Ödsmål, Kville sn, Bohuslän

Hällristning Fiskare från bronsåldern

Rock carving Bronze age fishermen

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SEASONAL FLUCTUATIONS OF COPEPODS IN KUNGSBACKAFJORD, SWEDEN 1967-68

by

Eva Ölundh

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Abstract

Ölundh,E.Seasonal fluctuations of copepods in Kungsbackafjord, Sweden,1967-68.

The density of the copepod fauna in Kungsbackafjord fluctuated during 1967-68 with peaks in July and September 1967 and in April,in July and in August 1968.The most important copepods in the fjord were Oithona similis,Pseudocalanus minutus elongatus, Paracalanus parvus,Acartia longiremis and Acartia clausi. Oithona similis and Acartia clausi showed the same seasonal fluctuations with three peak abundance:April,July and August-September.Acartia longiremis appeared mainly in the spring and late fall.The adults of Pseudocalanus occurred mainly in the spring and those of Paracalanus in the autumn.The populations of Pseudocalanus,Paraclanus and Oithona were smaller in 1968 than i in 1967 and only partly replaced by Acartia clausi. Acartia discaudata,Temora longicornis,Centropages hamatus, Centropages typicus,Oithona spinirostirs and Calanus finmarch-icus occurred occasionally in small numbers in the fjord.

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Sammanfattning.

Zooplanktonprov togs i Kungsbackafjorden, juni-december 1967 och april-oktober 1968. Avsikten var att studera variationen i copepodfaunans täthet (ind./m^3) och artsammansättning under året. Proven togs genom vertikala drag med Nansenhåv - 50 cm i diameter, 165 cm lång och nät med 0,160 mm maskvidd. Den av håven filtrerade vattenvolymen mättes med en flow-meter - Tsurumi - som monterats centralt i håvens öppning. Håvens filtrerings - kapacitet var ca. 70 %.

Proven visade att de vanligaste copepoderna inom området var Oithona similis, Pseudocalanus minutus elongatus, Paracalanus parvus, Acartia longiremis och A. clausi. Tillfälligt påträffades Acartia discaudata, Temora longicornis, Centropages hamatus, C. typicus, Oithona spinirostris och Calanus finmarchicus.

Copepodfaunan visade sig ha täthetstoppar i juli och september 1967 samt i april, juli och augusti 1968,

Oithona similis och Acartia clausi visade samma variation under året och förekom talrikast i april, juli och augusti/september.

Acartia longiremis fanns huvudsakligen på våren och senhösten.

Adulta Pseudocalanus fanns fram för allt på våren medan adulta Paracalanus förekom mest under hösten. Copepoditstadierna till dessa båda arter var vanliga i juli/augusti och september 1967 samt mycket talrika i april/maj 1968, under 1968 kunde uppgång i tätheten noteras i juli och augusti/september.

Storleken av populationen av Oithona similis, Pseudocalanus och Paracalanus var mindre 1968 än 1967 medan däremot populationen av Acartia clausi var större 1968 än 1967.

Acartia clausi hade förmodligen fyra generationer per år i området och Oithona similis hade minst fyra generationer.

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by

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1. Introduction

The purpose of this zooplankton investigation was to study the seasonal changes in relative abundance and the composition of the copepods fauna as well as to get some information of the life cycles of the most important copepods in the fjord.
The reliability of the sampling method was tested and the efficiency of the net was studied.

2. Methods and material

2.1. Netsampling

The zooplankton was sampled with a Nansen net, 50 cm in diameter and 165 cm long. A nylon cloth was used which had a mesh size of 0.160 mm. Vertical net hauls were taken at the three stations 63, 67 and 69 (fig.1) twice a month from June until December 1967 and from April until October 1968. The volume of water filtrated by the net was measured by a flow meter of Tsurumi type mounted in the centre of the net opening. The samples were preserved in 4 % formic aldehyde.

2.2. The efficiency of the net

The water flow in the opening of the Nansen net was studied in a tank of standing water: size 18 m in length, 2 m in width and 1.5 m in height. The water flow was registrated by a flow meter. The velocity of water flow was higher at the periphery than in the centre of the net opening at all hauling speeds tested, 40 - 95 cm/s.
The filtration coefficient was about 70 % at hauling speeds of 50 - 60 cm/s far a new net measured in the tank and with the flow meter fixed in the centre of the net opening. The filtration coefficient was 10 % lower for a net that had been used for a short time. The filtration coefficient increased with increasing hauling speeds from 40 - 95 cm/s.

At sea the net was nearly always clogged and the filtration capacity will probably be less than 70 %.The use of a flow meter in the net will give fairly reliable comparative values for the minimum volume of water filtrated.

2.3.The variability between different net hauls

In order to get a rough estimate of the magnitude of variability between plankton samples the coefficient of variation (=standard deviation) can be calculated for a set of vertical samples.It was calculated to 16.36 %.

2.4.Hydrographical notes

Kungsbackafjord is located on the swedish west coast,40 kilometers south of Gothenburg (fig.1).The fjord may be described as an estuary.The influx of fresh water causes a seaward surface stream in the fjord and this outflow is compensated by an inward bottom stream of saline water.The fjord is about 15 kilometers long and the total area of it is 50 km^2:about 50 % of this is shallower than 6 m and the greatest depth is about 30 m.The drainage of fresh water is on an average 15 m^3 per second.The current speed of the seaward stream indicates that it will take less than 24 hours for the fresh water to be transported along the fjord.The general hydrographic conditions have been investigated and described by Olsson (1969) and Olsson and Andrén(1968). Usually a halocline appears in the fjord.The salinity of the water above the halocline is generally 15-20 ‰.The saline stratification is influenced by the wind and air pressure.Winds from south and southwest retard the outward surface stream.When the winds are from the north and east the transportation of the surface water out of the fjord is more rapid and the outgoing water loss is replaced by a more saline bottom water and the halocline is raised.

3. Result

3.1. Hydrography

The salinity and temperature were measured by an Electronic Switchgear measuring bridge type M C 5. The instrument did not, however, measure the temperature correctly during Oktober-December 1967.

The uppermost layers were heavily diluted in April and May of both years, due to drainage from land (snow melting) fig.2. Periods of heavy rain measurably diluted the surface water in the uppermost parts of the fjord in October 1967 and July 1968. During the summer both years the position of the halocline fluctuated and from October on it was located much nearer the surface than for the rest of the year. In August and in September 1967 at station 63 the salinity (19 ‰) was nearly the same from the bottom to the surface. In 1968 the autumn the water in the fjord was more saline-stratified. At stations 67 and 69 a thick layer of more saline water always covered the bottom. The fluctuations of the salinity were the same here as at station 63. Olsson and Andrén (1968) found that the variations in salinity in the fjord were allied to those at the lightship Fladen.

From April on the surface water was warmer than the bottom water at station 63. In the summer there was a thermocline which usually coincided with the halocline. From the beginning of June 1967 and the middle of May 1968 the whole water mass was warmer than 10°C. In September 1967 it was 15°C and in October 1968 it was about 10°C. In the autumn the water was homotherm: late August 1967 (17°C) and late September 1968 (13°C). The surface water was warmer in 1968 than in 1967 from the middle of June to the beginning of September. The temperature conditions were nearly the same at stations 67 and 69 as at station 63. At these stations the bottom water was 7-14°C.The surface water was not warmed up as much as at station 63 in the summer.

3.2.Seasonal changes in the copepod fauna

The density of the copepod fauna in the fjord fluctuated during the years:peaks in July and September,1967,and a great peak in April and smaller peaks in July and August 1968 (fig.3).The dominant copepods in April were P-calanus(short for Pseudocalanus minutus elongatus and Paracalanus parvus).The peak in July was caused by the developing stages of Oithona similis,Acartia clausi, Acartia longiremis and P-calanus.These species also built up the autumn maximum.From June/July the different stages of Oithona similis were aa numerous as those of P-calanus.In October-December Oithona similis was the dominating copepod all over the fjord.

The adults and different stages of P-calanus and Oithona similis were more abundant in 1967 than in 1968;as regards Acartia clausi and its copepodite stages ,the reverse applied.

3.3.Acartia longiremis Lilljeborg.

Acartia longiremis was found in maximum numbers in late Aptil and early May,1968 (fig.4).In both years the density of this species was low during the summer months.In 1967 the density increased markedly at the end of November and remained high until the investigation ended in late December.It was found more often in the outer parts of the fjord but the density was often highest in the inner parts.

3.4.Acartia clausi Giesbrecht

Acartia clausi was found in greatest numbers in June 1967,then it was absent until September.In 1968 a small crop was found at the beginning of April,but at the end of April it was very numerous,about 5000 organisms per m^3.Another peak was reached in late July and a third at the end of August. The density of Acartia clausi was nearly always highest in the middle of the fjord and lower the nearer the entrance to the fjord the samples were taken (fig.4)

All nauplii and copepodites of Acartia spp. were treated as a unit. The abundance of the nauplius larvae was low in 1967. The only higher densities observed were at the beginning of July and December. The abundance of copepodites increased in July, September and December in 1967. In 1968 both nauplii and copepodites were numerous in early April, with a marked peak at the end of April. The nauplius larvae were very rare from June to the end of the investigation period on 10 October. The copepodites were found in every collection in 1968, with peaks in April, July and late August.

3.5. Pseudocalanus minutus elongatus (Boeck) and Paracalanus parvus Claus

The adults of Pseudocalanus minutus elongatus were found mainly in the spring and those of Paracalanus parvus mainly in the autumn. The adult individuals were only found in very small numbers. A marked seasonal fluctuation was observed in the density of the developing stages of Pseudocalanus and Paracalanus (P-calanus)(fig.5). The abundance of nauplius larvae was extremely high in April and then the density decreased and the nauplius larvae were found in small numbers for the rest of the year. The copepodites were found in great numbers in April, at the end of July and in September. The same changes in abundance was observed in both years.

3.6. Oithona similis Claus

Fluctuations were found in the density of the adults and copepodites of Oithona similis. The observations indicate that peaks ocurred in July and September in 1967. In 1968 the abundance was rather similar from the middle of April to the end of the investigation period in October with a small increase in the autumn (fig.6).

3.7. Rare copepods

Tempra longicornis P.Müller occurred sparsely in the fjord during the whole investigation period, April-December. Adults were found only in the outer parts. Centropages hamatus (Lilljeborg) was found in small numbers sometimes. Centropages typicus Kröyer was sometimes found during the spring and summer months. Calanus finmarchicus Gunnerus was found in the outer parts of the fjord in small numbers. The specimens caught were most often copepodites. Oithona spinirostris Claus was only found in the fjord on 12 July 1967 at station 63. Acartia discaudata Giesbrecht was caught at station 63 in July and August 1968.

4. Discussion

4.1. Method

The method used may give a lower value of the density of the copepod populations because the filtration coefficient of the net used was 60 - 70 %. The younger nauplius stages and the copepods and the nauplii of Oithona similis and certainly also the first copepodite stages are not caught by the net with 0.160 mm mesh size

4.2. Acartia longiremis and Acartia clausi

Acartia longiremis feeds on phytoplankton and the size of its broods is greatly affected by the supply of phytoplankton (Heinrich 1962). Its temperature range is 1.5 - 12 °C, according to Giesbrecht (1892). The changes in temperature and occurrence of this species in Kungsbackafjord indicate that Acartia longiremis may be a cold water species which avoids the higher summer temperature or does not tolerate it. From July on, the temperature was higher than $12^{\circ}C$.In spring the population was favoured by the great phytoplankton abundance (fig.7).Females with spermatophores were found in April-June and in December.Nauplii and copepodites of Acartia spp. were present in December.These observations indicate that Acartia longiremis may reproduce even in the winter months.

In Isefjoed,Jespersen (1949)found Acartia longiremis in January-May,and in the Göte Älv region this species was abundant from February until May (Eriksson 1968).

Acartia clausi showed three significantly separate density peaks of the adults viz. in April-May,June-July and August-September (fig.4)These peaks must to some extent be the result of the life cycle of this species.Heinrich (1962) says that its first breeding in the spring is dependent on the phytoplankton bloom. In 1968 the phytoplankton bloom started in February at the lightship Fladen (fig.7) which is located not far from Kungsbackafjord (fig.1).Somewhat later a peak in the abundance of the adults of Acartia clausi was observed in the fjord (fig.4).This may be the second generation.The third generation probably appeared in June-July and a fourth in the autumn,August-September.This fourth generation certainly produces the overwintering stages which mature early in the spring:the first generation next year.

The same fluctuations in the density of Acartia clausi adults were found both years and it seems likely that the production of Acartia clausi was affected by the supply of phytoplankton as the greatest abundance appeared in connection with high rates of primary production in the adjacent waters.

In Long Island Sound,Conover (1956) always found some females that were capable of oviposition.The effect of the breeding was influenced by the environment,which is thought to control the

the survival of the eggs and young and the speed of development. The density peaks in Kungsbackafjord appeared at somewhat different times the two years, probably due to different temperature conditions during the summer months. The span of a generation is increased if the temperature is low and shortened if the temperature is higher, provided that food is sufficiently abundant (McLaren 1963).

Conover (1956) suggested that Acartia clausi had four generations per year in Long Islnad Sound. Marshall (1949) suggested the same for this species in Loch Striven. In Northern European waters probably only two generations per year are produced (Wiborg 1954, Ruud 1929). Digby (1950) says that five generations are probably produced in the waters off Plymouth.

Acartia clausi was more abundant in 1968 than in 1967 in the fjord. Acartia clausi is not a filter-feeder in the strict sense (Lowdenes 1935) and the feeding mechanism of Acartia appears to be less efficient in competition with "true" filter-feeders (Conover 1956). As the adundance of the other copepods in the fjord was lower in 1968 than in 1967 the competition was reduced.

4.3. Pseudocalanus minutus elongatus and Paracalanus parvus

The adults of Pseudocalanus appeared mainly in the spring and in smallnnumbers in the fjord. According to Giesbrecht (1892), its temperature range is 0 - 18°C. In Loch Striven, Marshall (1949) observed that the great majority of all stages of this species among others retreated into deeper water in the summer. She says that light and temperature may be factors causing this. Jespersen (1949) found Pseudocalanus minutus mainly in the spring in Isefjord. In the Göta Älv region Eriksson (1968) found this species more numerous in the spring until June than after this time; after June Paracalanus parvus was more abundant than Pseudocalanus.

Paracalanus parvus prefer higher temperature than Pseudocalanus, its temperature range according to Giesbrecht (1892) being 8-28°C.The few adult caught were found mainly in the autumn in Kungsbackafjord.Jespersen (1949) and Jensen et al. (1904) found Paracalanus parvus mainly in the autumn in Isefjord and the Kategatt.Wiborg (1944) says that Paracalanus parvus is a typical autumn form and abundant in Nordåsvatn in October-November. The developing stages of these species are treated as a unit. Therefore it is difficult to say anything regarding the appearance of the developing stages of the different species.From the occurrance of the adults one may suppose that the copepodites found in the spring would be mainly Pseudocalanus and those in the autumn mainly Paracalanus.The three density peaks of the developing stages of P-calanus,which are significantly separate, appeared after the maxima in the rate of phytoplankton production at the lightship F_1aden (fig.5 and 7).The nauplius larvae of P-calanus were caught from April until December in the fjord (fig.5).They were very numerous in April.The copepodites of P-calanus were more common in the summer of 1967 than in 1968. The higher summer temperature in 1968 may have caused this situation,as Pseudocalanus,which probably made up the main part of the stock in the summer,seems to avoid too high temperature. The delay between high phytoplankton production and the appearance of P-calanus is shorter in the autumn than in the spring, becuase of the higher temperature in the autumn which speeds up the development of the young.stages.Katona and Moodie (1969) found that it took 37 days from egg to adult female with egg at a temperautre of 15°C for Pseudocalanus elongatus in a laboratory experiment.At a temperautre of about 6.7°C,McLaren (1965") indicates a generation span of about 50 days for Pseudocalanus.

In Oslofjord,Wiborg (1940) found three maxima of Pseudocalanus in February-May,June-July and probably one in the autumn, August-September.Ruud (1929) and Wiborg (1954) found three main spawing of Pseudocalanus elongatus:one in March,a second in May and a third at the end of July on the Norwegian coast.In Loch Striven,Marshall (1949) found three adult generations of Pseudo-calanus minutus;in the early spring,in April and in July.The brood of the third generation will only mature to Stage IV and form the overwintering stock which starts to breed early in the spring.It is likely that the same situation exists in Kungs-backafjord.By size measurment Digby (1950) observed in the water off Plymouth five generations per year of Pseudocalanus elongatus and of Paracalanus parvus.In Loch Striven,Marshall (1949) found Paracalanus parvus only occasionally before the middle of July and the maximal number came on 31 August:the copepodites were at their maximum at the beginning of October. Marshall suggested that the winter is passed in a late cope-podite stadium.

4.4.Oithona similis

It may be assumed that Oithona similis produces at least four generations per year in this area:the first early in the spring, the second matures in April,the third in July and the fourth in August-September (fig.6).In Loch Striven Marshall (1949) found that the production had already started in January,when 60-70 % of the population were nauplii.The reproduction may go on more or less continuously (Marshall 1949) and the generations may overlap each other in the summer and thus be hard to separate when only the density is studied.Fish(1936) found in the Gulf of Maine at least three and possibly four broods of Oithona similis,and that the developmental period was about six weeks in the summer and about two months during the early season.In the water off Plymouth.Digby(1950) separated the different generations by the size of the adults and he found five generations per year.

Heinrich (1962) says that Oithona similis is herbivorous producing dense broods after an abundant crop of phytoplankton has been available.Hargrave and Geen (1970) regard Oithona similis as a hervivorous copepod.On the other hand,Petipa et al.(1968) found that the adults of Oithona similis is carnivorouus but its copepodites are mixed-food consumers.Marshall and Orr (1962, 1966) suggest that Oithona similis is "almost wholly predatory". Diatoms are probably less important as food for Oithona than for most other copepepods.This may explain why Oithona similis id the dominating copepod during the winter,when the phytoplankton crop is low.

The greatest number of copepodites of Oithona similis in the fjord 1967 appeared shortly after the maximum rate of primary production at the lightship Fladen (fig.6 and 7).As females with egg-sacs were found from April until December,the production probably gies on most of the year.The result of the breeding seems to some extent to be affected by the supply of phytoplankton,which probably ensures the survival of the young omnivorous stages.The observed density of Oithona similis copepodites is lower than the true density because the net used certainly does not catch the smaller copepodties,nor the nauplii.The abundance of adults of Oithona similis and copepodites was higher in 1967 than in 1968.

4.5.Influence of primary production on copepod reproduction

The density of the copepod fauna in the fjord fluctuated during the years,with peaks in July and September 1967 and in April

July and August 1968 (fig.3).
The rate of primary production at the lightship Fladen varied a lot during the year 1967 with three tops of maximal rate of primary production;March,late June and late September.In the spring 1968 the maximum appeared in February (fig.7).The carbon-14 technique was employed (Steemann Nielsen 1952)
As may be seen from the above,it is presumed that dense zooplankton broods are produced after periods of high rate of primary production.High rate of primary production is not the same as high standing stock of phytoplankton,but the nutrient supply for zooplankton will certainly be good in connection with high rate of primary production.The food situation will affect both the spawning and the survival of the young.Nassonge (1970) found that the egg production in a herbivorous cyclopoid copepod increased after a period of dense phytoplankton crop.
It was also found that the size,type and concentration of the food particles was important for the production of copepods.
McLaren (1963,1965) has argued that reproduction and development of copepods may be intrinsically controled,when food is unlimited,and vary with the physical parameters of the environment especially the temperature.
The found differences in the copepod fauna were probably caused by a combination of several factors,such as temperature,salinity, water movements,predation,supply of nutrients and minute biological differences in the water.Many of which are very difficult, not to say impossible,to measure but their biological effect may not be less important than the more easily measured factors such as temperature and salinity.

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Fig.1.Map showing the position of the stations 63 (18 m), 67 (25 m) and 69 (30 m) in Kungsbackafjord,which is about 15 kilometers long.The depth lines of 10 m and 20 m are reproduced. A small map is inserted to show the position of Kungsbackafjord on the west coast of Sweden.

Fig.2.The temperature and salinity during 1967-68 at station 63 in Kungsbackafjord.

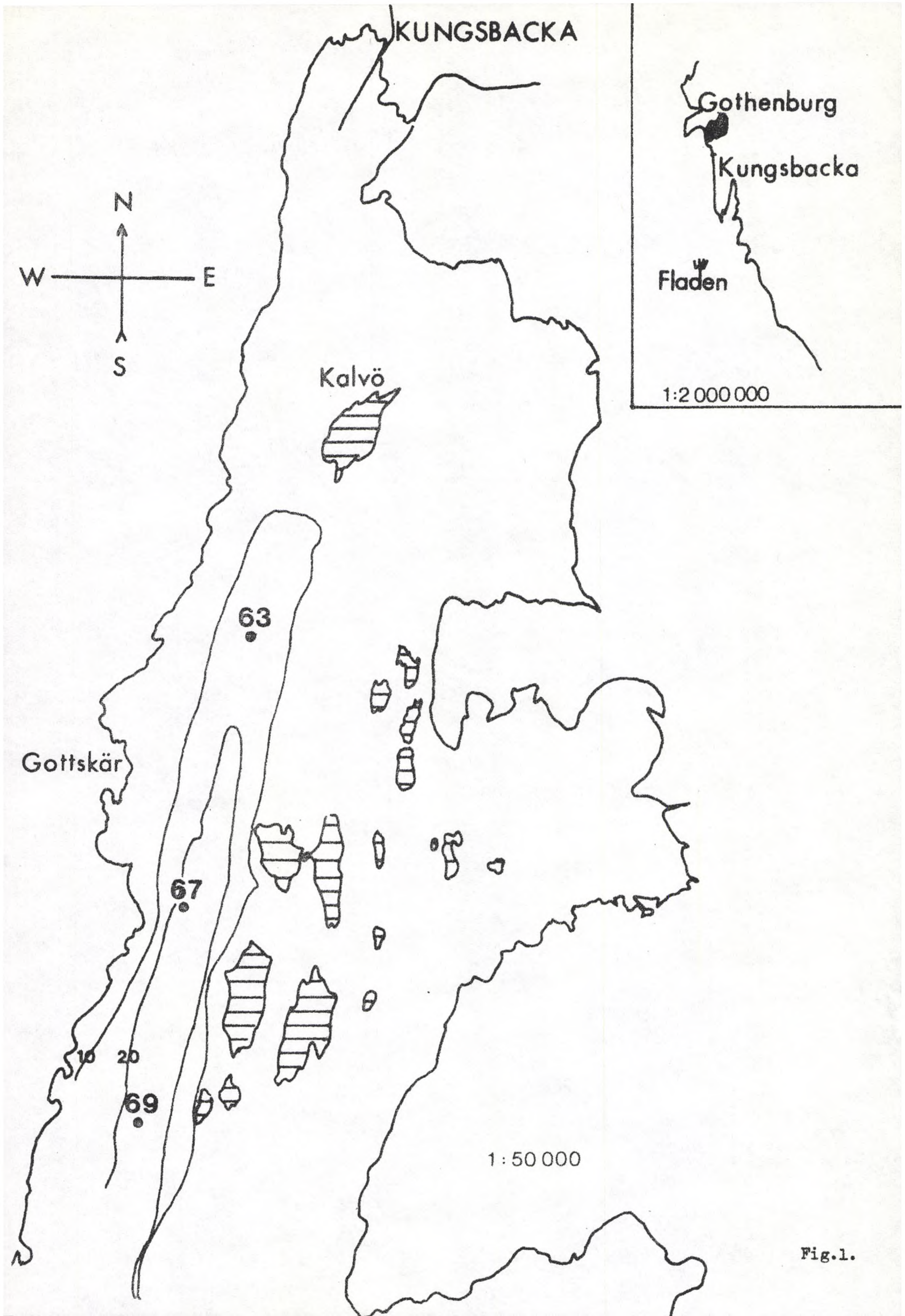
Fig.3.The total number of copepods found at station 63 in Kungsbackafjord in 1967-68.

Fig.4.The number of Acartia clausi and A.longiremis and their developing stages at station 63 in Kungsbackafjord 1967-68.

Fig.5.The combined number of different stages of Pseudocalanus minutus elongatus and Paraclanus parvus at staion 63 in Kungsbackafjord in 1967-68.

Fig.6.The number of adults of Oithona similis and its copepodite stages at station 63 in Kungsbackafjord in 1967-68.

Fig.7.The rate of phytoplankton production at the lightship Fladen,December 1966 - April 1968.(Data recieved from Dr. Vagn Hansen,Charlottenlund,Denmark.)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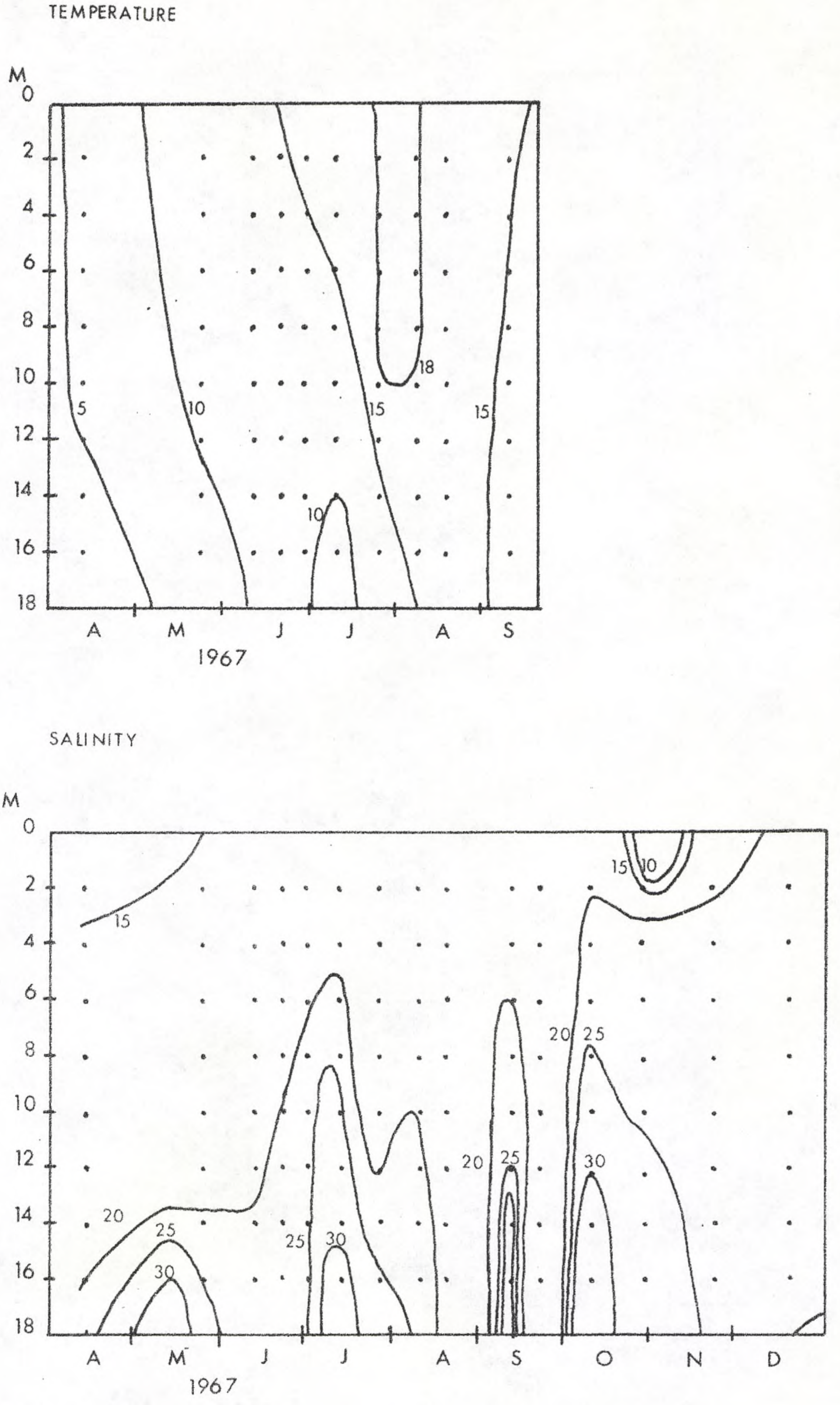
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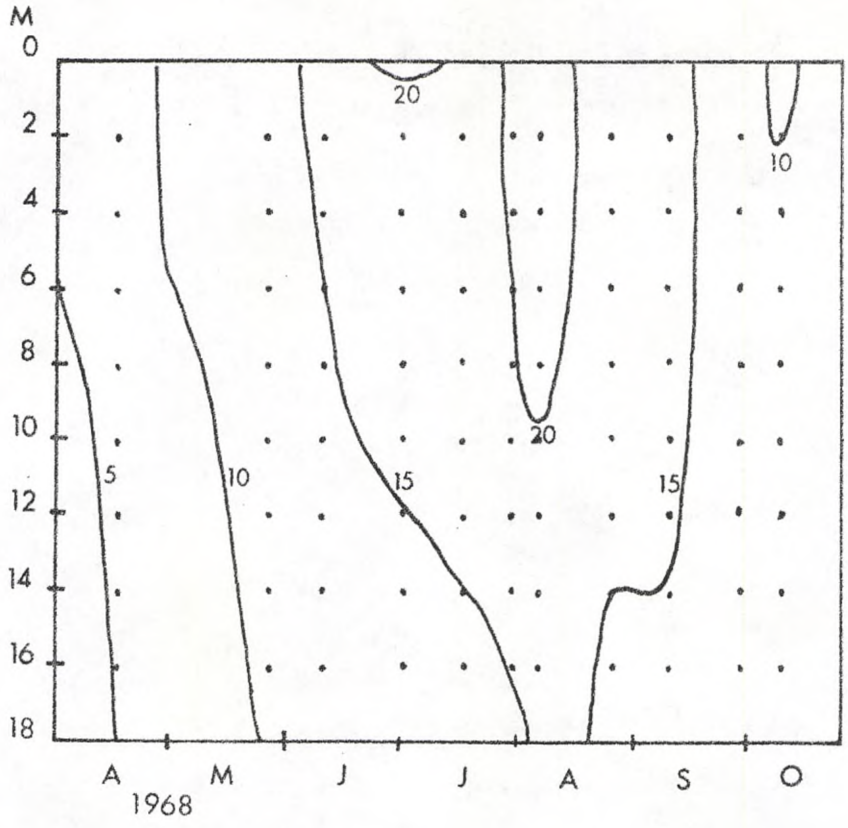
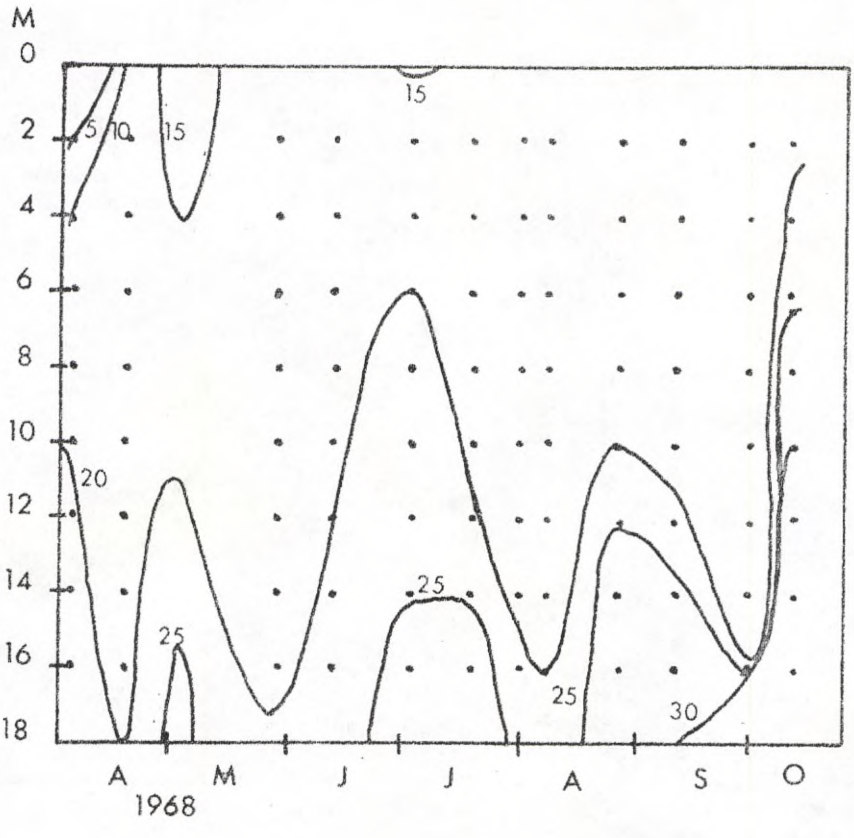
1967

Fig.2.



M
0
2
4
6
8
10
12
14
16
18
20
10
20
5
10
15
15
A
M
J
J
A
S
O
1968



M
0
2
4
6
8
10
12
14
16
18
15
5
10
15
20
25
25
25
30
A
M
J
J
A
S
O
1968

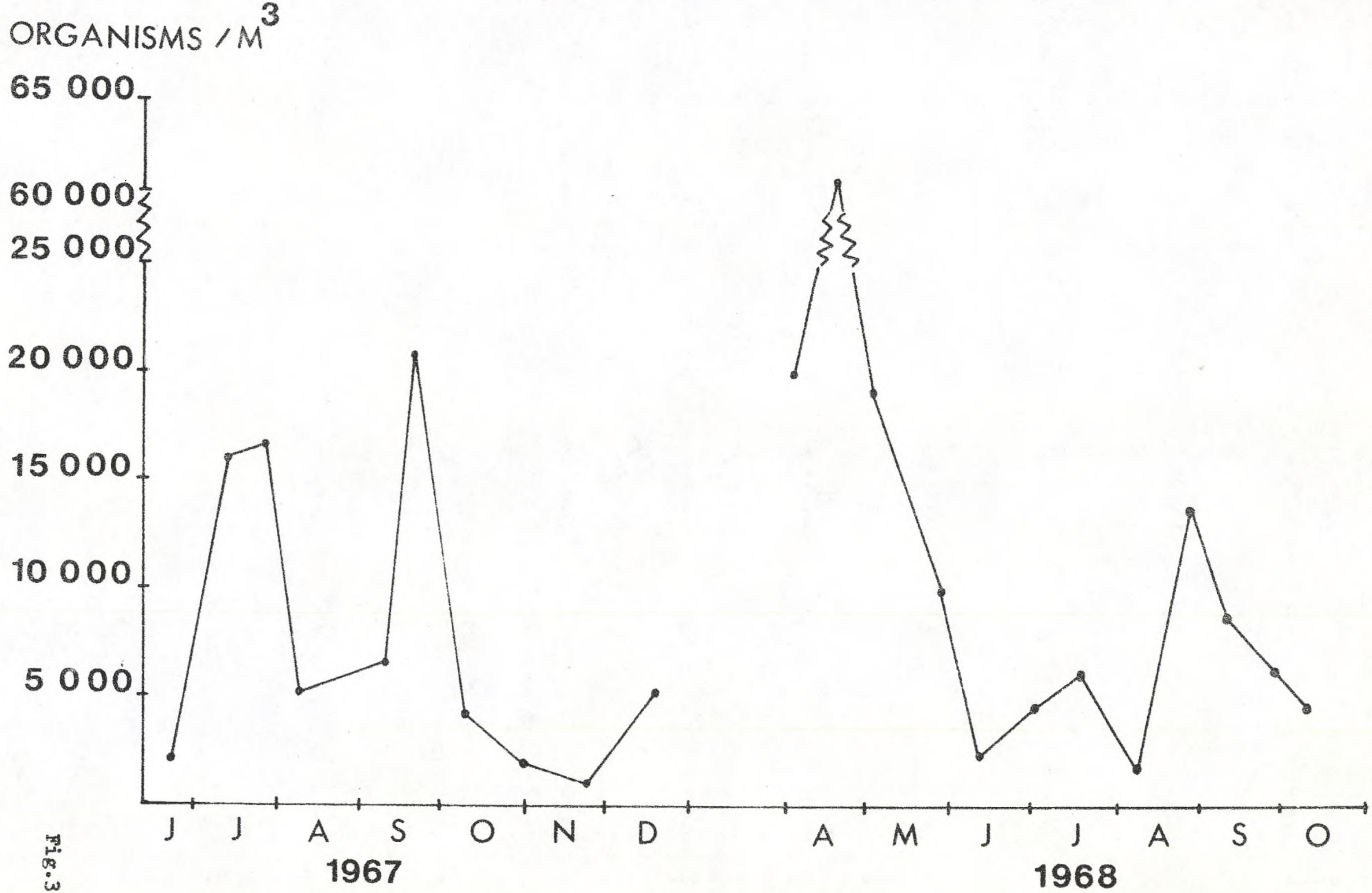

ORGANISMS / M3
65 000
60 000
25 000
20 000
15 000
10 000
5 000
J J A S O N D
1967
A M J J A S O
1968

Fig.3.

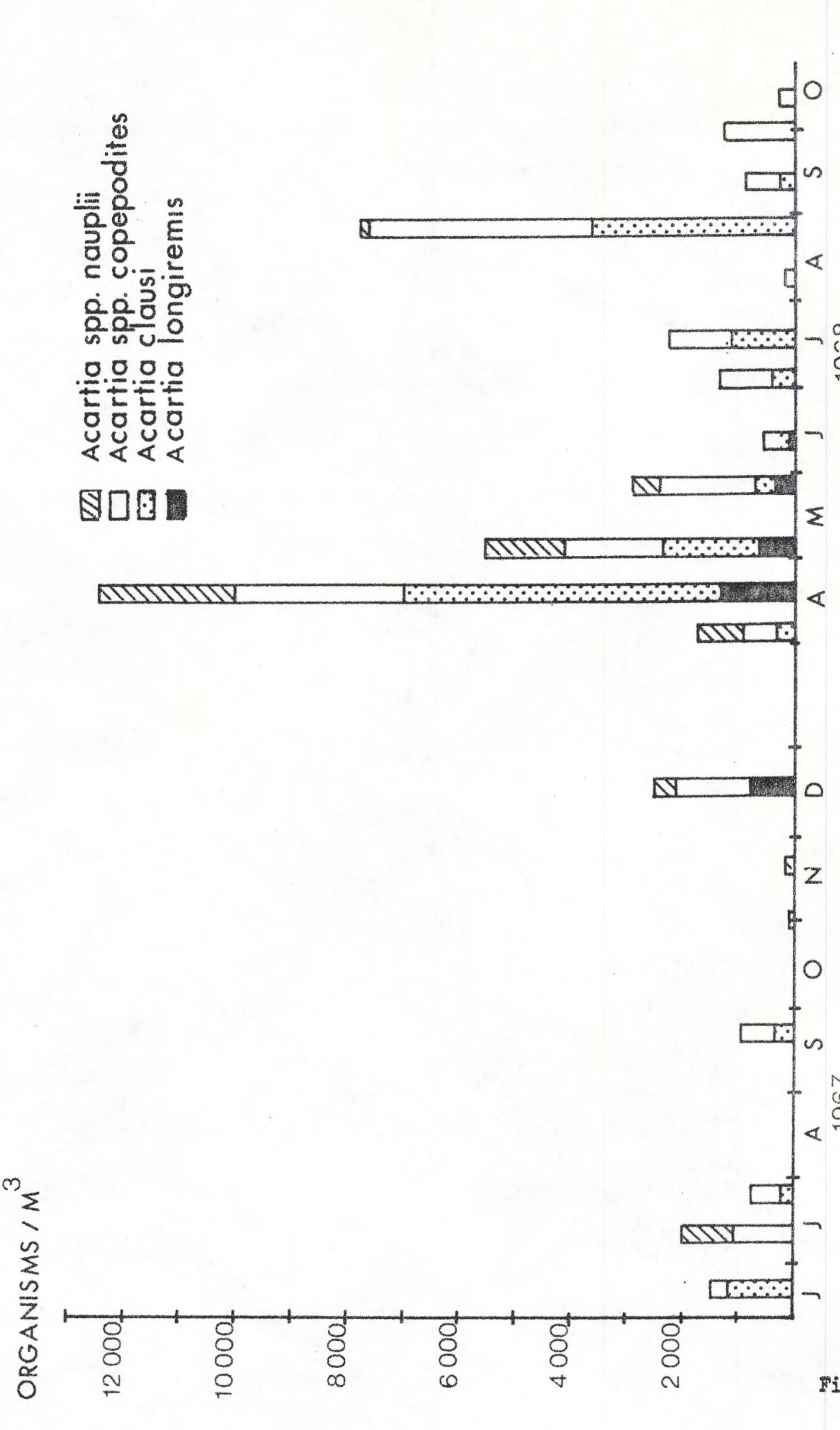

ORGANISMS / M3
12 000
10 000
8 000
6 000
4 000
2 000
Acartia spp. nauplii
Acartia spp. copepodites
Acartia clausi
Acartia longiremis
J
J
J
A
S
O
N
D
A
M
J
J
A
S
O
1967
1968

Fig.4.

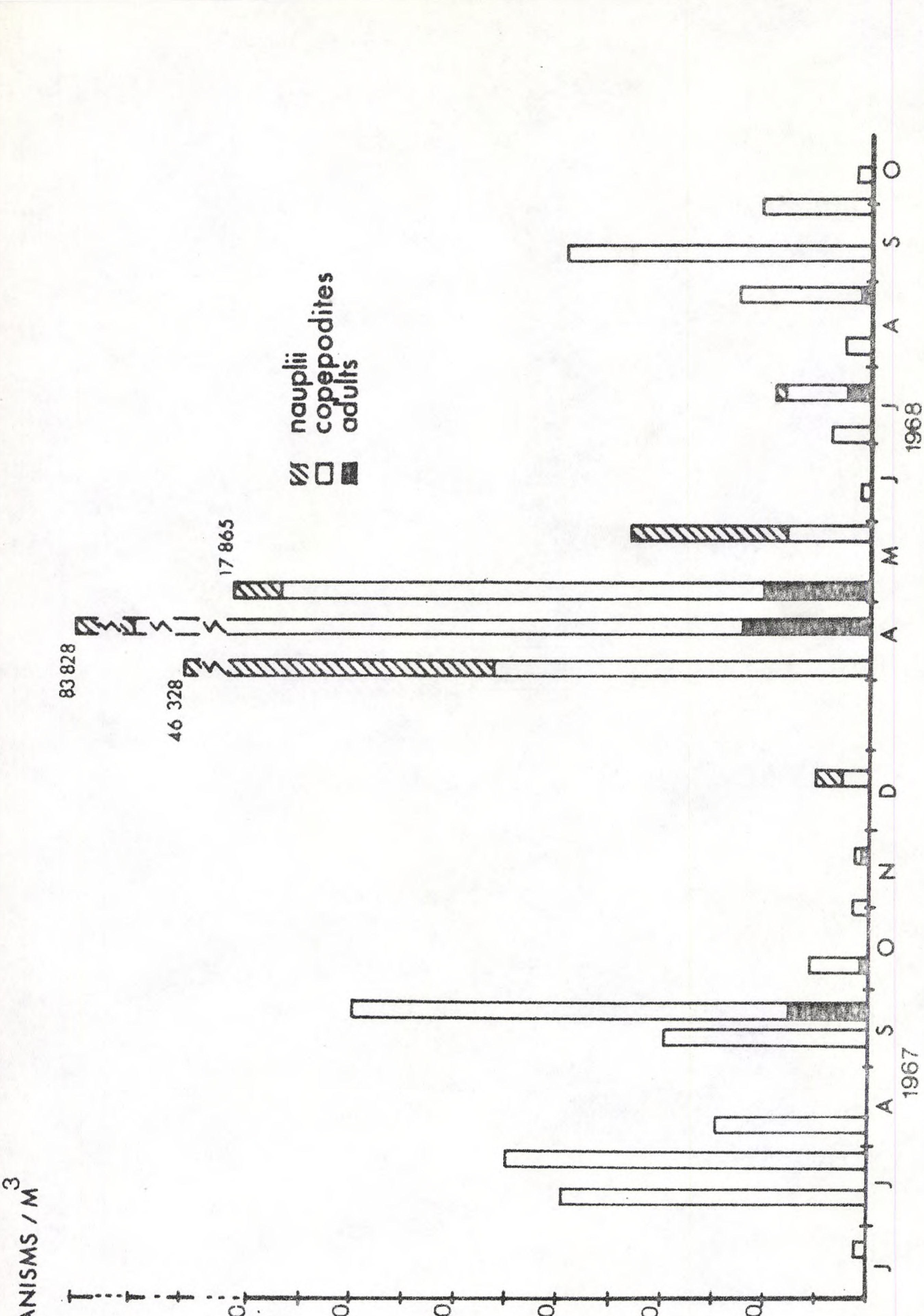

ORGANISMS / M3
12000
10000
8000
6000
4000
2000
J
J
A
1967
S
O
N
D
46 328
83 828
A
17 865
M
J
1968
J
A
S
O
nauplii
copepodites
adults

Fig.5.

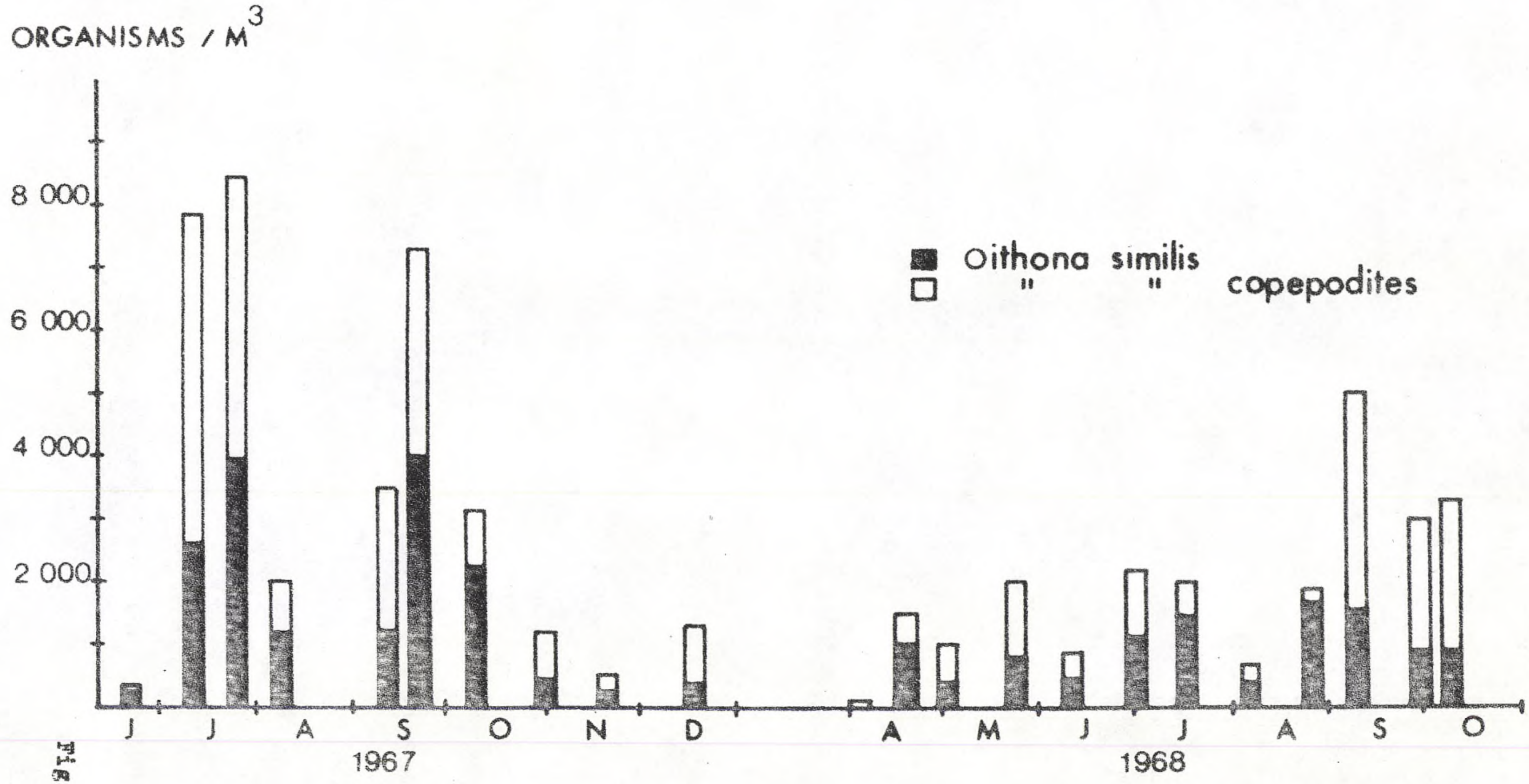

ORGANISMS / M3
8 000
6 000
4 000
2 000
Oithona similis
" " copepodites
J J A S O N D A M J J A S O
1967
1968

Fig.6.

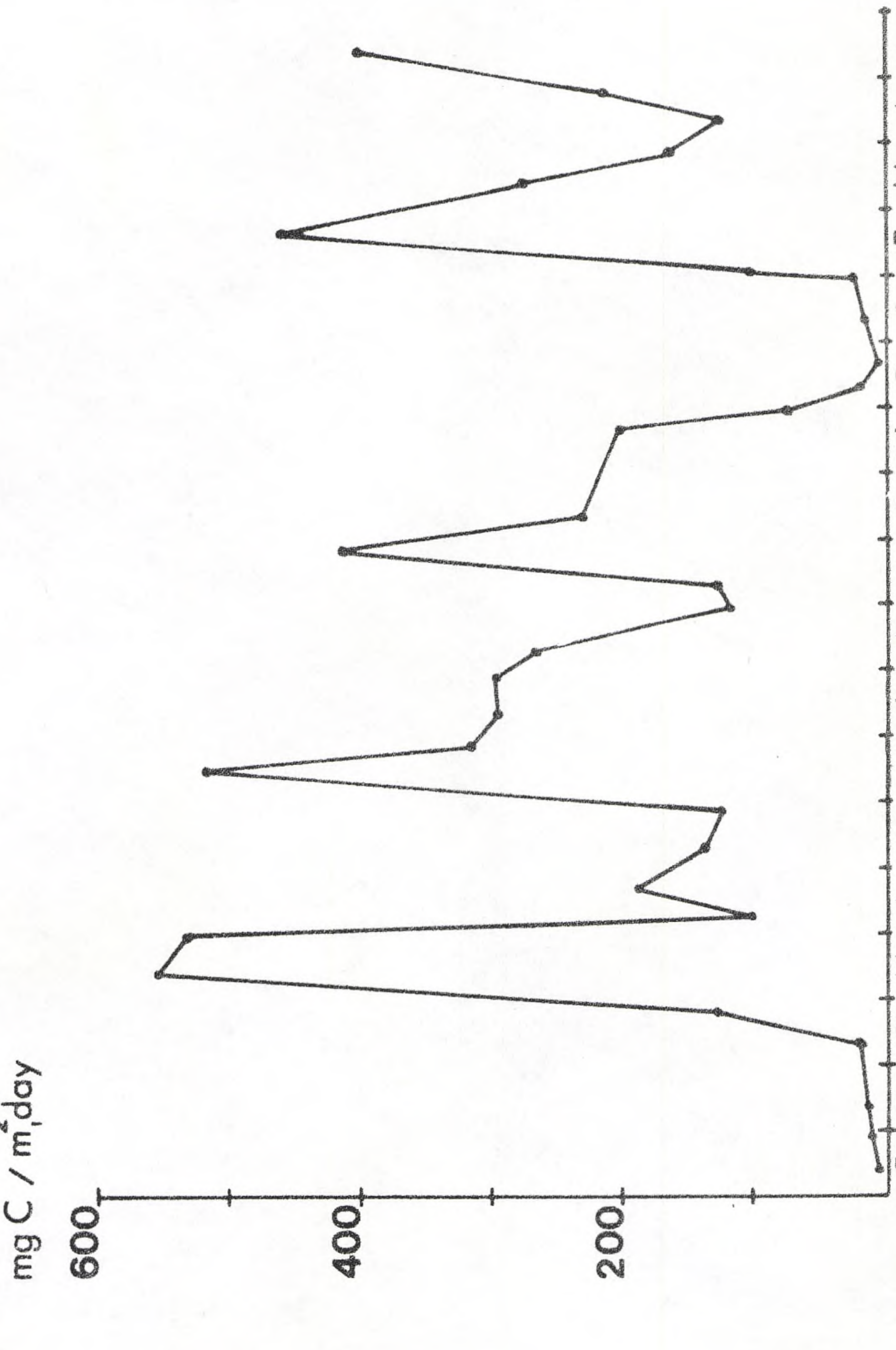


Fig.7.