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PHYTO- AND ZOOPLANKTON COMMUNITIES ON THE FAROE BANK AND THEIR RELATIONS TO THE PHYSICAL AND CHEMICAL ENVIRONMENT

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Abstract
Both the phyto- and zooplankton composition, biomass and productivity on the Faroe Bank differ much from that in the surrounding water. During spring the production and concentration of diatoms on the Bank is very high, and is much higher than in the surrounding area. This high primary production may cause a decrease of the nutrient concentrations on the Bank. Especially the silicate concentrations may decrease much. Further "new" production of diatoms on the Faroe Bank during the summer months therefore depends on input of nutrient rich water to the Bank. The dominant mesozooplankton species on the Faroe Bank was Cladocera and the copepods *Calanus finmarchicus*, *Oithona sp.* and *Pseudocalanus sp.* The concentration of the biggest of these copepods (*C. finmarchicus* stages CIV and CV) decreased very much in early summer 1992 and it is beleeved that this was because of predation. The zooplankton respiration rate was high in summer 1992, especially in spring while the diatom concentration was high.

INTRODUCTION

The Faroe Bank is placed about 40 nautic miles southwest of the Faroe Islands. It is the eastermost of the three banks in the northeast of the Rockall plateau. It covers an area of about 25 x 45 miles and its shallowest part is less than 100 meter. Towards east it is separated from the Faroe Plateau by a narrow (10 miles) and deep 850 m channel and towards west it is separated from the Bill Bailys Bank by a channel, which is less than 400 meters deep.

Earlier studies of phytoplankton (Paulsen, 1909, 1918) found that the composition was different from that of the surrounding areas. He found that the water above the Faroe Bank contained higher concentrations of diatoms than in the surrounding water but also contained oceanic species. He postulated that the water over the Bank is prevented to have free communications with the surrounding water.

Current measurements with sattelite-tracked drogues on the Bank have shown that the water has a anticyclonic circulation. One circulation last about 1 month. (Hansen *et al.*, 1986, 1991). There are however clear indications that the isolation of the watermasses on the Bank is varying with time (Lastein, 1992).

The cod stock on the Faroe Bank is also known to be isolated from that on the Faroe Plateau. Its growth is much faster (Taaning, 1943; Jones, 1966) and Schmidt (1930) showed that the number of vertibrae differed from the two stocks, indicating different races. Also analysis of hemoglobin in cod from the Faroe Bank and the Faroe Plateau indicate that the stocks are separated (Jamieson and Birley, 1989).

While the hydrography on the Faroe Bank has been well studied there have only been few and sporadic investigations on plankton and plankton ecology on the Bank. But since 1990 a series of cruises have been made to get a better understanding of the biological ocanography on the Faroe Bank. The aim of the studies was to get a better understanding of the plankton populations and production and the effect from the physical and chemical environment on both the phyto- and zooplankton on the Bank.

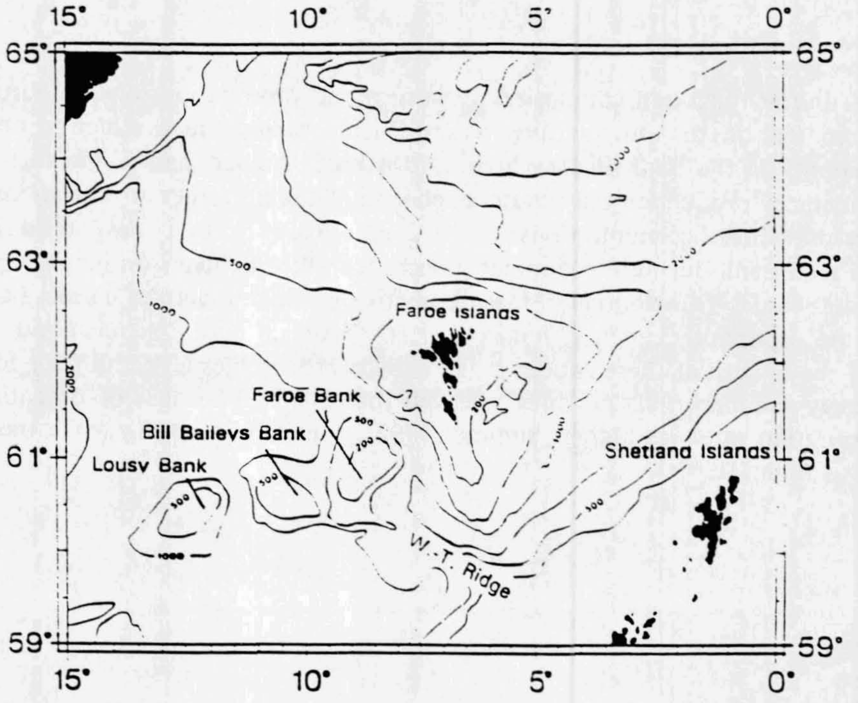


Fig. 1. The Faroe Bank and surrounding area

MATERIALS AND METHODS

The investigations were carried out with R/V "Magnus Heinason" on 5 cruises in 1991 and 1992. The dates of the cruises and the parameters measured are listed on Table 1. All stations were occupied during daytime.

Temperature and salinity were measured with a EG&G Mark III CTD equipped with a General Oceanics Rosette sampler. Salinity was calibrated from water bottles analyzed on a Autosal model 8400A salinometer. *In situ* fluorescence was measured with a Sea Tec fluorometer interfaced to the CTD and fluorescence values were calibrated from selected samples which were analyzed for chlorophyll *a*.

The chlorophyll *a* measurements were carried out using the method by Baltic Marine Biologists (1979) with the change that the homogenizations were carried out with a Soniprep 140 ultrasound homogenizer. When computing the results the equation of Jeffrey and Humphrey (1975) was applied.

The nutrients on cruise 4 were analyzed on board immidiatly after sampling using an automated nutrient autoanalyzer (Dansk Havteknik). The methods as are described by Grashoff *et al.* (1983) were used. On the other cruises, the samples for analysis of nitrate and silicate were frozen immidiately after sampling and analysed in the laboratory 1-4 weeks later. The samples for analysis of phosphate were preserved with 0.2 ml 4.5μM H_2SO_4/100 ml sample and stored in a refrigerator. The analyzis were carried out in the laboratory 2-6 days after sampling. The methods described by Grasshoff (1983) were used. Nitrate & nitrite was measured on an autoanalyzer and phosphate and silicate were analyzed manually.

The algae were preserved in 0.4% neutralised formaldehyde and were counted in an inverse microscope using 2, 5 or 10 ml of seawater.

The mesozooplankton was sampled on vertical hauls from 50 meters depth and to the surface. In 1991 was used a Hensen net and in 1992 a WP2 net. Both nets had a mesh size of 200 μm. The samples were preserved in 4% formaldehyd. On the laboratory the zooplankton from subsamples was identified, aged and counted. The samples were then rinsed and dried at 65°C until constant weight. When calculating the organic carbon content the estimation is made that org. C = dry weigth x 0.4 (Parsons *et al.*, 1977).

When measuring zooplankton respiration the samples were treated as described by Omori and Ikeda (1984). On the cod end of the WP2 net bucket a 1 liter plastic beaker was mounted to keep the specimens undamaged. Subsamples were transferred individually into 0.55 l glass bottles filled with 0.45 μm filtered natural seawater. The bottles were placed in an incubator which was adjusted to the average *in situ* temperature in the zone sampled. As control a bottle with filtered seawater was used. The samples were incubated for 3-6 hours in dim light. After the incubation the oxygen content was measured by Winkler titration and the respiration was calculated based on the difference between the oxygen content in the control and the samples. The organic carbon content in the zooplankton used in the respiration measurements were found using conversion factors given by Hay *et al.* (1991). When calculating carbon demand a respiratory quotient of 0.8 is used.

Table 1. Dates and parameters from the different cruises.

Cruise number	Dates	Parameters
1	22.-28. May 1991	CTD, chlorophyll a, phyto- and zooplankton
2	3.- 5. July 1991	CTD, nutrients, chlorophyll a, phyto- and zooplankton
3	22.-23. May 1992	CTD, nutrients, chlorophyll a, phyto- and zooplankton
4	5.- 9. June 1992	CTD, nutrients, chlorophyll a, phyto- and zooplankton
5	25.-28. June 1992	CTD, chlorophyll a, phyto- and zooplankton

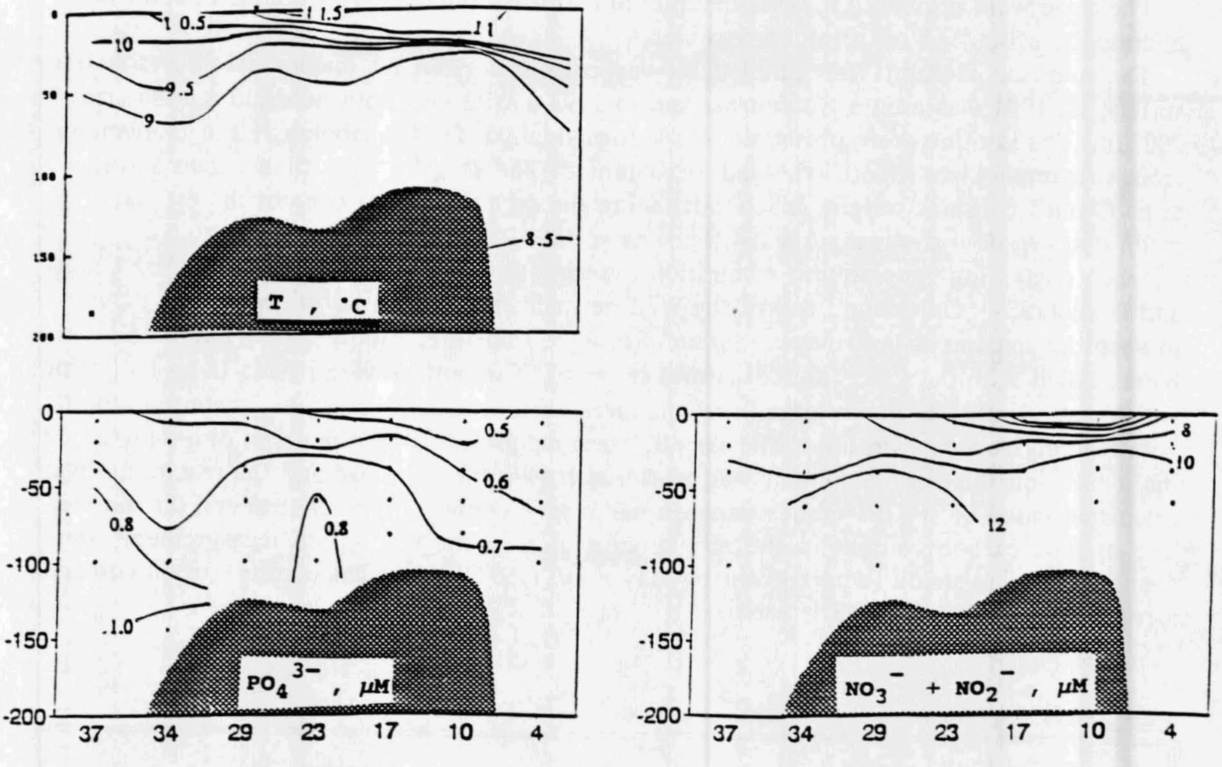
RESULTS

Hydrography and nutrient distributions

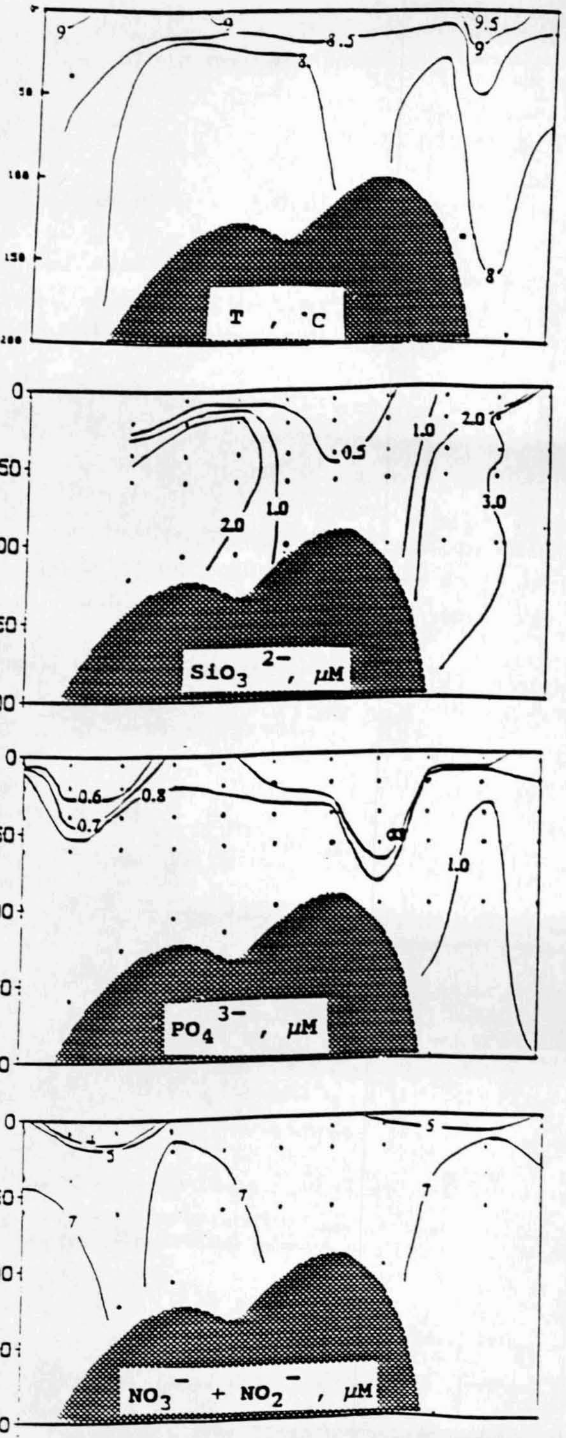
The temperature and nutrient concentrations on length sections over the Faroe Bank on cruises 2, 3 and 4 (Fig. 2 and 3) showed big differences between the Bank and the water around it. The nutrient concentrations were always lower on the Bank than outside it, and the concentration gradients followed the temperature gradients.

There were big differences in the nutrient concentration patterns between the two years. In 1991 the concentrations were only low above the termocline and were high below it. In 1992 the isolines were more vertical, indicating a higher isolation of the watermasses on the Bank than the year before. The concentrations on the Bank were much lower in 1992 than the year before and especially the silicate concentrations decreased to very low levels on the Bank in June.

The ammonium concentrations in June 1992 were generally low but showed higher concentrations on the Faroe Bank than in the water around it. This indicates higher catabolic activities on the Bank than in the surrounding water.



<u>Fig. 2.</u> Temperature and nutrient distribution on length section on 3.-6. July 1991 going from soutwest (left) to norteast (right) on the Faroe Bank



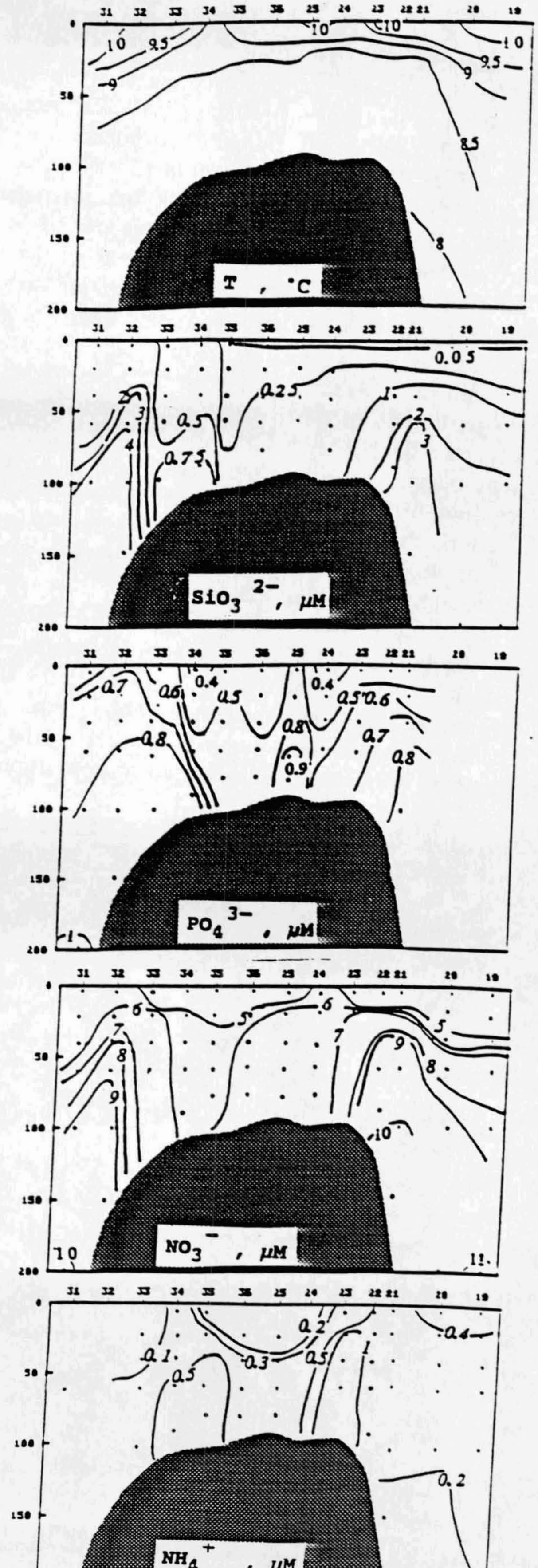


Fig. 3. Temperature and nutrient distribution on length sections on the Faroe Bank 22.-23. May (left) and 5.-8. june 1992 (right).

Phytoplankton distribution

The distributions of *in situ* fluorescense (approximately chlorophyll *a*) on length sections over the Bank show that most of the time the phytoplankton biomass on the Faroe Bank was very high and considerably higher than outside the Bank (Fig. 4). It can also be seen that the subsurface fluorescence maximum usually was close to the termocline.

Two examples of composition of the phytoplankton species are shown on Fig. 5. One is from 3.-5. July 1991 and the other is from 5.-8. June 1992. The samples are taken from 20 meters depth, which is close to the depth of the subsurface fluorescence maximum. The main difference between the species composition on the Bank and the water around was that the concentrations of diatoms were much higher on the Bank. One of these diatoms, *Rhizosolenia styliformis*, is extremely large and each cell usually had a length of 400-800 μm. This is a coloniforming species and most of the colonies had a length of around 1-3 mm. Also high concentrations of other *Rhizosolenia* and *Chaetoceros* species were common on the Bank. The concentrations of coccolithophorids and small naken flagellates were not higher on the Bank than outside it. Often they were found in higher concentrations outside the Bank. The total cell number therefore often was higher outside the Bank. But since the species on the Bank were much bigger the total phytoplankton biomass usually was higher on the Bank than in the water around. The very high chlorophyll *a* values on Figure 4 were always from high concentrations of diatoms.

The chlorophyll *a* values (Fig. 6) and diatom concentrations (Fig. 7) indicate that the diatom spring bloom in 1991 was somewhat delayed compared to 1992 and the diatom production continued longer than in 1992. In 1991 the diatoms were still abundant in july and were distributed all over the Bank while (Fig. 5). But in late june 1992 all diatoms were concentrated in the southwestern part of the Bank (Fig. 8). On the rest of the Bank the diatoms were absent. Instead the concentration of coccolithophorids had increased.

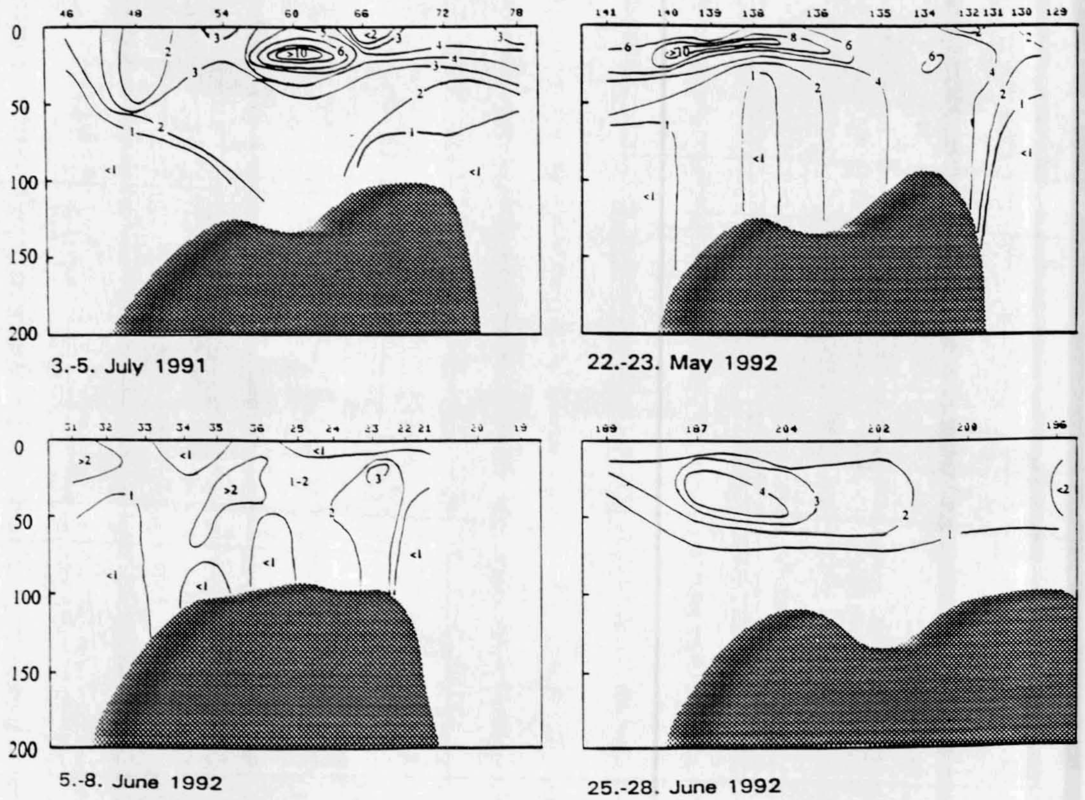


Fig. 4. Length sections of fluorescence (approximately chlorophyll a) on the Faroe Bank in 1991 and 1992.

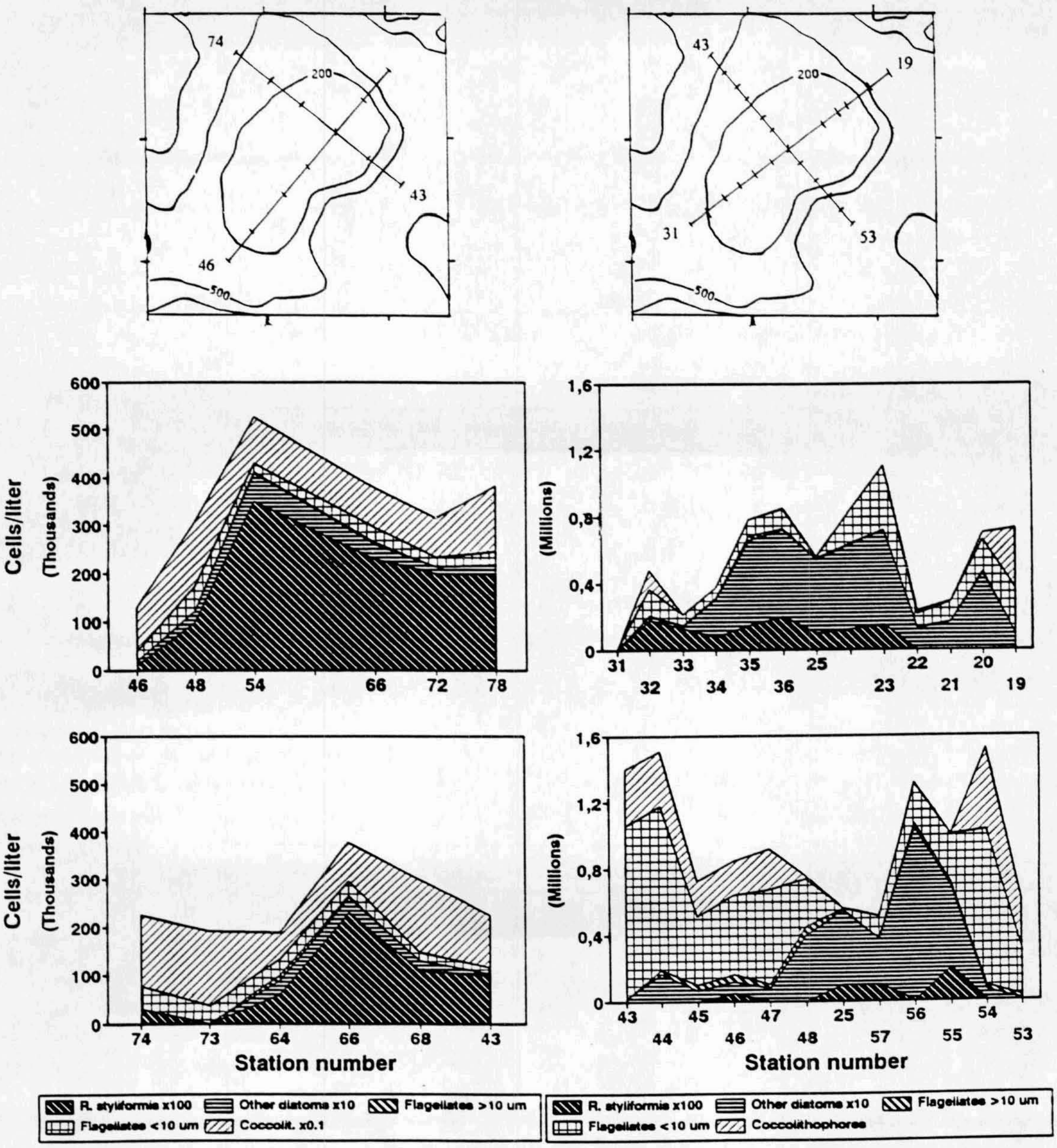


Fig. 5. Distribution of phytoplankton at 20 m depth on the Faroe Bank during the period 3.-5. July 1991 (left) and 5.-8. June 1992 (right).

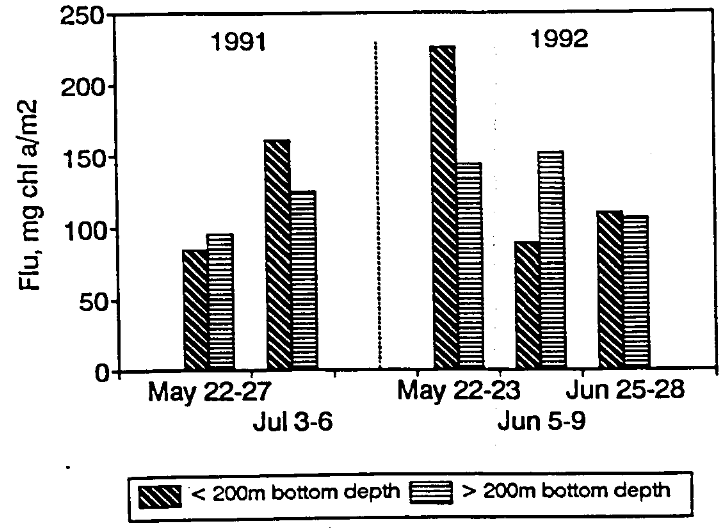


Fig. 6. Mean concentrations of chlorophyll a in the upper 50 meters respectively on the Faroe Bank and outside the bank during spring and summer 1991 and 1992.

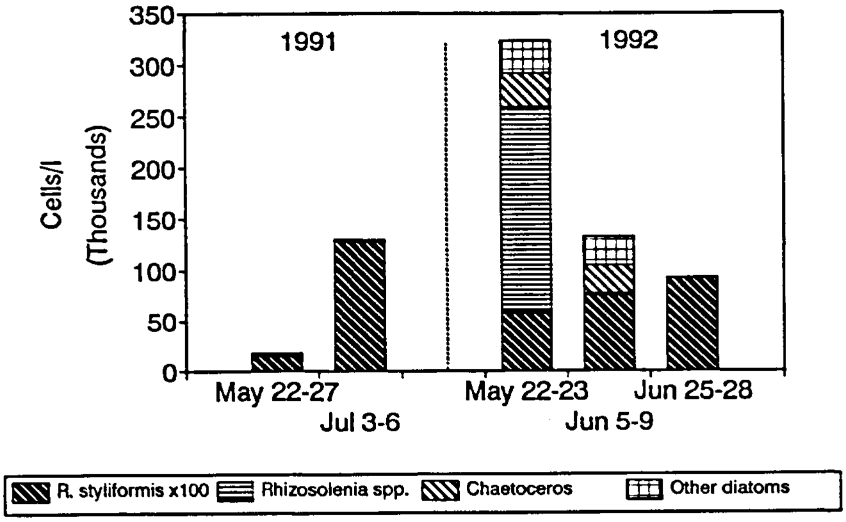


Fig. 7. Mean concentration of diatoms on 20 meters depth on the Faroe Bank during spring and summer 1991 and 1992. Note that the concentration of Rhizosolenia styliformis is multiplied hy 100.

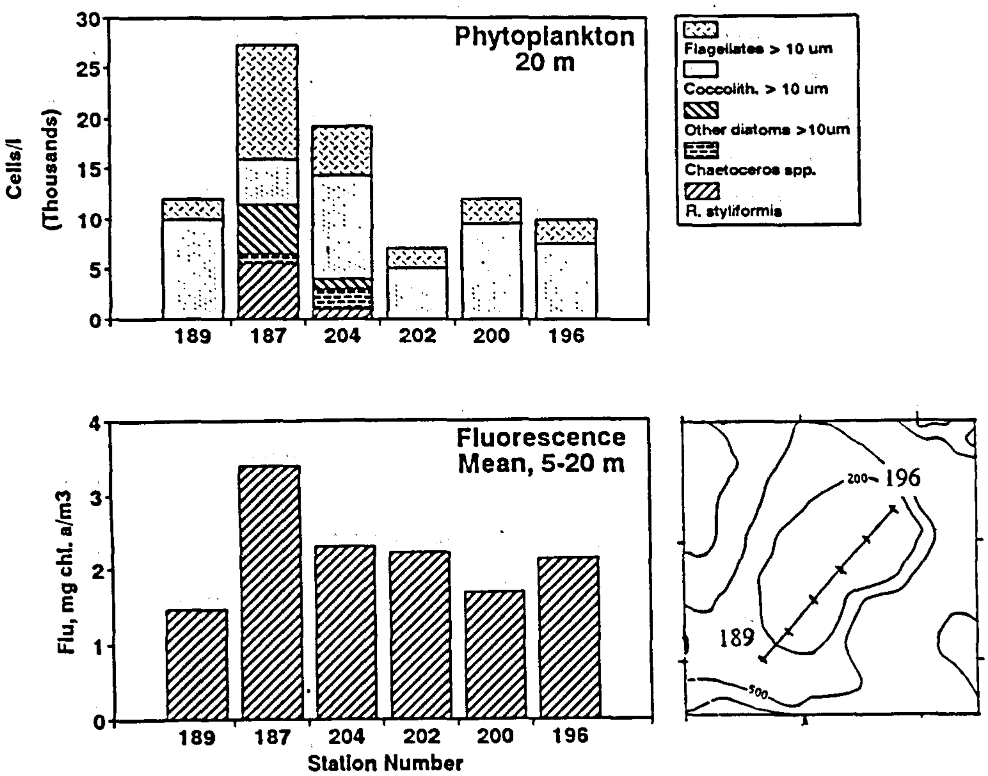


Fig. 8. Distribution of phytoplankton at 20 m depth and mean fluorescence at 5-50 m depth on Faroe Bank 25.-28. June 1992.

Zooplankton

The mean biomass of mesozooplankton in the upper 50 meters, respectively on the Faroe Bank and in the water around in spring and summer 1992 is shown in Figure 9. It increased much in the spring, both on the Bank and in the surrounding area but was always lower on the Bank than outside it. Especially it can be noted that the biomass on the Bank decreased from late May to early July while it increased in the water around it.

The dominating copepod species during spring was *Calanus finmarchicus* but it decreased much in concentration in June. Instead the concentration of other smaller copepod species, mainly *Pseudocalanus sp.* and the concentration of Cladocera increased.

The reproduction of *Calanus finmarchicus* seemed to start in late March or early April (Fig. 10). In early May the majority was as nauplii and copepodit stages I and II and in late May they were mainly as copepodits I-III. In early June the majority of the copepodits was stages III and IV and in late June stage IV and V. No samplings of copepods on the Faroe Bank were made later this summer but based on Figure 10 we have to assume that spawning of a second generation has startet in early July.

During spring and summer 1992 the zooplankton composition on the Faroe Bank differed more and more from that in the surrounding area (Fig. 11). Especially it may be noten that the concentration of *Calanus finmarchicus* decreased much in late March-early June and the concentrations of *Pseudocalanus sp.* and Cladocera increased.

The decreased zooplankton biomass on the Faroe Bank in June therefore was because of decreased concentration of *Calanus finmarchicus*. Figure 12 shows the zooplankton biomass and distribution of two sections on the Bank during June 5.-8. 1992. It can be seen that the biomass clearly followed the percentage concentration of this species. *C. finmarchicus* was the biggest of the copepods in the area and therefore affects much the biomass. A better overwiew of the percentage concentration of *C. finmarchicus* in the area can be seen on Figure 12 (right corner). In the center of the Bank this species appeared in less than 10% of the total mesozooplankton number while it increased to about 80% outside the Bank. The concentration gradients followed the front between the watermasses on the Bank and outside it and was very sharp in the southeastern area where the water on the Bank and outside move in opposite direction.

In summer 1991 the situation was quite different. The difference in zooplankton species composition between the Bank and outside it was not as distinct as the year before (Fig. 13). Especially it can be noted that neither the percentage concentration of *Calanus finmarchicus* nor the total zooplankton biomass decreased nearly as much on the Bank compared to the surrounding area as in 1992.

The respiration rates of the zooplankton were very high during spring 1992, both on the Bank and in the water around but decreased much in June (Table 2). The weigth specific respiration rates of were generally higher on the Faroe Bank than in the surrounding areas. But since the total biomass on the bank decreased much in early June the total respiration was higher outside during this period.

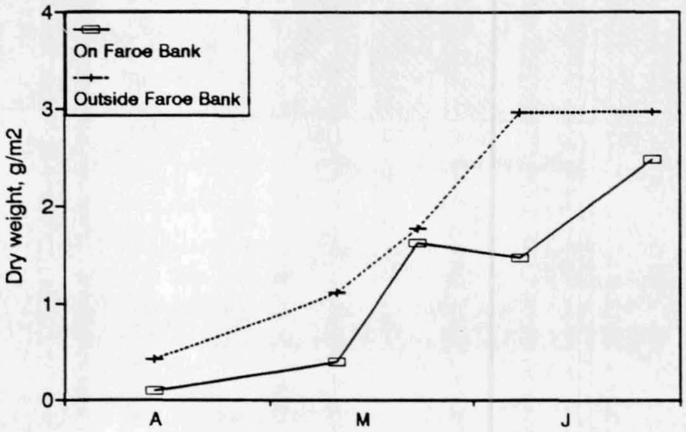


Fig. 9. Mean zooplankton biomass in the upper 50 meters depth on the Faroe Bank and the surrounding area during spring and summer 1992.

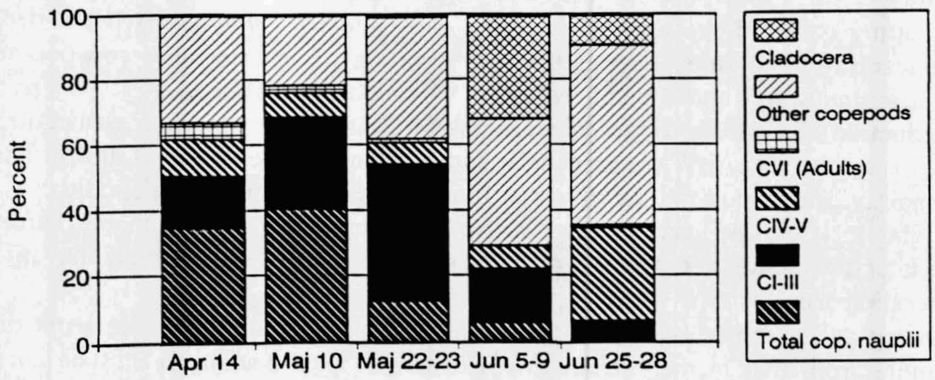


Fig. 10. Mean percentage distribution of copepod nauplii, developemental stages of Calanus finmarchicus and other copepods and Cladocera in the upper 50 meters on the Faroe Bank during spring and summer 1992.

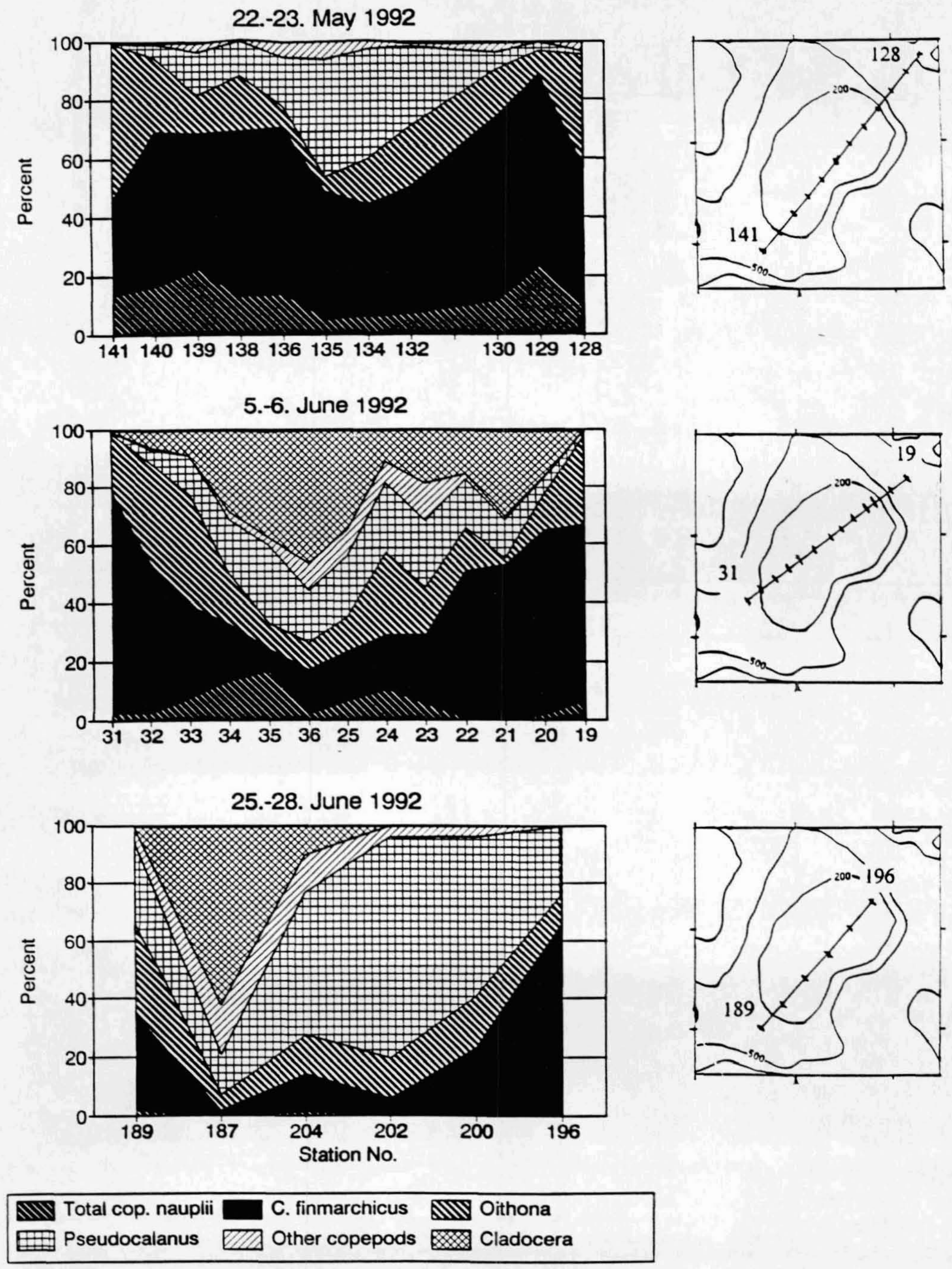


Fig. 11 Percentage distribution of zooplankton in the upper 50 meters on the Faroe Bank in May and June 1992.

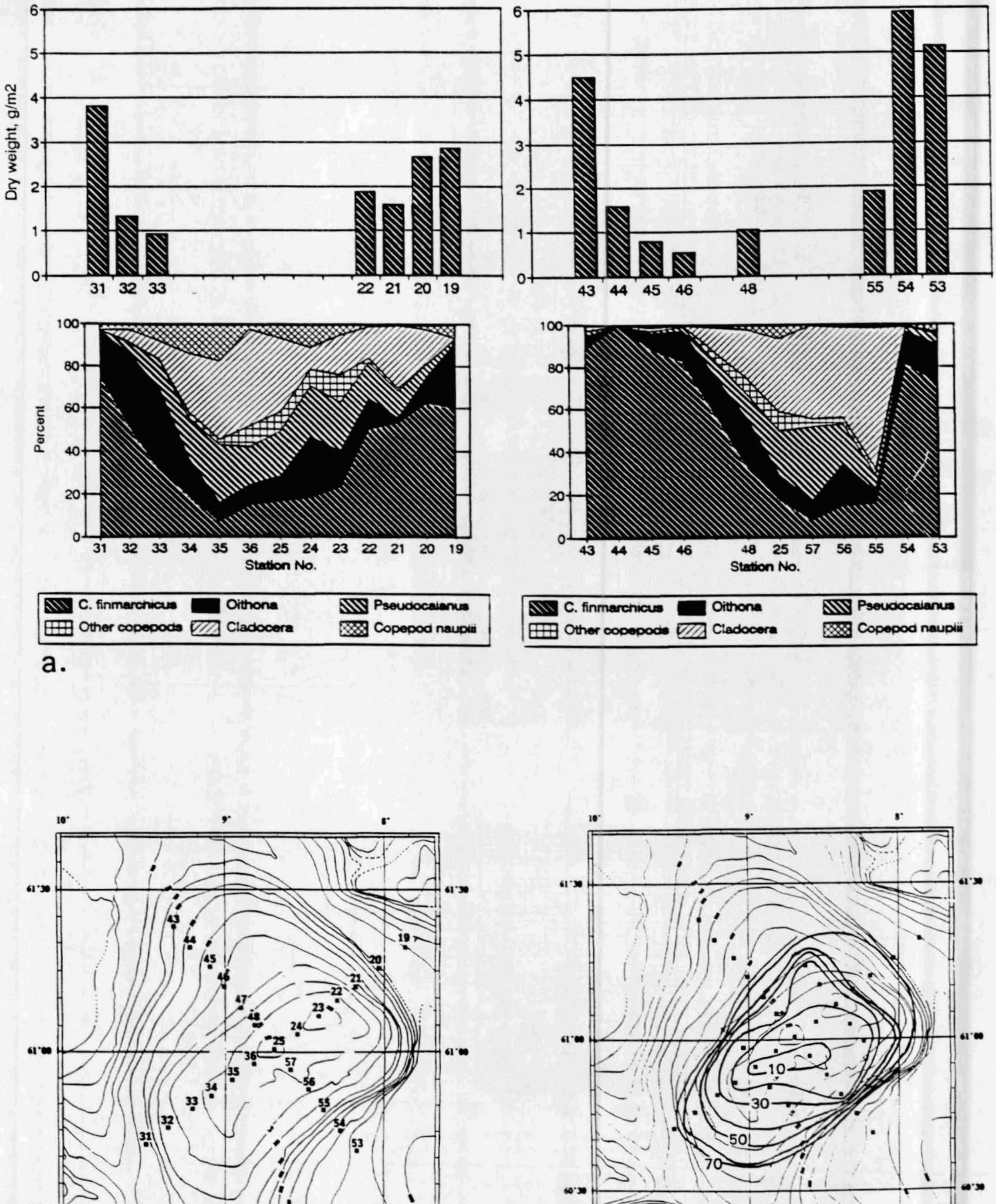


Fig. 12. Zooplankton biomass and species distribution (a), the station numbers (b) and the distribution of Calanus finmarchicus as percent of the total mesozooplankton number (c) in the upper 50 meters on the Faroe Bank during June 5.-9. 1992.

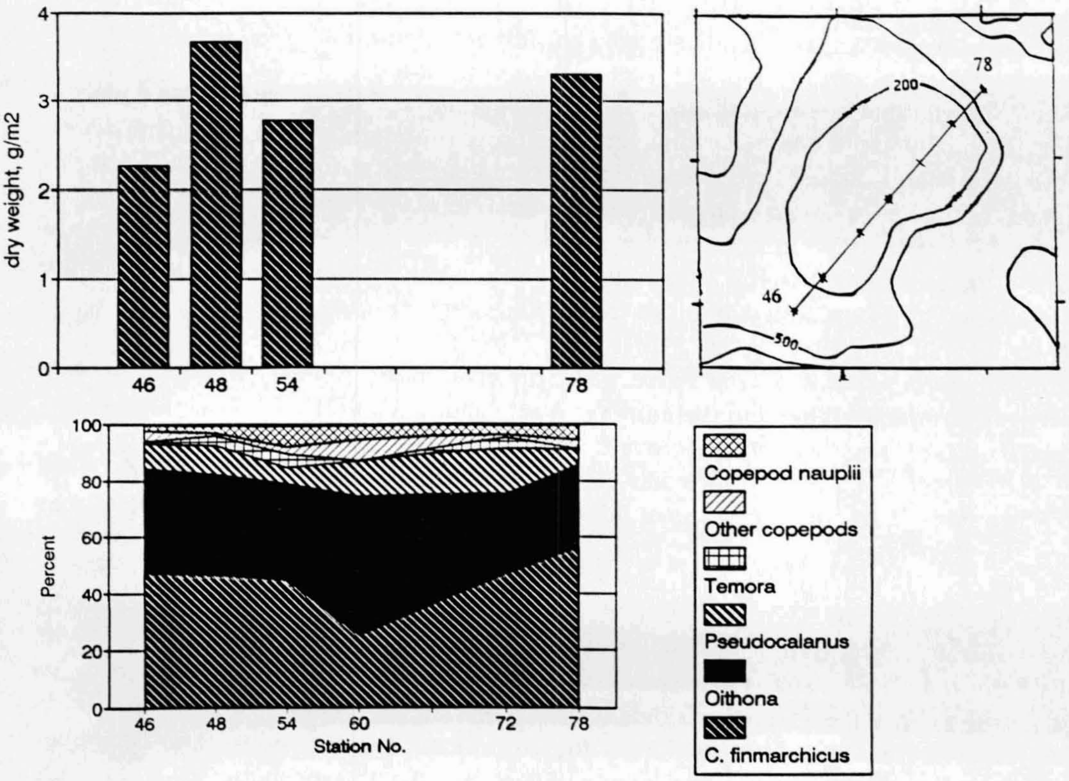


Fig. 13. Zooplankton biomass and copepod species distribution in the upper 50 meters on the Faroe Bank during July 3.-5., 1991.

Table 1. Zooplankton community respiration rates on the Faroe Bank and the surrounding area during spring and summer 1992.

Dates	Weight specific respiration		Total respiration		Calculated carbon demand	
	$gO_2/gC/day$		$gO_2/m^2/day$		$gC/m^2/day$	
	< 200 m	> 200 m	< 200 m	> 200 m	< 200 m	> 200 m
May 22.-23.	1.3	0.8	0.8	0.6	0.3	0.2
June 5.-9.	1.0	1.3	0.6	1.5	0.2	0.5
June 25.-28	0.6	0.3	0.6	0.3	0.2	0.1

DISCUSSION

Environmental influences on the phytoplankton

The phytoplankton composition on the Faroe Bank differs very much from that in the surrounding area. Provided that the silicate concentration on the Bank is sufficient high the diatom growth and concentration is much higher than outside the Bank.

It is well known that hydrographic conditions highly influence the phytoplankton composition. Normally large chain-forming diatoms are more abundant in turbulent water, while dinoflagellates and smaller flagellates are more common in stratified water. Most diatoms are large and not able to swim. They therefore tend to sink. Turbulence og upwelling therefore may be a necessary requirement for sustainment. But in stratified water turbulence is damped and diatoms not favored. Dinoflagellates and smaller flagellates, on the other hand, normally are able to swim and therefore these algae are favoured in stratified waters (Margalef, 1978; Holligan, 1987; Fogg, 1991).

The hydrographic conditions on the Faroe Bank therefore clearly are the reasons for, that diatoms were in so much higher numbers on the Bank than outside it.

There are however also shown differences in the growth rates between diatoms and flagellates so diatoms have a growth rate than flagellates (Thomas *et al.*, 1978; Langdon, 1988). Therefore, provided that the environmental conditions for diatoms are good the may outcompete the flagellates.

Egge and Aksnes (1992) found that silicate concentrations may be a regulating nutrient in phytoplankton competition. They found that diatoms, as a group, were outcompeted by flagellates at silicate concentrations below a treshold of about 2μM. This seems to agree with our results from the Faroe Bank. In early June 1992 the concentrations had decreased below this value and the concentrations of diatoms were decreasing.

The spring bloom seemed to start earlier on the Faroe Bank than outside it and was much stronger than in the surrounding water. One main reason for this probably is better light conditions on the Bank. According to Sverdrups theory, the spring bloom can only start when the depth of the upper mixed layer is less than the critical depth. Because of the relatively shallow depth on the Faroe Bank the critical depth may very well be deeper than the bottom depth during early spring. Therefore the spring bloom developement may be possible on the Faroe Bank even before the summer termocline makes it possible outside the Bank.

Another reason for why the spring bloom is stronger on the Faroe Bank than outside it may be that diatoms usually have a higher growth rate than flagellates.

The higher phytoplankton production on the Bank highly affected the nutrient. This was especially the case in 1992 when the nutrient concentrations decreased very much and became much lower than outside the Bank. The high production of diatoms caused that the silicate concentrations decreased to very low levels during spring and early summer 1992 to very low levels. This resulted in that the diatom populations collapsed in June 1992.

In 1991 this did not happen. On contrary the diatoms continued to grow as late as in July. The reason for this can either have been that the diatom production have been less in spring and summer 1991 than in 1992 or that the watermasses on the Bank have been less isolated that year. But since the concentration of diatoms was high in early summer 1991 and the copepod concentrations and therefore also the predation pressure on the diatoms probably have been higher in 1991 than in 1992, there is no reason to beleeve that the higher silicate concentration in the summer 1991 mainly was because of less primary productivity. On contrary the isolines on Figures 2 and 3 indicate a higher isolation of the watermasses on the Faroe Bank in summer 1992 than in 1991. There therefore probably have been less inport of nutrient-rich water to the Faroe Bank in summer 1992 than in 1991. This has affected very much both the "new" primary production, the diatom production and the phytoplankton composition. A high "new" primary production therefore depends on the import of nutrient-rich water to the Bank.

The fact that diatoms were only found in high concentrations in the soutwestern part and in smaller concentrations in the northwestern part of the Bank in late June 1992 can mean that new (silicate-rich) water was entering the Bank on the south-western part.

No measurements have been made of the primary production on the Bank, but from the decrease of the nutrient concentration the "new" production in spring and early summer 1992 can be estimated. The winter concentration of nitrate is about 12 μmol/l and in early june it had decreased to about 6 μmol/l. Assuming a mean depth of about 120 meters on the Bank and a C/N ratio in the phytoplankton of 106/16, the "new" primary production from the start of the production in spring and to early june have been about 57 gC/m^2. From this it can be estimated that the mean "new" production in spring and early summer has been about 1.4-2 gC/m^2/day. In addition to this comes input of nutrients from outside the Bank which are assumed to have been of minor importance compared to the production based on the nutrient store on the Bank during this period. It therefore is clear that the primary productivity on the Faroe Bank during the spring bloom period has been very high. The phytoplankton was mainly diatoms. This makes potential for the short classical food chain.

Zooplankton distribution, biomasses and metabolic activities

During spring and early summer *Calanus finmarchicus* was the dominant copepod on the Faroe Bank. The spawning started in March-April and this generation is estimated to be adult in mid summer. This also agrees with investigations of developemental times, made by Thompson (1982) and Tande (1988). In late spring and early summer other species, mainly *Pseudocalanus sp.* became more important. The species composition on the bank differed more and more from that in the surrounding water during spring. The possibilities for survival of the copepods therefore have been different on the Bank than outside it. Furthermore the frontal system around the bank has prevented import of new animals to the Bank.

It has earlier been shown that the zooplankton metabolic rate depends much on the food available. The size of primary producers is also found to be important. Copepods feed mainly on phytoplankton larger than 5-10 μm while small phytoplankton on the other hand may enter the microbial loop (e.g. Azam *et al.*, 1983; Fencel, 1988; Nielsen and Richardson, 1989; Kiørboe *et al.*, 1990). There seems to be a high production of large phytoplankton on the Faroe Bank, based largely on "new" production. This makes potential for the short classical food chain. It therefore is not surprising that the mean weight specific respiration rate was higher on the Faroe Bank than outside it.

The respiration rates of the copepods were very high during the spring and early summer, both on the Faroe Bank and in the surrounded water. The rates were high, and the reason for this probably was the very high phytoplankton concentration at this time. The measurements were carried out during the spring bloom when the algal concentrations were very high, both on the Bank and in the surrounded water. In late june, when the concentrations had decreased, the weight specific respiration rates also decreased and were only high on the southwestern part of the Bank. This was also the only place, were diatom concentrations were high at this time (Fig. 8).

The concentration of *Calanus finmarchicus* decreased very much on the Faroe Bank in teh Period from late May to early June and remained low the rest of June 1992. The reason for this may be that there has been a specific heavy predation on the biggest copepods on the Bank (which was *Calanus finmarchicus*) and that this predation have been higher than the import of new individuals from the surrounding water. The majority of this species was in stages CIV and CV during June 1992.

When the same decrease in the concentrations of *C. finmarchicus* was not found in 1991 this may have been because of less predation on and/or because of higher import of new animals this year.

LITERATURE CITED.

Azam, F., T. Fenchel, Fenchel, T., Field, J. G.,Gray, J. S. Gray, J. S., Meyer-Reil, L. A., Tingstad, F. (1983). The ecological role of water-column microbes in the sea. Mar. Ecol. Prog. Ser. 10: 257-263.

Baltic Marine Biologists (1979). Recommendations on methods for marine biological studies in the Baltic Sea. Phytoplankton and chlorophyll. Working group 9. Ed.: L. Edler. The Baltic Marine Publications No. 5, 1-38.

Egge, J. K., Aksnes, D. L. (1992). Silicate as regulating nutrient in phytoplankton competition. Mar. Ecol. Prog. Ser. 83: 281-289.

Fencel, T. (1988). Marine plankton food chains. Ann. Rev. Ecol. Syst. 19: 19-38.

Fogg. G. E. (1991). The phytoplankton ways of life. New Phytol. 118: 191-232.

Grasshoff, K., Ehrhardt, M., Kremling K. (Eds.) (1983). Methods for Seawater Analysis. Second, revised and extended edition. Verlag Chemie. 419 pp.

Hansen, B., Ellett, D., Meldrum, D. (1986). Evidence for an Anticyclonic circulation on Faroe Bank. ICES C.M. 1986/C:15, 1-15. (Mimeo.)

Hansen, B., Kristiansen, A., Reinert, J. (1990). Cod and haddock in Faroese waters and possible climatic influences on them. ICES C.M. 1990/ G:33, 1-23. (Mimeo.)

Hansen, B., Meldrum, D., Ellett, D. (1991). Satellite-tracked drogue paths over Faroe Bank and the Faroe-Icland Ridge. ICES C.M. 1991/C:25, 1-13. (Mimeo.)

Hay, S. J. Kiørboe, T., A. Matthews (1991). Zooplankton biomasses and production in the North Sea during the Autumn Circulation Experiment, October 1987-March 1988. Cont. Shelf. Res. 11(12): 1453-1476

Holligan, P. M. (1987). The physical environment of exceptional phytoplankton blooms in the Northeast Atlantic. Rapp. P.-v. Réun Cons. Int. Explor. Mer, 187: 9-18.

Jamieson, A. and Birley, A. J. (1989). The demography of haemoglobin polymorphism in the Atlantic cod, *Gadus morhua* L., J. Fish Biol. 35 (supl. A): 193-204.

Jeffrey, S. W., Humphrey, G. F. (1975). New spectrophotometric equations for determining chlorophylls a, b, c_1 and c_2 in higher plants, algae and natural phytoplankton. Biochem. Physiol. Pflanzen (BPP). 167.

Jones, B. W. (1966). The cod and the cod fishery at Faroes. Fishery Invest. London., Ser. II, 24(5).

Kiørboe, T., Kaas, H., Kruse, B., Møhlenberg, F., Tiselius, P. Ærtebjerg, G. (1990). The structure of the pelagic food web in relation to water column structure in the Skagerrak. Mar. Ecol. Prog. Ser. 59: 19-32.

Langdon, C. (1988). On the causes of interspecific differences in the growth-irradiance rela tionship for phytoplankton. II. A general review. J. Plankton Res. 10: 1291-1312.

Lastein, L. (1992). Hydrographic investigations on the Faroe Bank 1985-1992. ICES 1992/C:13, 1-17. (mimeo.)

Margalef, R. (1978). Life-forms of phytoplankton as survival alternatives in an unstable en vironment. Oceanologica Acta, 1(4): 493-509.

Nielsen, T. G., Richardson, K. (1989). Food chain structure of the North Sea pæankton communities: seasonal variations of the role of the mocrobial loop. Mar. Ecol. Prog. Ser. 56: 75-87.

Omori, M., Ikeda, T. (1984). Methods in marine zooplankton ecology. John Wiley & Sons. 332 pp.

Parsons, T. R., Takahashi M. and Hargrave, B. (1977). Biological oceanographic processes. 2nd. ed. Pergamon Press, Oxford, 332 pp.

Paulsen, O. (1909). Plankton investigation in the waters around Iceland and the North Atlantic in 1904. Medd. Komm. Havund. Ser.: Plankton, Bd. 1, No. 8., 1-57.

Paulsen, O. (1918). Plankton and other biological investigations in the sea around the Færoes in 1913. Medd. Komm. Havund. Ser.: Plankton, Bd. 1, No. 13., 1-27.

Schmidt, J. (1930). Racal investigations. X. The Atlantic cod (*Gadus callarias* L.) and local races of the same. Comptes rendus des travaux du Laboratorie Carlsberg, 18, 6.

Tande, K. S. (1988). Aspects of developemental an mortality rates in *Calanus finmarchicus* related to equipropotional developement. Mar. Ecol. Prog. Ser. 44: 51-58.

Thomas, W. A., Dodson, A. N., Reid, F. M. H. (1978). Diatom productivity compared to other algae in natural marine phytoplankton assemblages. J. Phycol. 14: 250-253.

Thompson, B. M. (1982). Growth and developement of *Calanus finmarchicus* and *Calanus sp.* in the laboratory. J. mar. biol. Ass. U. K. 62: 359-372.