ICES CM 2002/N:18

Winter distribution of microzooplankton in the Nordic Seas

Else Nøst Hegseth[1] and Jan Backhaus[2]

[1]The Norwegian College of Fishery Science, Univ. Tromsø, 9037 Tromsø, Norway
[2]Institute of Oceanography, University of Hamburg, Troplowitzstr.7, D-22529 Hamburg, Germany

emailadr. for correspondance: elseh@nfh.uit.no

INTRODUCTION

Winter investigations of both phytoplankton and microzooplankton in open oceans are few, hence we know very little about the processes taking place outside the traditional growth seasons. However, winter survival is crucial to all organisms, and to get a better understanding of the winter processes, cruises to the Nordic Seas were organized during two winter seasons (1999 and 2000). The purpose was primarily to study the connection between winter convection and phytoplankton, based on knowledge from a winter study of shelf areas in Northern Norway (Backhaus et al. 1999). From this study we knew that the deep convection was a vital process for initiation of the spring bloom in shallow areas. Now we wanted to investigate the effects on plankton in open oceans where the convective mixing was supposed to transport phytoplankton cells up and down in the water column and keeping them from sinking to the bottom in these deep areas. Additional to the phytoplankton we also collected microzooplankton in our samples, and that gave us an opportunity to include a study of the smallest zooplankton forms in relation to both convective mixing and phytoplankton distribution during winter

MATERIAL AND METHODS

Plankton was collected during three winter cruises to the North Atlantic Ocean in March 1999, to the Norwegian Sea in April 1999 and to the Greenland Sea in March 2000. Temperature and salinity were measured with a Seabird CTD, and fluorescence (FL) with a FL sensor. Chlorophyll was measured fluorometrically onboard in water samples from 10-15 depths within and below the Convectively Mixed Layer (CML). Microzooplankton was sampled along with phytoplankton in 5 and 10 l Niskin water bottles from 4-5 depths within and below the CML. All water from each sampling depth (180 l) was filtered through a plankton net (25 µm mesh size) on deck, concentrated to a 250 ml sample. Subsamples of 50 ml were counted in an inverted microscope

RESULTS

North Atlantic Ocean

The depth of the CML varied from 250 to 800 m depending on the surface heat loss. Water temperature in the CML varied between 7.5° and 9° C.
The chlorophyll (0.5-0.6 µg l^{-1}) was confined to the CML, and vertical distribution of chlorophyll and nauplii in the CML were closely related (Fig. 1). Correlation of nauplii and large cells (diatoms, dinoflagellates) in the CML was good, r = 0.77 (Fig. 2). Most of the nauplii varied between 65 and 130 µm in size, and were dominated by the size group of 65-100 µm. The majority probably belonged to the genera *Microcalanus* (and *Paracalanus?),* and tha largest one to *Oithona.* Very little chl and lower numbers of nauplii were found below the CML (Tab. 1).
Copepodites, mostly *Oithona* spp., were not related to chlorophyll distribution, but found in equal numbers above and below the deep thermocline

Table 1. Abundance of nauplii and copepodites in the North Atlantic winter waters within and below the Convectively Mixed Layer (CML)

Area	Av. No. nauplii (no. m^{-3})	Av. no. copepodites (no. m^{-3})
North Atlantic Ocean – within the CML	1500	450
North Atlantic Ocean – below the CML	275	315

Norwegian Sea

The depth of the CML was shallower than for the Atlantic Ocean, the deep thermocline was normally found between 150 and 200 m. Water temperature within the CML varied from 1° to 3° C.
The chlorophyll (0.5-1.5 µg l^{-1}) was found within the CML. Vertical distribution of chlorophyll and nauplii in the CML were not closely related. Max number of nauplii was found at about 100 m depth regardless of chl distribution (Fig. 3). Correlation between nauplii and the large cells (diatoms, dinoflagellates) exhibited less good correlation than for the North Atlantic, r = 0.60 (Fig. 4). The size range and species composition of the nauplii was in general the same as found for the North Atlantic Ocean. Very little chl and lower numbers of nauplii were found below the CML (Tab. 2).

Copepodites exhibited a different distribution than the nauplii, with the highest numbers below the deep thermocline.

Table 2. Abundance of nauplii and copepodites in the Norwegian Sea winter waters within and below the Convectively Mixed Layer (CML)

Area	Av. no. nauplii (no. m^{-3})	Av. no. copepodites no. m^{-3})
Norwegian Sea – within the CML	950	250
Norwegian Sea – below the CML	500	1300

Greenland Sea

The vertical mixing was deep in some areas, although no convection reaching the bottom was observed. The depth of the CML varied between 200 and 900 m, with an average of 400 m. Water temperature was in the range of 0° to –0.5° in the CML.
The vertical distribution of chlorophyll and nauplii was not correlated (Fig. 5a). Extremely low phytoplankton biomass was observed in the CML, and virtually nothing below. However, high numbers of nauplii were found within the CML, and low numbers below in the central Greenland Sea. The Atlantic water masses in the branch of the North Atlantic Current passing on the western side of Spitsbergen exhibited extremely high numbers of nauplii below the CML at 500 m depth (Fig. 5b).
No correlation between nauplii and large cells, but a relatively good correlation between nauplii and tintinnids, $r = 0.65$ (Fig. 6) was found in the CML. The size of the nauplii was comparable to the areas further south, with a dominance in the 60-100 μm range. The nauplii probably belonged to the small copepod genera *Microcalanus* and *Oithona.* Occasionally a few female *Microcalanus* were observed, in general with egg sacs. Copepod eggs were also found in low numbers.
Copepodites (*Oithona* spp.) occurred in low numbers both within and below the CML (average 90 and 50 ind. m^{-3}, respectively) (Tab. 3)

Table 3. Abundance of nauplii and copepodites in the Greenland Sea winter waters within and below the Convectively Mixed Layer (CML)

Area	Av. no. nauplii (no. m^{-3})	Av. no. copepodites no. m^{-3})
Central Greenland Sea – within the CML	2000	90
Central Greeenland Sea – below the CML	110	50
Atlantic water – below the CML –	8000	170

Distribution of *Oncaea*

The cyclopoid copepod *Oncaea* was found in a thick layer of detritus below the CML in the North Atlantic Ocean and in the Norwegian Sea (Tab. 4). The thickness of this layer is unknown, but must be at least 50-150 m.
In the Greenland Sea *Oncaea* was found within the CML except for the one station in Atlantic water, where this species was distributed below the CML

Table 4. Abundance of *Oncaea* spp. in the Nordic Seas winter waters within and below the Convectively Mixed Layer (CML)

Area	Location	Av. no m^{-3}
North Atlantic Ocean	Below the CML	300
Norwegian Sea	Below the CML	1250
Greenland Sea – Atlantic water	Below the CML	1350
Greenland Sea – central areas	Within the CML	360

DISCUSSION

Sampling of small copepods, and particularly the young stages, requires proper equipment. The first nauplii stages will probably escape even the finest standard zooplankton nets of 90 µm, and hence may be overlooked or at least greatly underestimated. The present investigation suggests that the secondary production of small copepods may be significant in the Nordic Seas in winter. At this time *C. finmarchicus* is hibernating in the deep water well below the convectively mixed layer .

The microzooplankton, mostly tintinnids and young stages of small copepods, dominated the zooplankton populations since larger zooplankton species, not just *C. finmarchicus,* are rare at this time of the year. These populations of small zooplankton probably serve as an intermediate link between the winter phytoplankton populations and larger copepods.

Both the phytoplankton and the microzooplankton seemed to be caught in the vertical, convective mixing processes, being moved up and down in the water column with frequent visits to the surface layers (Backhaus et al. 1999). As long as the convection is going on all particles, including small plankton forms, will be evenly distributed in the entire mixed layer (CML). During daytime convection often slows down, and phytoplankton in the surface layers may resume some growth. Hence the biomass in the upper layers will increase (Hegseth, unpubl.), and obviously the zooplankton are able to take advantage of this, as seen from the good correlation between the distribution of nauplii and diatoms in the North Atlantic Ocean. It is an indication that the small nauplii actually feed on the diatom populations here, in spite of low cell numbers which may still be sufficient to feed the secondary production. Larger nauplii and copepodites may also feed on the tintinnids which are present in relatively high numbers compared to large phytoplankton cell, and the tintinnids probably feed on the small flagellates which form the majority of the phytoplankton biomass in the winter waters.

The correlation between the nauplii and the diatoms were less pronounced in the Norwegian Sea, where the nauplii seemed to congregate closer to the thermocline. The reason for this is not clear. The considerably higher number of copepodites below the CML is an indication that these larger animals are able to choose their own position in the water column.

In the Greenland Sea no correlation was found between diatoms and nauplii, but this could be an effect of the extremely low diatom numbers. Still, all the phytoplankton biomass and most of the microzooplankton were found within the CML as further south. The nauplii showed a better correlation with the tintinnids, but this may be an effect of higher tintinnid abundance rather than a functional link.

The total numbers of young stages of small copepods (the sum of nauplii and copepodites) were remarkably similar in the three oceans investigated. This could mean that the number of spawning females was quite comparable and independent of water temperature and latitude. The time of spawning, however, is probably dependent of these factors as the number of copepodites were considerably lower in the Greenland Sea, and the number of eggs higher than further south. This was also the only area where females with egg sacs were observed. The time of sampling was similar in the North Atlantic Ocean and in the Greenland Sea, hence the difference in population stage development represented the difference in time of spawning and maybe also a slower growth rate of the young stages in the low temperature waters of the Greenland Sea.

The *Oncaea* populations seemed to spend the winter below the deep thermocline in areas south of the Arctic Circle. Deep distribution patterns have also been observed in earlier investigations (Wiborg 1955). Here they probably survived by feeding on an extensive detritus layer.
North of the Arctic Circle no such detritus layer was observed, rather the detritus was distributed all over the CML in considerable amounts. The *Oncaea* populations exhibited a similar distribution.

REFERENCES

Backhaus,JO , Wehde H, EN Hegseth, J Kämpf(1999): "'Phyto-convection': the role of oceanic convection in primary production." Marine Ecology Progress Series Vol. 189:pp 77-92.
Wiborg, KF (1955). Zooplankton in relation to hydrography in the Norwegian Sea. Fisk. Dir. Skr. Ser. Havunders. XI: 1-66.

FIGURES

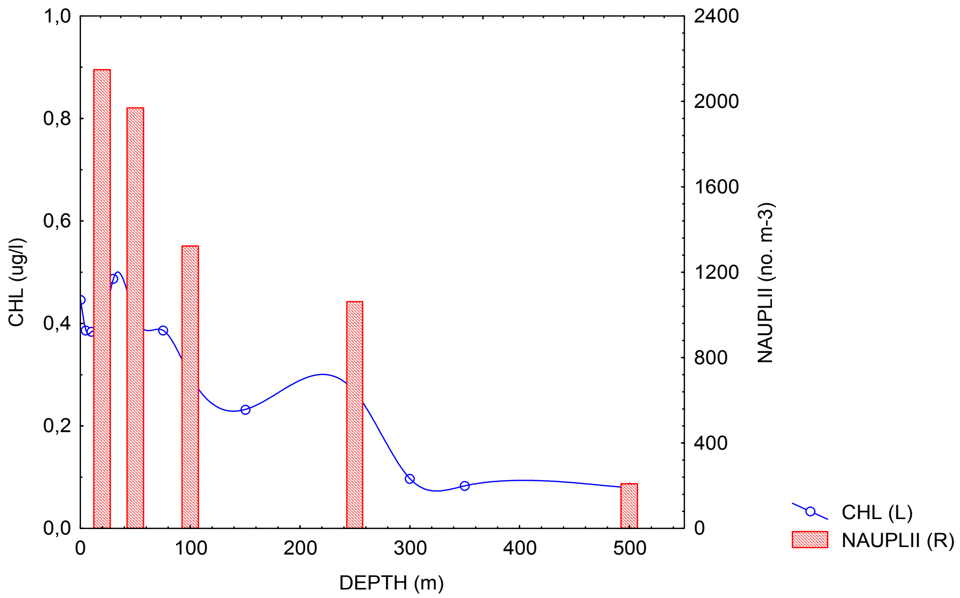

Fig. 1. Vertical distribution of chlorophyll and nauplii in the North Atlantic Ocean in March 1999.

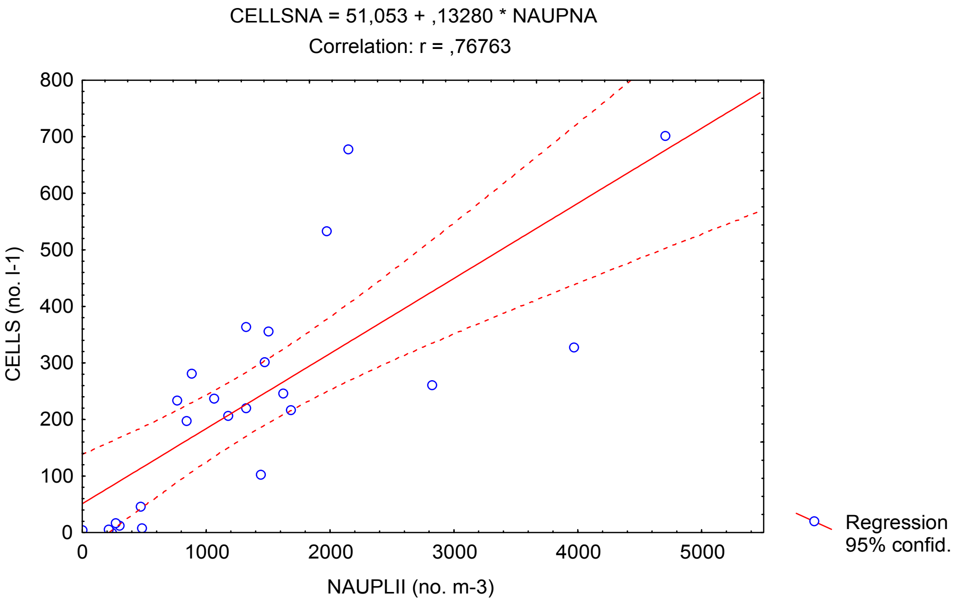

Fig 2. Correlation between nauplii and large phytoplankton cells (diatoms, dinoflagellates) in the North Atlantic Ocean in March 1999.

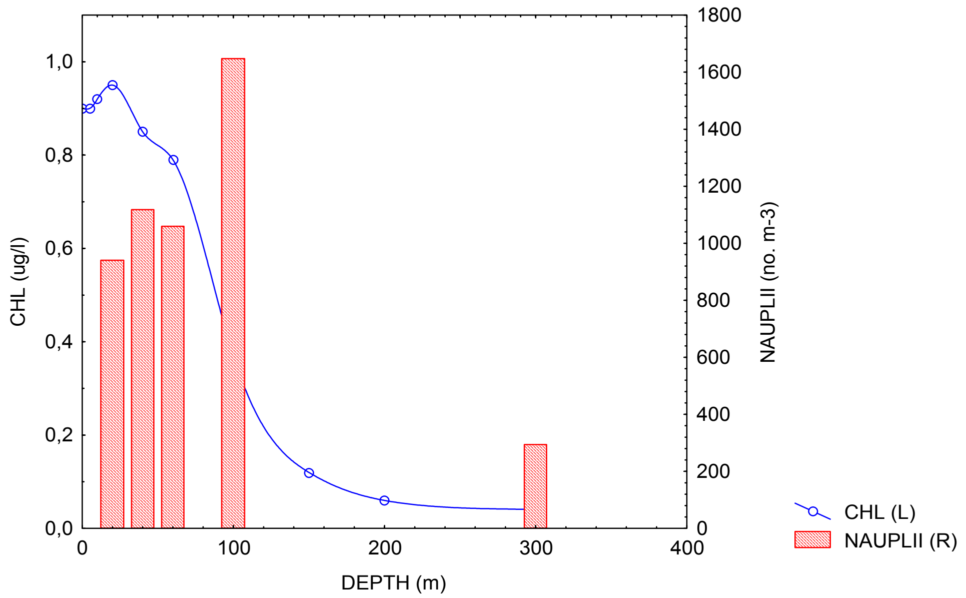

Fig. 3. Vertical distribution of chlorophyll and nauplii in the Norwegian Sea in April 1999.

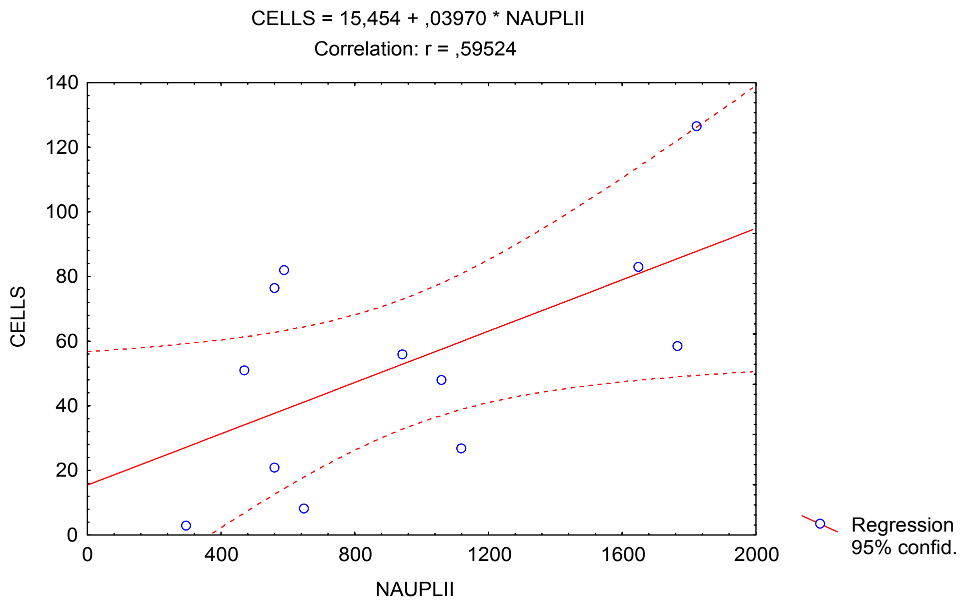

Fig 4. Correlation between nauplii and large phytoplankton cells (diatoms, dinoflagellates) in the Norwegian Sea in April 1999.

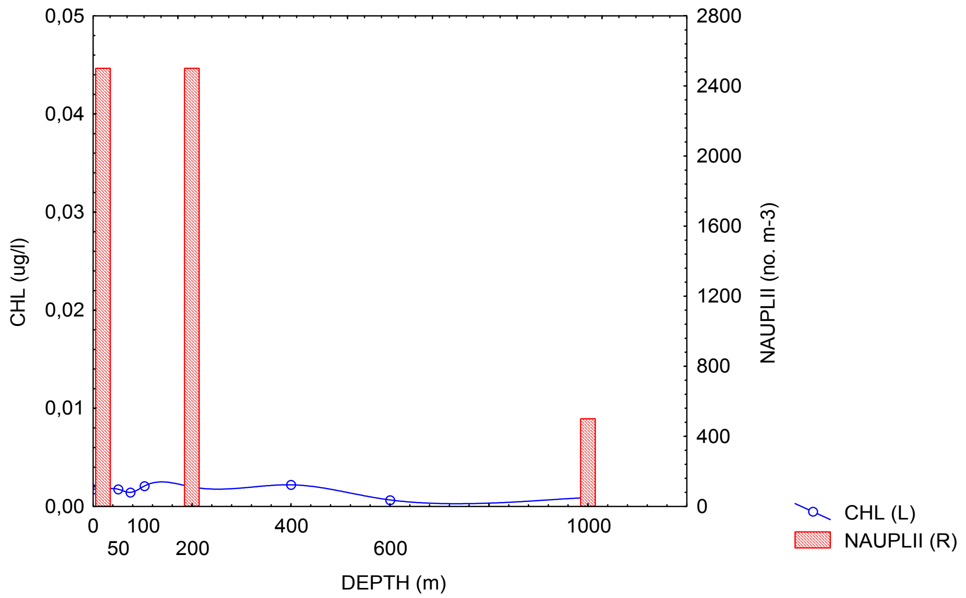

Fig. 5. Vertical distribution of chlorophyll and nauplii in the central Greenland Sea in March 2000.

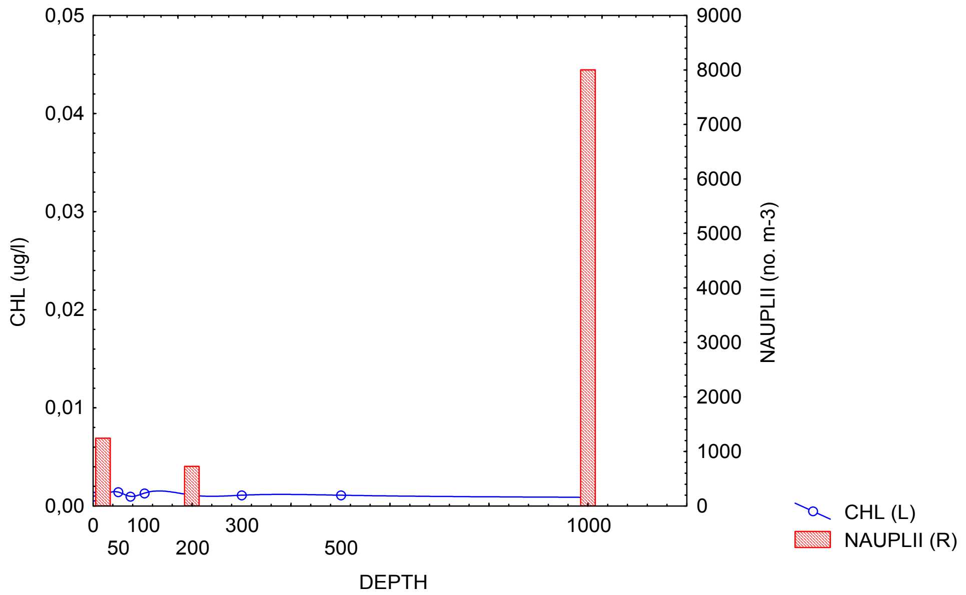

Fig. 6. Vertical distribution of chlorophyll and nauplii in Atlantic waters of the eastern Greenland Sea in March 2000.

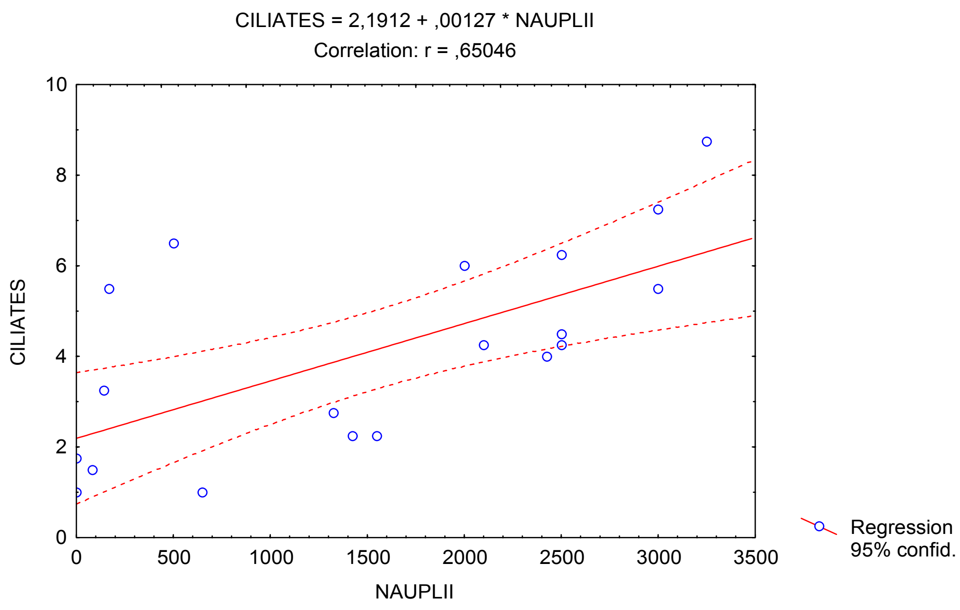

Fig 7. Correlation between nauplii and tintinnids in the Greenland Sea in March 2000.