sebastes* sp.) per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.

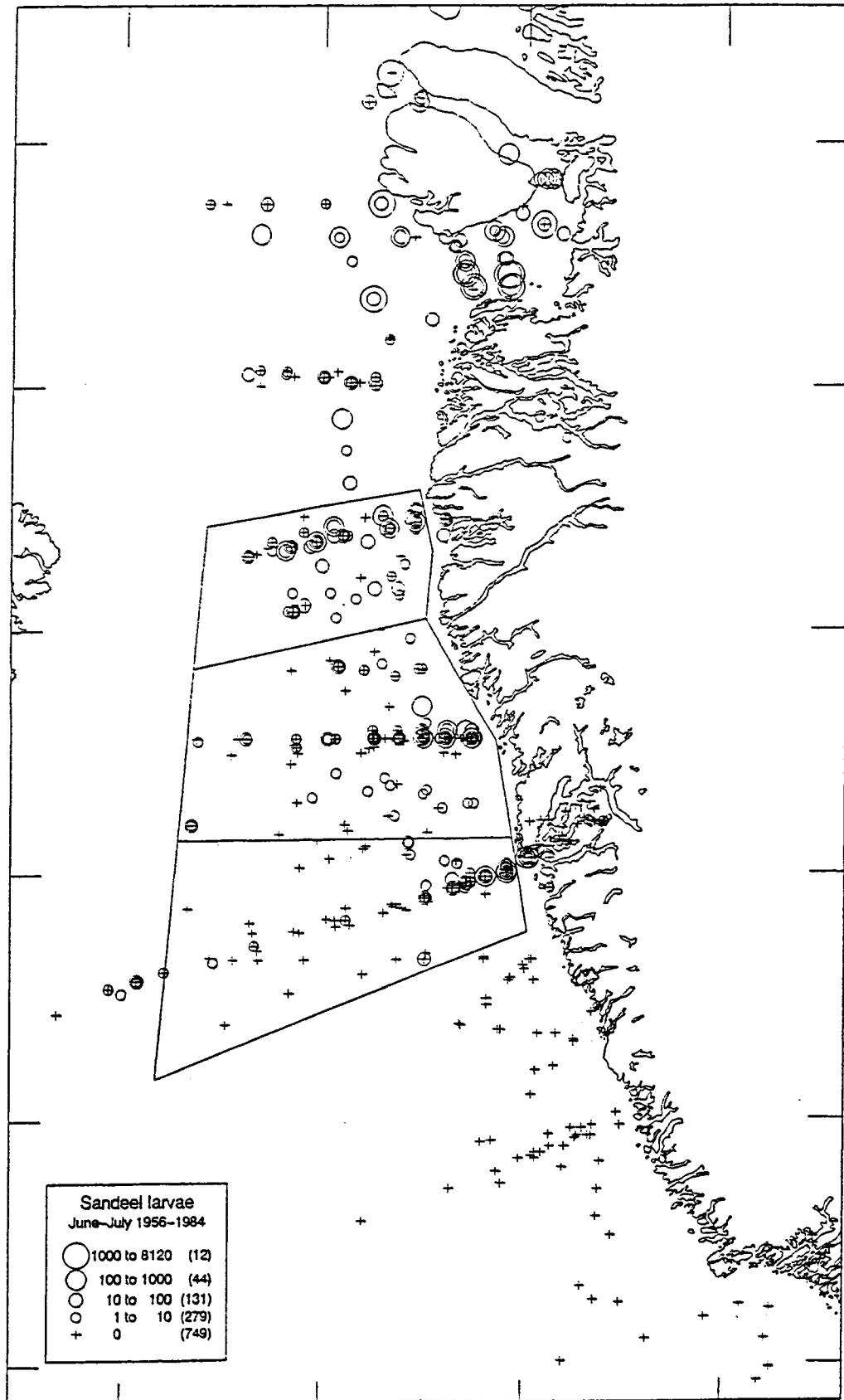


Fig. 24. Number of sandeel larvae per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.

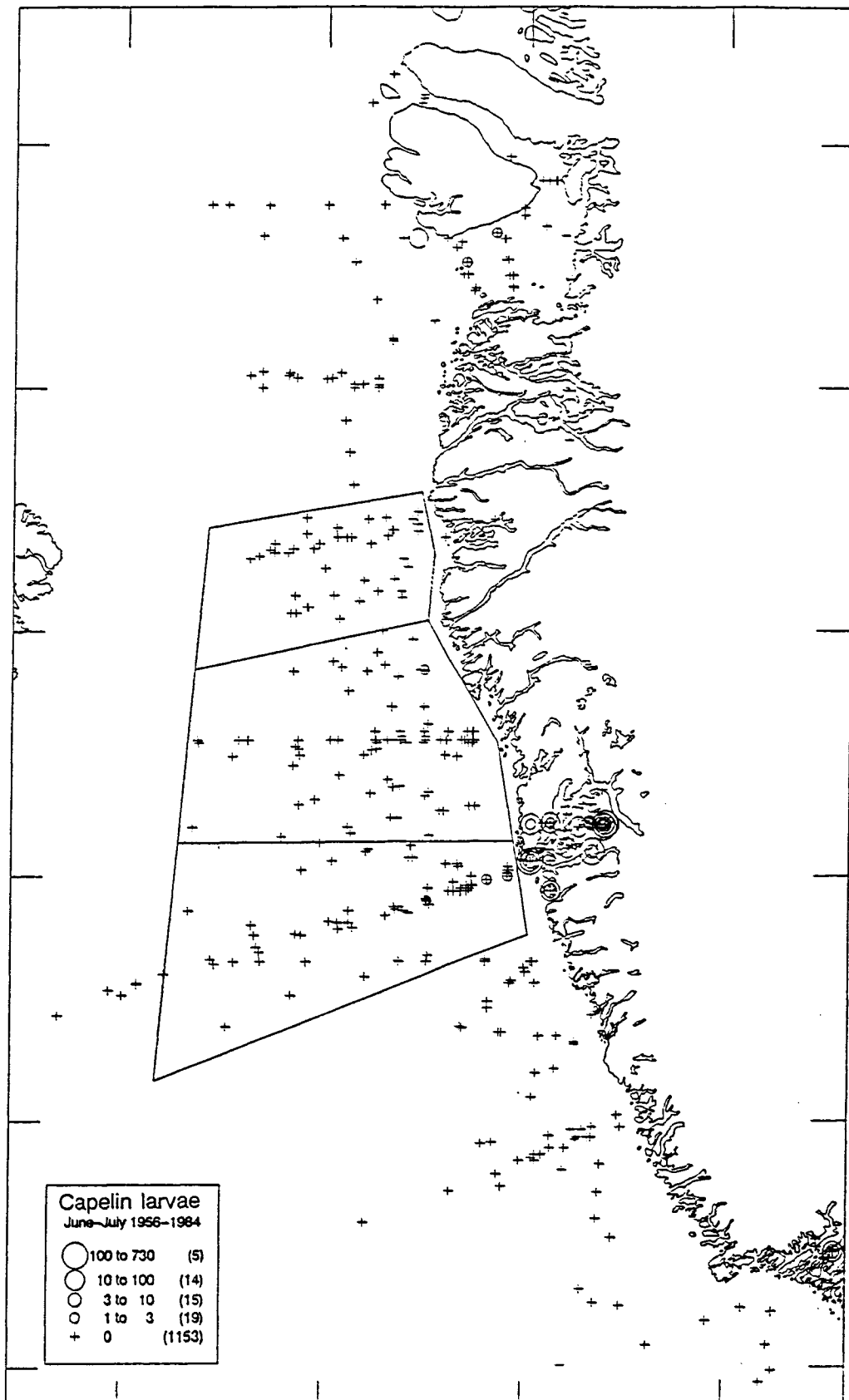


Fig. 25. Number of capelin larvae per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.

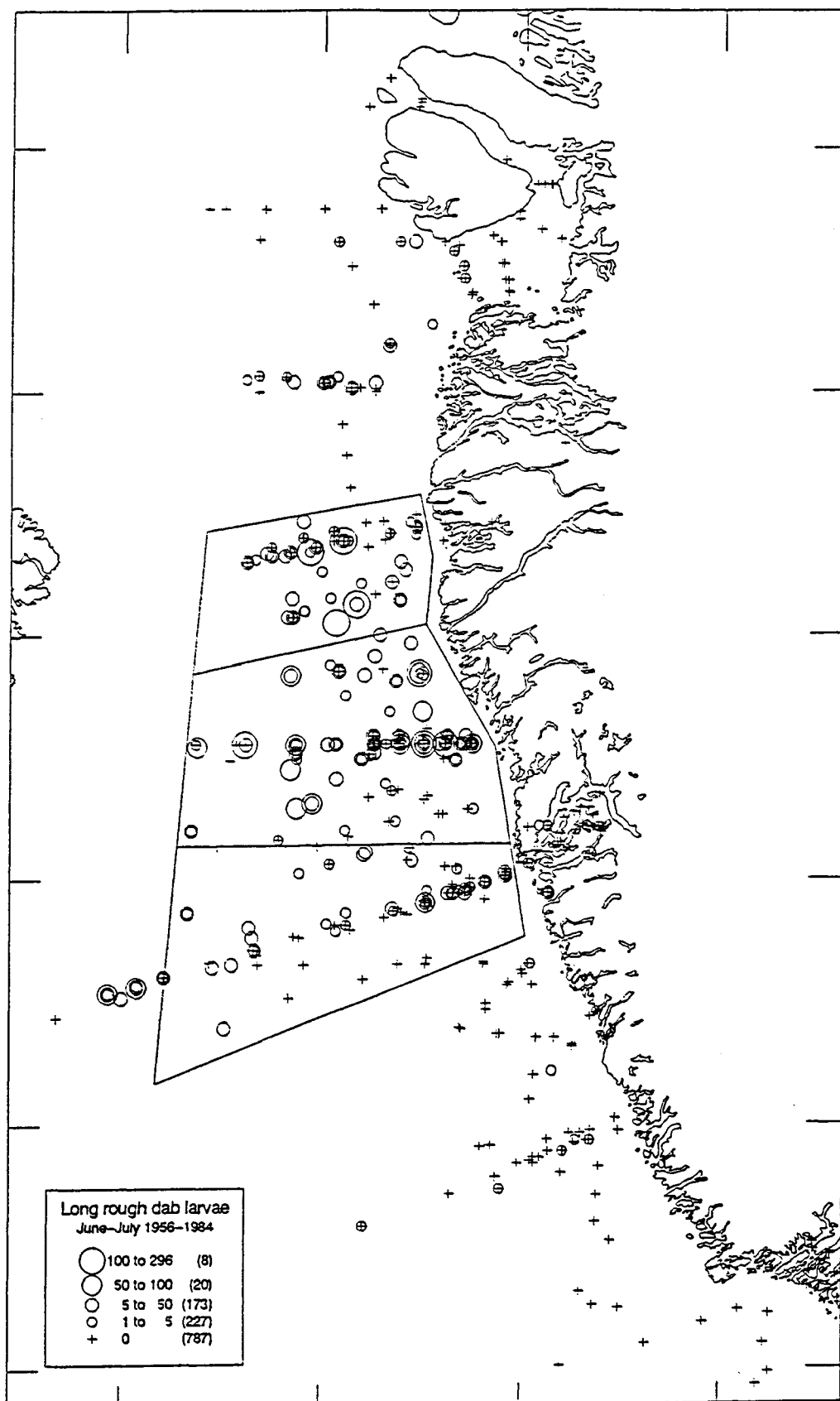


Fig. 26. Number of long rough dab larvae per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.

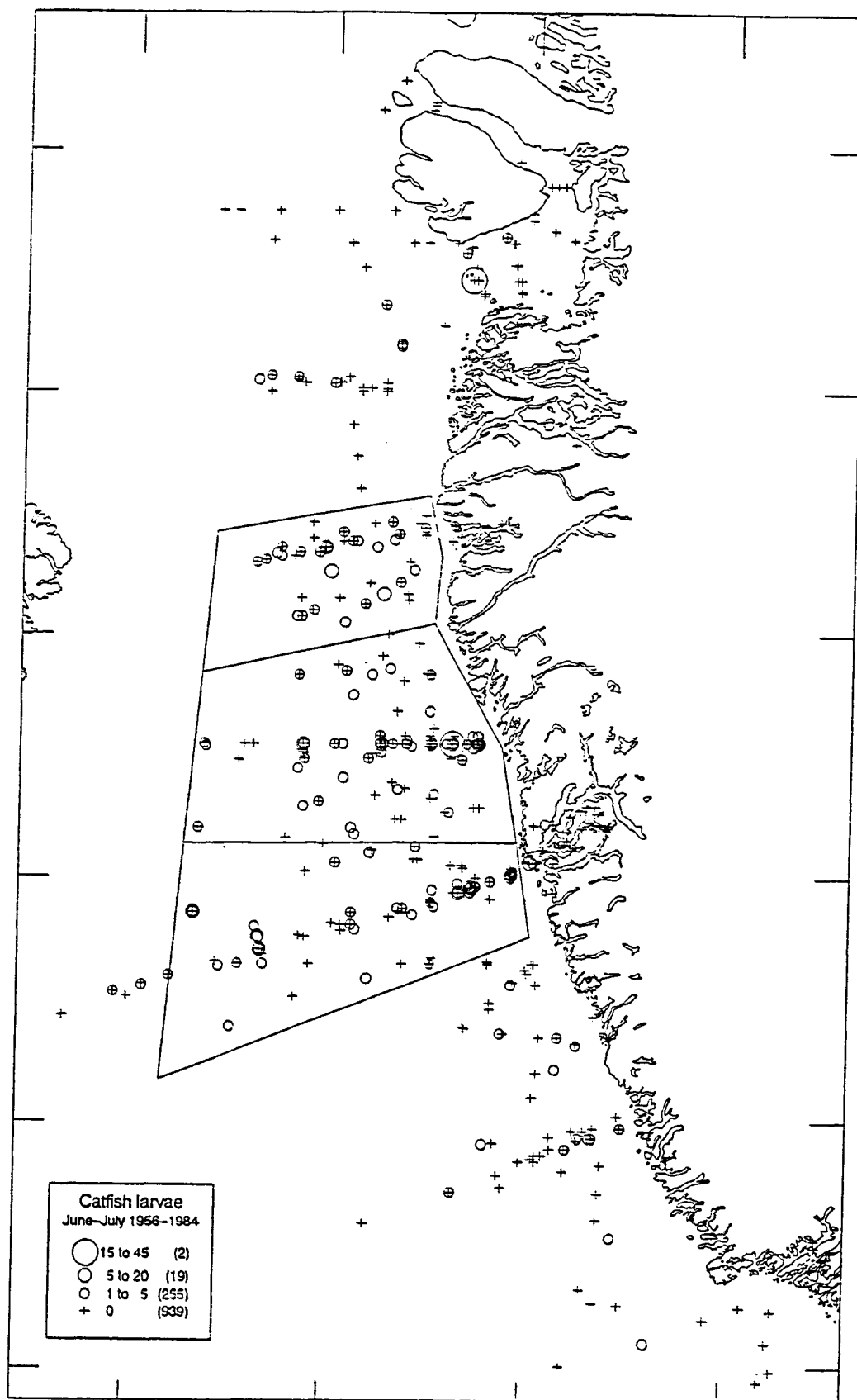


Fig. 27. Number of catfish larvae per 30 min. stramin net haul all samples in June-July, 1956-1984, off West Greenland. Frequency of occurrence in brackets.

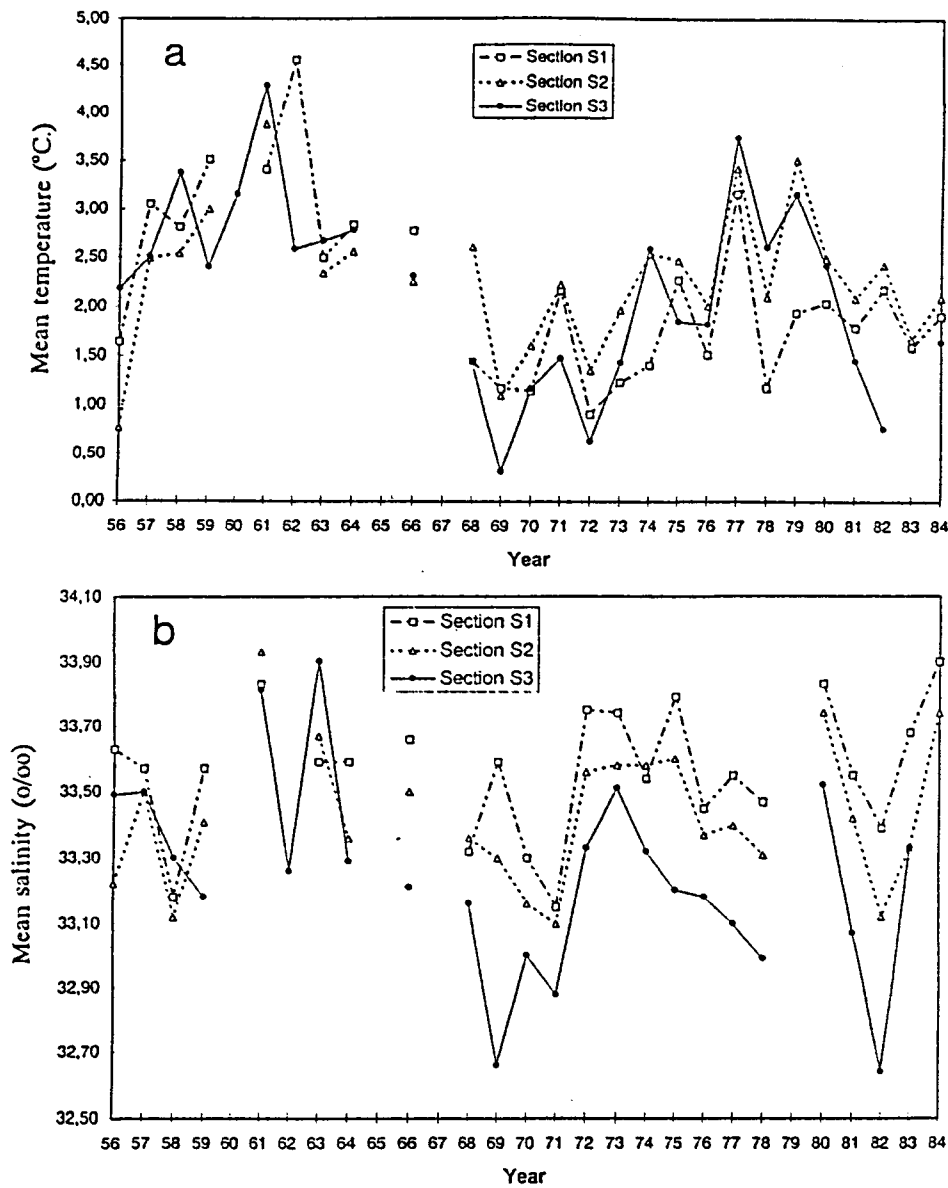


Fig. 28. Mean sea temperatures (a) and salinities (b) of the 10-50 m layer in June-July by section and year.

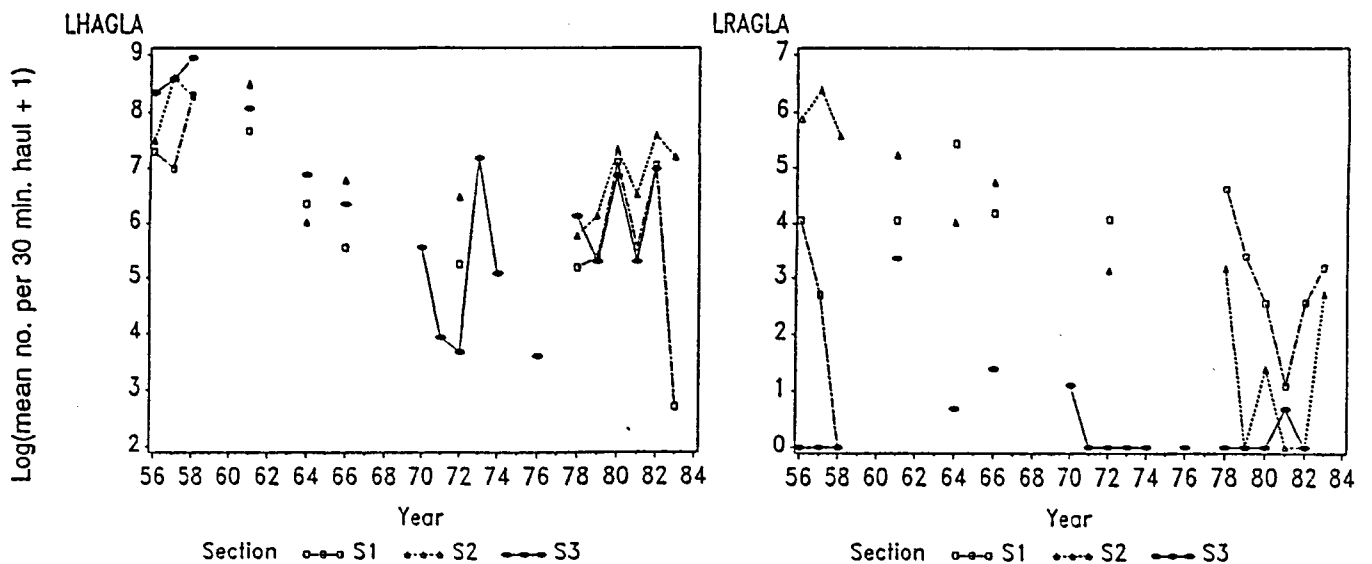


Fig. 29. Mean number of white (LHAGLA) and red (LRAGLA) *Aglantha digitale* per 30 min. stramin net haul in June-July by sampling section and year.

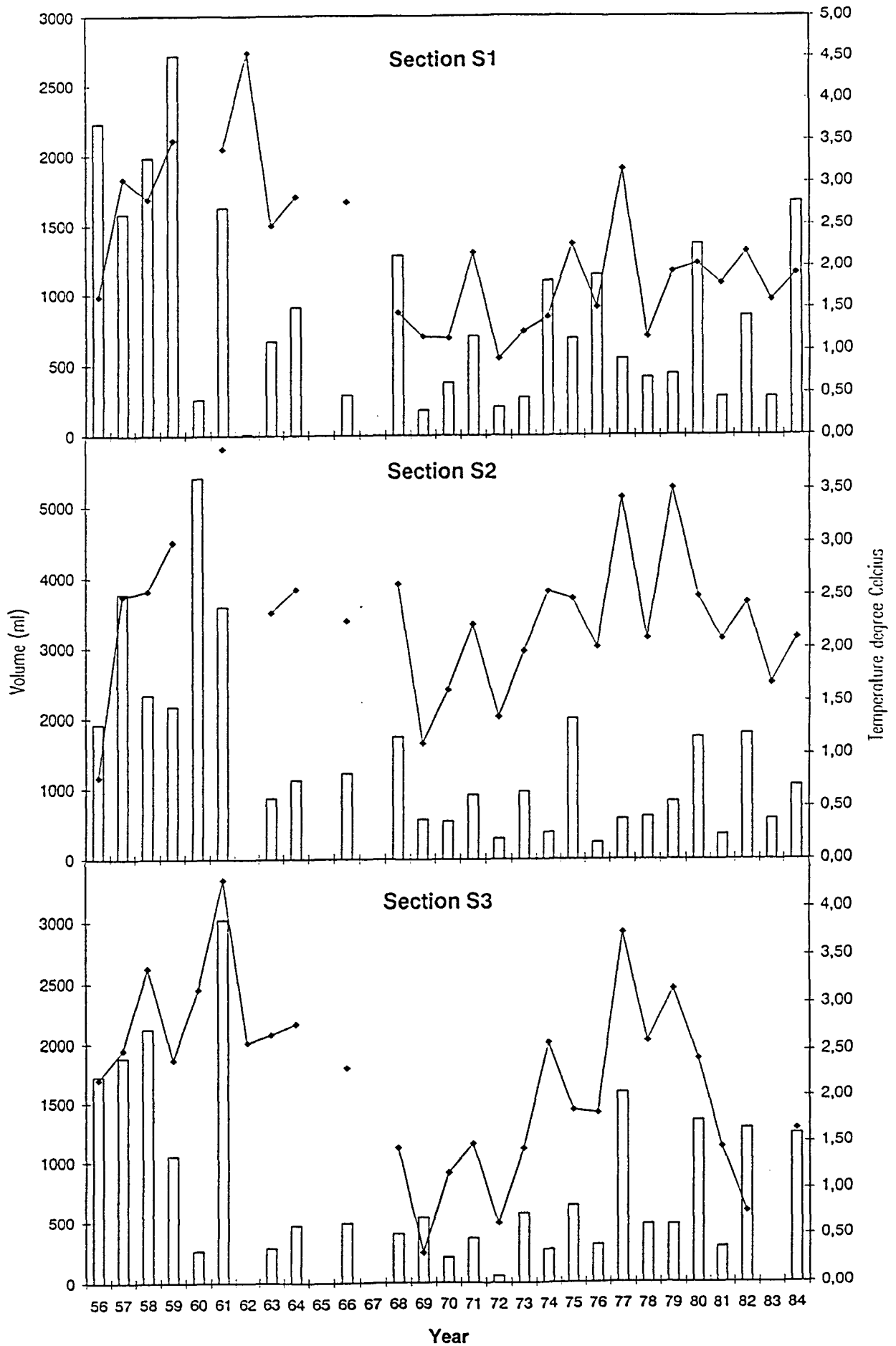


Fig. 30. Mean plankton volume (ml) per 30 min. stramin net haul and mean temperature (the 10-50 m layer) in June-July by sampling section and year.



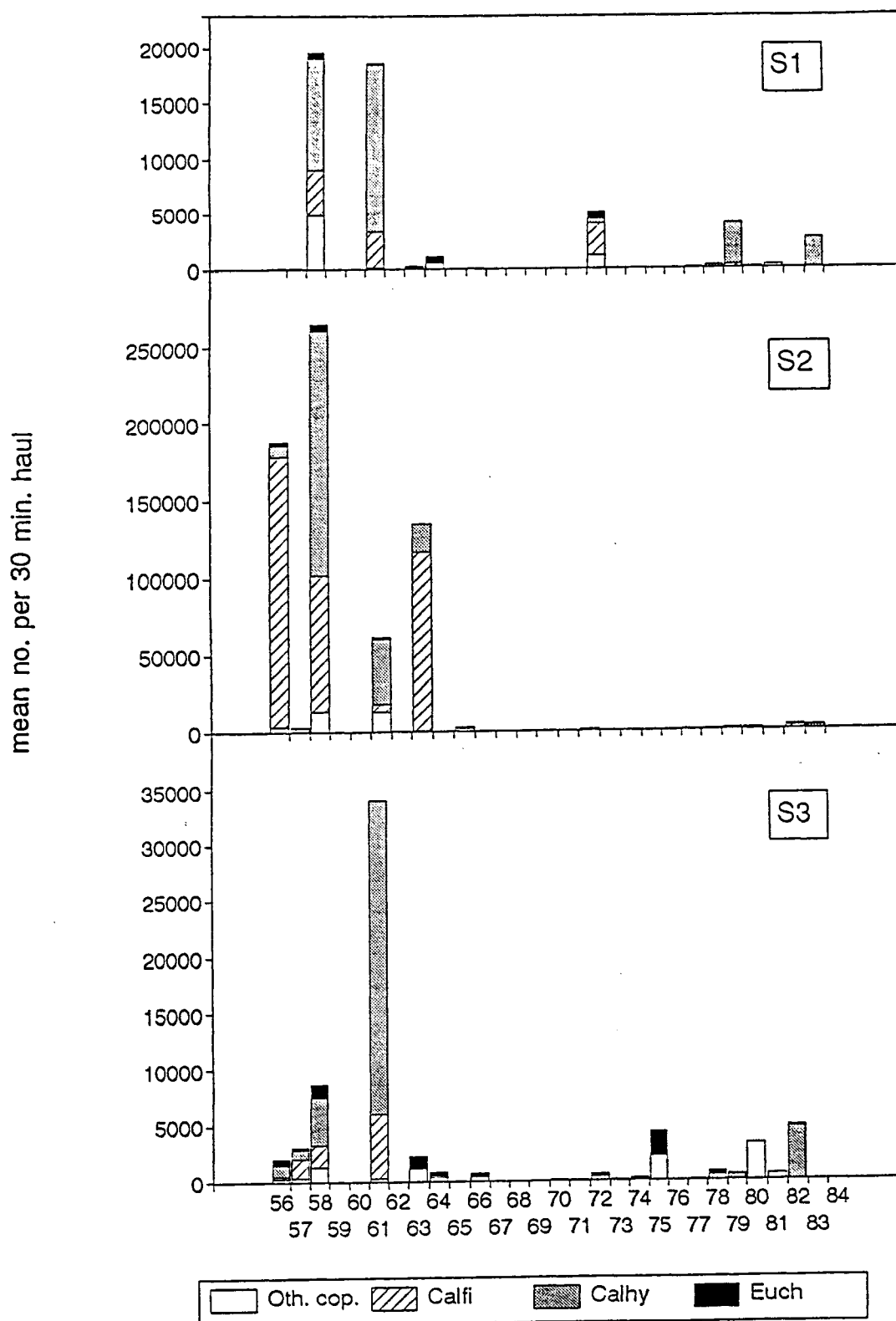


Fig. 31. Mean number of *Calanus finmarchicus* (include also *C. glacialis*) (Calfi), *Calanus hyperboreus* (Calhy), *Euchaeta* (*Pareuchaeta*) *norvegica* (Euch) and other copepod species (Oth. cop.) per 30 min. stramin net haul in June-July by sampling section and year.

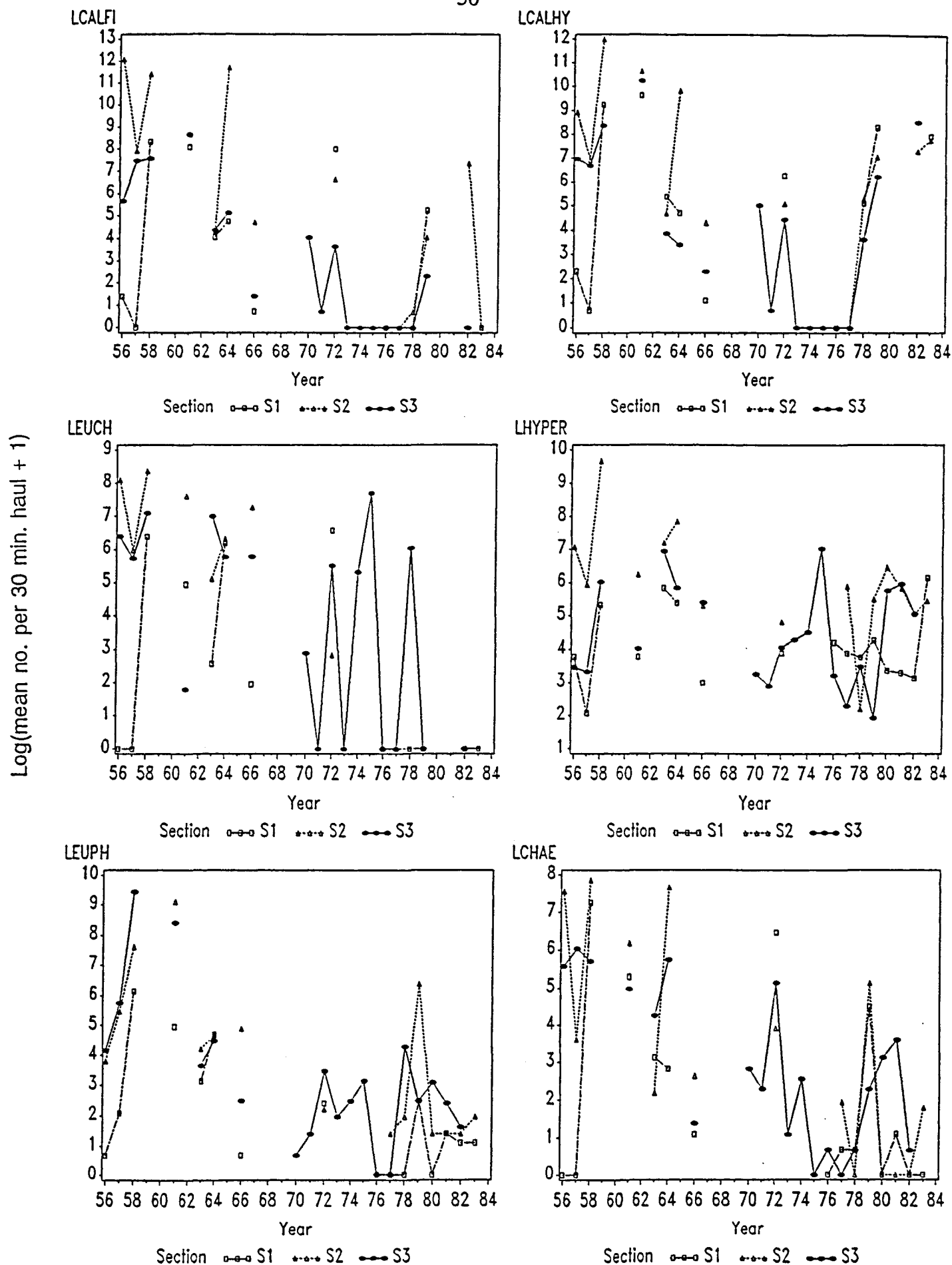


Fig. 32. Mean number of *Calanus finmarchicus* (include also *C. glacialis*) (LCALFI), *Calanus hyperboreus* (LCALHY), *Euchaeta* (*Pareuchaeta*) *norwegica* (LEUCH), hyperiids (LHYPER), euphausids (LEUPH), Chaetognatha (LCHAE) per 30 min. stramin net haul in June-July by sampling section and year.

Log(mean no. per 30 min. haul + 1)

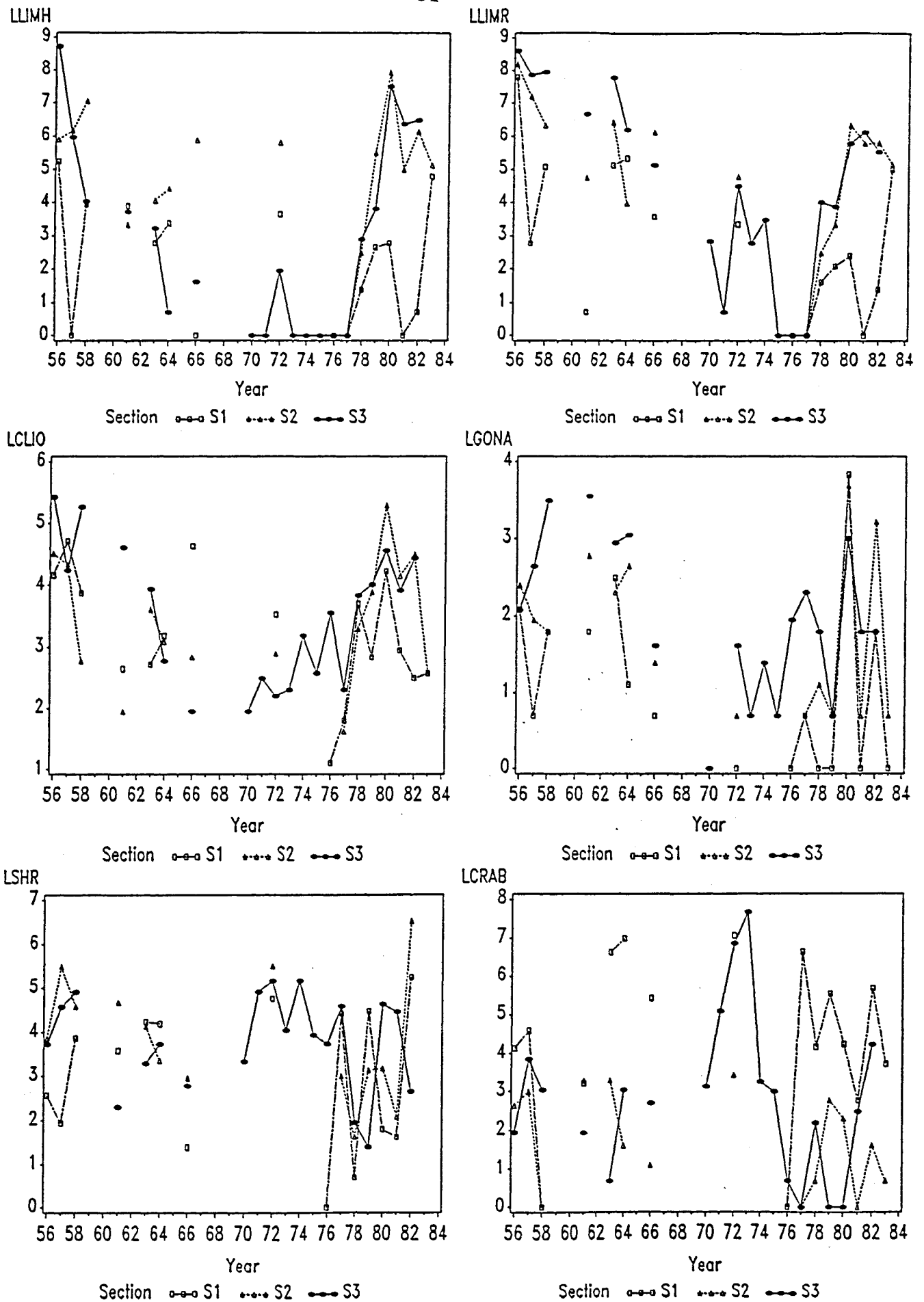


Fig. 33. Mean number of *Limacina (Spiratella) helicina* (LLIMH), *Limacina (Spiratella) retroversa* (LLIMR), *Clione limacina* (LCLIO), *Gonatus fabricii* (LGONA), Shrimp (*Pandalus* sp.), mainly *Pandalus borealis* (LSHR), Crab (LCRAB) per 30 min. stramin net haul in June-July by sampling section and year.

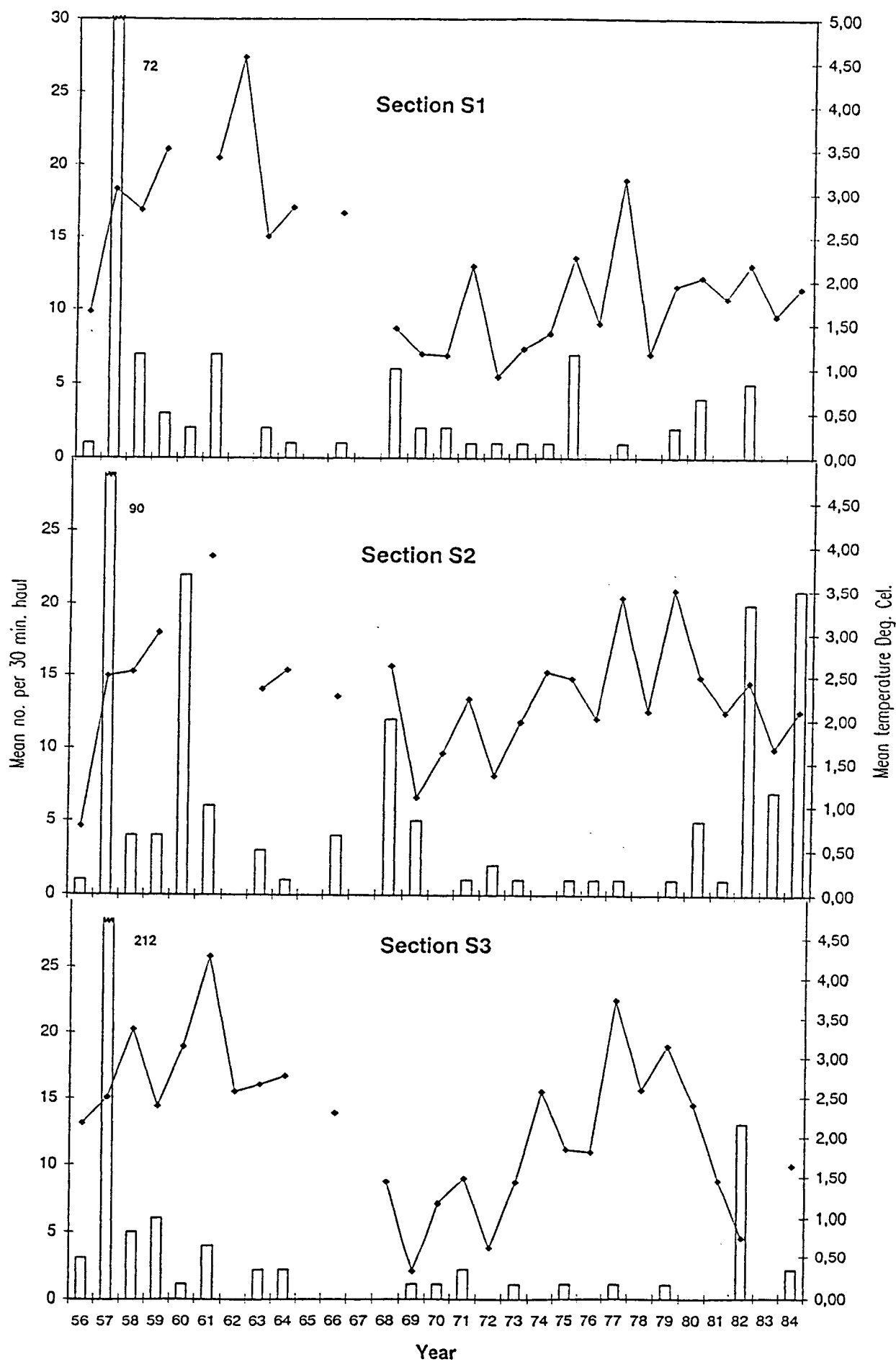


Fig. 34. Mean number of Atlantic cod larvae per 30 min. stramin net haul and mean temperature (the 10-50 m layer) in June-July by sampling section and year.

Log(mean no. per 30 min. haul + 1)

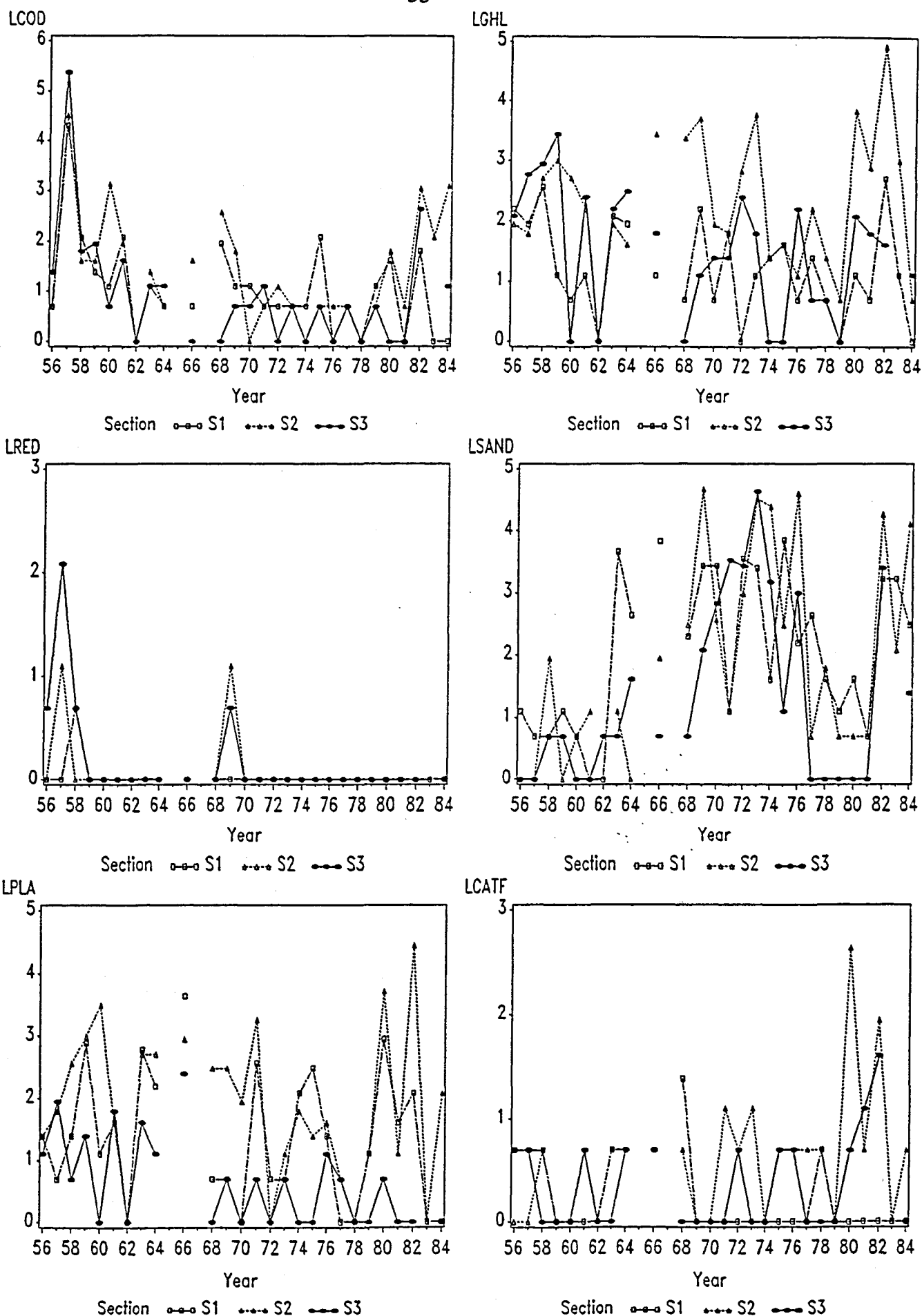


Fig. 35. Mean number of Atlantic cod larvae (LCOD), Greenland halibut larvae (LGHL), redfish larvae (LRED), sandeel larvae (LSAND), long rough dab larvae (LPLA) and catfish larvae (LCATF) per 30 min. stramin net haul in June-July by sampling section and year.