DET KGL. NORSKE VIDENSKABERS SELSKAB
MUSEET

MISCELLANEA

1

Tor Strømgren

ZOOPLANKTON INVESTIGATIONS IN SKJOMEN

Preliminary report, November 1969 - January 1971

TRONDHEIM 1971

TROMSØ MUSEUMS SKJOMENUNDERSØKELSER

MARINE UNDERSØKELSER

HEFTE XVIII

ZOOPLANKTON INVESTIGATIONS IN SKJOMEN

Preliminary report, November 1969 - January 1971

by

Tor Strømgren

University of Trondheim
Royal Norwegian Society of Sciences and Letters
The Museum
7000 TRONDHEIM

INTRODUCTION

Marine investigations in Skjomen were initiated by Tromsø Museum and started in November 1969. This report gives a preliminary survey of the zooplankton in Skjomen from November 1969 to January 1971.

No previous investigations on zooplankton are carried out in Skjomen, but in the area outside, in Ofotfjorden and in Vestfjorden, SØMME (1934) gave an account of the annual cycle of Calanus finmarchicus and Calanus hyperboreus. In Vestfjorden WIBORG (1954) investigated the zooplankton, especially the copepods, for a three year cycle.

MATERIAL AND METHODS

Zooplankton samples were taken at three stations; St. 01, depth 39 m, St. 04, depth 150 m, and St. 09, depth 300 m. The position of the sampling stations is indicated in the map, Fig. 1.

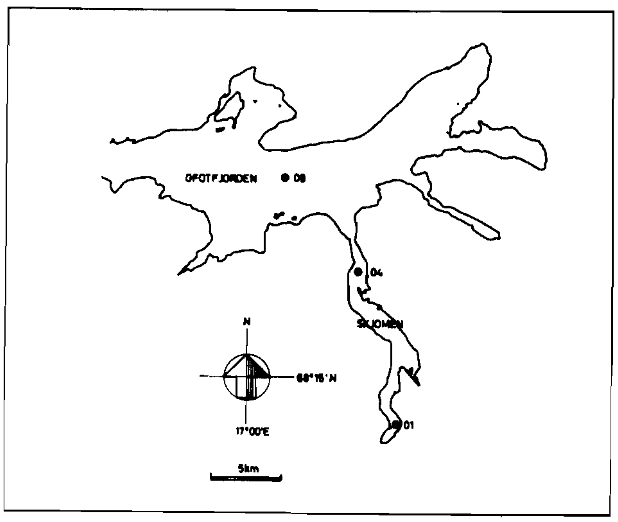

Fig. 1. Skjomen and the inner part of Ofotfjorden, sampling stations indicated.

All hauls were vertical with a large Juday-net, opening 0.4 m^2, equipped with a closing device. The net was closed at depths partly defined by hydrographic relations: bottom - 100 m, 100 m - thermocline, and thermocline - 0 m.

Samples were taken in November 1969, in January, March, April, May, June, July, September, and November 1970, and in January 1971. In November 1969 and in April 1970 the mesh size was 554μ. The rest of the sampling dates the mesh size varied from 195 to 182μ.

Sampling has alternated irregularly between day and night, and the same station has been visited at different parts of the day different dates. The vertical distribution at different stations and of different seasons are therefore not directly comparable, and the sampling of near bottom living species and stages is also affected.

The sampling conditions are summarized in Table 1.

Table 1. The zooplankton sampling. Occupation of stations, light conditions (○ day, ◑ twilight, ● night) and mesh size.

	1969 Nov.	1970 Jan.	March	April	May	June	July	Sept.	Nov.	1971 Jan.
St. 01	○	○	○	–	○	○	○	○	○	–
St. 04	◑	◑	○	◑	○	○	○	●	●	○
St. 09	●	●	●	●	○	○	○	●	○	○
Mesh size in μ	554	195	195	554	182	182	182	182	182	182

Hydrographic data; temperature, salinity, and oxygen, were collected simultaneously at standard depths. The hydrography of the area is surveyed by SKRESLET (1971).

The samples were preserved in formalin. Volume was determined by the displacement method (WIBORG 1954). Large samples were subsampled in a Wiborg-Lea plankton divider (WIBORG 1951).

The errors and problems concerning the methods used are discussed by STRØMGREN (1970).

TOPOGRAPHY

Skjomen is separated from Ofotfjorden by a threshold of approx. 60 m. St. 09 is situated outside this threshold, St. 04 and St. 01 inside. The maximal depth in Skjomen proper, 150 m, is found at St. 04. St. 01 lies in a branch of the fjord which forms a shallow shelf of approx. 40 m of depth.

Skjomen penetrates about 20 km inland from the threshold. Approx. 15 km from the threshold, the Skjoma river enters the fjord. Thus, St. 01 is not directly influenced by this large supply of fresh water. Smaller quantities of freshwater, however, are supplied locally.

HYDROGRAPHY

During winter and spring 1970 Skjomen proper was characterized by homogenous water masses. The salinity was fairly high, above 33 o/oo. In the turn of the months April-May a deep inflow took place into Skjomen (SKRESLET 1971). The vernal flood started in the end of May and reached high levels from June. Because the Skjoma river is fed by glaciers, the flow of water is high until autumn, and is reflected by low surface salinities. In the inner part salinities below 5 o/oo were recorded in June, while at the outer station 04 the minimum salinity was observed in July with nearly 12 o/oo. Generally, St. 04 showed higher surface salinities than St. 01. At St. 09 salinities below 21 o/oo were not recorded. The surface runoff must have generated a counter current below the discontinuity layer. The configuration of the bottom towards St. 01, however, may perhaps modify the course and the strength of subsurface influxes.

In June the summer heating of the water started. This situation with brackish surface layer and relatively high temperature persisted during summer and early autumn. St. 01 showed slightly higher temperatures than the other stations in September.

The transport of surface water in Skjomen is probably rather dependent on wind conditions.

Skjomen seems to be very exposed to tidal currents, and a rapid change of the water at St. 04 is recorded (WENDELBO pers. comm.).

COMPOSITION OF THE ZOOPLANKTON

The organisms recorded are listed in Tables 2 - 4 and show total number of organisms from bottom to surface. The numbers in paranthesis refer to mesh size 554μ.

Table 2. Zooplankton at st. 01. (Numbers in paranthesis see text)

Species	1969 Nov.	1970 Jan.	March	April	May	June	July	Sept.	Nov.	1971 Jan.
Calanus finmarchicus	(2)	1	310	-	47400	27900	11800	1000	40	-
Pareuchaeta norvegica	(0)	0	10	-	0	0	0	0	0	-
Pseudocalanus elongatus	(1)	356	230	-	1200	6700	4900	18600	16140	-
Microcalanus pusillus	(0)	52	380	-	0	0	0	100	40	-
Temora longicornis	(0)	0	0	-	1200	5200	1300	1500	0	-
Acartia longiremis	(2)	10	10	-	600	0	0	0	40	-
Acartia clausi	(4)	0	0	-	0	0	0	0	0	-
Acartia spp.	(0)	0	0	-	0	200	0	0	0	-
Centropages hamatus	(1)	0	0	-	0	100	0	0	0	-
Oithona similis	(0)	295	920	-	2700	3800	500	24700	1040	-
Oithona spinirostris	(2)	0	10	-	0	0	100	0	0	-
Harpacticoida	(0)	0	10	-	0	0	0	100	0	-
Copepoda indet	(0)	0	10	-	0	100	0	200	0	-
Podon polyphemoides	(0)	0	10	-	300	100	0	100	0	-
Evadne nordmanni	(0)	0	0	-	0	100	0	0	0	-
Ostracoda	(0)	0	20	-	0	0	0	0	0	-
Eukronhia hamata	(1)	0	0	-	0	0	0	0	0	-
Limacina retroversa	(3)	30	110	-	0	700	1200	7200	200	-
Decapoda larvae	(0)	0	0	-	900	300	100	0	0	-
Fritillaria borealis	(0)	0	80	-	300	0	0	600	40	-
Oikopleura spp.	(0)	0	0	-	0	0	0	700	0	-
Cirriped larvae	(0)	0	2740	-	0	0	0	0	0	-
Polychaet larvae	(0)	0	120	-	600	0	0	0	0	-
Bivalvia larvae	(0)	0	0	-	0	8100	2300	0	0	-
Cyphonautes	(0)	0	0	-	0	0	500	300	0	-
Number of organisms	(16)	744	4970	-	55200	53300	22700	55100	17540	-
Number of species	(8)	6	15	-	9	12	9	12	7	-

Table 3. Zooplankton at st. 04. (Numbers in paranthesis see text).

Species	1969 Nov.	1970 Jan.	March	April	May	June	July	Sept.	Nov.	1971 Jan.
Calanus finmarchicus	(266)	68	385	(324)	45100	53200	13900	338	67	107
Calanus hyperboreus	(0)	0	0	(39)	150	250	50	0	0	0
Pareuchaeta norvegica	(7)	0	5	(9)	80	0	0	0	10	6
Metridia longa	(0)	0	0	(1)	0	0	0	0	0	2
Pseudocalanus elongatus	(2)	7	55	(0)	20	200	1110	180	35	0
Microcalanus pusillus	(0)	238	280	(0)	340	1250	500	345	475	447
Scolecithricella minor	(3)	3	0	(0)	0	0	0	0	0	0
Temora longicornis	(0)	0	0	(0)	110	200	100	10	0	0
Acartia longiremis	(1)	0	20	(0)	0	0	0	0	0	0
Acartia clausi	(1)	0	0	(0)	0	0	0	0	0	0
Paracalanus parvus	(0)	0	0	(0)	0	0	0	20	0	0
Centropages sp.	(0)	0	0	(0)	0	200	0	10	0	0
Oithona similis	(1)	497	370	(5)	2620	1000	9400	4195	1015	601
Oithona spinirostris	(3)	14	5	(0)	100	0	0	10	20	11
Harpacticoida	(0)	7	10	(0)	0	0	0	10	0	0
Copepoda indet	(0)	0	10	(0)	0	0	0	65	0	0
Podon polyphemoides	(0)	0	0	(0)	0	0	0	25	0	0
Evadne nordmanni	(0)	0	5	(0)	0	0	0	0	0	0
Euphauciaceae	(2)	0	0	(1)	100	0	0	5	14	0
Temisto abyssorum	(1)	0	0	(0)	0	0	0	0	0	2
Conchoecia spp.	(0)	0	0	(0)	0	0	0	0	10	0
Sagitta elegans	(9)	1	0	(0)	0	0	0	20	5	1
Eukrohnia hamata	(21)	18	4	(9)	0	30	0	0	10	3
Limacina retroversa	(0)	1	5	(0)	0	200	1900	195	20	1
Decapoda larvae	(0)	0	0	(0)	30	0	0	0	0	0
Fritillaria borealis	(0)	1	0	(0)	0	0	0	145	0	0
Oikopleura spp.	(0)	0	0	(0)	0	0	0	5	0	0
Cirriped larvae	(0)	0	250	(0)	0	200	0	0	0	0
Polychaet larvae	(0)	6	10	(0)	0	0	0	0	0	0
Bivalvia larvae	(0)	0	50	(0)	0	1000	2500	0	0	0
Echinoderm larvae	(0)	0	10	(0)	900	0	0	0	0	0
Cyphonautes	(0)	0	0	(0)	0	200	1300	75	0	0
Ascidia larvae	(0)	1	0	(0)	0	0	0	0	0	0
Number of organisms	(317)	862	1474	(388)	49550	57930	30760	5653	1681	1181
Numbere of species	(12)	13	16	(7)	11	12	9	17	11	10

Table 4. Zooplankton at st. 09. (Numbers in parantheais aee text).

Species	1969 Nov.	1970 Jan.	March	April	May	June	July	Sept.	Nov.	1971 Jan.
Calanus finmarchicus	(3013)	2073	1055	(718)	32210	26830	11150	5818	4336	2934
Calanus hyperboreus	(78)	456	253	(428)	290	700	500	950	330	373
Pareuchaeta norvegica	(79)	37	65	(55)	230	70	150	56	45	42
Metridia longa	(26)	10	5	(20)	60	50	0	13	0	0
Metridia lucens	(1)	0	0	(0)	0	0	0	0	0	0
Metridia spp.	(0)	20	0	(0)	10	60	0	0	0	0
Heterohabdus norvegicus	(0)	0	0	(3)	0	0	0	0	0	0
Pseudocalanus elongatus	(26)	15	11	(5)	550	830	200	76	20	21
Microcalanus pusillus	(0)	495	394	(0)	2100	1360	550	725	955	443
Scolecithricella minor	(3)	1	0	(0)	0	10	0	1	0	0
Temora longicornis	(0)	0	5	(0)	0	0	0	10	0	0
Acartia clausi	(1)	0	0	(0)	0	0	0	0	0	0
Acartia spp.	(0)	0	0	(0)	0	0	0	10	0	0
Paracalanus parvus	(0)	0	0	(0)	0	0	0	145	0	0
Centropages typicus	(0)	0	0	(0)	0	0	0	10	0	0
Aetideus armatus	(2)	0	0	(0)	10	0	0	0	10	0
Oithona similis	(1)	810	65	(0)	1670	910	850	4595	1660	583
Oithona spinirostris	(5)	65	6	(0)	0	20	50	110	45	26
Oncaea borealis	(0)	0	0	(0)	10	10	50	0	10	0
Harpacticoida	(0)	10	0	(0)	0	0	0	20	0	5
Copepoda indet	(0)	0	9	(0)	20	210	0	30	0	4
Podon polyphemoides	(0)	5	0	(0)	0	0	0	0	0	0
Evadne nordmanni	(0)	0	0	(0)	100	0	0	0	0	0
Eupheuciacea	(2)	0	1	(35)	0	0	0	0	0	0
Temisto abyssorum	(2)	1	0	(0)	0	0	10	15	1	2
Conchoecia spp.	(1)	121	69	(18)	150	80	150	160	310	206
Isopoda	(0)	0	0	(0)	0	0	0	1	0	0
Sagitta elegans	(21)	0	2	(1)	1	0	10	22	4	0
Eukrohnia hamata	(78)	74	65	(35)	92	80	90	56	32	25
Chaetognatha larvae	(0)	0	50	(0)	0	0	0	0	0	0
Limacina retroversa	(0)	5	0	(0)	50	0	350	150	5	1
Decapoda larvae	(0)	0	0	(0)	240	0	0	0	0	1
Fritillaria borealis	(0)	20	1	(0)	200	0	0	115	105	9
Oikopleura spp.	(0)	0	0	(0)	0	0	300	0	0	0
Cirriped larvae	(0)	10	33	(0)	0	0	200	0	0	0
Polychaet larvae	(0)	0	0	(0)	100	0	0	0	0	0
Bivalvia larvae	(0)	0	32	(0)	0	100	650	5	0	0
Echinoderm larvae	(0)	0	0	(0)	250	0	0	0	0	0
Cyphonautes	(0)	0	0	(0)	0	300	100	30	90	10
Ascidiae larvae	(0)	0	0	(0)	0	0	0	0	0	2
Number of organisms	3339	4228	2121	1318	38343	31620	15360	13123	7958	4687
Number of species	16	18	18	10	20	16	17	24	16	17

Both below and above 100 m the copepods dominated and constituted normally more than 90% of the stock calculated by number. Above 100 m the gastropod Limacina retroversa showed small percentages at all seasons. Larvae of bottom invertebrated were of greatest importance above 100 m, especially in March at St. 01. The same date bottom invertebrates also gave significant percentage below 100 m at St. 04. Below 100 m Ostracoda occurred regularly at St. 09. Also Chaetognatha was of some importance, mainly at St. 09. Other organisms were quite unimportant both above and below 100 m.

COMPOSITION OF THE COPEPODS

The composition of the copepods showed greater diversity, and the difference between the stations and the layers was significant.

Above 100 m

In January Oithona similis was of greatest importance at all three stations. At the inner station, however, Pseudocalanus elongatus in 1970 made 50% of the stock and in 1971 about 90% of the stock, while at the outer stations this species was rather unimportant. At the outer stations Microcalanus pusillus and Calanus spp. made a significant percentage.

In March C. finmarchicus became more important at all stations. M. pusillus showed unchanged importance, while O. similis showed a reduced percentage at the outer station 09.

In May, June and July C. finmarchicus dominated very much, especially at the outermost station 09, with more than 80% of the stock in average. At St. 04 O. similis was of some importance in July, while at St. 01 P. elongatus showed significant percentages both in June and July.

In September the importance of C. finmarchicus was reduced and was replaced by O. similis at the outer stations 09 and 04, by O. similis and P. elongatus at St. 01.

In November this situation persisted at the two outer stations, although the importance of M. pusillus increased. At the innermost St. 01, P. elongatus was responsible for nearly 95% of the stock in November.

Below 100 m

Below 100 m St. 04 and 09 showed a significant different composition of the copepods.

In January C. finmarchicus and C. hyperboreus together made more than 80% of the stock at St. 09, while at St. 04 these species were responsible for less than 20% of the stock, with O. similis and M. pusillus as the most important species.

In March the percentage of Calanus spp. increased at St. 04 and reached maximum in May, June and July. At St. 09 maximal percentages of Calanus spp. did not occur until July, and in May and June M. pusillus and Pareuchaeta norvegica were of relatively greater importance.

In September and November C. finmarchicus dominated at St. 09, and O. similis at St. 04. C. hyperboreus was generally of much greater importance at the deepest station 09.

INDEX OF COPEPOD DIVERSITY

The copepod diversity is calculated by the index $d = (S - 1 / \ln N)$, given by MARGALEF (1958), where S is the number of species and N is the number of specimens.

The index is calculated for St. 01, 04 and 09 in Skjomen for January, March, May, June, July, September and November 1970 and January 1971 (Table 5).

Table 5. Index of copepod diversity.

Station	1970 Jan.	March	May	June	July	Sept.	Nov.	1971 Jan.
01	0.61	0.93	0.37	0.47	0.41	0.47	0.41	-
04	0.89	1.00	0.65	0.55	0.49	0.94	0.68	0.71
09	1.21	1.06	0.86	0.97	0.74	1.38	0.90	0.83

A general feature is increasing index values from St. 01 outwards to St. 09, reflecting a greater diversity at the deepest stations. The lowest indexes are recorded in May, June and July.

Compared to Trondheimsfjorden the index of copepod diversity in Skjomen is quite small and describes a community with few, but numerous species.

VOLUME VARIATIONS

The variation of zooplankton volume from November 1969 to January 1971 is shown in Fig. 2. The numbers are given in volume below 1 m^2 of the surface. The volumes above and below 100 m are separated. Above 100 m the volume maximum was recorded in the

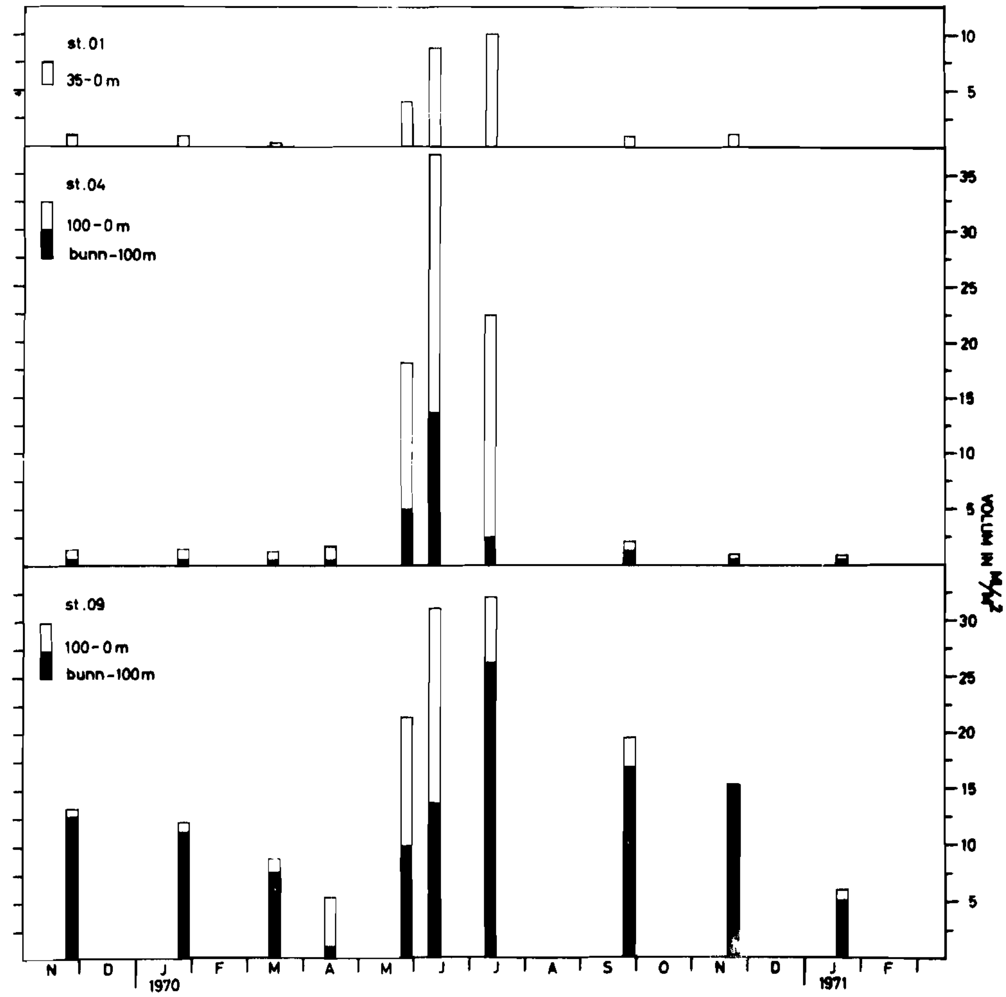

Fig. 2. Variation in displacement volumes. (Variation in mesh size see Table 1)

period May-July at all stations. Below 100 m the maximum at St. 04 occurred in May-June, at St. 09 in July. At St. 09 significant volumes were found at all seasons.

The volume maxima coincided with maximal numbers of Calanus finmarchicus and C. hyperboreus.

Zooplankton volumes in ml/m^2 from different Norwegian fjords are compared in STRØMGREN (1970). The volumes found in Skjomen are relatively small, of the same size as those found in Hardangerfjorden and in Lusterfjorden in Sogn, and in the inner part of Trondheimsfjorden during poor years. The reservation, however, must be held that the results from Skjomen represent one year only, and as shown in STRØMGREN (1970), one year cycle observations in fjord localities must be interpretated with caution.

VARIATIONS IN NUMBERS

Maximum of number was found at all stations in May-June (Table 6). At St. 01 a secondary maximum occurred in September. At St. 04 few numbers were found throughout the autumn, while at St. 09, relatively high numbers seemed to persist.

Table 6. Total number of organisms.

Station	1969 Nov.	1970 Jan.	March	April	May	June	July	Sept.	Nov.	1971 Jan.
01	-	744	4970	-	55200	53300	22700	55100	17540	-
04	-	862	1474	-	49550	67930	30760	5653	1681	1181
09	-	4218	2170	-	38343	31620	15360	13123	7958	4687

In May-June maxima were mainly due to young stages of Calanus finmarchicus at all stations. The September maximum at St. 01 was made up by the copepods Oithona similis and Pseudocalanus elongatus, and the gastropod Limacina retroversa, while the relatively high numbers found at St. 09 in autumn were mainly due to old copepodite stages of C. finmarchicus below 100 m, and to O. similis.

CALANUS FINMARCHICUS (GUNN.)

C. finmarchicus is the dominating copepod. Maximum in number was found at all stations in May-June (Fig. 3). In July and August small numbers were also found at the same stations, while from September significant numbers occurred only at St. 09. The maximum in May-June was mainly due to small stages, and the largest numbers were found at St. 01 and 04 in Skjomen proper.

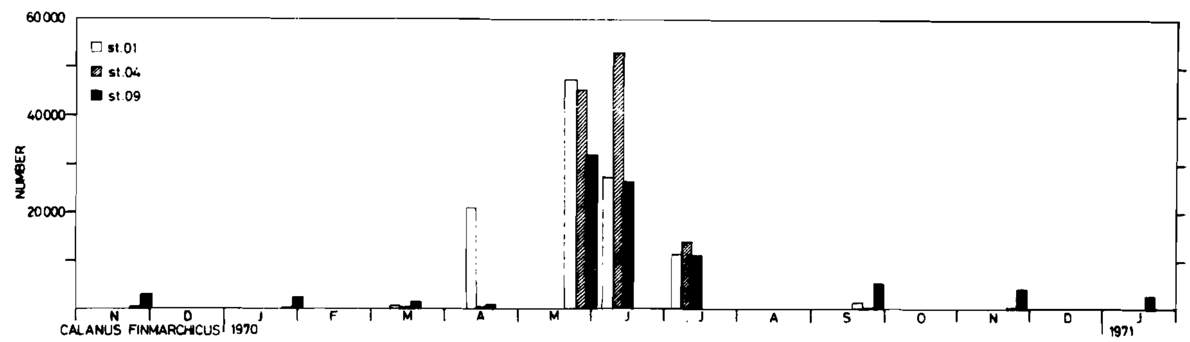

Fig. 3. Calanus finmarchicus, variation in numbers.
(Variation in mesh size see Table 1)

Stage distribution

The stage distribution of C. finmarchicus is shown in Fig. 4. The nauplii showed a prominent maximum at all stations in the end of

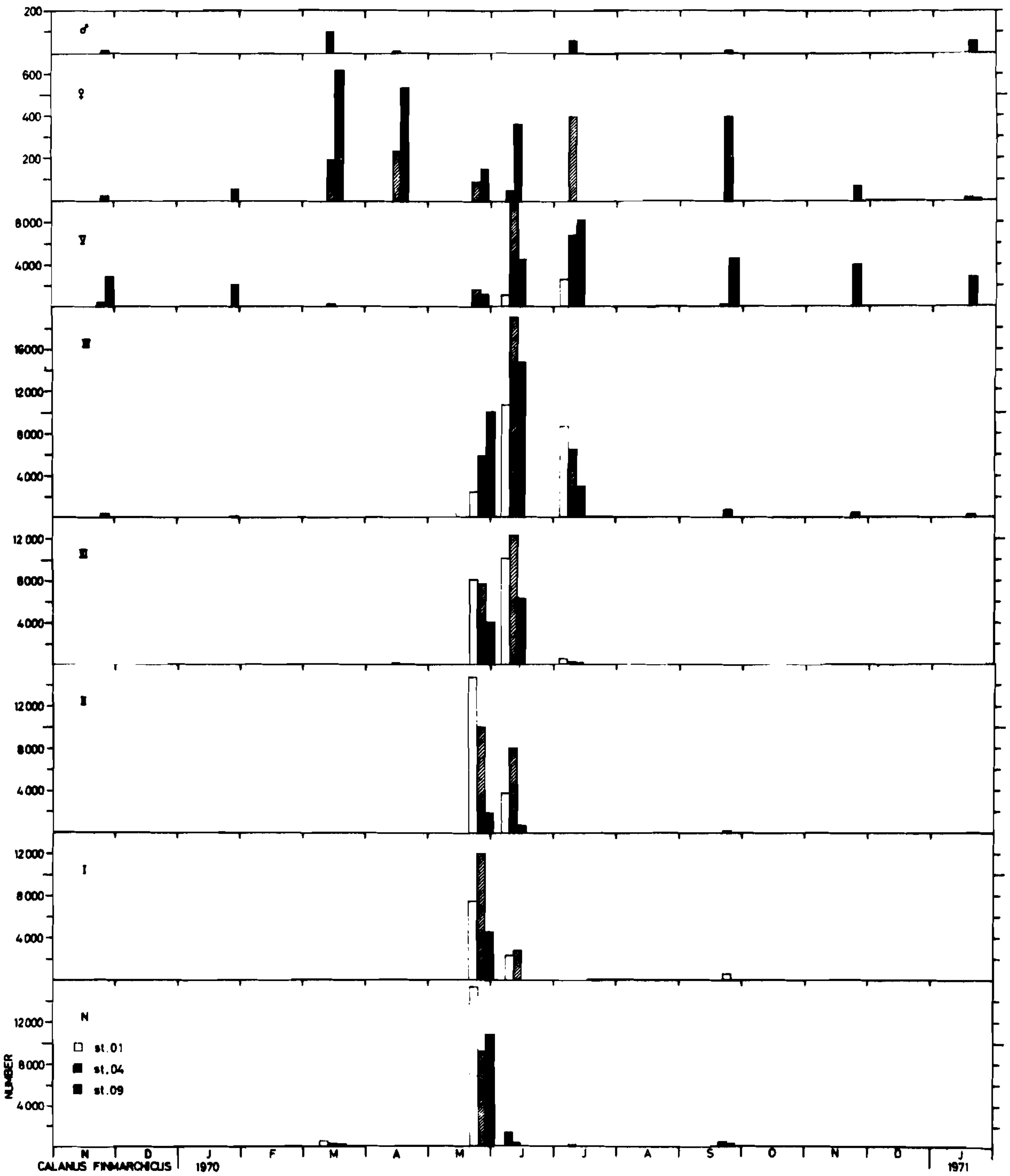

Fig. 4. Calanus finmarchicus, stage distribution. (Variation in mesh size see Table 1)

May, but the abundance of adults in March and April indicates that a rich spawning took place in the area also in April. For the copepodite stages, the maximum shifted from the end of May to June with increasing age. In July small numbers of copepodite stage III and significant numbers of copepodite stages V-IV and adults were observed. A few nauplii were observed in March, June and September. In September also a few numbers of copepodite stages I and II occurred. At St. 09 older stages were taken at all seasons, and males were found only at this station. Very few adults and copepodite stave V were observed at St. 01 and spawning is hardly of any importance at this station.

The stage distribution indicates that although reproduction may take place from March to September, the main spawning is concentrated to spring time. According to WIBORG (1954) the spawning of C. finmarchicus in the Vestfjord usually started about the 1st of April and lasted for 3-4 weeks, and in some years the spawning might be extended and last from about 20th of March to the beginning of May.

Vertical distribution

The younger stages showed a significant preference for the upper layers. In May the hauls were divided at 7 and 10 m of depth at St. 04 and 09 respectively. Unfortunately, the hauls in June were not divided between 100 m and the surface, and the detailed distribution this month is lost.

The vertical distribution of nauplii and copepodite stages IV-I in May is shown in Table 7. At St. 04 nearly 50% of the stock was found in the upper 7 m. At St. 09 in average 90% of these younger stages occupied the upper 10 m. If volume of water filtered is considered, the concentration in the uppermost layers is significantly larger than in the

Table 7. Calanus finmarchicus, percentage vertical distribution of copepodite stages IV-I and nauplii at St. 04 and 09 in May 1970.

Stage	St. 04. 0-7	Depth in m 7-100	100-bunn	St. 09. 0-10	Depth in m 10-100	100-bunn
IV	40	59	2	96	3	0
III	47	53	0	99	1	0
II	45	55	0	95	5	0
I	47	53	0	89	11	0
N	34	64	2	69	30	1

layers below at both stations. Below 100 m only a few specimens were encountered. The vertical distribution of the zooplankton seems to correspond to the salinity and temperature distribution (Fig. 5).

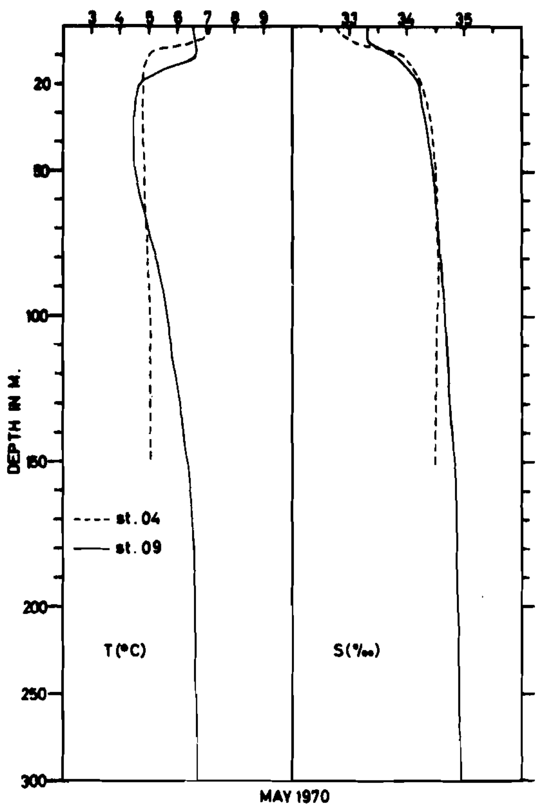

Fig. 5. Salinity and temperature distribution at St. 04 and 09 in May 1970.

The vertical distribution found in Skjomen corresponds to that found in Vestfjorden by SØMME (1934) and in Trondheimsfjorden and other Norwegian fjords, and indicates that the young stages of C. finmarchicus keep to the uppermost layers.

Length distribution

The carapace length of females and copepodite stage V is measured of, when possible, 50 specimens from each date and station.

The mean length of females (Table 8) shows uniform distribution (minimum 2.60 - maximum 2.93 mm). At Skrova WIBORG (1954) found a similar distribution.

Copepodite stage V shows a slightly larger variation (minimum 2.21 - maximum 2.88 mm). Although the differences are small, both females and copepodite stage V at St. 09 are generally larger than at St. 04. It is possible that larger specimens have the deepest distribution.

Table 8. Calanus finmarchicus, mean length of female and copepodite stage V.

	Station	1969 Nov.	1970 Jan.	March	April	May	June	July	Sept.	Nov.	1971 Jan.
♀	04	-	-	2.60	2.63	2.67	2.72	2.57	-	-	-
	09	2.76	2.79	2.67	2.74	2.93	2.89	-	2.82	2.64	2.86
V	01	-	-	-	-	-	2.40	2.34	-	-	-
	04	2.32	2.31	2.21	-	2.74	2.66	2.31	2.68	2.54	2.77
	09	2.60	2.63	2.43	-	2.88	2.84	2.72	2.65	2.60	2.60

The largest mean length occurred in May-June, while minimum was found in March. This trend shows a parallel to Skrova (WIBORG 1954). The decrease in mean length of copepodite stage V in March coincided with a rapid increase in number of females (Fig. 4), and may confirm WIBORG's assumption that a large sized fraction or generation of the copepodite stage V stock developed into females, while smaller individuals remained immature.

The length distribution of females (Fig. 6) showed bimodality at all seasons with range 2.1 mm - 3.1 mm, and no seasonal variation seemed to be significant.

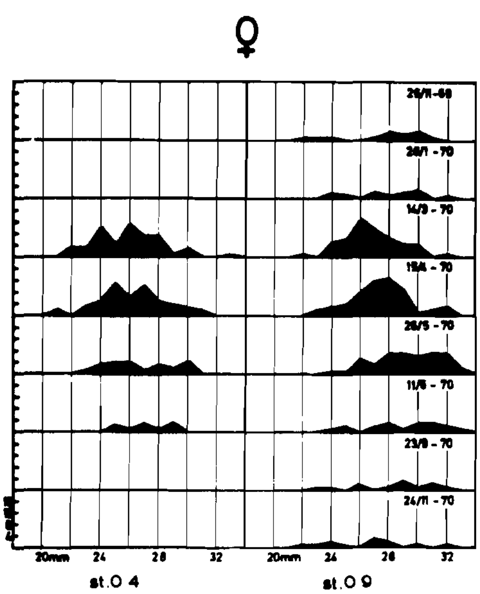

Fig. 6. Calanus finmai length distributioi. females.

Copepodite stage V (Fig. 7) also showed a bimodal distribution with little seasonal variation with total range 1.8 - 3.3 mm, but in May and June a fraction of relatively large specimens dominated. Also this

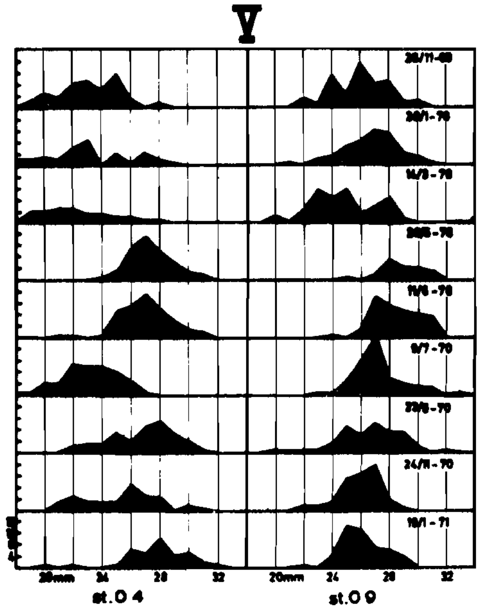

Fig. 7. Calanus finmarchicus, length distribution of copepodite stage V.

trend shows a parallel to Skrova (WIBORG 1954). The increase in length coincided with a sudden appearance of the copepodite stage V and may be related to the deep influx into Skjomen in April-May. The large specimens indicate a new stock brought up in colder water, perhaps an early spring generation. WIBORG (1954) traced a peak of copepodite stage V at Skrova in June back to a spawning in April-May.

CALANUS HYPERBOREUS KRØYER

C. hyperboreus was quite common at St. 09 outside Skjomen proper, while small numbers were recorded at St. 04 and no specimens were taken at the innermost St. 01 (Fig. 8). The numbers refer mainly to copepodites V-III and adults. At St. 09 the species was present at all seasons, and the largest numbers were found in September. At St. 04 a small peak occurred in May-June, and may be related to the simultaneous deep inflow into Skjomen.

Due to its great size, C. hyperboreus is of rather significant importance for the biomass at St. 09, especially in autumn. At Skrova WIBORG (1954) recorded maxima in February-March, mainly due to larval stages. SØMME (1934) reported this species to keep quite near

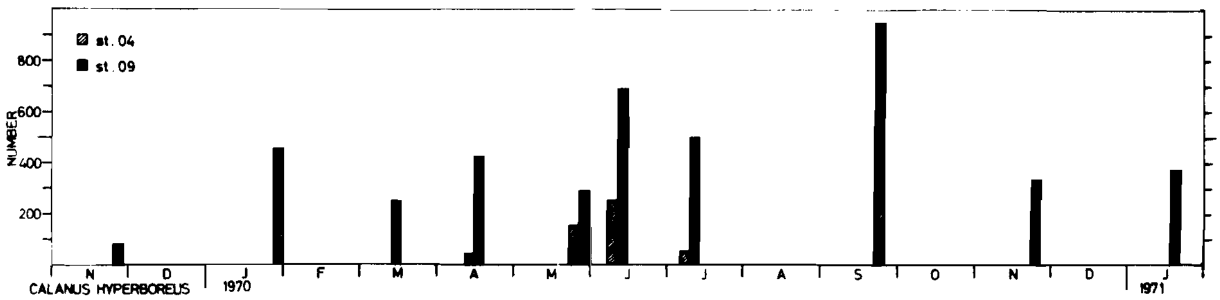

Fig. 8. Calanus hyperboreus, variation in numbers. (Variation in mesh size see Table 1).

the bottom, and it may thus excape the vertical hauls. The maximal record in September was taken in a night haul, and this may explain the large numbers.

Stage distribution

Significant numbers of young stages of C. hyperboreus were recorded in April 1970 at St. 09, and indicate spawning. SØMME (1934), however, stated that C. hyperboreus in Vestfjorden propagated only once a year, in February-March, but as shown by WIBORG (1954) significant numbers of nauplii were also found in April in Vestfjorden.

Vertical distribution

Nearly all specimens of C. hyperboreus were taken below 100 m, and this vertical distribution may explain its preference to St. 09.

MICROCALANUS PUSILLUS G. O. SARS

M. pusillus showed a maximum in number at St. 09 and 04 in May-June (Fig. 9), but significant numbers were also found at these stations during the rest of the year. At St. 01 M. pusillus seemed to be rather insignificant.

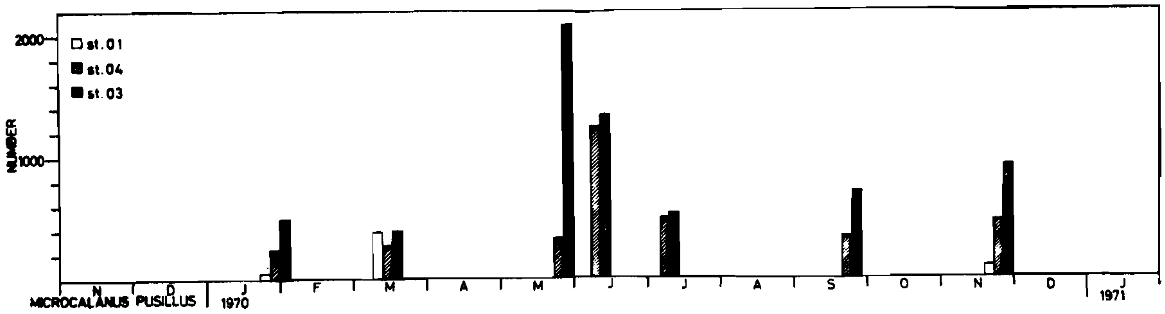

Fig. 9. Microcalanus pusillus, variation in numbers. (Variation in mesh size see Table 1).

Stage distribution

The stage distribution of M. pusillus is shown in Table 9.

Table 9. Microcalanus pusillus, stage distribution. (Number in paranthesis, mesh size 554).

Stage	Station	1969 Nov.	1970 Jan.	March	April	May	June	July	Sept.	Nov.	1971 Jan.
	01	(0)	12	10	-	0	0	0	100	0	-
♂	04	(0)	1	10	(0)	100	0	100	35	10	13
	09	(0)	5	6	(0)	70	100	100	60	35	10
	01	(0)	10	50	-	0	0	0	10	0	-
♀	04	(0)	111	40	(0)	110	250	200	95	235	110
	09	(0)	115	132	(0)	250	280	100	140	460	50
	01	(0)	30	320	-	0	0	0	0	40	-
V-IV	04	(0)	126	230	(0)	130	1000	200	215	230	324
	09	(0)	375	256	(0)	1780	980	350	525	460	383

Both males and females were found at all sampling dates at St. 04 and 09, and no distinct maximal periods were observed. The lowest values, however, occurred in winter. At St. 01 very few specimens were found during summer, although a small stock existed in winter. This distribution may be related to a deeper distribution of M. pusillus during summer.

PSEUDOCALANUS ELONGATUS BOECK

P. elongatus showed an irregular distribution, with very large numbers in September and November at St. 01, while at St. 04 and 09 very few specimens occurred. The winter stock was very small (Fig. 10).

The maximum in September was mainly due to stages III-I (Table 10), while copepodite stages V-IV were more significant in November.

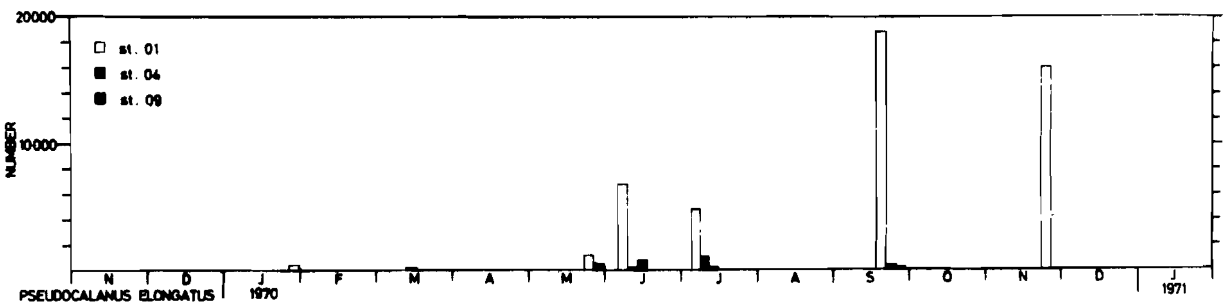

Fig. 10. Pseudocalanus elongatus, variation in numbers. (Variation in mesh size see Table 1).

Table 10. Pseudocalanus elongatus, stage distribution. (Numbers in paranthesis, mesh size 554).

Stage	Station	1969 Nov.	1970 Jan.	March	April	May	June	July	Sept.	Nov.	1971 Jan.
	01	(0)	1	60	-	300	700	0	100	0	-
♂	04	(0)	0	0	(0)	0	0	0	5	0	0
	09	(0)	0	0	(0)	0	200	0	10	0	0
	01	(1)	1	130	-	0	400	800	700	40	-
♀	04	(0)	0	30	(0)	10	200	200	25	0	0
	09	(1)	0	6	(0)	0	400	0	1	0	0
	01	(0)	242	40	-	600	2100	3000	3400	14360	-
V-IV	04	(2)	7	25	(0)	10	0	310	80	30	0
	09	(25)	10	5	(5)	550	130	150	35	20	21
	01	(0)	112	0	-	300	3500	1100	14400	1740	-
III-I	04	(0)	0	0	(0)	0	0	600	70	5	0
	09	(0)	5	0	(0)	0	100	50	30	0	0

Males showed maximum in June, the females in July. The stage distribution indicated that although spawning occurred both summer and autumn, the main propagation took place in September and coincided with maximum average temperature in the upper 40 m, above 11°C at St. 01.

TEMORA LONGICORNIS MULLER

T. longicornis also showed a preference to the inner St. 01 (Fig. 11) with maximum number in June. This maximum was constituted mainly by copepodite stages III-I. Peaks of abundance were found in May and indicated a local spawning. The maximum coincided with very low salinities in the surface, but immediately below rather high salinities were found.

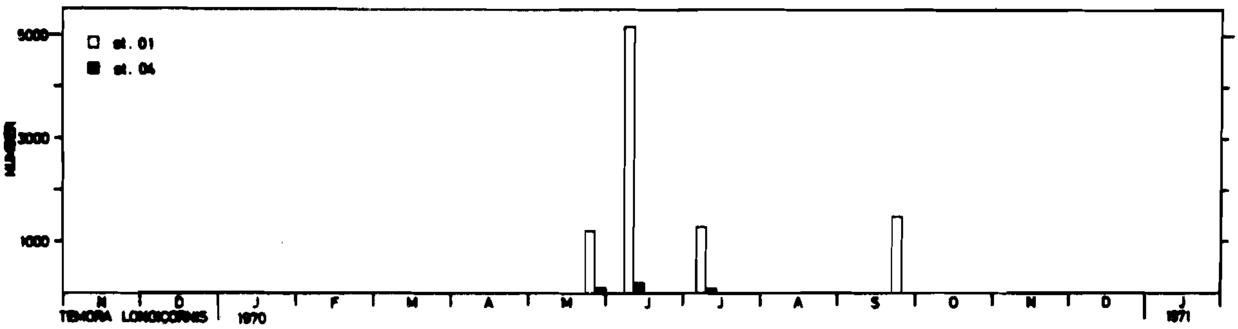

Fig. 11. Temora longicornis, variation in numbers. (Variation in mesh size see Table 1).

This preference of T. longicornis to the inner St. 01 shows a parallel to P. elongatus, but the time for the maximum differ.

T. longicornis seems to be of reduced importance in Skjomen compared to the fjords further south. The maximum in Skjomen in June is of the same size as the small spring maxima found in Trondheimsfjorden in April-May. At the latter locality, however, the large autumn maxima later in summer seemed to some extent to be dependent on supply from outside areas (STRØMGREN 1970). WIBORG (1954) stated that the high numbers found at Eggum and Skrova might be due to transport from southern areas, although a local stock might grow successfully.

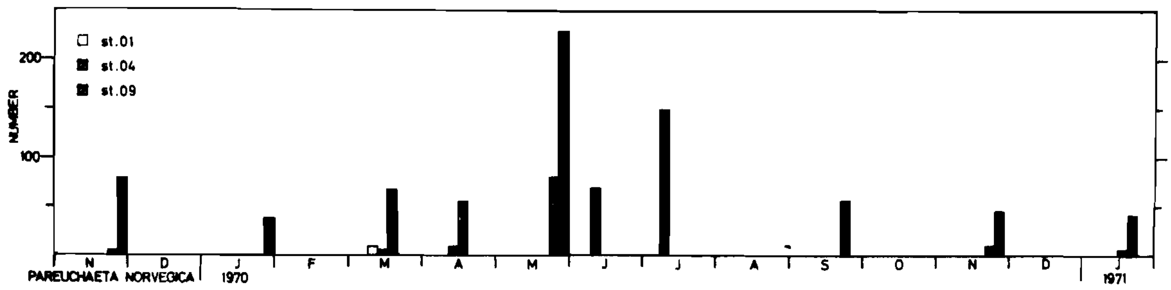

Fig. 12. Pareuchaeta norvegica, variation in numbers. (Variation in mesh size see Table 1).

water into Skjomen. At the inner station 01 only single specimens were encountered. The distribution observed is probably related to the preference to deep water.

OITHONA SIMILIS CLAUS

O. similis was found in greatest numbers at St. 01 with maximum in September (Fig. 13). At St. 04 a small peak was observed in July, while at St. 09 relatively small numbers occurred. During winter O. similis was insignificant at all stations.

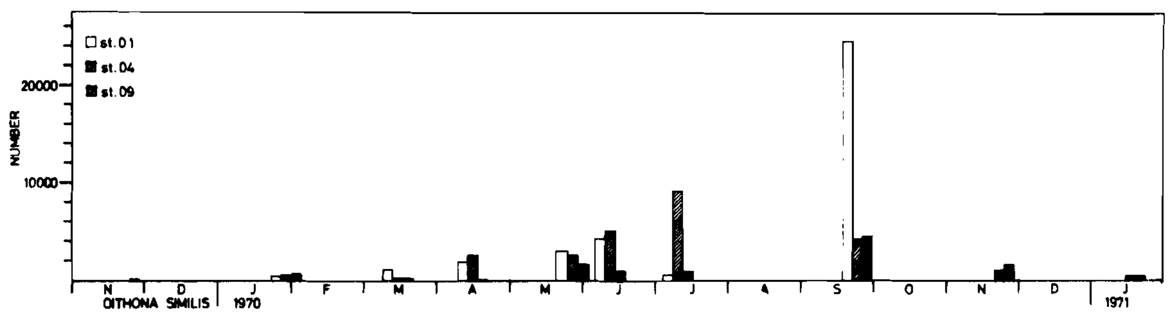

Fig. 13. Oithona similis, variation in numbers. (Variation in mesh size see Table 1).

It was mainly found in the upper layers, but significant numbers also occurred below 100 m at all seasons. The distribution of O. similis showed a close parallel to P. elongatus.

LIMACINA RETROVERSA (FLEMING)

L. retroversa showed a maximum at St. 01 in September and a small peak at St. 04 in July, while very few numbers occurred at the outer station 09 (Fig. 14). This species thus showed a distribution similar to O. similis and P. elongatus.

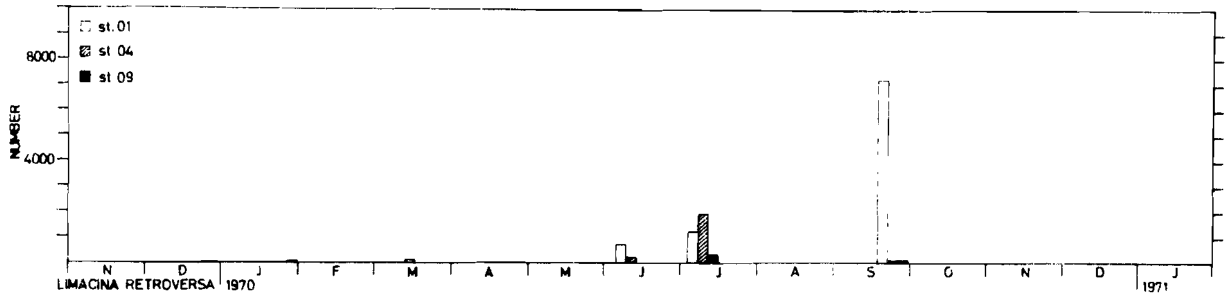

Fig. 14. Limacina retroversa, variation in numbers. (Variation in mesh size see Table 1).

OTHER ORGANISMS

The numerical variation of less important organisms appears from Tables 1-3.

Two probably allochthonous species, Paracalanus parvus and Centropages typicus occurred in September 1970, the former at St. 09 and 04, the latter at St. 09 only.

An indicator of Atlantic water, Metridia lucens, was found once in November 1969, and Acartia clausi, which is probably dependent on supply from southern coastal area, was found in the same month at all stations.

A number of neritic organisms, which in Trondheimsfjorden are abundant with main maximum in autumn, were found in very few numbers or were nearly absent. Centropages hamatus was recorded only twice, at St. 01 in November 1969 and in June 1970. Podon polyphemoides and Evadne nordmanni occurred at all stations with no prominent peaks, but were most abundant at the inner station 01. Acartia longiremis was found in small numbers both in spring and autumn at St. 01 and 04. In May 1970 a single record at St. 01 showed 600 specimens.

Fritillaria borealis occurred at all seasons, while Oikopleura spp. was found only during summer 1970.

Species which normally prefer deeper water, Metridia longa, Oncaea borealis, Conchoecia spp., Sagitta elegans and Eukrohnia hamata were confined to the outer stations, mainly St. 09.

Larvae of bottom invertebrates occasionally contributed with large numbers, mainly at St. 04 and 01.

DISCUSSION

The plankton community in Skjomen is characterized by a few species, mainly boreal, which occur in relatively large numbers. The community in Skjomen resembles that found by WIBORG (1954) at Skrova in the outer part of Vestfjorden.

Calanus finmarchicus dominated with very large numbers in spring, but a summer-autumn maximum was not observed in any part of the water column. The spring maximum was found before the spring increase in river discharge. The runoff keeps at a high level until autumn, and because young stages prefer the upper layers, this outward transport of surface water may reduce the summer and autumn stocks of C. finmarchicus. SØMME (1934) recorded an outward transport of C. finmarchicus by surface currents in Vestfjorden, and in Trondheimsfjorden runoff above the normal level in winter and early spring is assumed to affect the stock of C. finmarchicus greatly (STRØMGREN 1970).

Certain species which normally prefer deep water, Calanus hyperboreus, Pareuchaeta norvegica, Microcalanus pusillus, Metridia longa, Oncaea borealis, Conchoecia spp., Sagitta elegans and Eukrohnia hamata were of little importance at St. 04, while they might be relatively abundant at St. 09. This may indicate that if these species are brought into Skjomen by deep inflows they are rapidly redistributed, and a gradient in abundance is maintained.

Another group of species, Temora longicornis, Pseudocalanus elongatus, Limacina retroversa, and Oithona similis, had their main distribution at St. 01, while very few specimens were normally taken at St. 04 and 09. The first species, T. longicornis, showed maximum in June at St. 01, while the three others had a prominent maximum in September at the same station. The temperature at St. 01 was slightly

higher than at the outer stations, but may hardly be responsible for the difference in number. Surface salinities in September, however, seemed to be in average lower at St. 04 than at St. 01, evidently due to the position of the two stations in relation to the Skjoma river. As discussed in STRØMGREN (1970) variable runoff may cause significant variations in species with main maxima in summer and autumn, affecting both immigration and emigration. In Trondheimsfjorden the autumn maxima of these species is assumed to be partly dependent on water movements in the upper layers, and a part of the stock seems to be transported in from areas outside the fjord. Unfortunately, no samplings were made in Skjomen in August, and possible maxima at the outer stations might have been lost. The separate maxima at St. 01 may thus be due to the combination of two phenomena. They may be remnants from a late summer influx into Skjomen or have resulted from a local propagation, both combined with reduced dispersal. The higher average temperature at St. 01 may indicate reduced circulation in this branch of the fjord. Probably the local stocks are of greatest importance, and the populations at the outer stations might have been lost by the surface brackish water runoff, or diluted by the tidal currents. On the other hand, the high concentration may also be due to accumulation below the brackish top layer, caused by impenetrable hydrographic barriers or by preference to certain water masses, but unfortunately the detailed vertical distribution of the species at St. 01 is not known. The idea of an influx in the upper layers in August-September 1970 is supported by the simultaneous occurrence at St. 09 and 04 of the allochthonous species Paracalanus parvus and Centropages typicus. In November 1969 an indicator of Atlantic water, Metricia lucens, occurred together with another southernly species, Acartia clausi; the former at St. 09 only, the latter at all stations.

The mainly neritic species, Acartia longiremis, Centropages hamatus, Podon polyphemoides and Evadne nordmanni, normally keep to the upper layers. Compared to Trondheimsfjorden, the numbers found in Skjomen were very small, but of the same size as in Hardangerfjorden (GUNDERSEN 1953, LIE 1967).

Both Skjomen and Hardangerfjorden have rivers which are fed by glaciers, and show an extensive flood period, lasting from spring to autumn. On the contrary, Trondheimsfjorden has a large freshwater supply in spring, while the river discharge during summer is much smaller. In STRØMGREN (1970) the difference between Trondheimsfjorden and Hardangerfjorden for the summer-autumn species was proposed to be

related to the runoff, which in Hardangerfjorden might increase the outward transport as well as preventing significant supply from areas outside. Although the observations from Skjomen show a single year cycle only, the results fit into this assumption.

As discussed in STRØMGREN (1970) and indicated in this report, the freshwater supply to a fjord system, both in respect of annual cycle as well as of the quantities discharged, may be of great importance to the standing stock of zooplankton at all seasons. The annual variations of the zooplankton, however, also depend on several other very variable factors, and long term investigations are needed to give a reliable account of the zooplankton in a fjord. The regulation of Skjoma river will cause a thorough change in the annual cycle of freshwater supply to Skjomen, and continued investigations will offer an excellent opportunity to throw light upon this problem. Due to the rapid displacement of water in Skjomen, a study of the effect on the zooplankton requires that the upper layers are sampled at much shorter intervals and are combined with simultaneous current recordings above and below the discontinuity layer.

R FERENCES

GUNDERSEN, K.R. 1953. Zooplankton Investigations in some Fjords in Western Norway during 1950-1951.
Rep. Norw. Fishery mar. Invest. 10 (6): 1-54.

LIE, U. 1967. The natural history of the Hardangerfjord. 8. Quantity and composition of the zooplankton, September 1955 - September 1956.
SARSIA (30): 49-74.

MARGALEF, R. 1958. Temporal succession and spatial heterogenity in phytoplankton.
Pp. 323-349 in Perspectives in Marine Biology. Univ. California Press.

SKRESLET, S. 1971. Årsoversikt hydrografi. 1969-70.
Tromsø Museums Skjomenundersøkelser. Marine undersøkelser. Hefte 15.

STRØMGREN, T. 1970. Zooplankton investigations in Trondheimsfjorden, 1963-69. University of Trondheim, Royal Norwegian Society of Sciences and Letters, Trondheim. (Manuscript)

SØMME, J. 1934. Animal plankton of the Norwegian coast waters and the open sea. I. Production of Calanus finmarchicus (Gunner.) and Calanus hyperboreus (Krøyer) in the Lofoten area.
Rep. Norw. Fishery mar. Invest. 4 (9): 1-163.

WIBORG, Kr.Fr. 1951. The whirling vessel, an apparatus for the fractioning of plankton samples.
Rep. Norw. Fishery mar. Invest. 9 (13): 1-16.

WIBORG, Kr.Fr. 1954. Investigation on Zooplankton in Coastal and Offshore Waters of Western and Northwestern Norway.
Rep. Norw. Fishery mar. Invest. 11 (1): 1-246.