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Interannual variability of non-crustacean macrozooplankton in the surface waters of the northern Norwegian Sea and the Svalbard shelf

ABSTRACT: Non-crustacean plankton was studied during summer cruises to the northern Norwegian Sea from 1996 to 1998. The dominant species in the investigated area were *Aglantha digitale* (Hydrozoa) and *Sagitta elegans* (Chaetognatha). The average density, mean biomass, and interannual changes of zooplankton are presented against the background of sea temperatures. The results of this work indicate the very strong inter-annual variability of non-crustacean zooplankton abundance. Correlations with minor changes in sea temperature were noted only for hydromedusae.

Key words: Arctic, macrozooplankton.

Introduction

Non-crustacean macrozooplankton are pelagic organisms devoid of chitinous skeleton and composed mainly of water. Hydromedusae, ctenophores, chaetognaths, and pteropods, among others, belong to this group.

The present work describes the abundance and biomass of the most abundant gelatinous macrozooplankton species collected in the north Norwegian and Greenland seas. Few studies describe the vertical distribution and abundance of macroplankton, even though these organisms can be predominant in the plankton biomass (Sameoto 1987, Clarke and Peck 1990).

Chaetognaths, constituting the bulk of the non-crustacean zooplankton, are major planktonic carnivores in Arctic waters, both in terms of numbers and biomass (Longhurst 1985). Their prey consists primarily of copepods, but other forms of zooplankton are also eaten (Pearre 1981). Field studies have shown that

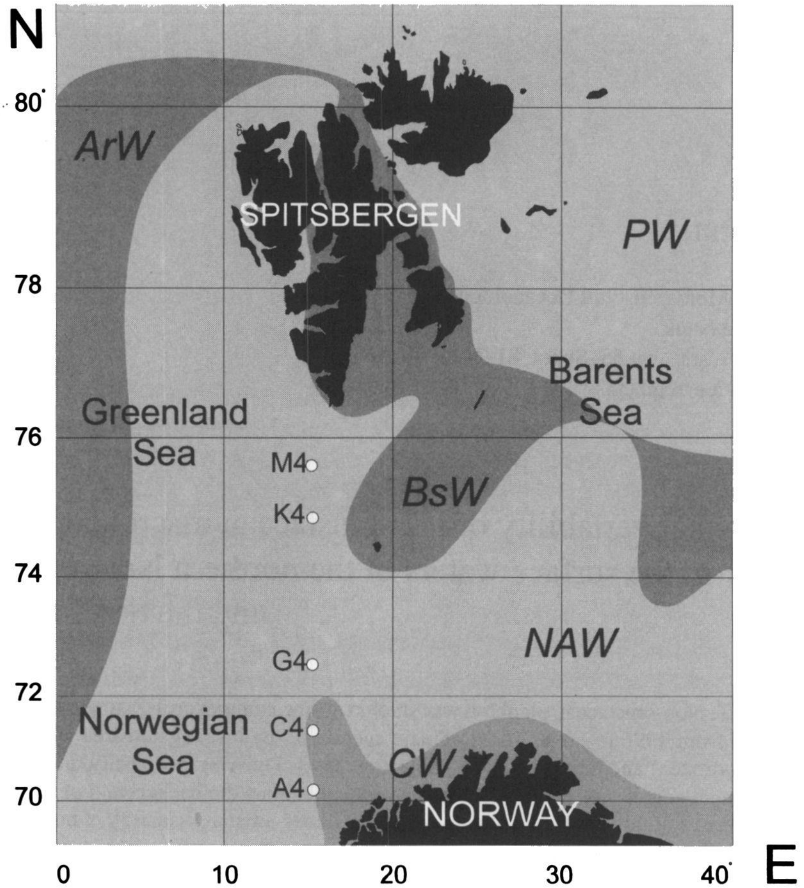

Fig. 1. The grid of sampling stations, water masses and fronts in Barents Sea region (after Koszteyn *et al.* 1995): *PW* – Polar Water, *ArW* – Arctic Water, *NAW* – North Atlantic Water, *BsW* – Barents Sea Water, *CW* – Coastal Water.

chaetognaths can have a major impact on the population of their copepod prey (Sameoto 1971, 1973).

The aim of this work is to assess the interannual changes in non-crustacean plankton abundance and biomass in the European Arctic.

Materials and methods

Study area. — The area between Nordkapp and Spitsbergen (70° to 76° N and 15° E) constitutes the border between the Arctic and Sub-arctic marine zoogeographical zones (Dunbar 1968). Three water masses are present in this area: Atlantic (West Spitsbergen Current and South Spitsbergen Current), Arctic (Barents Current), and coastal waters of mixed origin (Sorkapp Current) (Koszteyn *et al.* 1995) (Fig. 1). Year-to-year fluctuations in the volume of water transported

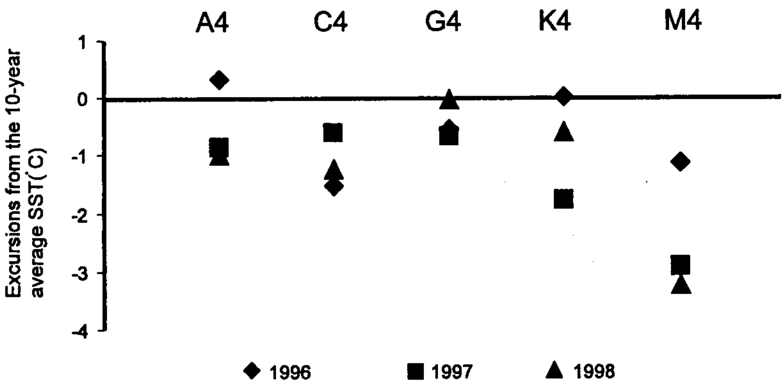

Fig. 2. Thick line shows 10-year average of Sea Surface Temperature, symbols shows positive (above the line) and negative (below) excursions from the average at each station in given year.

(Mandel 1976), as well as the geographical position (Taylor and Stephens 1980) of the North Atlantic Current-West Spitsbergen Current system cause the irregular appearance of "cold" and "warm" years in the investigated area (Węsławski and Adamski 1987, Piechura and Walczowski 1996).

Throughout the study period, the sampling area was characterised by variable sea surface temperature. The variability was very high when compared to inter-annual average temperatures (Fig. 2).

Methods. — Data were collected during summer cruises of the r/v *Oceania* in July of 1996, 1997, and 1998 (Fig. 1). Zooplankton was sampled with a WP-2 net with 200 mm mesh size gauze and a closing device. The net was hauled vertically in the 0–50 m layer, in the same geographical location (1996-fourteen samples, 1997-nine and 1998-seven) (Fig. 1). The size and weight of planktonic animals were assessed in the materials preserved in 4% formalin and identified 6 to12 months after collection. Samples were examined under a stereoscopic microscope. The length of animals, excluding the tentacles, was measured to the nearest 0.1 mm. Wet formalin weight was measured for 2-mm length classes. The dry weight was measured with an accuracy of 1 mg after specimens being oven-dried at 60°C for 24 hours. The biomass of plankton species was calculated by multiplying the density of a given size class in samples by its respective mean individual weight (Tab. 1). Simple correlation analysis was performed to examine the relationship between animal abundance and temperatures (Sea Surface Temperature-SST). The data were logarithmically transformed.

Results

Hydromedusa *Aglantha digitale* (Müller, 1776) (mean density 11 ind.m^{-3}), a chaetognath *Eukrohnia hamata* (Möbius, 1875) (4 ind.m^{-3}), and a pteropod

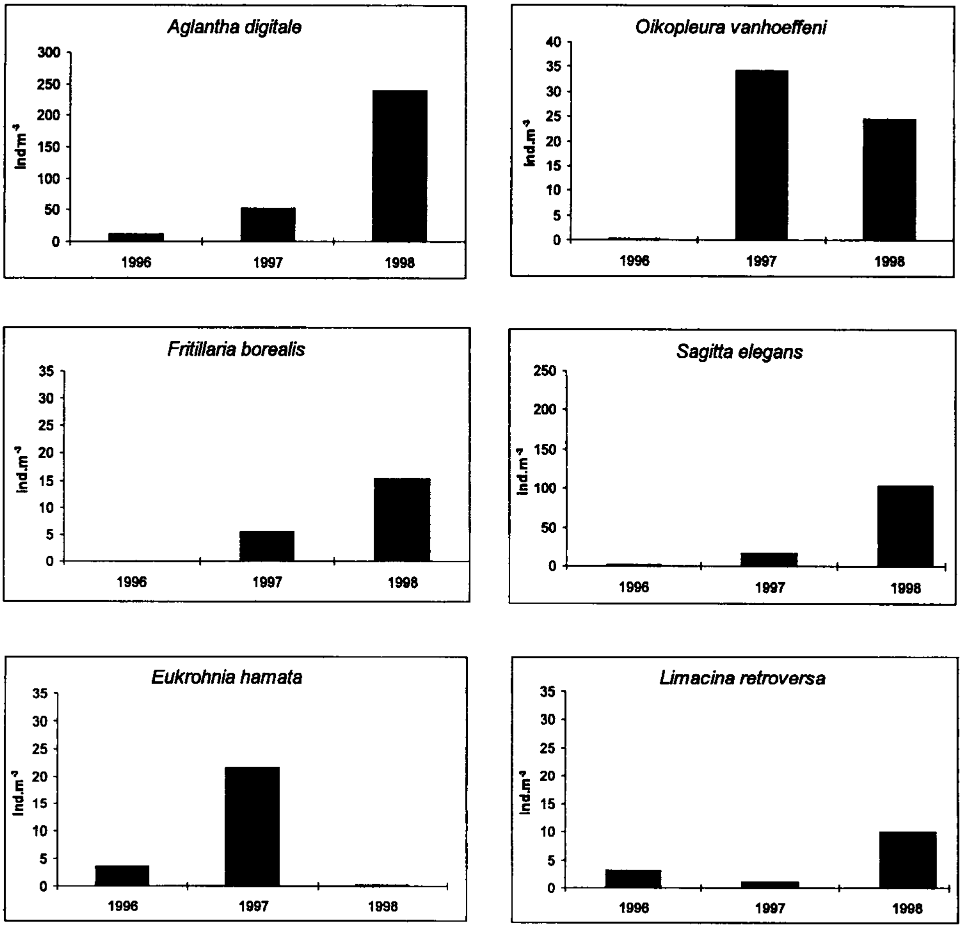

Fig. 3. Average abundance [ind.m^{-3}] of non-crustacean species at all stations of the Norwegian Sea, during three years of observations.

Limacina retroversa (Fleming, 1823) were the only comparatively abundant zooplankton species found in the samples from 1996 (Fig. 3). In the next year *E. hamata* and *A.digitale* were five times more abundant; appendicularians *Oikopleura vanhoeffeni* (Lohmann, 1896) (34 ind.m^{-3}) and *Fritillaria borealis* (Lohmann, 1896) (5 ind.m^{-3}) were also present. All species were also observed in 1998, including *A. digitale* (238 ind.m^{-3}), *Sagitta elegans* (Verrill 1873) (103 ind.m^{-3}), *O. vanhoeffeni* (25 ind.m^{-3}), *F. borealis* (15 ind.m^{-3}) and even the pteropod *Clione limacina* (Phipps, 1744) (three individuals only), however the abundance of *E. hamata* was very low (Fig. 3). The pteropod, *Limacina retroversa*, was observed in all three years and was rather abundant in 1998 (10 ind.m^{-3}) while only single specimens of *L. helicina* (Phipps, 1774) were found in 1997.

Table 1
Average biomass of non-crustacean plankton [mg dw.m^{-3}] collected in Norway Sea.

SPECIES	Biomass [mg dw.m^{-3}]		
	1996	1997	1998
Aglantha digitale	1.5	3.5	53
Sagitta elegans	0.1	1.5	17
Eukrohnia hamata	3	2.5	4
Oikopleura vanhoeffeni	0.02	2	2
Fritillaria borealis	0.05	2.3	2

The mean biomass of zooplankton was the lowest in 1996 and the highest in 1998, with most of the biomass being constituted by *A. digitale*. In 1996 the mean biomass of *A.digitale* was 1.5 mg dw m^{-3} and in 1998 53 mg dw m^{-3}. The biomass of *S. elegans* was 0.1 mg dw m^{-3} in 1996 and 17 mg dw m^{-3} in 1998 (Tab. 1).

Of the eight macroplankton species studied here, *S. elegans* was the second most abundant (Fig. 3). The chaetognaths were the subdominant invertebrate predators in terms of both numbers and biomass at all stations.

Abundance of *E. hamata* was relatively high in 1997 when the abundance of *S. elegans* was low. A reverse situation was observed in 1998 when the abundance of *S. elegans* was high and *E. hamata* low (Fig. 3).

A significant linear correlation was found between the abundance of *A. digitale* and Sea Surface Temperature (measured at 1 m depth) ($r = 0.81$; $p < 0.001$) and temperatures measured under the thermocline ($r = 0.6$; $p < 0.01$). No important correlation was found between temperatures and abundance of other species.

Discussion

Investigations of the non-crustacean plankton in the studied area, carried out in 1996–1998, indicated low density and biomass in 1996 and relatively high in 1998.

The occurrence of zooplankton depends mainly on two factors; the first is food availability, which, in this case, is mesozooplankton (populations of *Calanus* spp.) (Pages and Gonzalez 1996). In the years studied the average concentrations of *Calanus* spp. ranged from 53 ind.m^{-3} in 1996 to 249 ind.m^{-3} in 1997, and 443 ind.m^{-3} in 1998 (Wencki *unpubl.*). The second factor responsible for plankton occurrence is temperature. Chidress and Thuesen (1993) noted that temperature changes in the range of 5°C and hydrostatic pressure both influence the occurrence of plankton. Clarke and Peck (1990) reported a similar situation in the Central Arctic basin. In the present study the temperatures varied within the span of 3°C in particular stations from year to year. The lowest temperatures were noted at the K4

Table 2
Comparison of density [ind.m^{-3}] and biomass [mg ww m^{-3}] of non-crustacean plankton in the different areas and seasons.

Taxon	Density [ind.m^{-3}]	Biomass [mg ww m^{-3}]	Area	Season, year	Author
Sagitta elegans	–	0.72–3.03	western English Chanel	November 1988 – July 1990	Zouhiri and Dauvin, 1996
E. hamata	–	10.5–12.2	Chesapeake Bay	summer, 1987	Purcell *et al.*, 1994
S. elegans	19	–	Baffin Bay	summer, 1985	Sameoto, 1987
E. hamata	4.4	–			
**S. elegans*	17.8	–	Kara Sea	summer, 1985	Timofeev, 1990
E. hamata	7–56.6	–	Antarctic	April, 1992	Froneman and Pakhomov, 1998
S. elegans	760	–	North of Iceland	1993–1994, all year	Gislason and Astthorsson, 1998
E. hamata + *S.elegans*	10-67	–	Atlantic US coast	winter, 1992 and 1993	Baier and Purcell, 1997
Aurelia aurita	–	1600 in 1980 16000 in 1995	Black Sea	1980-1995 all year	Kovalev, 1998
A. digitalie	57.4	–	Norway, fiords	spring, 1992	Pages and Gonzales, 1996
A. aurita	–	321–1322	Baltic Sea	September–November 1993	Janas and Witek, 1993

* *Parasagitta* in original paper.

and M4 stations in 1997. The highest temperature in 1996 was noted in station A4 and the lowest in C4.

Abundant organisms in 1996 and 1997 were *A. digitale* and *S. elegans*. The latter species was found to be the most abundant to the north of Iceland (790 ind.m^{-3}, Gislason and Astthorsson 1998), but other authors usually reported densities from 10–50 ind.m^{-3} in the North Atlantic (Sameoto 1987, Timofeev 1990, Baier and Purcell 1997, Kovalev 1998), or similar values from 7–56 ind.m^{-3} in the Antarctic (Froneman and Pakhomov 1998). The data presented here for *S. elegans* show that its densities were in the lower range of those reported in the scientific literature (Tab. 2). The second important species, *A. digitale*, was found in densities of 57 ind.m^{-3} by Pages and Gonzalez (1996). This value is similar to our observations from 1998.

Sameoto (1987) found *E. hamata* to be dominant in the northern Baffin Bay and the southern part of this bay may be dominated by *S. elegans*. A similar situation was observed in the present material when the density of *S. elegans* was higher in southern stations (C4 – 350 ind.m^{-3}) and was the lowest in northern stations (M4 – 30 ind.m^{-3}). The densities of *E. hamata* were similar in the northern and southern stations of the present study. According to Kasatkina (1982) in the northern hemisphere this species has a boreal distribution.

Conclusions

The abundance and biomass of non-crustacean plankton in 1996 was minimal, in 1997 it was intermediate, and in 1998 it was maximal. The differences in plankton density among years were five fold. Only *A. digitale* abundance was statistically correlated with Sea Surface Temperature changes.

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Streszczenie

Materiał pobrano podczas rejsów r.v. *Oceania* na Spitsbergen w latach 1996–1998 z poligonu badawczego znajdującego się pomiędzy 15° długości geograficznej zachodniej i 70–76° szerokości geograficznej zachodniej w warstwie 0–50 m. Do poboru materiału użyto siatki WP-2 z gazą filtrującą 200 µm, pobrany materiał konserwowano 4% formaliną.

Określono liczebność i zmiany tej liczebności w poszczególnych latach dla *Aglantha digitale, Sagitta elegans, Eukrohnia hamata, Oikopleura vanhOffeni, Fritilaria borealis* i *Limacina* sp. Rys. 3 ilustruje dotyczące różnice międzyletnie.

W niniejszej pracy zaobserwowano duże międzyletnie zmiany w ilości zooplanktonu, jak również znaczącą zmianę w temperaturze mas wodnych, która miała wpływ na rozmieszczenie i liczebność poszczególnych gatunków. Jednak tylko korelacja dla *A. digitata* była korelacją znaczącą. Pozostałe korelacje dały wartości nie znaczące statystycznie.