Variations in zooplankton densities in Icelandic waters in spring during the years 1961–1982

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ABSTRACT

The available data on the density and composition of zooplankton obtained in spring surveys (late May – early June) of Icelandic waters during 1961–1982 have been analysed. On 13 transits all around Iceland and extending from coastal to offshore waters the long term average densities have been calculated and inter-annual changes in the densities and of the most important species investigated.

On the sections off the north coast of Iceland average densities ranged from 4–7 ml/21 m^3. In the whole northern area a marked decrease in the zooplankton was observed during the mid sixties. During the early sixties the zooplankton densities were usually above 10 ml/21 m^3 while around 1965 they suddenly decreased to levels below 5 ml/21 m^3. More recently some increase has again been observed, but nevertheless, the high values frequently observed in the early sixties have not again been recorded. These results are discussed in relation to the great environmental changes which are known to have occurred north of Iceland during the same period.

In the other areas around Iceland data series are available for shorter periods (9–15 years) and thus long term changes are more difficult to detect. Considerable year to year variations have, however, been observed in the zooplankton densities at most of these sections but the long term averages (4–13 ml/21 m^3) are similar to those recorded north of Iceland. On the spawning grounds off the southwest coast greatest zooplankton densities were found during 1973 and 1976. Since 1976 a prominent peak in the zooplankton has not been observed. These findings are considered in relation to downward trends in abundance estimates of the 0-group stage of some commercially exploited fish stocks.

Calanus finmarchicus constituted usually about 50–80% of the animals in the zooplankton samples and it is by far the most common species at most stations. Other species (groups) of considerable importance in certain areas are *C. hyperboreus*, Euphausiacea nauplii and Cirripedia larvae. There are in the data some indications that north of Iceland the percentage frequency of *C. finmarchicus* has decreased since the mid sixties while that of *C. hyperboreus*, *Metridia longa* and Euphausiacea nauplii has increased. Furthermore, *C. hyperboreus* and *M. longa* have in recent years been found closer to the shore than in the early sixties.

INTRODUCTION

For more than 20 years zooplankton studies have been carried out in North Icelandic waters during late May and early June. Initially the studies were undertaken in connection with herring investigations in spring and summer, but since the decline of the herring fishery, during the late sixties, they have been expanded to cover the waters all around Iceland and continued as a part of a general environmental survey (hydrography, chemistry, phyto- and zooplankton) in spring.

Stefánsson (1962) reviewed the hydrographical conditions in North Icelandic waters during 1947–1962. More recent investigations and comparison to Stefánsson's (1962) detailed work has demonstrated that, during the past two decades great environmental changes have taken place both in the hydrographic character of North Icelandic waters (e. g. Malmberg 1969, 1979; Malmberg and Svansson 1982) and also in the climate around Iceland (Dickson et al. 1975). Similarly, changes in phytoplankton primary production have been reported by Thórdardóttir (1977, 1980). During the earlier part of this century an extensive fishery was based on herring migrating to feeding grounds off the north coast of Iceland (Fridriksson 1944; Jakobsson 1978, 1980). Hallgrímsson (1960) suggested that mixing processes northwest of Iceland were an important factor in determining the growth conditions for the rich zooplankton stocks in the area. When discussing the decline which took place in this North Icelandic herring fishery during the sixties, Jakobsson (1978) concluded that along with heavy exploitation the deteriorating hydrographic conditions and declining zooplankton densities played an important role. Jakobsson (1978) pointed out that the abundant stock of *Calanus finmarchicus,* usually observed north of Iceland in spring, almost completely disappeared from these waters during the mid sixties. More recent observations on the distribution and densities of the zooplankton in Icelandic waters (Hallgrímsson, unpublished data) have not been quantitatively evaluated in relation to the events in the sixties. Such an analysis is, however, of great interest as it may yield information on the recovery of the zooplankton stocks and the long term changes in the area. During the past 30 years the data from the Continuous Plankton Recorder Surveys (CPRS) have demonstrated certain consistent trends in the variation of both phyto- and zooplankton from the northeastern North Atlantic and the North Sea (e. g. Colebrook 1978a, b; Glower et al. 1972; Garrod and Colebrook 1978).

Recently great changes have taken place in the stock sizes of cod, haddock (Anon. 1976a) and capelin (Vilhjálmsson et al. 1982; Vilhjálmsson 1983) around Iceland. Some of the variations in these exploited fish stocks are undoubtedly related to changes in fishing effort. However, they could to some extent also be the result of changes in the zooplankton biomass and composition, and its influence on year class strength (cf. Vilhjálmsson 1983).

The present paper describes the distribution of zooplankton biomass around Iceland during 1961–1982. Variations in zooplankton volumes on fixed sections and stations have been analysed. Similarly, changes in species composition have been investigated. In an attempt to put the results into a wider marine ecological and fisheries context they are also discussed in relation to data on hydrography, primary production and 0-group fish.

MATERIALS AND METHODS

Throughout the investigation period the zooplankton has been sampled at fixed stations along sections extending from coastal to offshore waters (Fig. 1). The longest time series (22 years) are available for the sections off the northwest and north coasts, but off the east and south coasts time series of 8–12 years have been collected. It has not been possible to sample all the stations on a particular section every year (Tables 1, 2), while in some years additional stations were occupied in certain areas (Figs. 2–23). For calculation of zooplankton density on different sections and for between year comparison only the density measurements made on the fixed stations have been used.

During the early part of the investigation period the surveys started off the west and northwest coasts of Iceland and then proceeded clockwise to the waters off the northeast coast. However, since 1971 the surveys have started off the southwest coast (Selvogsbanki section, Fig. 1), then proceeded clockwise, and the Selvogsbanki sec-

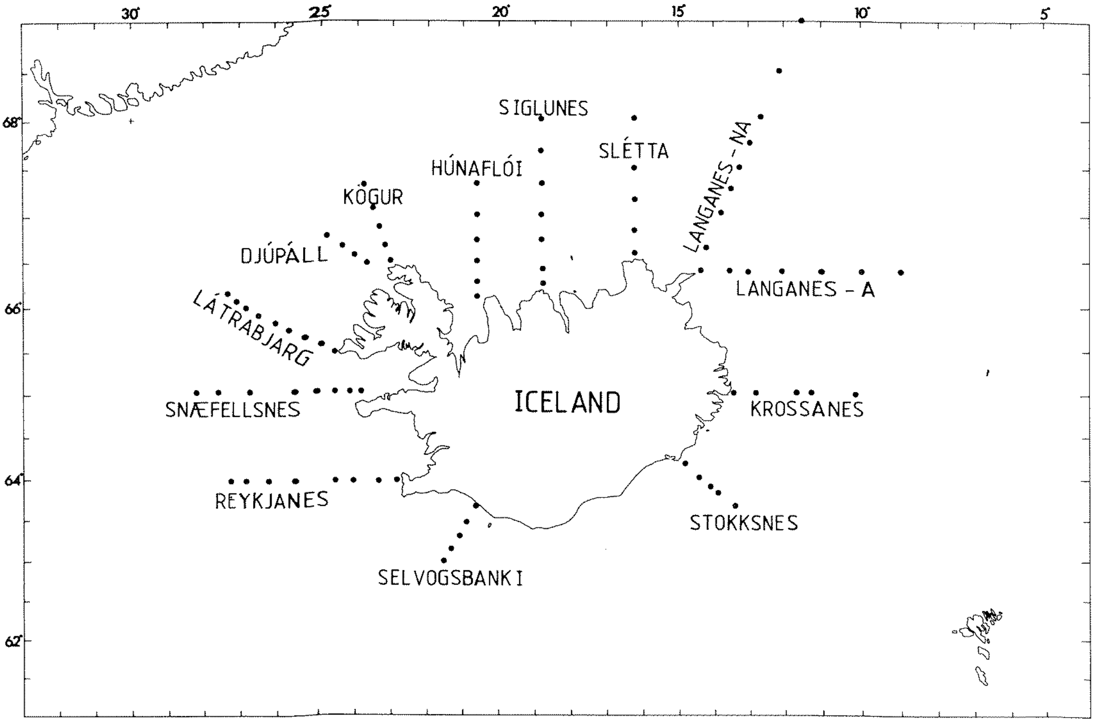

Fig. 1. Sections and stations used in the analysis of the variations in zooplankton densities.

tion surveyed again at the end of the cruise. For comparison of inter-annual zooplankton densities on the Selvogsbanki section the mean of the densities observed during the beginning and the end of each year's surveys has been used.

The zooplankton was sampled with a Hensen-net in vertical hauls from 50 m to 0 m (or from the bottom to the surface where the depth was less than 50 m). The net had an opening diameter of 73 cm and a mesh size of approximately 0.20 mm. Thus the calculated filtration in each 50 m haul was approximately 21 m^3. After collection the zooplankton volumes were determined by displacement. Large organisms such as salps and medusae were, however, removed from the samples before volume measurement. Shipboard analyses of the species composition of the plankton were made according to the shortcut method described by Einarsson (1956) and Hallgrímsson (1958).

RESULTS

1. Distribution of zooplankton in different years.

The quantitative distribution of the zooplankton in the waters around Iceland during the period 1961—1982 is shown in Figures 2—23. The main features of most years have previously been described in the Annales Biologiques of the relevant year and by Jakobsson (1978). However, as an important background to the analyses of the inter-annual variations during the whole period, a brief description of the zooplankton distribution characterizing each year is given below. Throughout the summer changes are continuously taking place in the biomass of

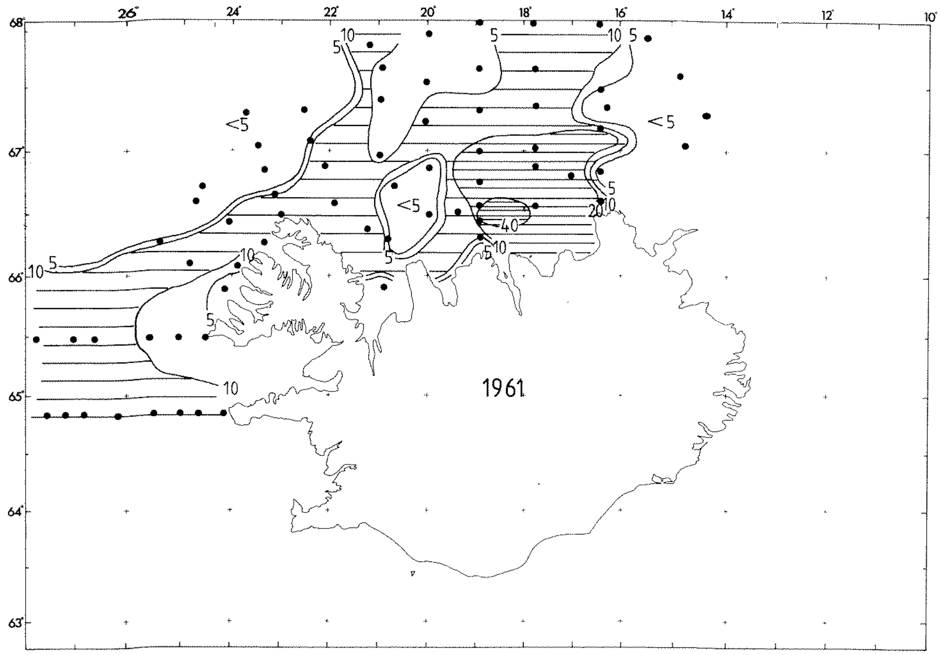

Fig. 2. Zooplankton distribution during 7–16 June 1961 (ml/21 m^3, Hensen net 50–0 m). The isolines and the shading in Figs. 2–23 are drawn on the following density scale (indicating ml of zooplankton per 21 m^3 haul): <5 = 0–4, 5 = 5–9, 10 = 10–19, 20 = 20–39, 40 = 40 and greater.

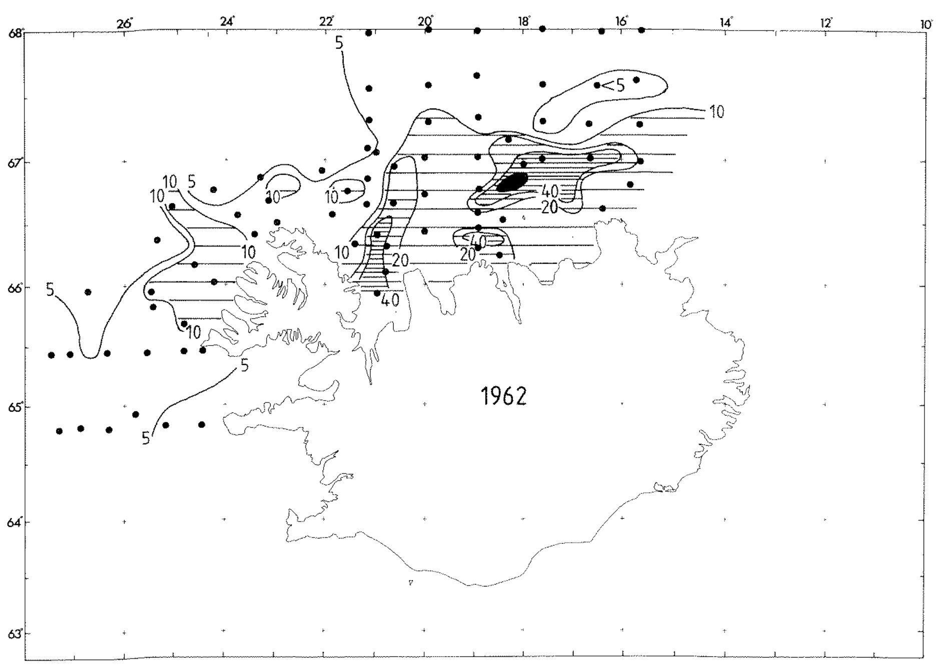

Fig. 3. Zooplankton distribution during 23 May – 22 June 1962 (ml/21 m^3, Hensen net 50–0 m).

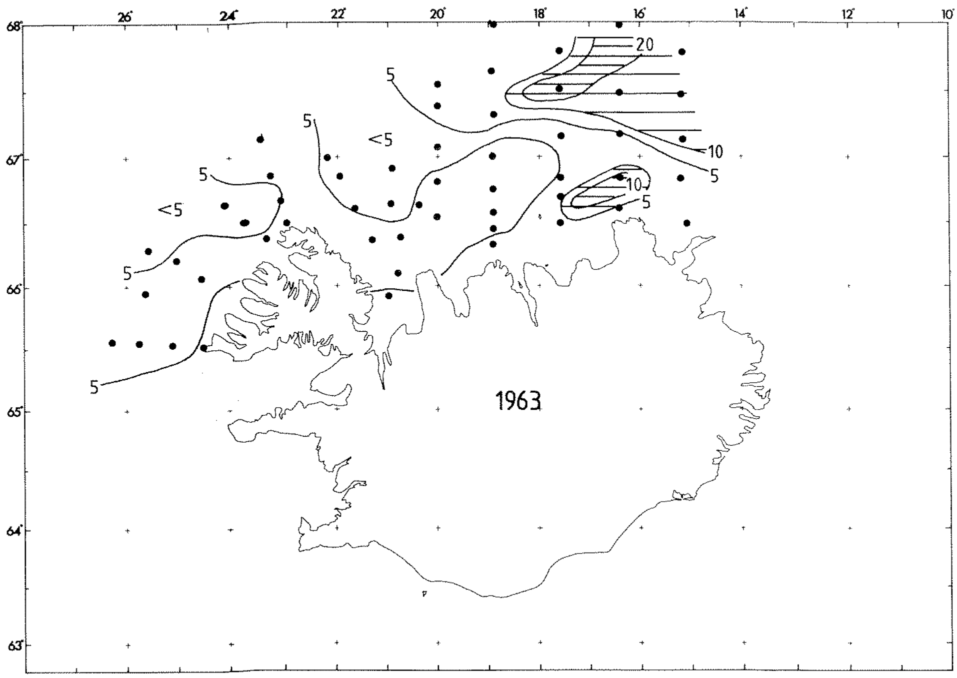

Fig. 4. Zooplankton distribution during 22 May – 21 June 1963 (ml/21 m³, Hensen net 50–0 m).

the plankton and its distribution. Thus it must be born in mind that maps such as shown in Figures 2–23 only give the large scale distribution of the plankton biomass during the time of investigation, but provide only limited information on the development later in the year.

1961 (Fig. 2)

During 1961 zooplankton volumes from 10–20 ml/21 m³ were measured over extensive areas off the west and north coasts. The highest concentrations (up to 60 ml/21 m³) were found off the northeast coast between 66° and 67°N.

1962 (Fig. 3)

Densities up to 10 ml/21 m³ were observed in the shelf area northwest of Iceland, while the highest concentrations of the zooplankton biomass occurred off the north coast proper where 3 patches with volumes greater than 20 ml/21 m³ extended over considerable part of the area. In these patches the maximum concentrations were about 80 ml/21 m³. Moderate densities of zooplankton were also recorded off the southern part of the Vestfirðir (Westfjord) peninsula (Anon. 1964).

1963 (Fig. 4).

In general the zooplankton volumes west and north of Iceland were found to be rather low. The maximum concentrations were in a relatively small area off the northeast coast between 15° and 18°W and 60–120 miles offshore (Anon. 1965).

1964 (Fig. 5).

The highest concentrations of zooplankton (>10–20 ml/21 m³) were found far off the northwest and north coasts. Low density

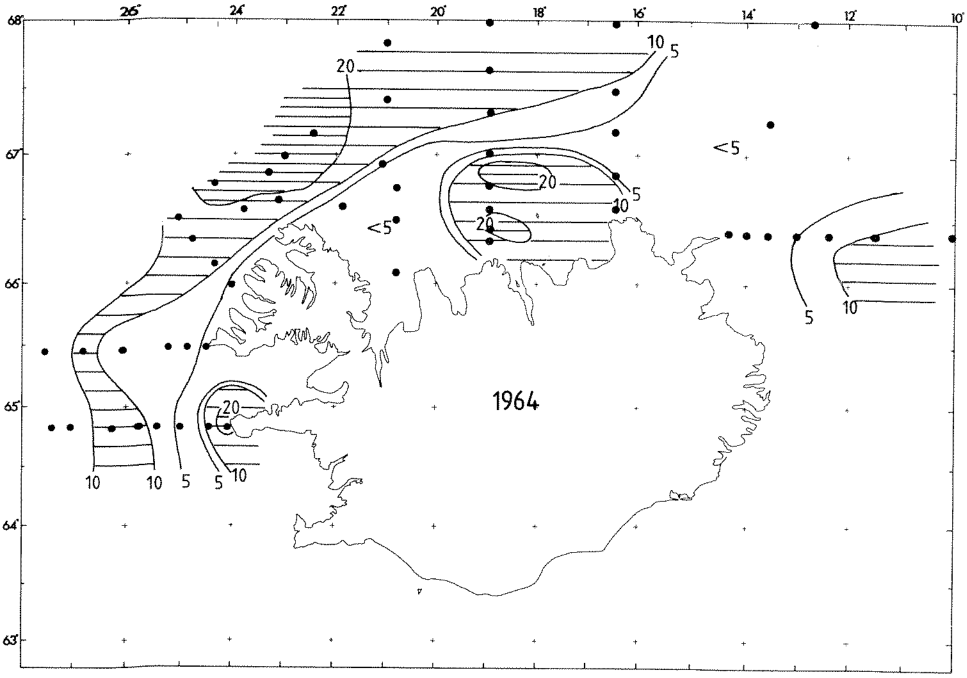

Fig. 5. Zooplankton distribution during 27 May – 20 June 1964 (ml/21 m^3, Hensen net 50–0 m).

was observed closer to the shore except for a relatively small area off the eastern part of the north coast (Anon. 1966).

1965 (Fig. 6)

Compared to previous investigations considerable environmental changes had occurred in the waters north of Iceland by the spring of 1965. Temperatures off the western part of the north coast were influenced by drift ice and at the surface they were about 3°C below normal. There were also indications that the East Icelandic Current consisted of more Polar water than in previous years. Primary production in the area was very limited and zooplankton volumes were also low in the whole area. At only a few stations west and northeast of Iceland did the zooplankton volumes exceed 10 ml/21 m^3 (Anon. 1967).

1966 (Fig. 7)

As in 1965 very low concentrations of zooplankton were measured both in coastal and offshore waters northwest and north of Iceland. However, in a considerable area northeast of Iceland along the northern reaches of the East Icelandic Current concentrations greater than 10 ml/21 m^3 were observed (Anon. 1968).

1967 (Fig. 8)

Within the whole study area northwest and north of Iceland zooplankton concentrations were very low (1–5 ml/21 m^3) and only at one station (67°00'N, 8°00'W) a volume greater than 10 ml/21 m^3 was measured. Worth noting is the proximity of the ice border off the western and the middle part of the north coast (Anon. 1969a).

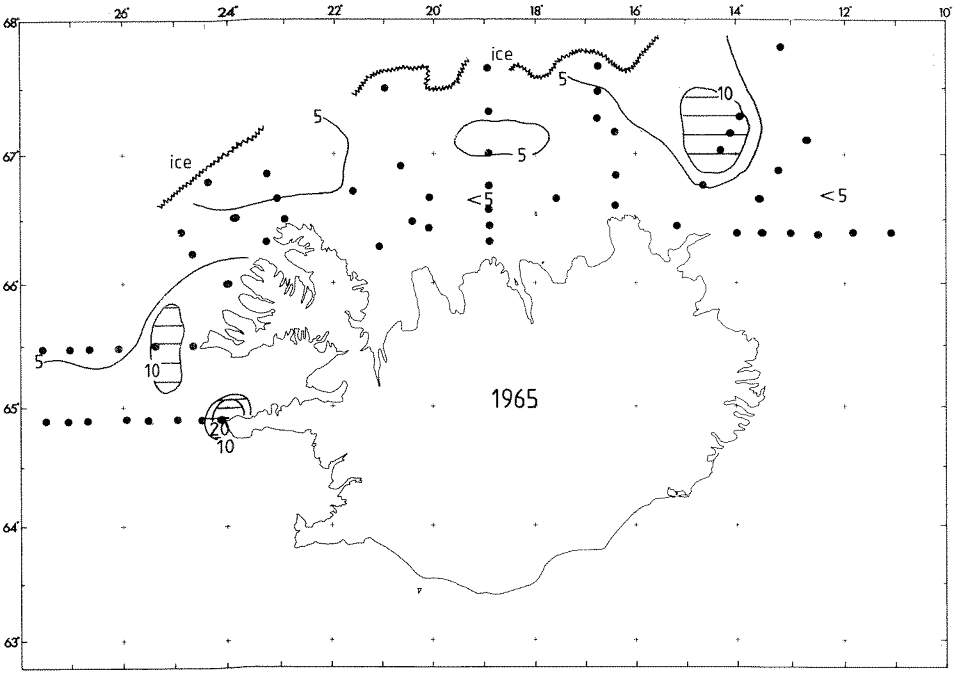

Fig. 6. Zooplankton distribution during 25 May – 20 June 1965 (ml/21 m³, Hensen net 50–0 m).

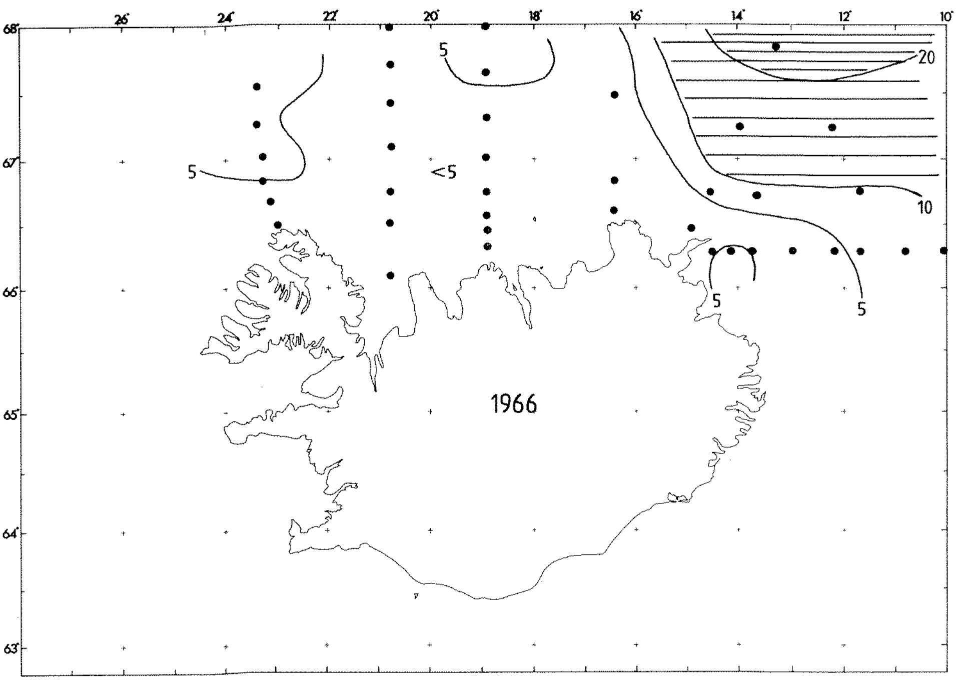

Fig. 7. Zooplankton distribution during 26 May – 12 June 1966 (ml/21 m³, Hensen net 50–0 m).

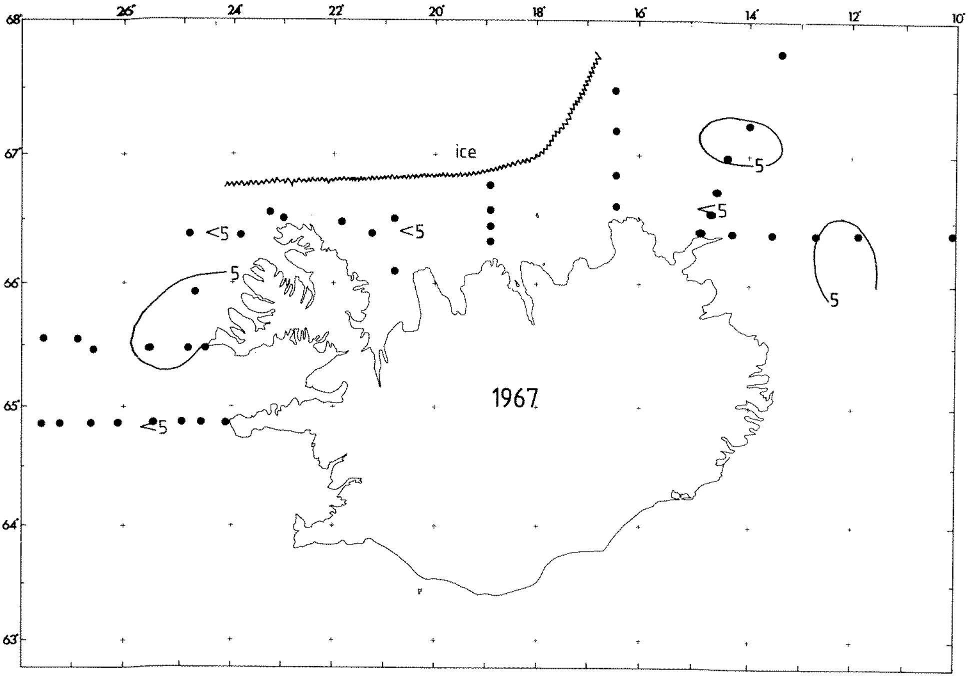

Fig. 8. Zooplankton distribution during 29 May – 15 June 1967 (ml/21 m³, Hensen net 50–0 m).

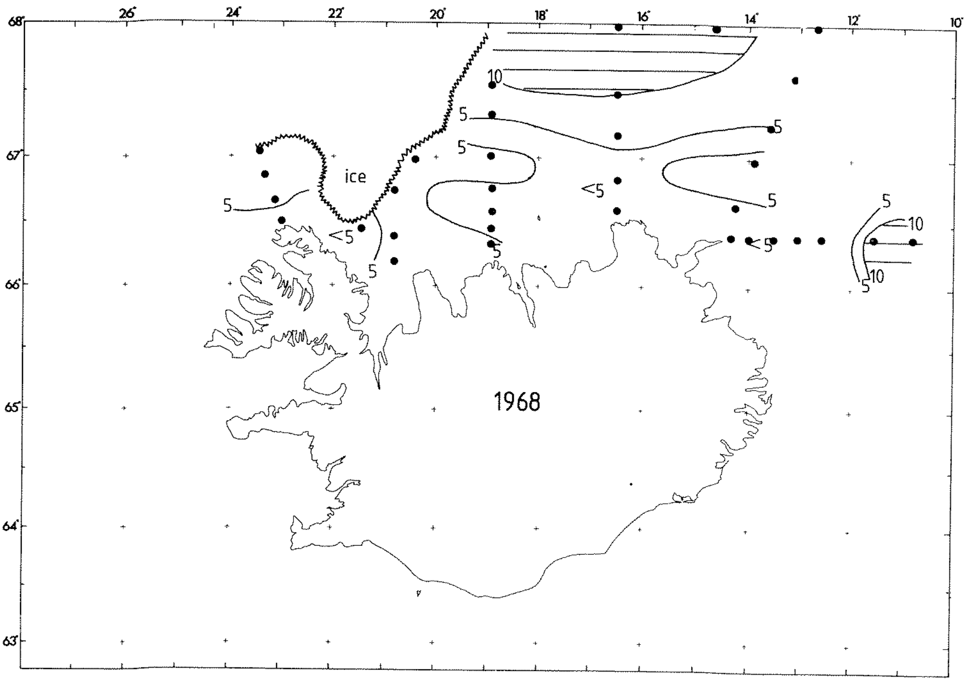

Fig. 9. Zooplankton distribution during 28 June – 3 July 1968 (ml/21 m³, Hensen net 50–0 m).

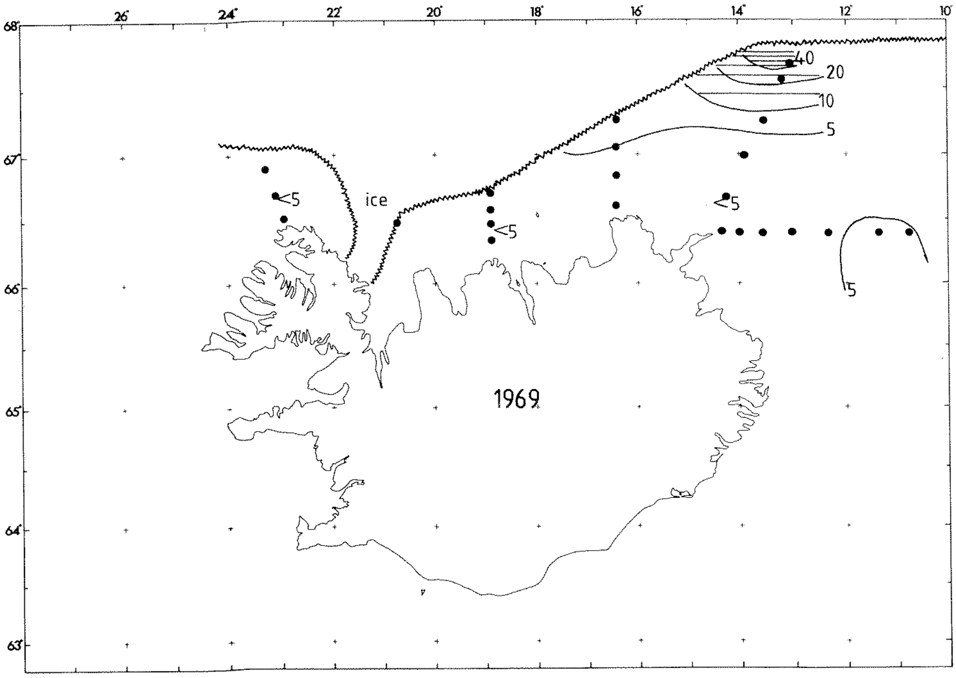

Fig. 10. Zooplankton distribution during 4–9 June 1969 (ml/21 m³, Hensen net 50–0 m).

1968 (Fig. 9)

Over the shelf northwest, north and northeast of Iceland the zooplankton density was very low (<5 ml/21 m³) at most stations. Farther offshore the densities were somewhat greater with the highest ones (20 ml/21 m³) recorded at the outermost stations northeast and east of Iceland (Anon. 1969b).

1969 (Fig. 10)

Again the ice conditions were unfavourable but not as severe as in 1968. Except for a relatively small but dense (20–40 ml/21 m³) patch along the ice border in the offshore area northeast of Iceland zooplankton concentrations north and east of Iceland were low. At several stations off the northwest and north coasts no zooplankton was recorded at all (Anon. 1970).

1970 (Fig. 11)

The waters over the continental shelf northwest, north and east of Iceland were characterized by low densities of zooplankton (<5 ml/21 m³). In the cold East Icelandic Current along the continental shelf north and northeast of Iceland, zooplankton densities between 10 and 30 ml/21 m³ were observed (Anon. 1972).

1971 (Fig. 12)

Over the shelf west and north of Iceland zooplankton volumes were below 5 ml/21 m³ at most stations. Farther off the north coast, at the southern border of the cold polar water, an area of moderate densities was recorded (10–20 ml/21 m³).

During the spring of 1971 the survey was extended to include stations on the main spawning grounds of exploited fish stocks

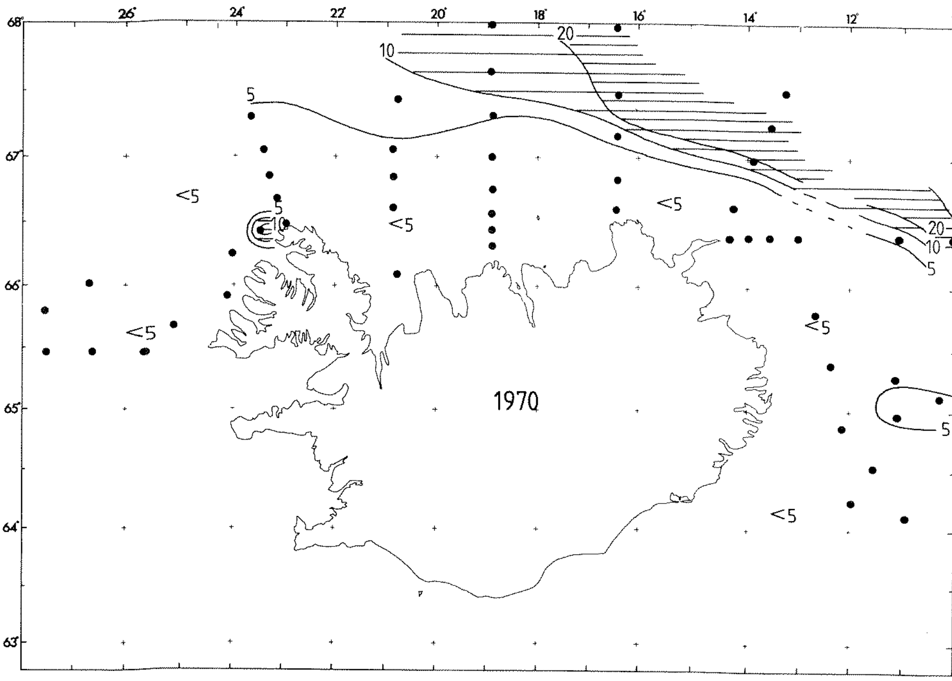

Fig. 11. Zooplankton distribution during 6–22 June 1970 (ml/21 m³, Hensen net 50–0 m).

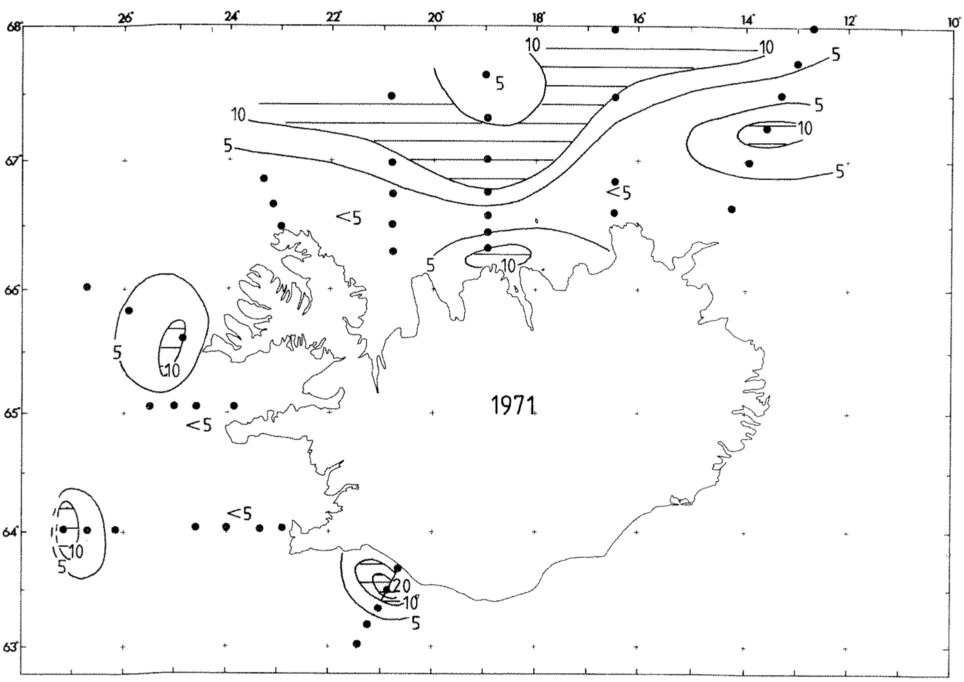

Fig. 12. Zooplankton distribution during 22–27 May 1971 (ml/21 m³, Hensen net 50–0 m).

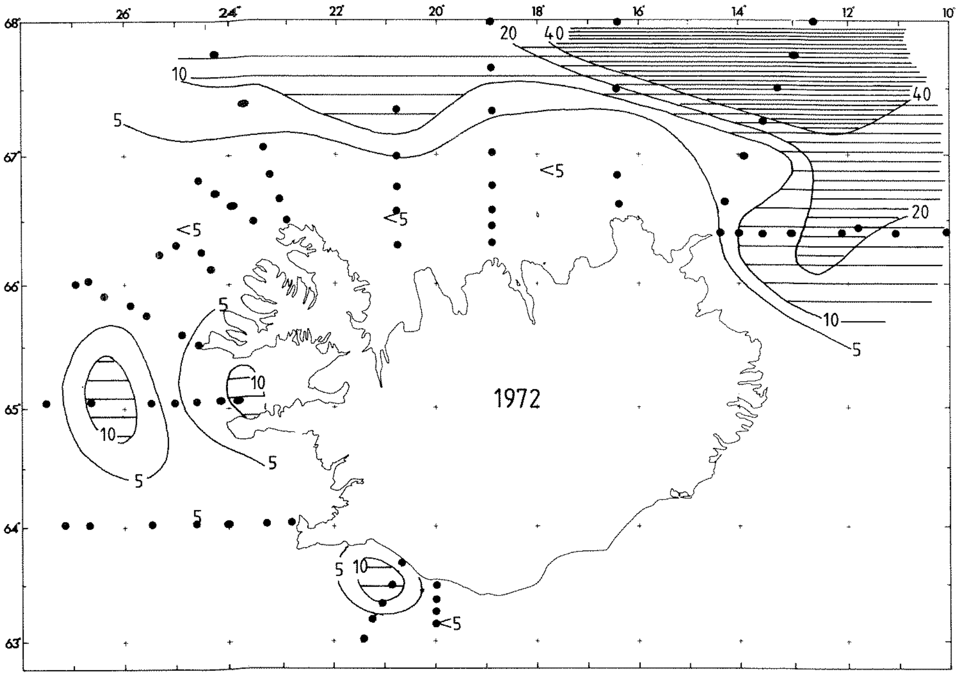

Fig. 13. Zooplankton distribution during 25 May – 9 June 1972 (ml/21 m³, Hensen net 50–0 m).

off the southwest coast. There the densities were generally low except for the stations closest to the shore on the Selvogsbanki section (Anon. 1973).

1972 (Fig. 13)

Northwest and north of Iceland the zooplankton distribution was very similar to that of the previous year. Low densities (<5 ml/21 m³) were measured over the shelf area, but in the colder water farther offshore, the densities were 10–20 ml/21 m³. The highest densities, up to 60 ml/21 m³, were measured far off the northeast coast. Generally low zooplankton concentrations (<5 ml/21 m³) were found off most of the southwest and west coasts (Anon. 1974).

1973 (Fig. 14)

In the coastal waters off the southwest coast and in the Breiðafjörður area on the west coast moderate (10–30 ml/21 m³) densities of zooplankton were recorded. Similarly, in the deep water off the west coast continental shelf, there was an area of zooplankton densities between 10 and 30 ml/21 m³. Off the norhtwest and north coasts zooplankton densities were low (<5 ml/21 m³) at most stations. However, off the northeast continental shelf, an extensive area of moderate (10–30 ml/21 m³) concentrations was observed (Anon. 1975).

1974 (Fig. 15)

Except for a few small patches the zooplankton concentrations south, west and north of Iceland were very low (<5–10 ml/21 m³). However, about 50–100 nautical miles off the east coast an extensive area of densities between 10 and 20 ml/21 m³ was observed (Anon. 1976).

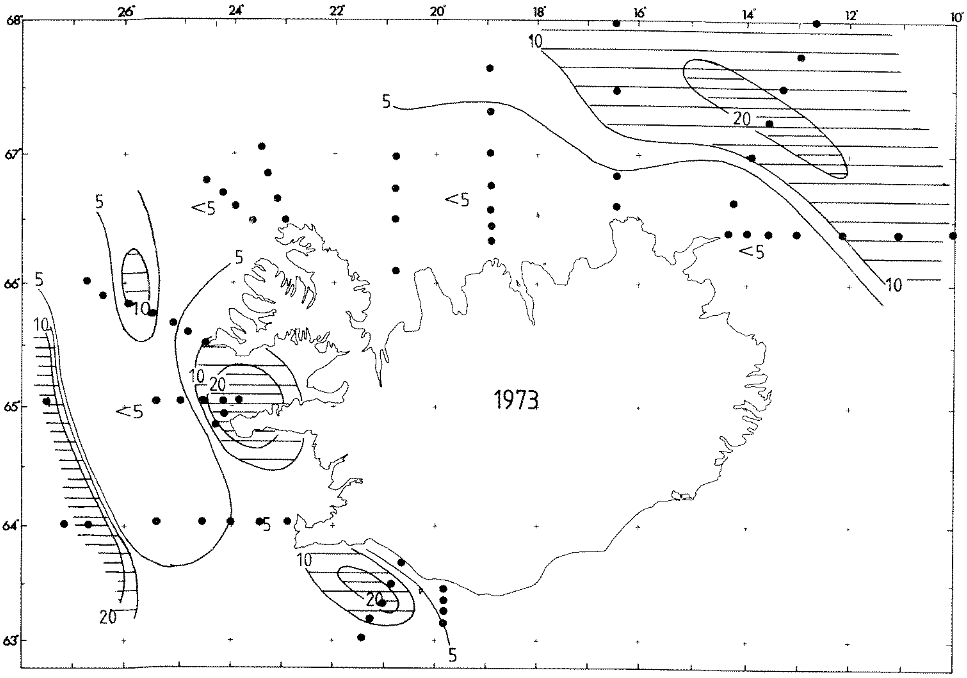

Fig. 14. Zooplankton distribution during 1–16 June 1973 (ml/21 m³, Hensen net 50–0 m).

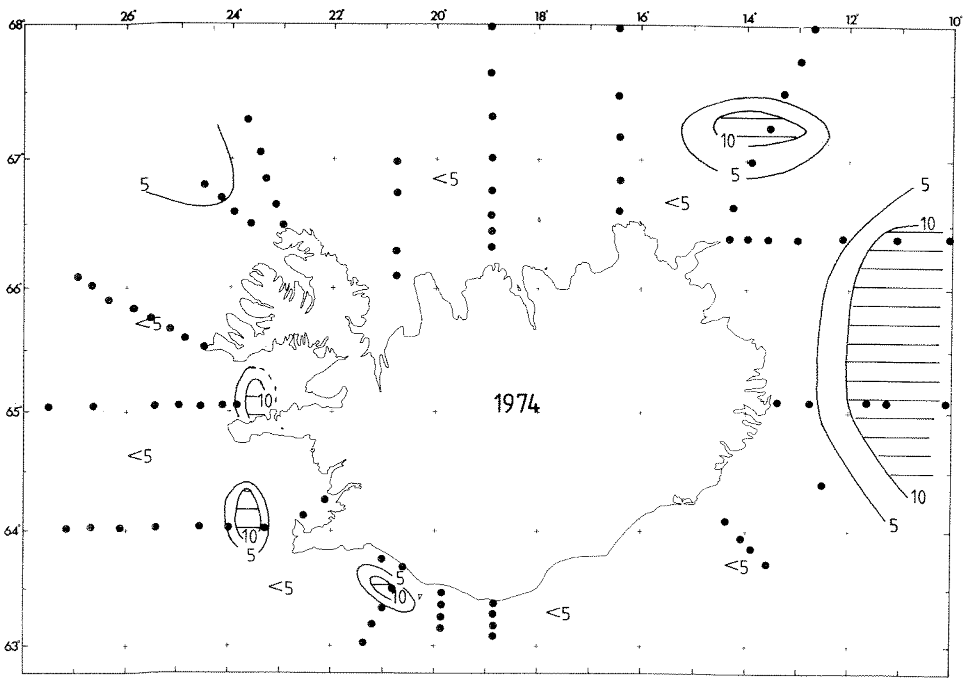

Fig. 15. Zooplankton distribution during 21 May – 8 June 1974 (ml/21 m³, Hensen net 50–0 m).

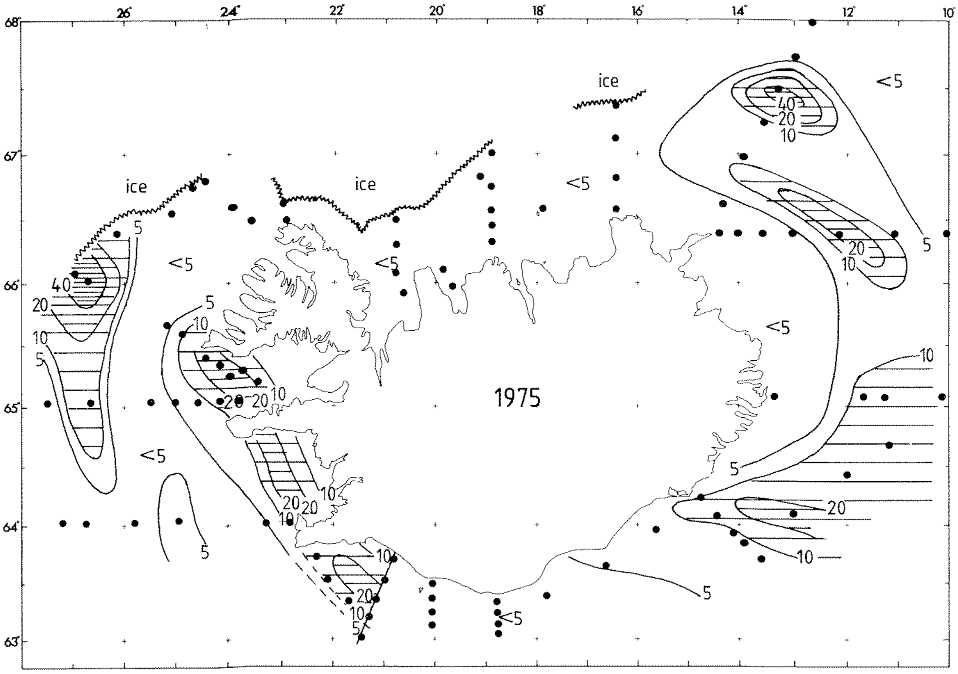

Fig. 16. Zooplankton distribution during 22 May – 10 June 1975 (ml/21 m³, Hensen net 50–0 m).

1975 (Fig. 16)

In the coastal waters southwest and west of Iceland and farther offshore west of the country narrow bands of dense zooplankton were observed (20–40 ml/21 m³). However, except for two dense plankton patches in the East Icelandic Current, the zooplankton concentrations north of Iceland were low (<5 ml/21 m³). Off the southeast coast moderate concentrations were found (Anon. 1978a).

1976 (Fig. 17)

Except for the shallow waters of the Breiðafjörður area off the west coast and the Húnaflói area off the north coast, low concentrations of zooplankton were found off the southwest, west and north coasts of Iceland. In the oceanic area off the shelf northeast of Iceland, high zooplankton concentrations (20–40 ml/21 m³) were recorded. In the coastal waters off the east coast the zooplankton concentrations were low, but farther offshore and along the southeast coast an extensive area of concentrations between 10 and 20 ml/21 m³ was observed. The Selvogsbanki section off the southwest coast was again surveyed at the end of the cruise. By that time concentrations had increased considerably from the earlier survey and now they ranged from 10 to 40 ml/21 m³ (Anon. 1978b).

1977 (Fig. 18)

During the spring of 1977 the distribution of the zooplankton was in general similar to that of 1976. Small patches were observed in Breiðafjörður on the west coast and over the shelf off the northwest coast. Similar to what was found in many of the previous years high (10–20 ml/21 m³) zooplankton densities were recorded in offshore areas

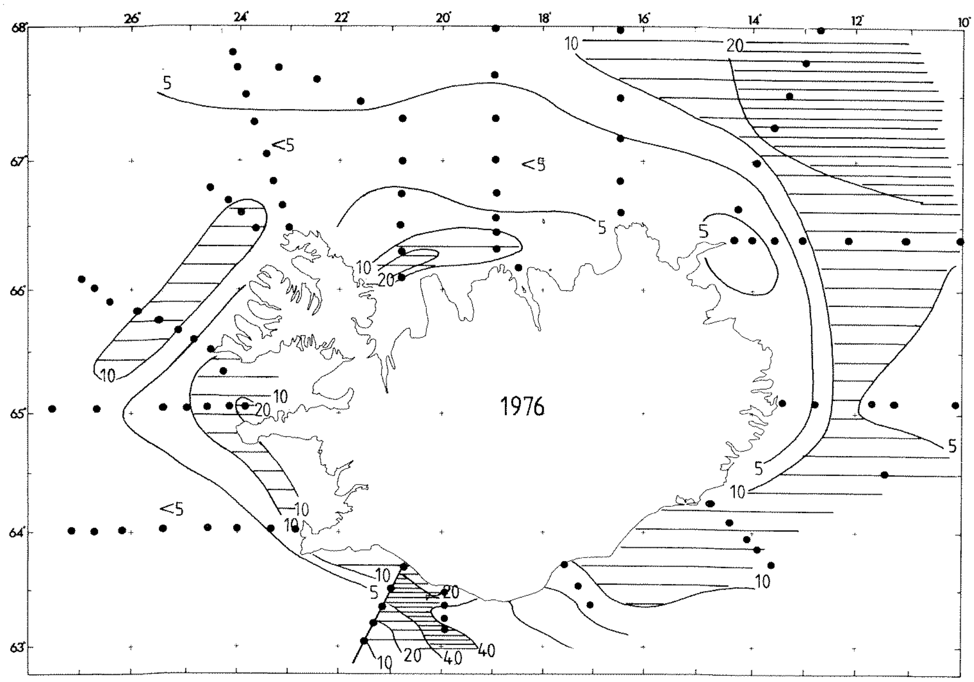

Fig. 17. Zooplankton distribution during 26 May – 15 June 1976 (ml/21 m³, Hensen net 50–0 m).

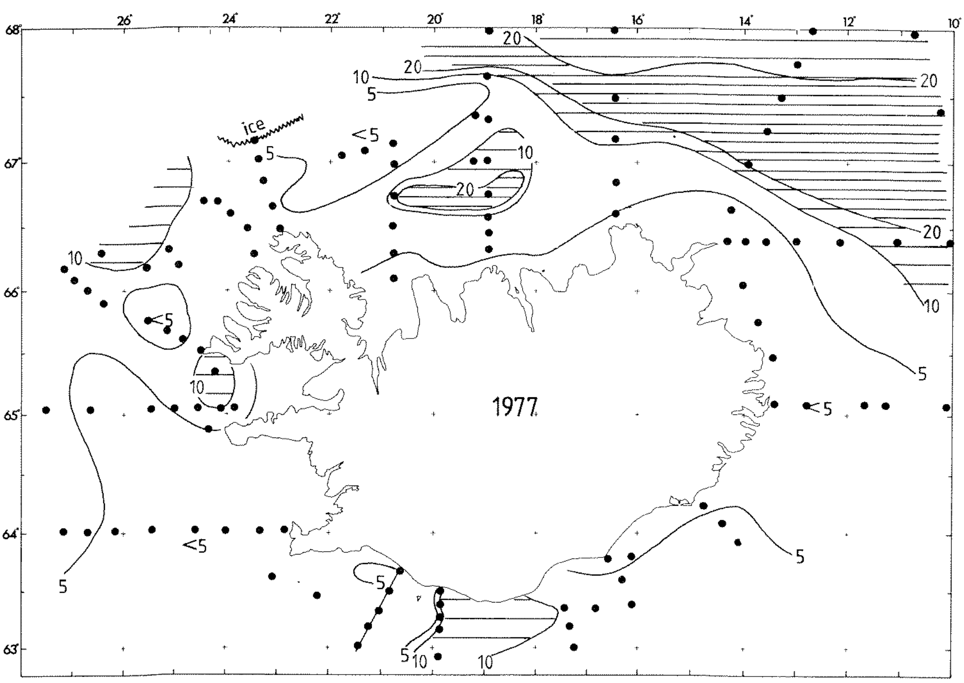

Fig. 18. Zooplankton distribution during 21 May – 10 June 1977 (ml/21 m³, Hensen net 50–0 m).

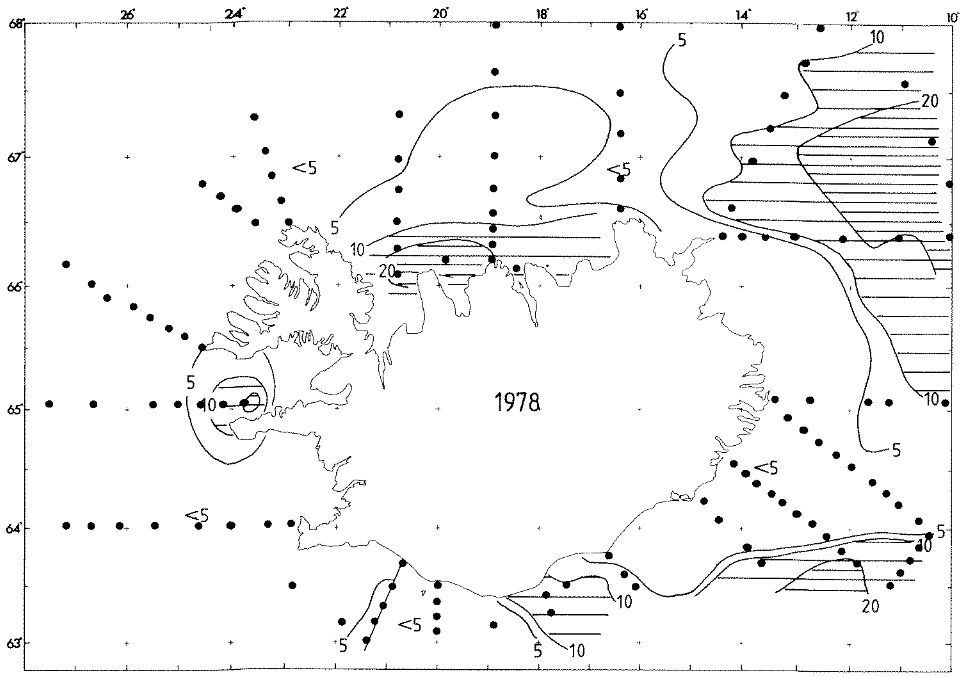

Fig. 19. Zooplankton distribution during 23 May – 14 June 1978 (ml/21 m³, Hensen net 50–0 m).

northeast of Iceland. East and south of Iceland the zooplankton densities were low (5 ml/21 m³) except for a small area east of Vestmannaeyjar (Westman Islands) off the south coast (Anon. 1979a).

1978 (Fig. 19)

Very low (<5 ml/21 m³) zooplankton densities were observed in extensive areas off the southwest, west and north coasts. However, there were some maxima in coastal areas off Snæfellsnes and in the western part of the waters north of Iceland (10–20 ml/21 m³). In the East Icelandic Current, 50–100 miles east of Langanes, high (20–40 ml/21 m³) concentrations were recorded. Coastal waters off the east and southeast coasts were characterized by very low (<5 ml/21 m³) zooplankton concentrations while higher densities were recorded farther offshore over the Iceland-Faroe Ridge (Anon. 1980a).

1979 (Fig. 20)

Throughout the whole survey very low concentrations of zooplankton were observed this year and only at 3 stations in the coastal waters of Breiðafjörður and at a single station off the southwest coast were densities greater than 20 ml/21 m³ recorded. Contrary to the findings of the 3 previous years no particular zooplankton maxima were observed in the waters northeast of Iceland (Anon. 1981a).

1980 (Fig. 21)

Except for the area around Vestmannaeyjar off the southwest coast, the waters south, west and north of Iceland were characterized by very low concentrations of zooplankton (<5 ml/21 m³) at most stations. However, outside the shelf off the northeast and east coasts extensive areas of high (20–40 ml/21 m³) zooplankton densities were recorded (Anon. 1983a).

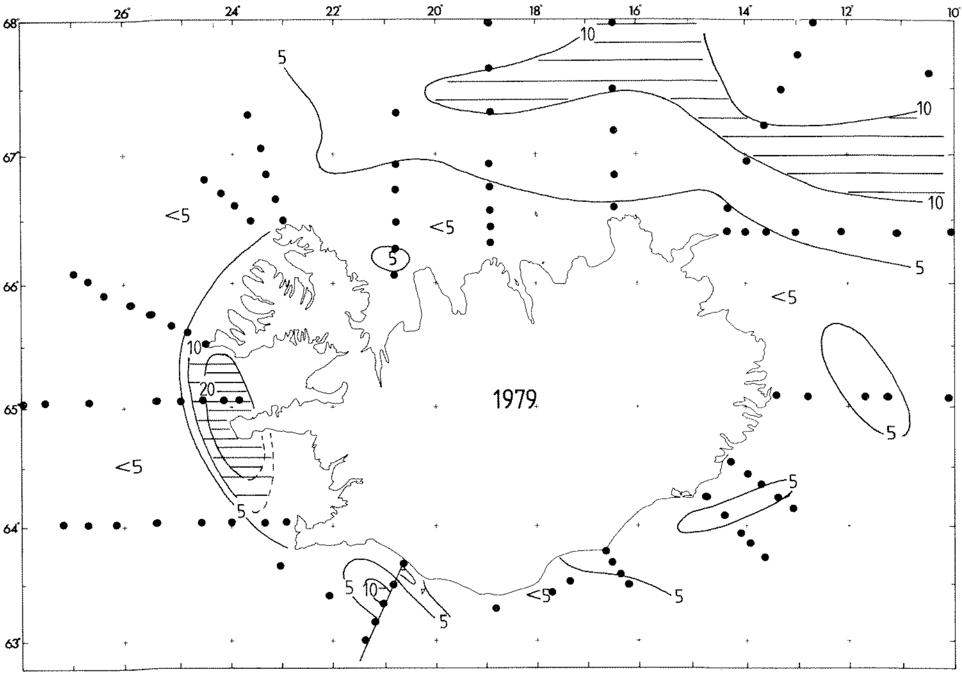

Fig. 20. Zooplankton distribution during 26 May – 16 June 1979 (ml/21 m³, Hensen net 50–0 m).

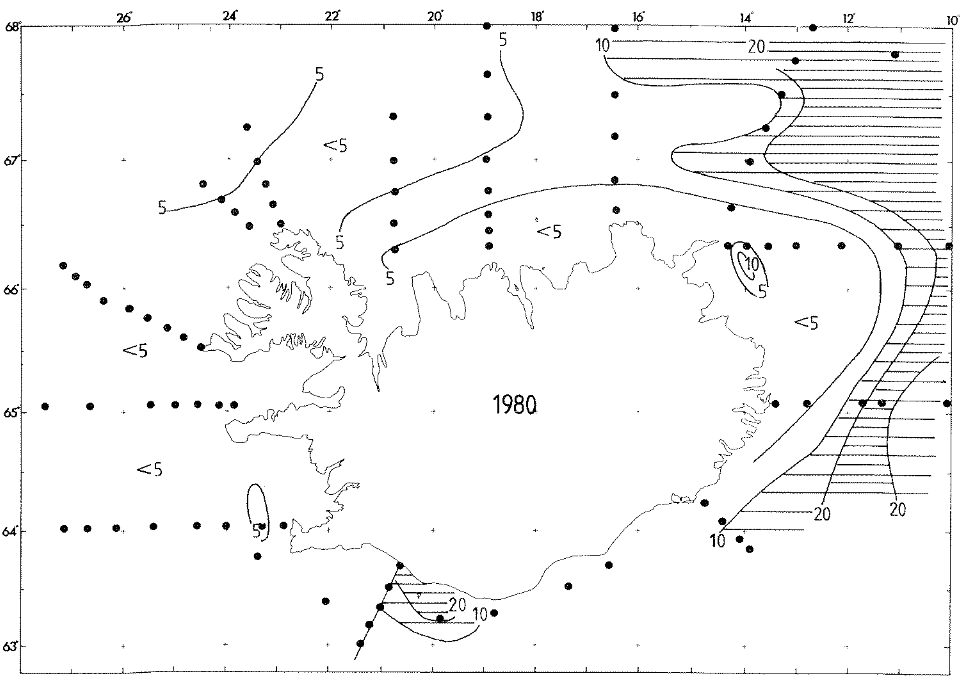

Fig. 21. Zooplankton distribution during 23 May – 10 June 1980 (ml/21 m³, Hensen net 50–0 m).

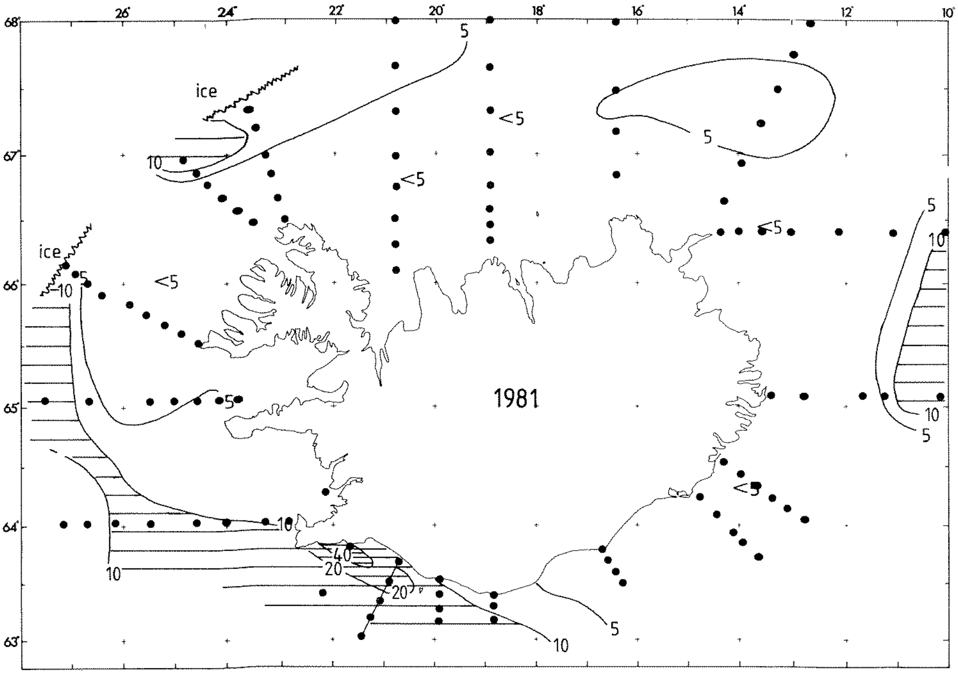

Fig. 22. Zooplankton distribution during 20 May – 10 June 1981 (ml/21 m³, Hensen net 50–0 m).

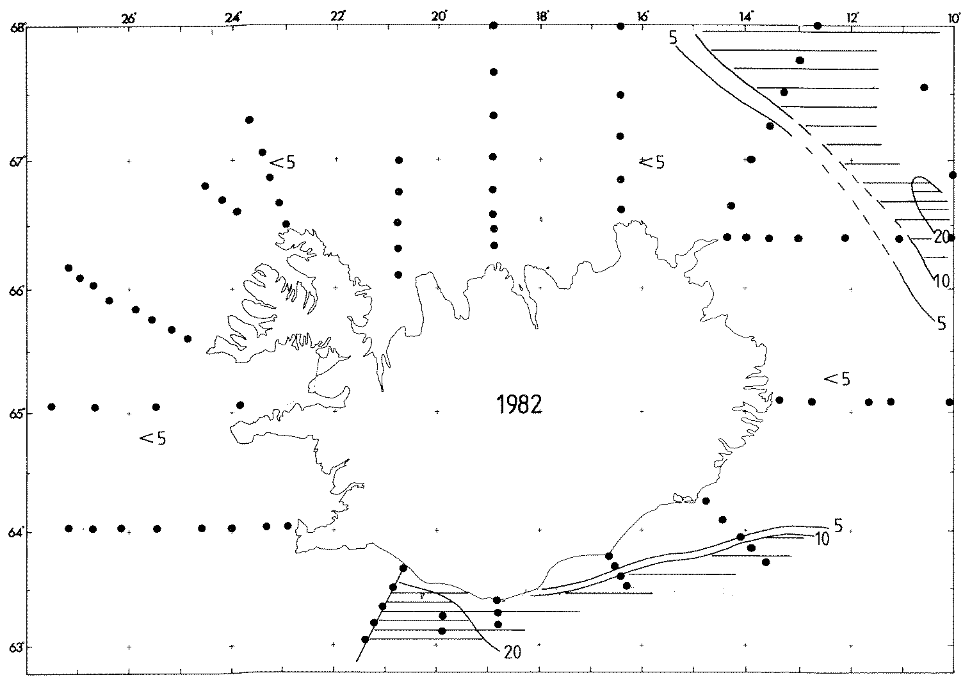

Fig. 23. Zooplankton distribution during 25 May – 14 June 1982 (ml/21 m³, Hensen net 50–0 m).

1981 (Fig. 22)

The highest zooplankton densities were found in the Selvogsbanki region off the southwest coast (20–40 ml/21 m³). Farther offshore, off the southwest and west coasts, a narrow band of moderate (10–20 ml/21 m³) densities was observed. Except for an area about 100 miles off the east coast, zooplankton concentrations in other areas were very low (<5 ml/21 m³) at most stations (Anon. 1981b).

1982 (Fig. 23)

Very low (<5 ml/21 m³) zooplankton volumes characterized most of Icelandic waters during the spring of 1982. Only in the cold waters off the northeast continental shelf and over the south coast shelf moderate (10–30 ml/21 m³) concentrations were recorded. The Selvogsbanki section (off the southwest coast) was surveyed both at the beginning (25/5) and at the end (14/6) of the cruise. Between the two surveys the zooplankton volumes had increased from an average (of the five stations) of 4 ml/21 m³ to 17 ml/21 m³ (Anon. 1982). This clearly demonstrates that great changes can occur in the zooplankton biomass within a relatively short period of time.

2. Variations in zooplankton densities on fixed sections

Using available volume measurements from fixed stations (Tables 1, 2) the average zooplankton densities during each year and the grand means for the whole observation period have been calculated for the different sections (Table 3).

The values in Table 3 indicate that on the sections north of Iceland (Kögur, Húnaflói, Siglunes and Slétta) there has been a drastic decrease in the zooplankton volumes from the year 1965 onwards (1964 onwards on the Húnaflói section). During 1961–1964 mean zooplankton volumes of 10–30 ml/21 m³ were frequently observed on these sections. However, since 1964 densities above 10 ml/21 m³ have only been recorded three times. This decrease in the zooplankton densities north of Iceland is further demonstrated in Figure 24, which for each year shows the deviation in zooplankton volume from the 22 years grand mean. In general, the devia-

TABLE 1

The number of stations taken during different years on the various sections. Exactly which stations were taken each year can be seen from the distribution map for the relevant year (Figs. 2–23).

Section	*Year*																					
	61	*62*	*63*	*64*	*65*	*66*	*67*	*68*	*69*	*70*	*71*	*72*	*73*	*74*	*75*	*76*	*77*	*78*	*79*	*80*	*81*	*82*
Kögur	5	3	3	2	3	3	1	4	3	5	3	4	4	5	2	5	4	5	5	5	5	5
Húnaflói	1	2	1	3	0	3	2	1	1	1	5	5	4	4	3	6	5	6	6	6	6	6
Siglunes	8	8	8	8	7	8	4	7	4	8	7	8	7	8	5	8	8	8	8	8	8	8
Slétta	5	2	5	5	3	3	4	5	4	5	4	4	4	5	4	5	5	5	5	5	4	5
Langanes–NA	–	–	–	–	–	–	–	5	5	4	6	8	8	7	8	8	8	8	8	8	8	7
Langanes–A	–	–	–	–	–	–	–	4	4	6	0	8	8	7	7	8	8	8	8	8	8	8
Krossanes	–	–	–	–	–	–	–	–	–	–	–	–	–	5	4	6	6	6	6	5	6	6
Stokksnes	–	–	–	–	–	–	–	–	–	–	–	–	–	4	5	5	3	4	5	3	5	5
Selvogsbanki	–	–	–	–	–	–	–	–	–	–	5	5	5	5	5	5	5	5	5	5	5	5
Reykjanes	–	–	–	–	–	–	–	–	–	–	7	7	7	7	4	8	8	8	8	8	8	8
Snæfellsnes	–	–	–	–	–	–	–	–	–	–	4	8	7	8	8	8	8	8	8	8	8	5
Látrabjarg	–	–	–	–	–	–	–	–	–	–	3	6	7	8	2	8	8	8	8	9	9	9
Djúpáll	–	–	–	–	–	–	–	–	–	–	–	4	4	4	3	4	4	4	4	4	4	3

TABLE 2

Numbers of years during which observations have been made on a particular fixed station (cf. Fig. 1).

Section	*Station*								
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Kögur	21	21	20	13	9	–	–	–	–
Húnaflói	17	13	15	14	11	7	–	–	–
Siglunes	22	22	22	22	20	19	19	15	–
Slétta	21	21	17	19	17	–	–	–	–
Langanes–NA	15	15	15	14	14	13	11	9	–
Langanes–A	14	14	14	14	11	12	12	9	–
Krossanes	9	8	9	9	9	–	6	–	–
Stokksnes	8	9	8	7	7	–	–	–	–
Selvogsbanki	12	12	12	12	12	–	–	–	–
Reykjanes	11	12	11	11	10	9	12	12	–
Snæfellsnes	12	10	11	11	12	10	11	11	–
Látrabjarg	10	12	10	10	10	10	11	7	5
Djúpáll	10	11	10	11	–	–	–	–	–

TABLE 3

Average zooplankton volumes (ml/21 m^3) on selected sections in Icelandic waters.

Year	*Section*												
	Kö	*Hú*	*Si*	*Sl*	*LN*	*LA*	*Kr*	*St*	*Se*	*Re*	*Sn*	*Lá*	*Dj*
1961	6	18	22	12	–	–	–	–	–	–	–	–	–
1962	10	35	24	10	–	–	–	–	–	–	–	–	–
1963	11	6	7	13	–	–	–	–	–	–	–	–	–
1964	19	3	15	9	–	–	–	–	–	–	–	–	–
1965	5	–	3	0	–	–	–	–	–	–	–	–	–
1966	3	1	2	1	–	–	–	–	–	–	–	–	–
1967	1	1	1	1	–	–	–	–	–	–	–	–	–
1968	5	6	5	6	5	4	–	–	–	–	–	–	–
1969	1	1	2	3	16	2	–	–	–	–	–	–	–
1970	1	1	4	12	13	4	–	–	–	–	–	–	–
1971	1	4	9	7	6	–	–	–	14	4	4	8	–
1972	4	9	5	16	23	14	–	–	8	3	9	6	4
1973	4	4	4	9	15	6	–	–	18	7	22	4	3
1974	2	3	2	2	6	7	11	3	6	3	5	1	3
1975	0	3	4	4	23	7	16	9	8	10	11	11	4
1976	2	8	6	5	21	9	5	12	23	5	15	6	6
1977	6	9	16	9	26	7	4	8	4	5	6	5	9
1978	2	12	8	4	8	10	4	4	5	3	20	2	2
1979	4	4	6	8	6	4	5	3	8	3	12	3	3
1980	4	4	4	7	14	11	12	8	7	2	3	2	4
1981	3	2	3	4	4	4	7	2	12	12	6	2	2
1982	2	1	1	2	7	6	2	6	11	2	3	1	1
Grand mean	4	6	7	7	13	7	7	6	10	5	10	4	4

Kö = Kögur, Hú = Húnaflói, Si = Siglunes, Sl = Slétta, LN = Langanes–NA, LA = Langanes–A, Kr = Krossanes, St = Stokksnes, Se = Selvogsbanki, Re = Reykjanes, Sn = Snæfellsnes, Lá = Látrabjarg, Dj = Djúpáll.

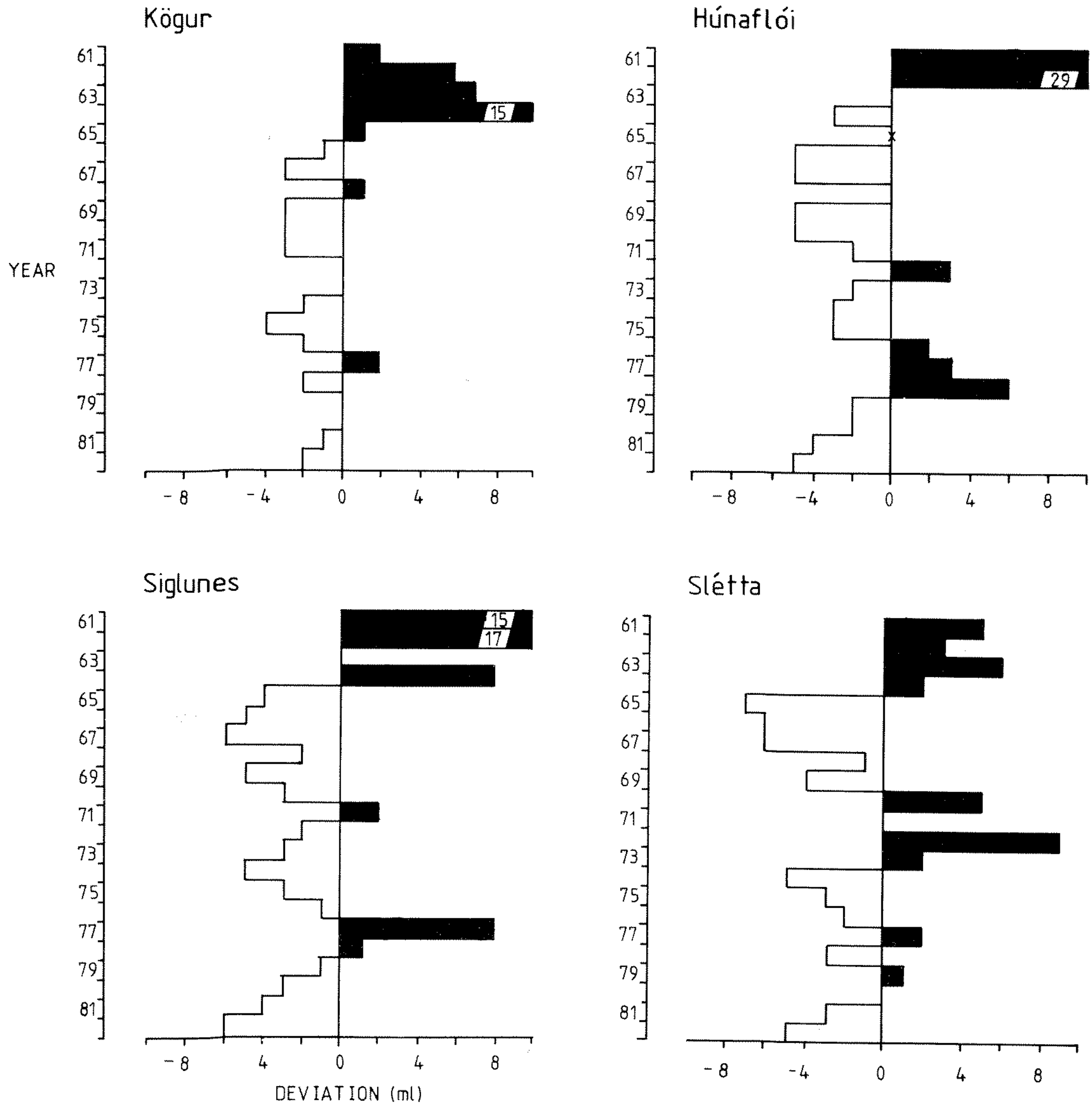

Fig. 24. Deviations of zooplankton volumes in May–June during 1961–1982 at Kögur, Húnaflói, Siglunes and Slétta sections north of Iceland.

tions in particular years are very similar at the four sections. At the beginning of the observation period positive deviations were observed, but negative deviations in most years after 1965. The year 1977 is the only one since the sharp decline around 1965 when positive deviations were observed at all four sections. During 1971, 1972, 1973, 1978, 1979 and 1980 zooplankton densities equal to or greater than the long term average were observed at two of the transits north of Iceland (Fig. 24).

For the Langanes–NA section, northeast of Iceland, data on zooplankton density are available from 1968 onwards (Table 3). Although information is lacking for the early sixties, it is apparent that on this section, the variation in zooplankton is somewhat different from that observed on the sections north of Iceland. The greatest densities were observed during 1972, 1975 and 1977. Considerable inter-annual variations are apparent on the Langanes–NA section, and deviations having the same sign lasting for more than three years have not occured during the observation period (Fig. 25). At most only two consecutive years were observed with negative deviations (1978–1979 and 1981–1982). However, these two year periods are separated only by one year (1980), and thus four out of the past five years show negative deviations (Fig. 25).

On the Langanes–A section, the inter-annual variations in the zooplankton volumes are less pronounced than on the Langanes–NA section (Table 3, Fig. 25). The three years from 1968–1970 constitute the longest consecutive period of similar deviations. The greatest density was observed during 1972, while over the whole study period the deviations show only limited fluctuations around the mean (Fig. 25).

Observations on the hydrographic conditions north of Iceland during the period under consideration (Malmberg 1969, 1979; Malmberg and Svansson 1982) have demonstrated that in the period 1965–1971 the inflow of Atlantic water to the area was much reduced. This led to a greatly deteriorating marine climate, with cold Polar water becoming more prominent north of Iceland during those years. In the period 1972–1974 the Atlantic water did somewhat regain its former distribution, but since 1974 the conditions do, however, seem to alternate rather regularly between years of weak and strong inflow of Atlantic water to the northern regions (Malmberg 1979; Malmberg and Svansson 1982). On the basis of these changes in the hydrographic conditions, the past 20 years are often grouped into three distinct periods (Malmberg, personal communication). The first period (1961–1964)

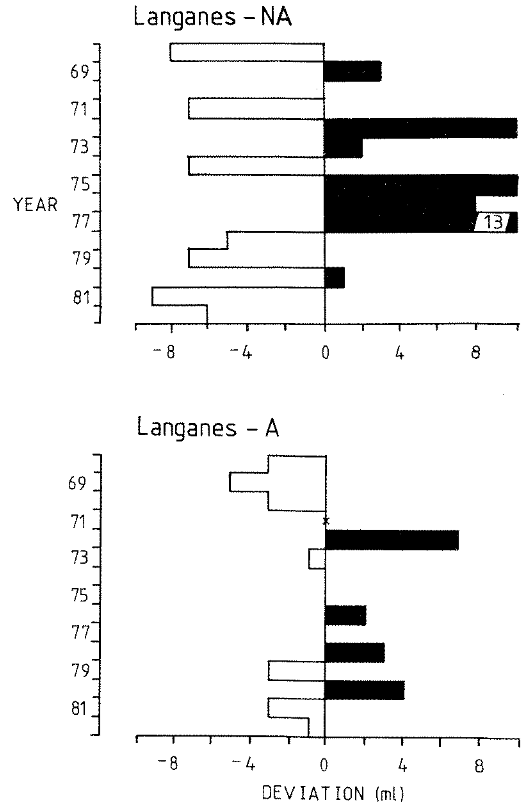

Fig. 25. Deviations of zooplankton volumes in May–June during 1968–1982 at Langanes–NA and Langanes–A sections northeast of Iceland.

was prior to the reduced inflow of Atlantic water to the areas north of Iceland, the second period (1965–1971) when Atlantic water was much reduced, and finally (1972 until present) a period when conditions have in some years been similar to those before 1965, while in other years they are more like those of the cold period 1965–1971.

A similar grouping of the zooplankton data into the three above periods further demonstrates the great changes which did take place in the zooplankton north of Iceland during the mid sixties. During 1961–1964 (Fig. 26) the average concentrations at all stations were above 5 ml/21 m^3. Furthermore, over extensive areas the densities were between 10 and 20 ml/21 m^3 and in the

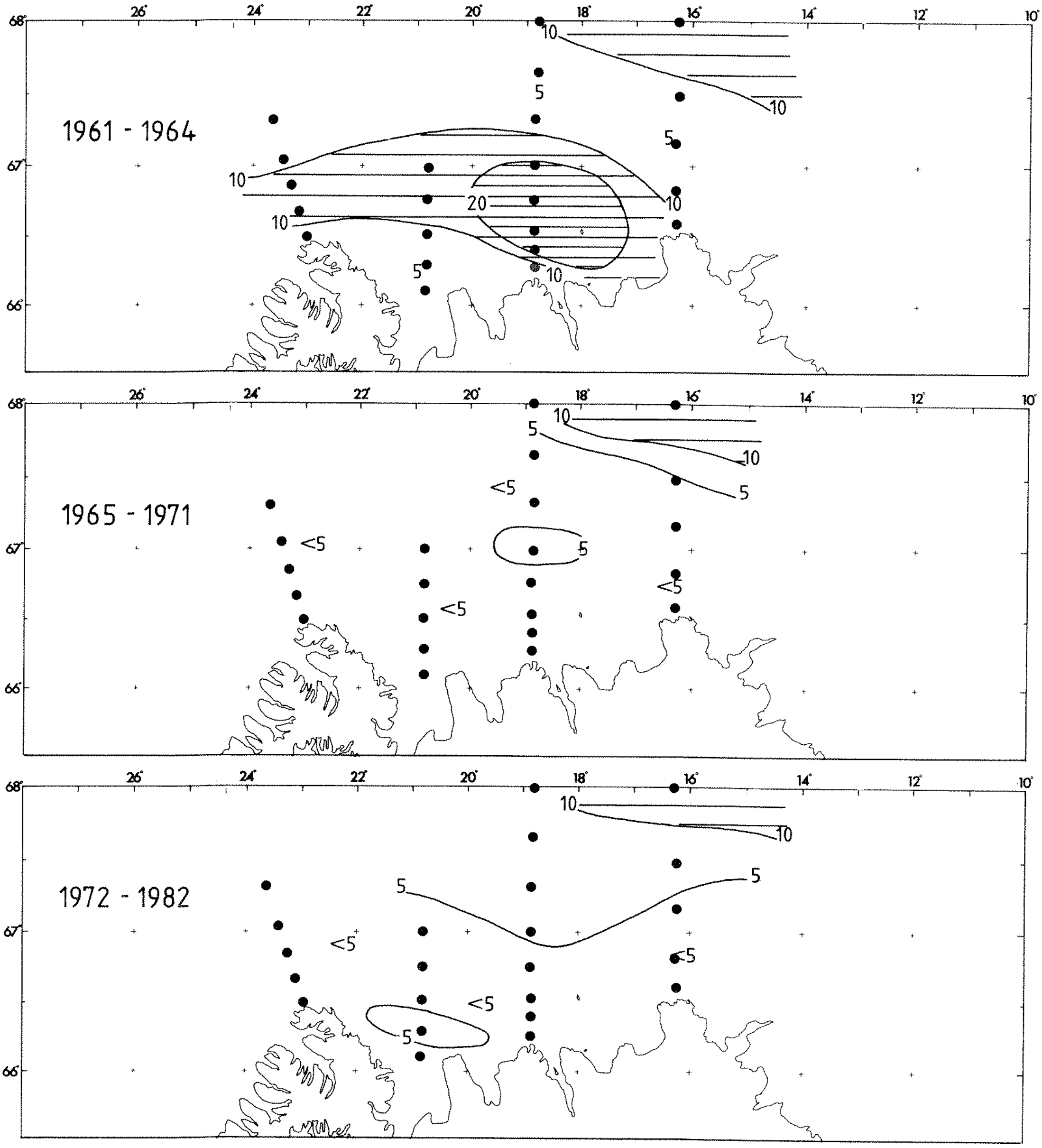

Fig. 26. Average zooplankton distribution north of Iceland in May–June during the periods 1961–1964, 1965–1971 and 1972–1982 (ml/21 m³, Hensen net 50–0 m).

middle of the area average densities greater than 20 ml/21 m³ were recorded at several stations. During 1965–1971 the very marked decrease in the zooplankton is apparent and densities below 5 ml/21 m³ were observed at most stations. Only within the tongue of cold water, far off the northeast coast, were the densities comparable to those observed prior to 1965. The distribution during 1972–1982 indicates that the densities were

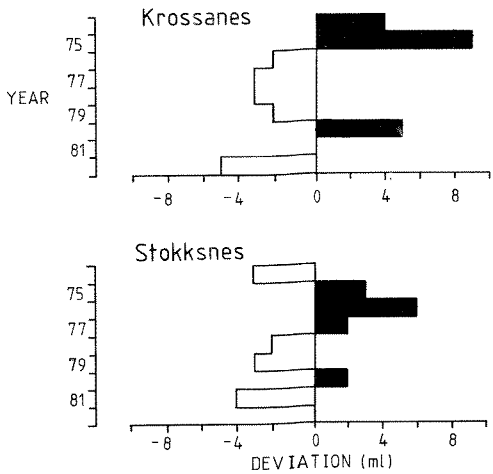

Fig. 27. Deviations of zooplankton volumes in May–June during 1976–1982 at Krossanes and Stokksnes sections east of Iceland.

somewhat greater than during 1965–1971 but still they were not comparable to those observed during the early sixties. It is, however, worth noting that at the stations farthest offshore the densities are almost the same throughout the 20 year period. At these stations arctic species usually make up a greater fraction of the samples than closer to land. The adverse hydrographic conditions seem to have had less effect on the arctic species than the more temperate ones, and thus their density is more consistent through the years (see also below).

The shortest time series included in Table 3 are for the Krossanes and Stokksnes sections, off the east and southeast coasts, respectively. On the Krossanes section the greatest density was observed during 1975 (16 ml/21 m^3) while the lowest density occurred in 1982 (2 ml/21 m^3). Since 1975 positive deviation has only occurred once (1980) on the Krossanes section (Fig. 27). On the Stokksnes section the highest volume was recorded during 1976 (12 ml/21 m^3) whereas the lowest density (2 ml/21 m^3) occurred during 1981 (Table 3, Fig. 27).

At the sections south and southwest of Iceland twelve years series (1971–1982) of data are available (Table 3). On the Selvogsbanki section the greatest densities were observed in 1973 and 1976, 18 and 23 ml/21 m^3 respectively. The lowest densities were, however, recorded in 1977 and 1978, 4 and 5 ml/21 m^3 respectively. The longest consecutive period of similar deviations on the Selvogsbanki transit are the four years of negative deviations between 1977 and 1980 (Fig. 28).

Maximum densities on the Reykjanes section were observed in 1975 (10 ml/21 m^3) and in 1981 (12 ml/21 m^3), while the lowest densities were recorded in 1980 and in 1982 (2 ml/21 m^3 in both years, Table 3). The changes in zooplankton densities on the Reykjanes section are less pronounced than those on the other sections southwest and west of Iceland and only in two years was the deviation greater than 4 ml (Fig. 28). The longest consecutive period with similar deviations are the three years 1978–1980 which all were found to be below the average.

On the Snæfellsnes section the zooplankton densities ranged from a minimum of 3 ml/21 m^3 in 1980 to a maximum of 22 ml/21 m^3 in 1973 (Table 3). Considerable changes were observed from year to year, but during the past three years densities have always been found to be below the average (Table 3, Fig. 28). A comparison of the three sections (south and southwest of Iceland) indicates that during only four years (1972, 1973, 1974 and 1980) out of the twelve for which data are available, similar deviations were observed. In two additional years (1976, 1977) similar deviations were observed on the Selvogsbanki and Snæfellsnes sections, while average densities were observed on the Reykjanes section. If, however, only two adjacent sections are considered, i. e. Selvogsbanki/Reykjanes and Reykjanes/Snæfellsnes, the deviations were, in both cases, similar in seven out of the twelve years (Fig. 28). Thus during some years, changes in the zooplankton are simi-

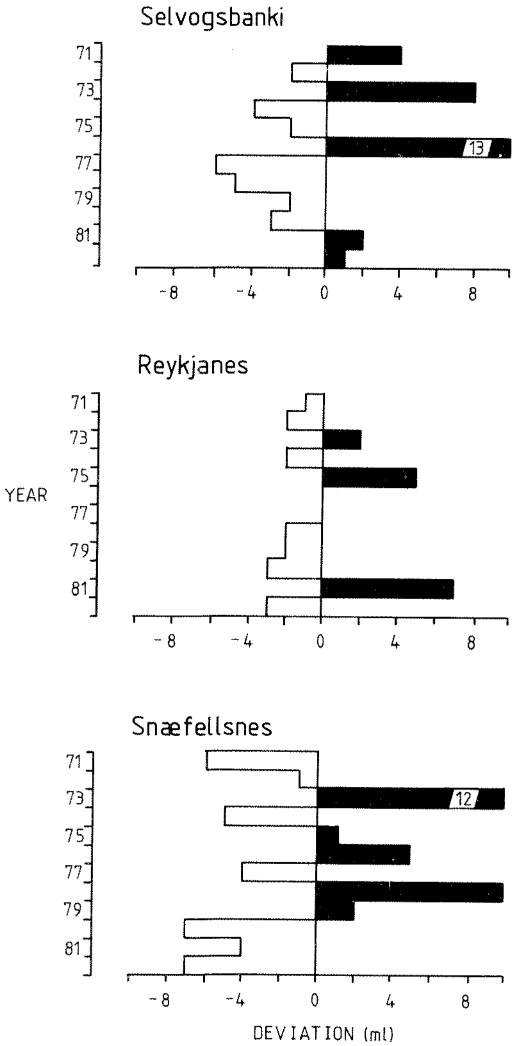

Fig. 28. Deviations of zooplankton volumes in May–June during 1971–1982 at Selvogsbanki, Reykjanes and Snæfellsnes sections southwest and west of Iceland.

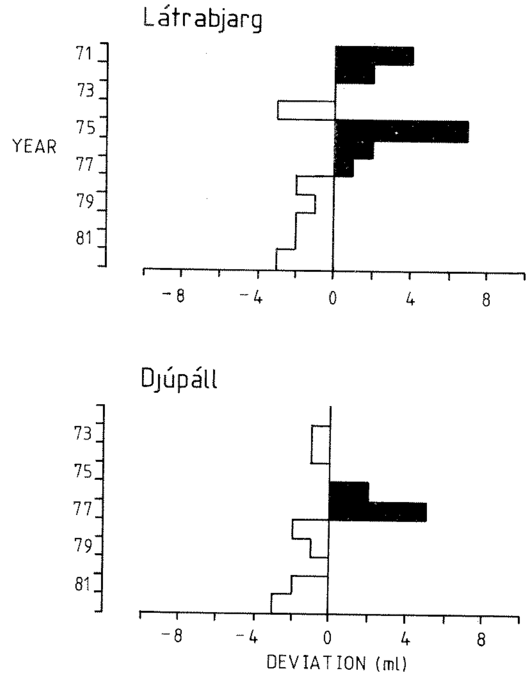

Fig. 29. Deviations of zooplankton volumes in May–June during 1971–1982 and 1972–1982 respectively at Látrabjarg and Djúpáll sections west of Iceland.

lar in the whole southwestern area, whereas in other years the zooplankton distribution is more patchy and different deviations observed in the different areas.

On the Látrabjarg and Djúpáll sections off the Vestfirðir peninsula the zooplankton densities are usually rather low (Table 3). On both sections the long term average is 4 ml/21 m^3 and deviations in different years are generally small (Fig. 29). Worth noting is the fact that on neither section have positive deviations been observed since 1977 (cf. Fig. 29).

Comparison of the long term average zooplankton densities observed at the different sections (Table 3) shows that the highest values have been observed on the Langanes–NA section (13 ml/21 m^3). At the Selvogsbanki and Snæfellsnes sections the long term densities are also rather high (10 ml/21 m^3). On the other hand the lowest densities (4 ml/21 m^3) occur on the three sections (Látrabjarg, Djúpáll, Kögur) off the west and northwest coasts.

3. Composition of the zooplankton

Analysis of the zooplankton composition has revealed that *Calanus finmarchicus* of different development stages usually dominated in the samples. Earlier plankton studies

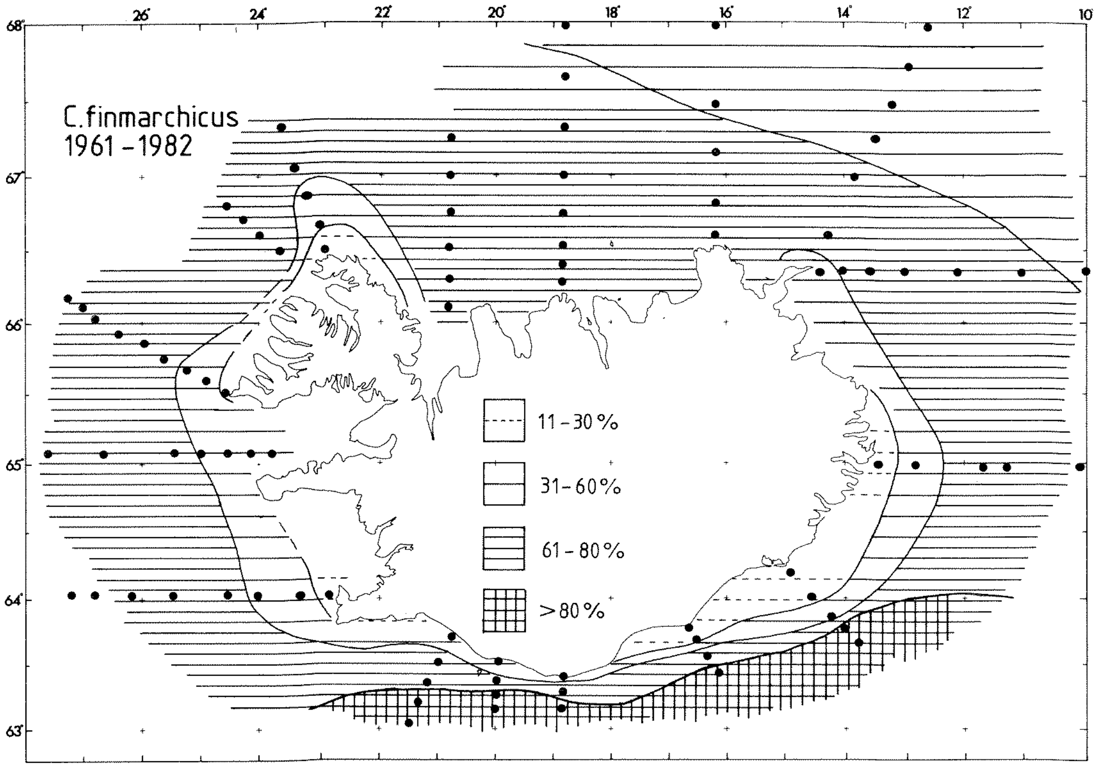

Fig. 30. Average percentage frequency of *Calanus finmarchicus* at stations around Iceland in May–June 1962–1982.

around Iceland (Paulsen 1906, 1909; Jespersen 1940a, b) have also demonstrated this and the same is true for extensive areas of the North Atlantic (Marshall and Orr 1952). To demonstrate this the average percentage frequency of *C. finmarchicus* at the different stations throughout the study period has been calculated (Fig. 30). The percentage frequency of *C. finmarchicus* is lowest (11–30%) at stations closest to land off the southeast and west coasts. Farther off the shore the percentage of *C. finmarchicus* in the samples increases and it becomes highest off the south coast where at some stations 80–90% of the animals are *C. finmarchicus*. In the cold Arctic or Polar water, far off the northeast coast, the dominance of *C. finmarchicus* decreases somewhat. On the average 31–60% of the animals in these waters are *C. finmarchicus*, compared to the 60–80% observed off most of the north coast. This decrease in the percentage frequency of *C. finmarchicus* is mainly due to the occurrence of *C. hyperboreus* and *Metridia longa* which are almost entirely confined to the cold water northeast of Iceland (Figs. 31 and 32).

The percentage frequency of Cirripedia larvae in the samples is shown in Figure 33. The Cirripedia larvae were most common in the shallow coastal waters off the southeast, west and northwest coasts (Fig. 33); at the offshore stations they were seldom observed. Comparison of the distribution of Cirripedia larvae to that of *Calanus finmarchicus* (Figs. 30 and 33) indicates that the increasing numbers of the Cirripedia larvae in the coastal waters is the main reason for the decreased relative importance of *C. finmarchicus* in these same waters.

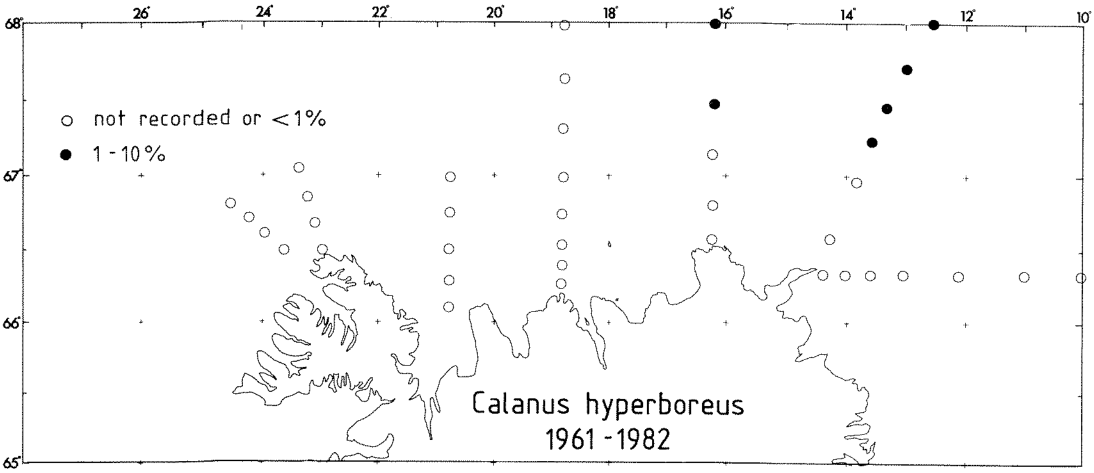

Fig. 31. Average percentage frequency of *Calanus hyperboreus* at stations north of Iceland in May–June 1961–1982.

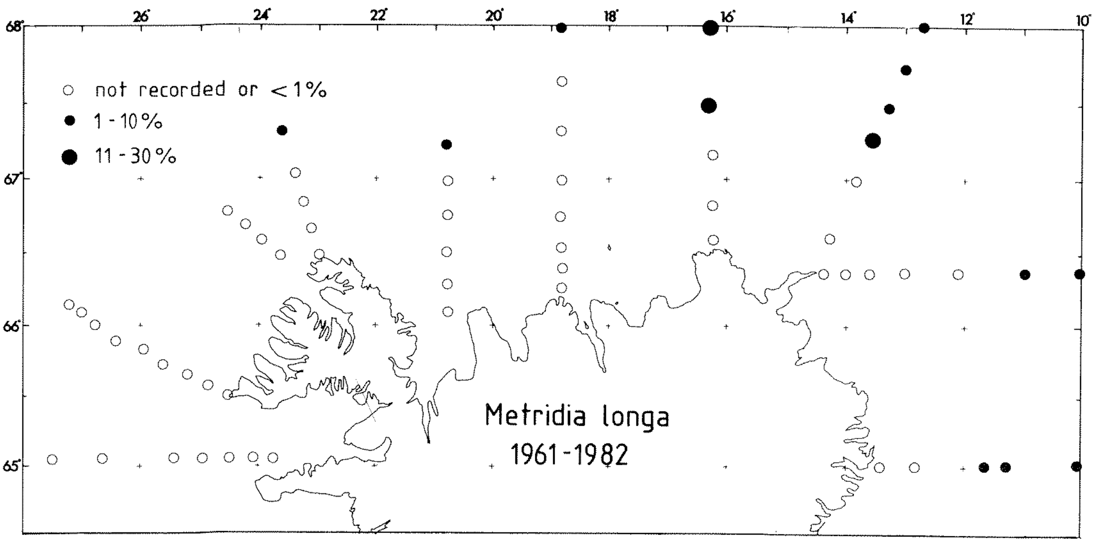

Fig. 32. Average percentage frequency of *Metridia longa* at stations north and east of Iceland in May–June 1961–1982.

At the time of sampling in May–June, the nauplii of Euphausiacea constituted a considerable percentage of the planktonic animals at most stations. Their percentage frequency was greatest, ranging from 11–30%, off the north and east coasts, whereas off the south and west coasts it was 1–10% (Fig. 34). The Euphausiacea nauplii were not identified to species. However, according to Einarsson (1945) the Euphausiacea nauplii observed north of Iceland in early June are almost exclusively due to the spawning of *Thysanoëssa inermis,* while off the south coast they are partly due to *T. inermis,* but mainly *Meganyctiphanes norvegica.*

At some stations off the south coast the Cladocera *Evadne nordmanni* was on the average up to 10% of the animals in the samples, whereas in other areas it has not

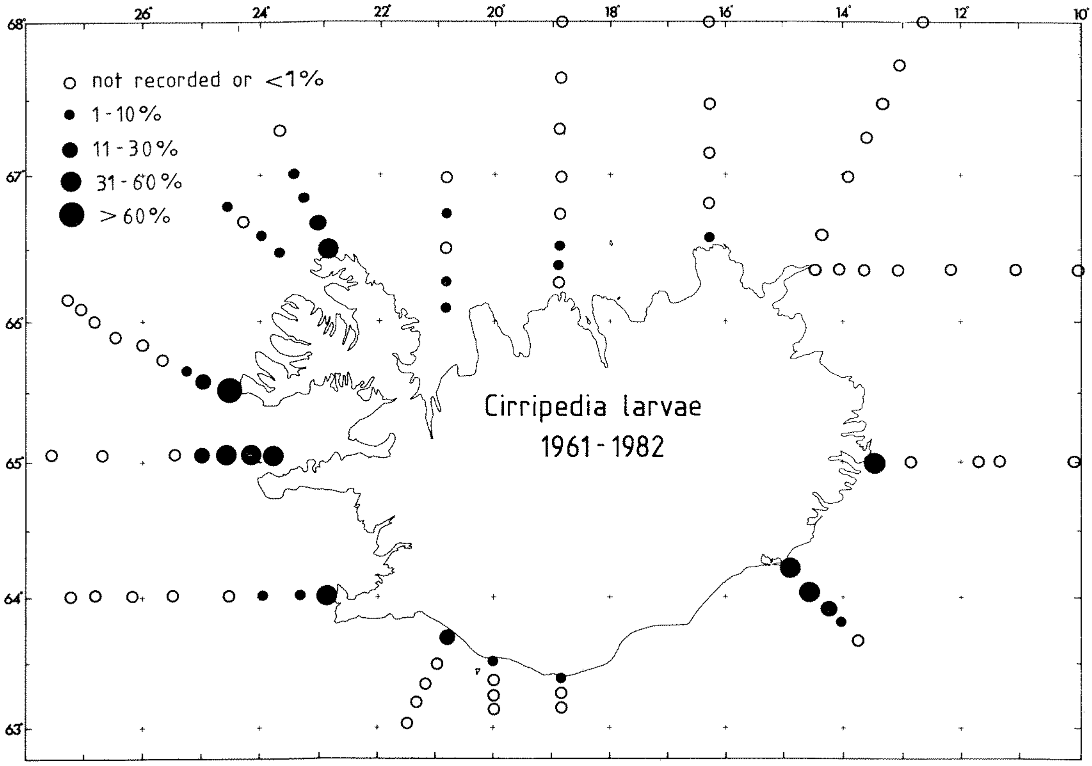

Fig. 33. Average percentage frequency of Ciripedia larvae at stations around Iceland in May–June 1961–1982.

been observed (Fig. 35). Similarly, *Podon leuckarti* has during spring only been recorded off the south coast. Jespersen's (1940b) observations on the distribution of *Evadne* and *Podon* around Iceland indicated that it varied throughout the summer. Agreeing with the present investigation they were during May–June confined to the south coast and the southern part of the west coast. In early July they were first observed off the north coast and during the latter part of July and August they were abundant all around Iceland. By September they had receded again with *Evadne* being confined to the south and west coasts, while *Podon* was only found off the west coast.

Species or taxonomic categories other than those mentioned above were of much less importance in the plankton samples. However, it should also be emphasized that the shortcut method, used in the analysis of the samples, only traces their main components, i. e. the most important species or groups. In his description of the shortcut method Hallgrímsson (1958) pointed out that due to the relatively few animals counted, the percentage of species which only occur in small numbers cannot be estimated with great accuracy. Nevertheless, the information presented in Figures 30–35 should illustrate the main features of the distribution during spring of the most common zooplanktonic animals around Iceland.

It was demonstrated above that during the study period marked changes have occurred in the zooplankton density north of Iceland. Significant decrease in the zooplankton was observed around 1965 and since then only limited recovery has taken place. It is of interest to investigate if in the

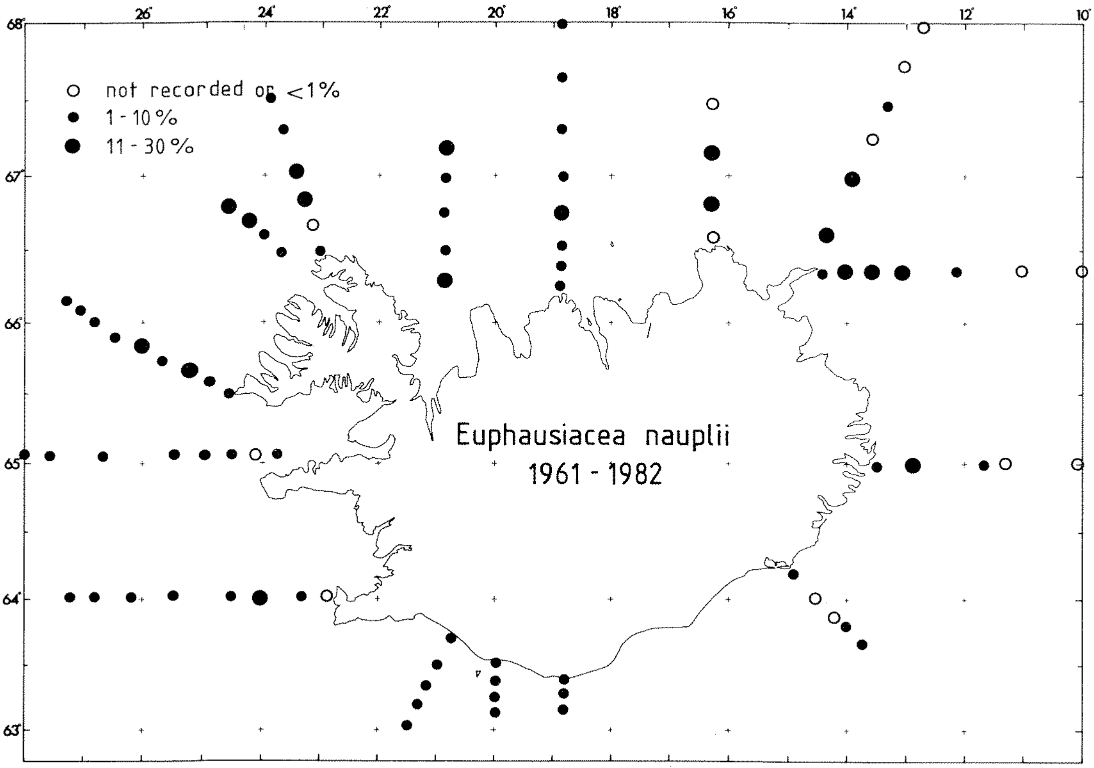

Fig. 34. Average percentage frequency of Euphausiacea nauplii at stations around Iceland in May–June 1961–1982.

same period, any apparent changes did occur in the zooplankton composition north of Iceland. For the different stations the percentage frequency of *Calanus finmarchicus, C. hyperboreus, Metridia longa* and Euphausiacea nauplii in the samples during the periods 1961–1964, 1965–1972 and 1972–1982 was calculated (Figs. 36–39). In most part of the area off the north coast *C. finmarchicus* usually accounts for about 60–70% of the animals in the samples (Fig. 36). However, during the first part of the investigation period (1961–1964) there were several stations off the northeast coast where *C. finmarchicus* exceeded 80% or even 90% of the animals in the samples. During the cold period 1965–1971 the dominance of *C. finmarchicus* at these stations appeared to be somewhat less and only at a single station did this species on the average account for more than 80% of the animals. Although there was a predominance of *C. finmarchicus* in the samples during the most recent period (1971–1982, Fig. 36) it was, however, never over 80% of the animals at any station. At the stations farthest offshore, off the northeast coast, there also appeared to be a decrease in the percentage frequency of *C. finmarchicus*. During 1961–1964 it was 60–80% of the animals at those stations, but during 1972–1982 in the range of 30–60% (Fig. 36).

Calculation of the percentage frequency of the different development stages of *Calanus finmarchicus* on the sections north of Iceland revealed that it was as a rule similar. The Siglunes section has been selected as an example and the results are presented in Figure 40. At the time of sampling in May–June copepodite stages II, III and IV consti-

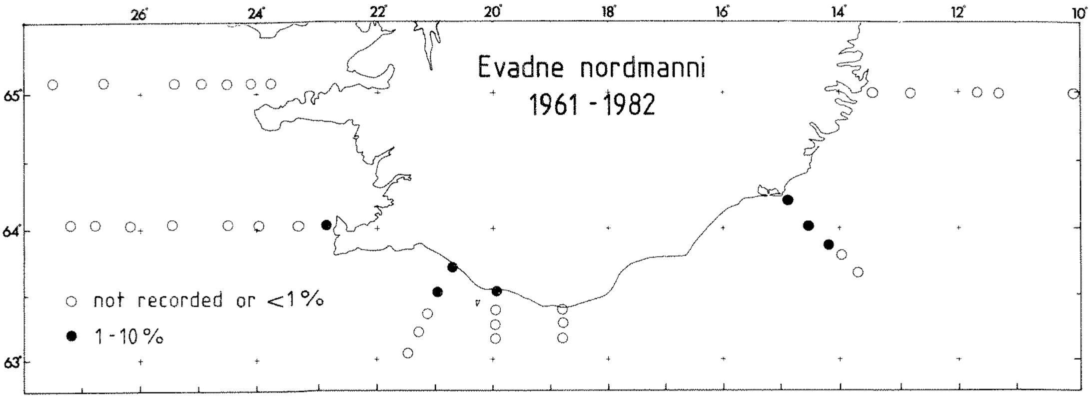

Fig. 35. Average percentage frequency of *Evadne nordmanni* at stations southwest, south and southeast of Iceland in May–June during 1961–1982.

tuted each usually about 15–20% of the animals in the samples. The low percentage frequency and considerable inter-annual variations of copepodite stage I are probably related to inefficient sampling of that stage by the 0.20 mm Hensen net (cf. Cushing and Tungate 1963; Matthews 1968). Each year mature females usually accounted for around 10% of the animals while mature males have only seldom been observed. Jespersen (1940a) believes that north of Iceland there is only one generation of *C. finmarchicus* each year, and that the copepodite stages observed in May–June are the descendants of the overwintering population which lived through the winter.

It is not possible to say whether a delay or retardation in the development of *Calanus finmarchicus* occurred north of Iceland during the adverse environmental conditions between 1965 and 1971. However, it is striking that during the spring of 1969 the percentage of females on the Siglunes section (Fig. 40) was far greater than in any other year. During 1969 the water temperatures north of Iceland were exceptionally low. No Atlantic water was observed on the Siglunes section and cold water reached closer to the shore than recorded at any time previously (Anon. 1970). Possibly the unusually high percentage frequency of females (Fig. 40) was related to a particularly late breeding during that year. Definite answers to questions such as these would, however, require more detailed seasonal study on the life cycle of *C. finmarchicus*, but unfortunately such a work has not yet been carried out in Icelandic waters.

The percentage frequency of *Calanus hyperboreus* at the different stations during the three periods is shown in Figure 37. During 1961–1964 *C. hyperboreus* was very seldom observed. Only at two stations, farthest offshore, on the Siglunes and Slétta sections it reached on the average 2% of the animals present. On the other hand, there appeared to be a marked increase in the frequency and an extension of the distribution area of *C. hyperboreus* during the cold period 1965–1971. At the station where *C. hyperboreus* was most frequently recorded it was between 20 and 30% of the animals in the samples. In recent years the distribution area of *C. hyperboreus* still is closer to the shore and it is more frequently found in the samples than prior to the cold period between 1965 and 1971. It is of interest to note that during some years *C. hyperboreus* was recorded at fjord stations much closer inshore than the ones shown in Figure 37. This was particularly noticeable in 1975 and in 1977 when it was even observed in the inner-

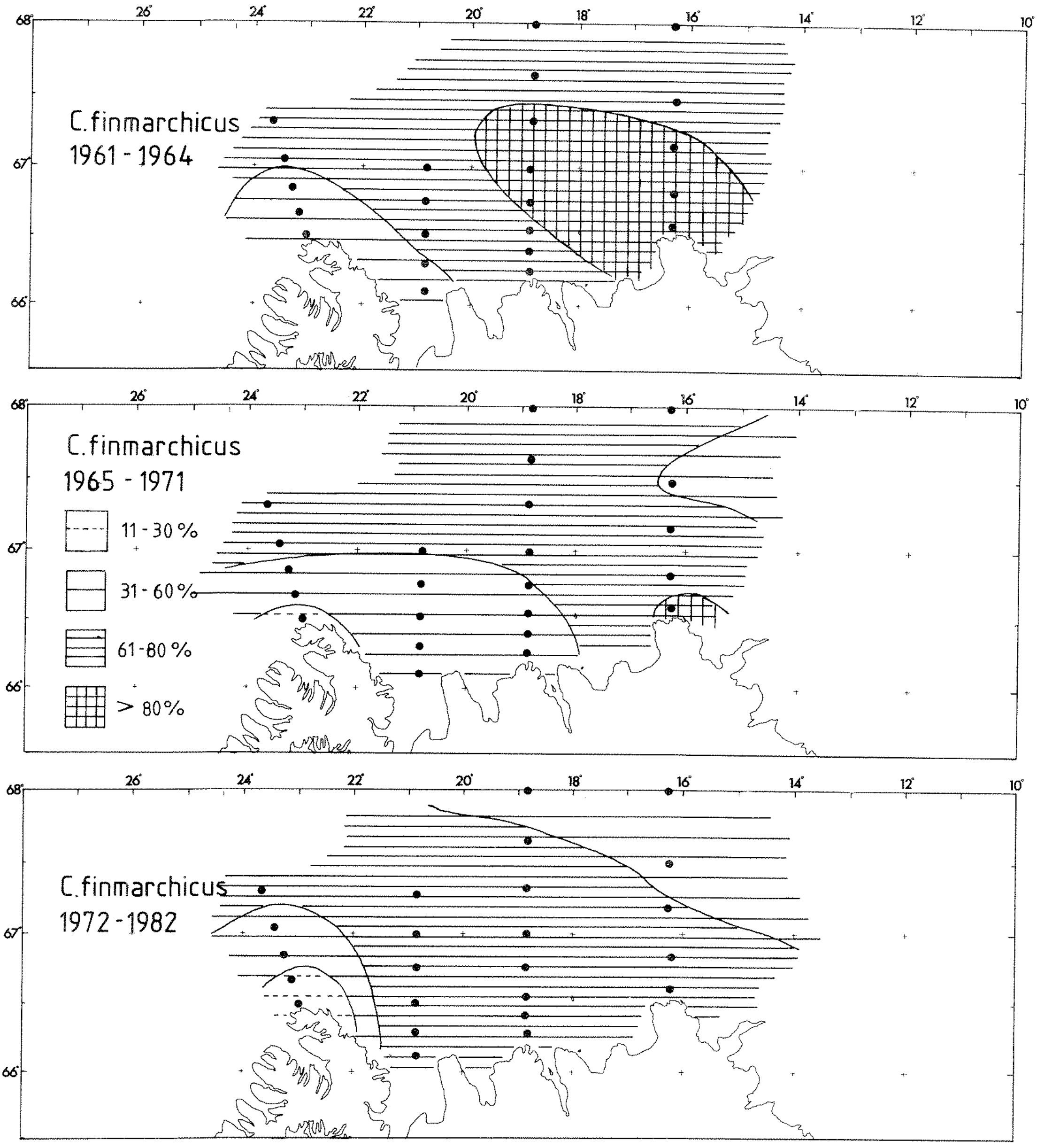

Fig. 36. Average percentage frequency of *Calanus finmarchicus* at stations north of Iceland in May–June during the periods 1961–1964, 1965–1971 and 1972–1982.

most reaches of Eyjafjörður (65°45′N, 18°10′W).

North of Iceland the distribution of *Metridia longa* has also shown changes similar to those observed for *Calanus hyperboreus* (Figs. 37, 38). Between 1961 and 1964 *M. longa* was only recorded at the two outermost stations on the Slétta section. During 1965–1971 the occurrence of *M. longa* north of Iceland was also sporadic, but it

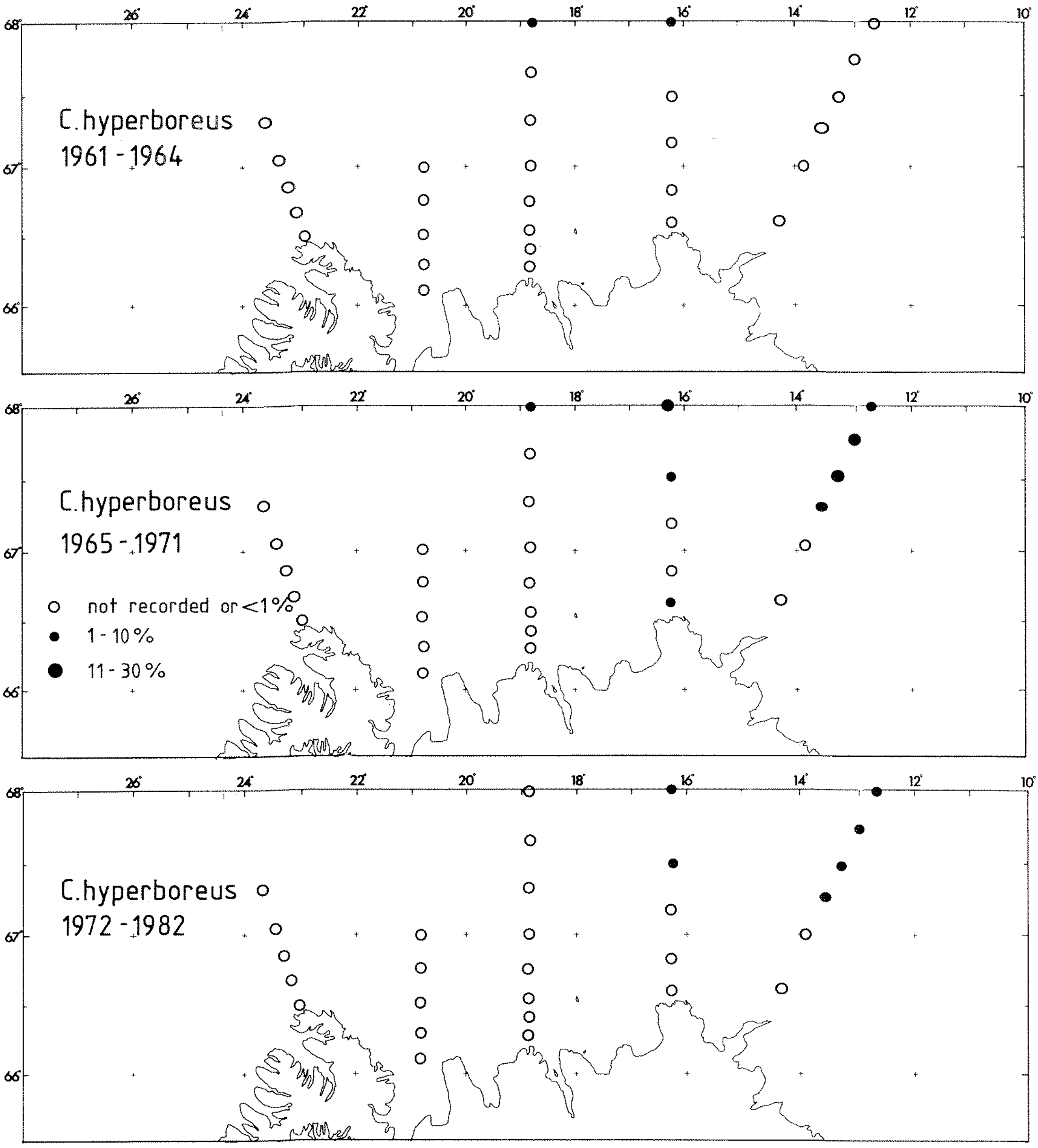

Fig. 37. Average percentage frequency of *Calanus hyperboreus* at stations north of Iceland in May–June during the periods 1961–1964, 1965–1971 and 1972–1982.

was recorded closer to the shore than in the earlier period. In the most recent period (1972–1982) *M. longa* has been observed at stations more to the west than previously and the distribution northeast of Iceland seemed more continuous than earlier. Both *C. hyperboreus* and *M. longa* are cold water species (Smidt 1979) and north of Iceland their distribution area appears to be mainly confined to the cold East Icelandic Current.

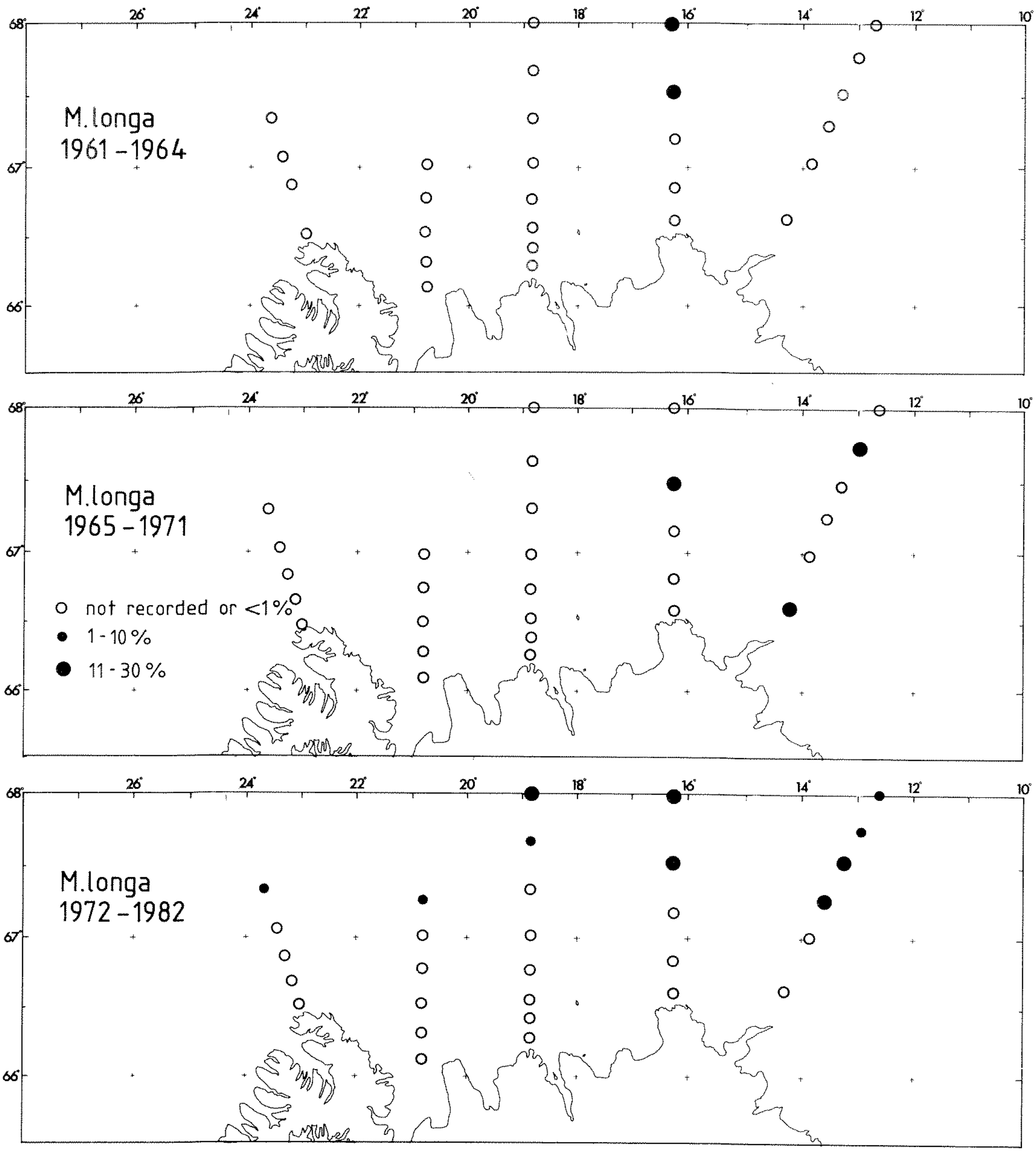

Fig. 38. Average percentage frequency of *Metridia longa* at stations north of Iceland in May–June during the periods 1961–1964, 1965–1971 and 1972–1982.

It has been demonstrated (Malmberg 1969, 1983; Malmberg and Stefánsson 1972) that since 1965 the tongue of cold water associated with the East Icelandic Current has during most years extended farther southwards than prior to 1965. Most likely this is also the reason why *C. hyperboreus* and *M. longa* were in recent years observed closer to the shore than before 1965. Around Iceland there are records of *C. hyperboreus*

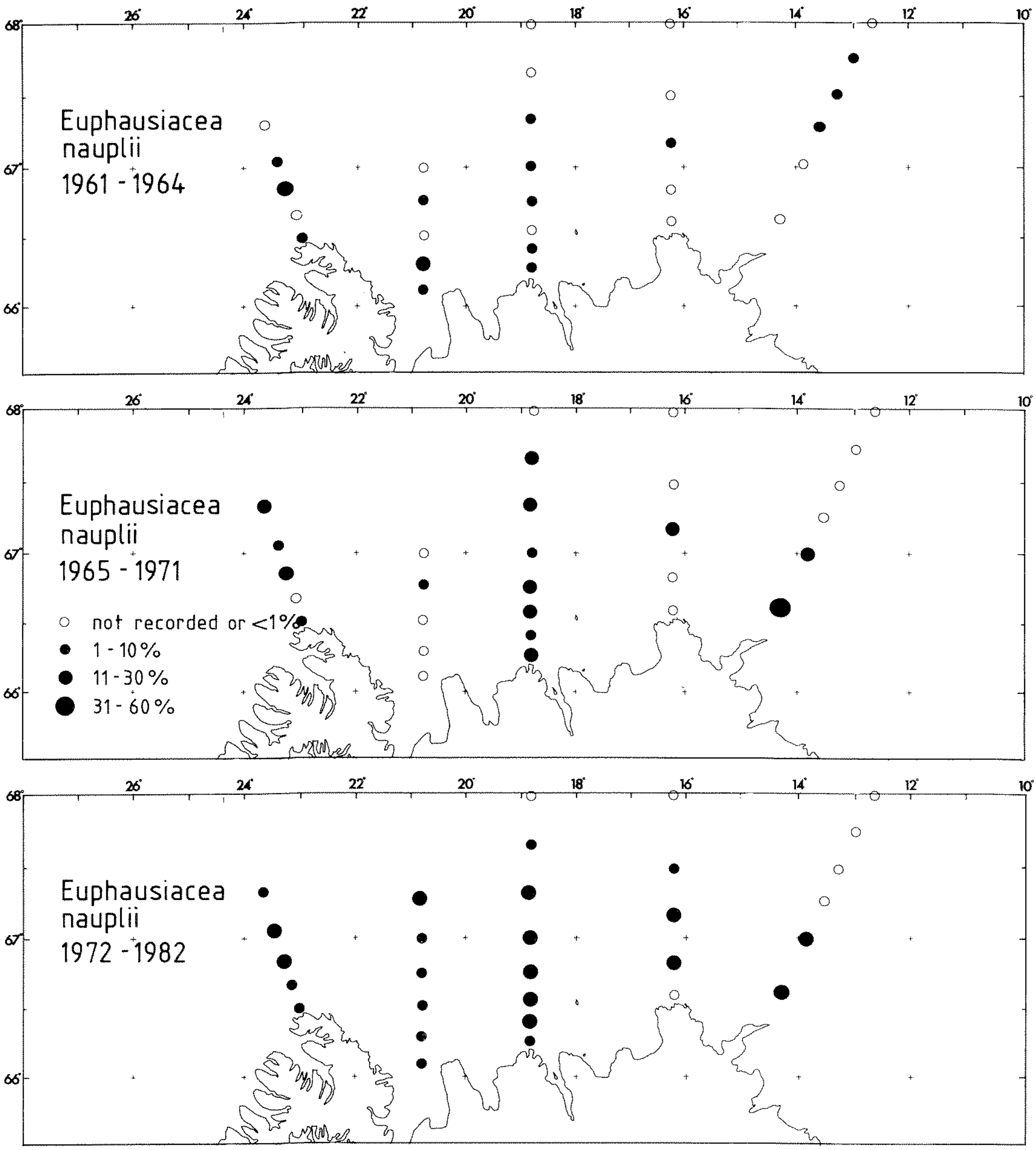

Fig. 39. Average percentage frequency of Euphausiacea nauplii at stations north of Iceland in May–June during the periods 1961–1964, 1965–1971 and 1972–1982.

and *M. longa* farther to the south than indicated in Figures 37 and 38, but these are usually confined to the waters below 50 m depth (Jespersen 1940a).

Some changes also seem to have occurred in the distribution and the percentage frequency of the Euphausiacea nauplii north of Iceland during the past twenty years (Fig. 39). At the time of sampling in May–June some nauplii are usually found at most sta-

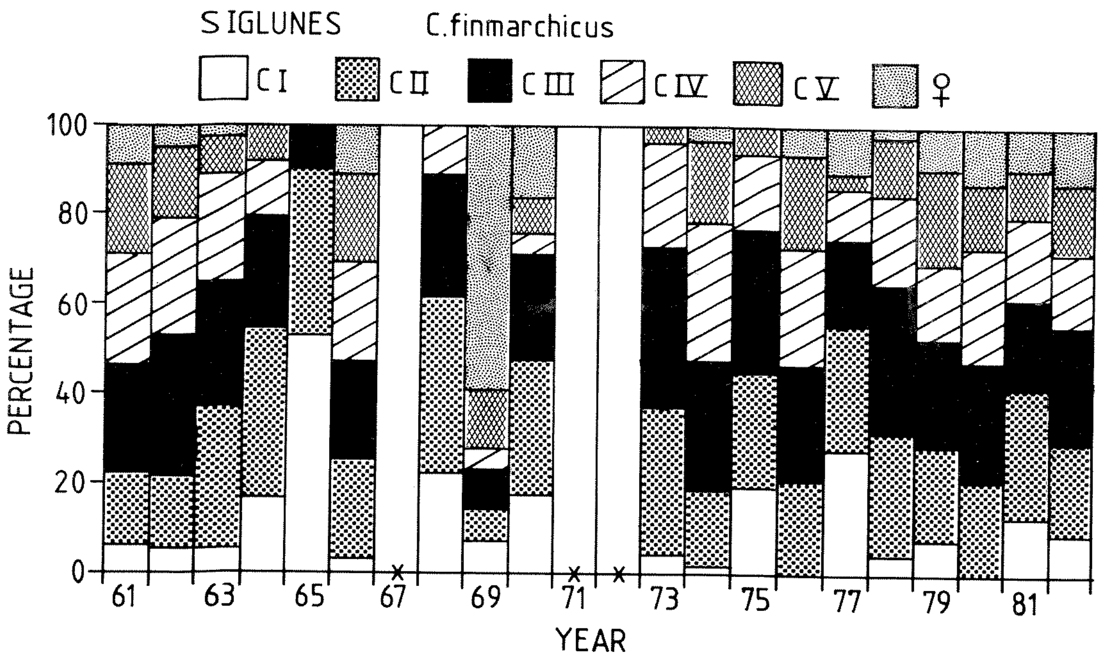

Fig. 40. Percentage composition of the different devolopmental stages of *Calanus finmarchicus* during May–June in samples from station Siglunes 3 north of Iceland.

tions off the north coast. However, during the most recent period (1972–1982) their percentage frequency was greater than during the earlier periods.

Comparison of the distribution and the percentage frequency of *Calanus finmarchicus* (Fig. 36), *C. hyperboreus* (Fig. 37), *Metridia longa* (Fig. 38) and the Euphausiacea nauplii (Fig. 39) demonstrates the relation between their percentage abundance at different stations. The decrease in the percentage frequency of *C. finmarchicus* at the offshore stations northeast of Iceland was mainly compensated for by the increase in *C. hyperboreus* and *M. longa*. Similarly, the decrease in the percentage frequency of *C. finmarchicus,* closer to the north coast, appears related to an increase in the percentage of the Euphausiacea nauplii. The above mentioned species and the nauplii of the order Euphausiacea were the most frequent animals in the samples. From the present investigation methods, however, it is impossible to evaluate, if any of the other less abundant species or groups have undergone marked changes in abundance or distribution.

The limitations of the shortcut method have been mentioned above. Similarly, the fact that the sampling is limited to 2–3 weeks during each year, makes it difficult to definitely evaluate observed changes in both the distribution and the percentage frequency of a particular zooplankton species. Furthermore, due to changes in water masses the distribution of individual species may vary both throughout the year and between years. Nevertheless, we feel that our observations allow us to conclude that, both with respect to zooplankton volume and to a lesser extent to the percentage frequency of the most common species (groups), marked changes have occurred north of Iceland during the past two decades.

DISCUSSION

The great seasonal changes which are known to occur in the abundance of zooplankton in temperate and arctic waters as well as the patchiness in its distribution (cf. Cushing 1975) may cause difficulties in the analysis and interpretation of data such as presented here. 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 (Table 3) one should get a measure of each year's conditions and the most marked changes taking place.

It has been pointed out (Thórdardóttir 1977, 1980) that the influx of Atlantic water to the areas north of Iceland is an important factor in maintaining mixing and renewal of nutrients in the surface layers and thus creating conditions for high and long lasting spring primary production in the western part of the area. In this way dense zooplankton stocks were supported (Hallgrímsson 1960) and they constituted an important source of food for migrating herring (Jakobsson 1978). During the mid sixties this pattern was, however, severly disrupted, and several authors (e. g. Stefánsson 1969; Dickson et al. 1975; Jakobsson 1978; Malmberg 1979; Malmberg and Svansson 1982) have discussed the marked changes which then occurred in the marine climate north of Iceland. Between 1965 and 1971 the influx of Atlantic water to the area north of Iceland decreased (Malmberg 1979, 1983) and the East Icelandic Current changed from an ice-free arctic current to a polar current (Malmberg 1969; Malmberg and Stefánsson 1972). The changes in the hydrographic conditions led to a strong stratification and prevented the renewal of nutrients in the surface layers, which in turn led to a greatly reduced primary production in the area north of Iceland (Thórdardóttir 1977). The primary production measurements which were carried out at the same stations and at the same time as the zooplankton investigations reported in the present study, indicate that on the Siglunes section at 10 m depth it was on the average 2.6 mg C/m^3/hr during 1958–1964, while during 1965–1971 it was 0.7 mg C/m^3/hr. On the other sections north of Iceland similar decrease has also been observed (Thórdardóttir 1977, 1980, and personal communication).

Due to the close relationship which usually exists between phyto- and zooplankton, it is not surprising that the adverse environmental conditions have also had a marked impact on the zooplankton biomass which decreased from an average level of 10–15 ml/21 m^3 in 1961–1964 to less than 5 ml/21 m^3 in 1965–1971 (cf. Table 3, Figs. 24 and 26). It is possible that, during the years of adverse hydrographic conditions, the onset of the spring primary production and thus also the increase in zooplankton may just have been delayed, rather than reduced when the whole summer growth period is considered. However, available data from the sections north of Iceland later in the year, both on the primary production (Thórdardóttir 1980) and on the zooplankton densities (Jakobsson 1978, 1980; Hallgrímsson unpublished data) suggest that in addition to a possible delay the observed spring decrease in zooplankton reflected an actual reduction in the zooplankton density of the area.

Since 1971 the influx of Atlantic water to the areas north of Iceland and the characteristics of the East Icelandic Current have in some years resembled the conditions prior to 1964, while in other years they have been more similar to what they were in the cold period 1964–1971 (Malmberg and Svansson 1982). These changing hydrographic conditions have again resulted in considerable year to year differences in the primary production north of Iceland. During 1972–1979 the primary production on fixed stations on the Siglunes section has alternated regularly between years of low (2–5 mg C/m^3/hr at 10 m depth in 1973, 1975, 1977, 1979) and high (6–10 mg C/m^3/hr at 10 m depth in 1972, 1974, 1976, 1978) primary production (Thórdardóttir 1980). The present data indicated that since the cold period 1965–1971 zooplankton densities north of Iceland have not regained their earlier high levels (Figs. 24, 26). It seems possible that the marked variability in the primary production may have led to a general reduction in the food available for the zooplankton and thus also in their standing stock. Possibly several consecutive years of high primary production are necessary for the zooplankton stocks to regain their former levels. A possible partial recovery of the zooplankton stocks, during a particular year with favourable conditions, may be prevented and the stock brought back to a former low level, if the subsequent year is of low primary production. Gudfinnsson (1977) reported an increase in the numbers of the algae *Phaeocystis pouchetii* north of Iceland during the period 1961–1974. Marshall and Orr (1952) quote Savage as observing that herring shoals may avoid rich concentration of *Phaeocystis,* while other reports suggest that it may be an important food source for both copepods (Weisse 1983) and fish larvae (Jones and Haq 1963; Wyatt 1976). Changes in the composition of the phytoplankton could possibly play a part in the low densities of zooplankton observed in recent years. This is, however, a mere speculation and much further work is necessary before one can fully explain why a recovery of the zooplankton stock has not taken place.

Glover et al. (1972) reported that around the British Isles the CPRS data demonstrated a decrease in the abundance of several species of zooplankton *(Calanus finmarchicus, Metridia lucens, Candacia armata, Centropages typicus, Spiratella retroversa, Pseudocalanus* and *Paracalanus).* Similarly they observed a decrease in the total abundance of copepods and the zooplankton biomass. Lindley (1979), also working on material from the CPRS, reported that in the eastern North Sea the abundance of euphausiids had increased during 1973–1977 compared to that observed between 1948 and 1971. Different sampling and analytical methods make it difficult to compare directly the results from the present Hensen samples to those from the CPRS. Nevertheless, it is interesting that to a certain extent similar changes have been observed both north of Iceland and in the Northeast Atlantic and the North Sea (Colebrook 1978a; Glover et al. 1972).

The calculation of the average zooplankton densities on the sections around Iceland (Table 3) indicated that at the time of observation in May–June the highest densities are on the Langanes–NA section (13 ml/21 m^3) off the northeast coast, the Selvogsbanki section (10 ml/21 m^3) off the south coast and the Snæfellsnes section (10 ml/21 m^3) off the west coast. However, the lowest densitites were recorded off the Vestfirðir peninsula on Látrabjarg, Djúpáll and Kögur sections (4 ml/21 m^3 on the average). Thus the values in Table 3 may give the impression that in general there are much greater densities of zooplankton off the northeast, south and west coasts than off the northwest, north and east coasts of Iceland. However, to a great extent this difference is likely to be related to differences in the production cycle of the zooplankton in the various areas around Iceland. In the Atlantic water off the south and west coasts the reproduction of *Calanus* begins in March (Paulsen 1906) and a spring increase in zooplankton is observed in April or before the middle of May (Jespersen 1940b). In the colder arctic or polar waters off the north and east coasts the planktonic fauna in May is, however, generally poorer and only a limited spring increase has occurred. Off the north coast the maximum densities are usually observed during the latter part of June or early July (Fridriksson 1944) while off the south and west coast they occur about a month earlier.

During the spring survey we are thus observing the plankton densities off the south and west coasts when they are close to their maximum, whereas in other areas a further increase is still to take place. However, the high zooplankton densities usually observed in the cold water off the northeast coast, even before marked spring increase has taken place, suggest high productivity in that area. The East Icelandic Current appears to bring with it arctic zooplankton to the waters over the edge of the northeastern shelf and also at times create physical conditions which can maintain those high densities.

The main spawning grounds of the fish stocks commercially exploited around Iceland are located off the southwest coast (Sæmundsson 1926). The spawning of most stocks takes place in March–April and after the hatching the larvae drift with the clockwise coastal current towards the main feeding grounds off the northwest, north and northeast coasts. Since 1970 the abundance and distribution of 0-group fish around Iceland has been estimated in August each year (Vilhjálmsson and Fridgeirsson 1976; Anon. 1979b, 1980b, 1983b; Vilhjálmsson and Magnússon 1981, 1982). Both larvae and the 0-group fish feed mainly on zooplankton (Bainbridge and McKay 1968; Pálsson 1974, 1980) and thus it is of interest to consider the observed changes in the zooplankton densities off the southwest coast of Iceland in relation to the results of the 0-group surveys.

Relative changes in the 0-group indices of cod, haddock and capelin (calculated from the 0-group survey references cited above) during 1972–1982 were compared (Fig. 41) to the relative changes in the zooplankton off southwest Iceland (Selvogsbanki, Reykjanes and Snæfellsnes sections). In general it is indicated that there has been a slight downward trend in the percentage index of zooplankton southwest of Iceland and since 1976 no prominent peak has been

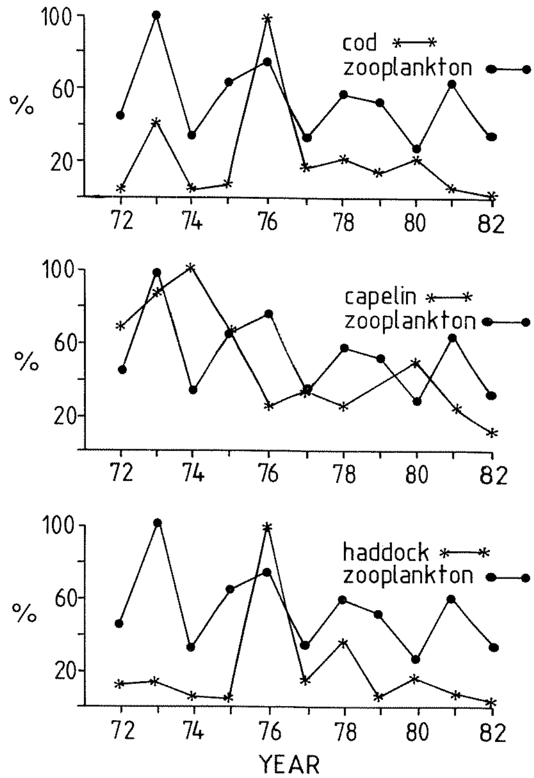

Fig. 41. Relative changes in the abundance of 0-group cod, capelin and haddock around Iceland along with relative changes in zooplankton density off the southwest and west coasts (Selvogsbanki, Reykjanes and Snæfellsnes sections).

observed. It is interesting to note that the 0-group indices have also shown a general downward trend since 1976. The relative changes in the abundance of 0-group cod have the closest similarity to that of the zooplankton. During 1973 and 1976 the greatest abundance of 0-group cod was observed, these years being the same as those during which the zooplankton densities off the southwest coast were greatest (Fig. 41). Haddock was also observed in greatest abundance during 1976, which corresponds to the high densities of zooplankton observed in that year. However, in 1973 when the greatest zooplankton densities were recorded, the abundance of 0-group haddock was relatively low. The second greatest abundance of capelin was observed during the year of the greatest zooplankton abundance (1973), while capelin was observed in greatest abundance during a year of relatively low zooplankton density (1974) when the cod and the haddock densities were also low.

We are aware that it is an over-simplication of the complex processes taking place in the sea to expect a direct relationship between the zooplankton densities and the 0-group fish species. Viborg (1978) considering the relation between zooplankton and cod larvae off the Norwegian coast pointed out that the quality of the zooplanktonic food and the size of the food was probably more important than its actual quantity. Furthermore, the 0-group fish considered above have been found to feed on almost the same prey *(Calanus finmarchicus,* other copepods and euphausiids being most important) and it has been suggested (Pálsson 1974, 1977) that 0-group capelin may not be able to compete for food with cod, haddock and redfish. The findings (Fig. 41) that 0-group capelin was observed in greatest abundance in 1974, a year when both cod and haddock were in low numbers, may lend some support to this. An additional support is provided by the results that during the years of the greatest zooplankton densities only two of the 0-group species (1973: cod, capelin; 1976: cod, haddock) were registered in great abundance.

More detailed studies and in limited areas around Iceland of all aspects of interactions between phyto- and zooplankton, larvae and 0-group fish are, however, necessary for further understanding of the processes determining the year class strength of the different fish stocks.

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