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Interannual variability in the occurrence of *Themisto* (Amphipoda) in the north Norwegian Sea

ABSTRACT: Two species of Amphipoda (Hyperiidae), *Themisto libellula* (Mandt, 1822) and *Themisto abyssorum* (Boeck, 1870), were collected with the use of a WP-2 net from the area between Nordkapp and Spitsbergen (73° to 78° N) in July of 1993, 1996, 1997, and 1998. Densities ranged from 6 to 992 ind. 100 m^{-3} (*T. abyssorum*) and from 8 to 448 ind. 100 m^{-3} (*T. libellula*), and respective total biomass of *T. abyssorum* from 65.6 to 81.2 mg d.w. 100 m^{-3} and *T. libellula* from 59.9 to 131.5 mg d.w. 100 m^{-3}.

Key words: Arctic plankton, *Themisto abyssorum*, *Themisto libellula*, density, biomass.

Introduction

The northern Atlantic is known for its variability in climate (Katsov and Walsh 1996). The effect of this variability on marine organisms has been reported by Węsławski and Kwaśniewski (1990) based on the example of Svalbard waters. This area is extremely changeable both with regard to environmental factors as well as trophic conditions (Sakshaug *et al.* 1994). The climatic fluctuations can change the composition of zooplankton and influence its total abundance (Cushing and Dickson 1976).

Macroplanktonic crustaceans, including hyperiid amphipods (*Themisto abyssorum* and *Themisto libellula*), are key species for Arctic pelagic food webs, since fish, seals, and whales feed on them (Mehlum and Gabrielsen 1993, Sakshaug *et al.* 1994). The north Norwegian Sea and Svalbard shelf have been relatively well studied with regard to zooplankton occurrence (Wiborg 1955, Kwaśniewski 1994), however data on hyperiid amphipod occurrence is scarce. Some information on the occurrence and density of hyperiid amphipods *T. abyssorum* and *T. libellula* can be

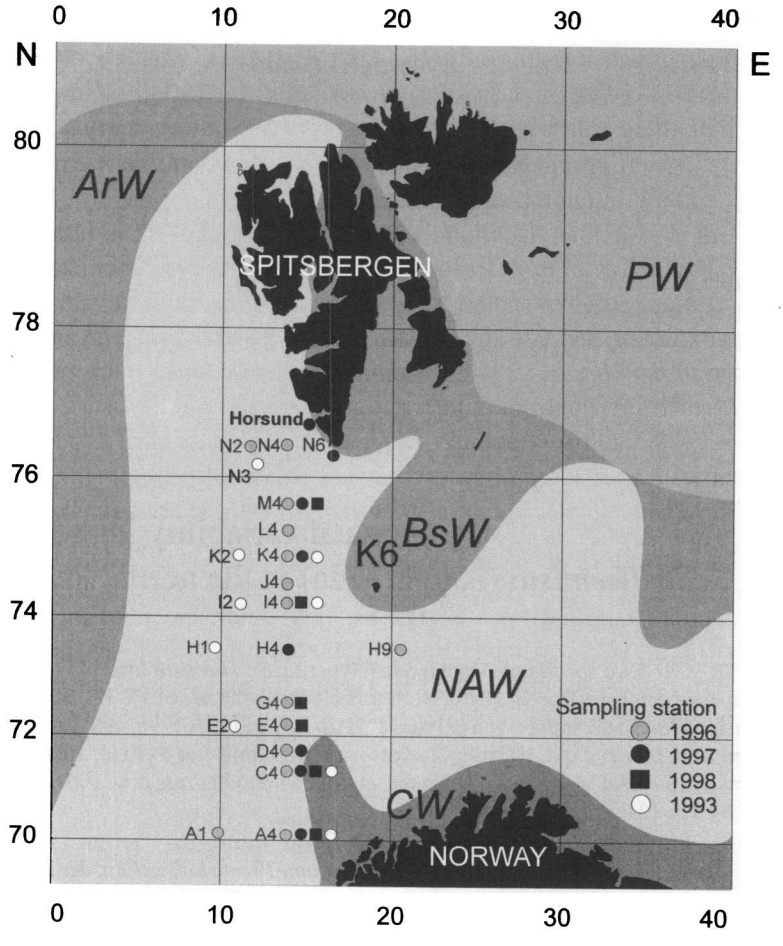

Fig. 1. The grid of sampling stations, water masses, and fronts in the Barents Sea region (after Koszteyn *et al.* 1995). PW – Polar Water; ArW – Arctic Water; NAW – North Atlantic Water; CW – Coastal Water; KG – multi-annual station.

found in the papers of Węsławski and Kwaśniewski (1990), Koszteyn *et al.* (1995), Dalpado *et al.* (1998) and Mumm *et al.* (1998).

T. abyssorum is an Arctic-boreal species, which occurs at depths of 0 to 1000 m and prefers temperatures between 0° and +6°C, and salinity over 34 PSU; its maximal length is 20 mm. *T. libellula* is an Arctic species, occurring mainly at depths of 0 to 100 m. It prefers temperatures below +4°C; its maximal length is 28 mm. *Themisto* spp. are numerous and common in ice-covered waters throughout the entire Arctic (Klekowski and Węsławski 1991).

The aim of the present study is to assess the interannual variability of *Themisto* amphipods regarding their abundance, biomass, and structure population. In view of the Global Change influence upon the pelagic system of Norwegian Sea, species of *Themisto* have been chosen as possible indicators of warm and cold periods.

Materials and methods

The investigation area is situated between Nordkapp and Spitsbergen (73° to 78° N) (Fig. 1). This region is situated in the border between the Arctic and Subarctic marine zoogeographical zones (Dunbar 1968). Three water masses are present in this area: Atlantic (West Spitsbergen Current and South Spitsbergen Current), Arctic (Barrents Current), and coastal waters of mixed origin (Sorkapp Current) (Koszteyn *et al.* 1995).

Year-to-year fluctuations in the volume of water transported (Mandel 1976) as well as the geographical position of the North Atlantic Current–West Spitsbergen Current system (Taylor and Stephens 1980) cause the irregular appearance of „cold" and „warm" years in the investigated area (Węsławski and Adamski 1987, Piechura and Walczowski 1996). The North Atlantic Oscillations (NAO) are the source of large-scale climate variability and a dominant factor in many biological processes. They follow the differences in pressure between Azores Anticyclone and Iceland Cyclone (Stephenson 1999).

Material was collected during summer cruises of r/v *Oceania* in July of 1993, 1996, 1997, and 1998 (Fig. 1). Zooplankton was sampled with the use of a WP-2 net with 200 μm mesh size gauze and closing device. The net was hauled vertically from 50 to 0 m. Data on the size and weight of zooplankton were taken from animals preserved in 4% formalin, and determined 6 to 12 months after their collection. The length of *Themisto* specimens was measured to the nearest 0.1 mm from the anterior margin of the head to the posterior margin of the third pair of uropods (Hoffer 1972). The biomass of *Themisto* was calculated by multiplying the number of a given size class in samples by its respective mean individual weight.

Results

The occurrence and density of *T. abyssorum* (Table 1) shows that the average abundance fluctuated from 14 to 992 ind. 100 m^{-3} during the investigated period *T. abyssorum* was most numerous in 1996 (values for stations A1, K4 and N2 exceed 800 ind. 100 m^{-3}), and in 1997 was least numerous (from 14 to 279 ind. 100 m^{-3} at all stations).

Maximal densities of *T. libellula* were found in 1996 (over 400 ind. 100 m^{-3} at station J4). In 1996 *T. libellula* was found as far south as station A1 near the coast of Norway (Table 1); while in the 1998 it was absent.

The relations of body weight to length size class were calculated for *T. abyssorum* as: $W = 0.035\ L^{1.887}$, and for *T. libellula* as: $W = 0{,}074\ L^{1.421}$, where W is mg dry weight, L is mm length.

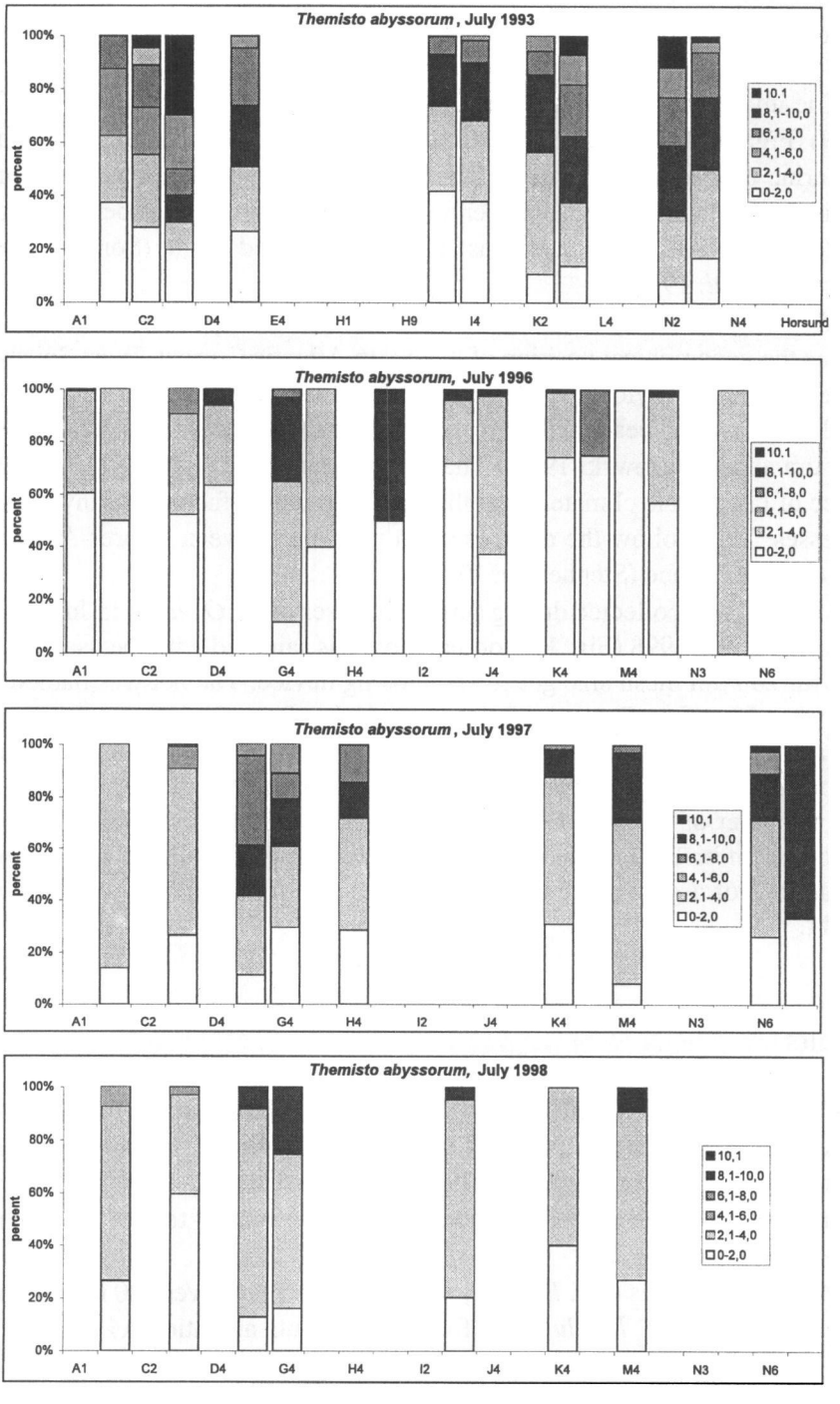

Fig. 2. Size structure of *Themisto abyssorum* in respective stations in the years 1993–1998 (size classes in mm).

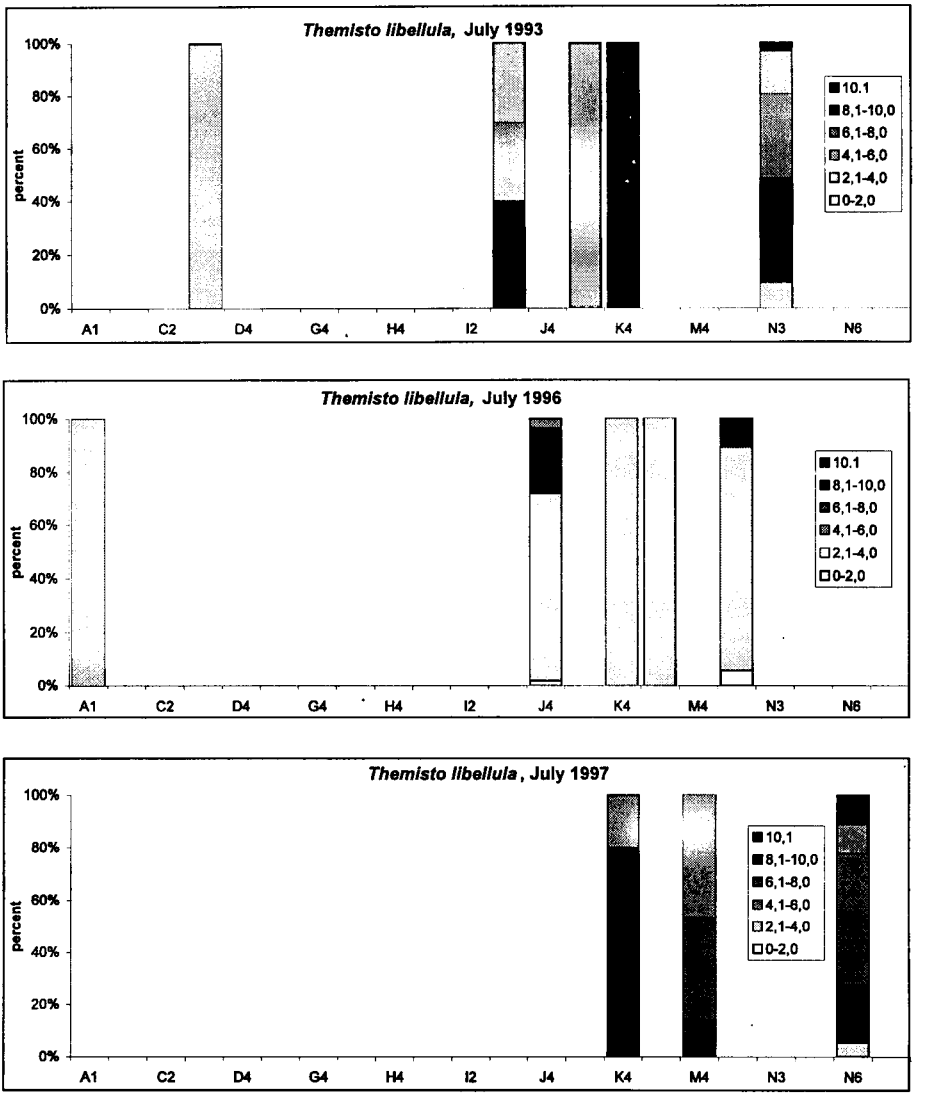

Fig. 3. Size structure of *Themisto libellula* in respective stations in the years 1993–1997 (size classes in mm).

Average biomass of *T. abyssorum* at all stations was highest in 1993 (151.3 mg d.w. 100 m^{-3}), and lowest in 1998 (65.6 mg d.w. 100 m^{-3}) (Table 1). Biomass of *T. libellula* fluctuated between 59.9 in 1993 and 131.5 mg d.w. 100 m^{-3} in 1996 (Table 1).

The length frequency distribution of *T. abyssorum* in 1993 shows two dominant classes, of 0–2 mm and 10.1–12.0 mm (Fig. 2). In 1996 the dominant individuals were in the 0 to 2 mm size class, while in 1997 and 1998 ranged from 2 to 4 mm. *T. libellula* individuals from the 8 to 10 mm length class dominated samples

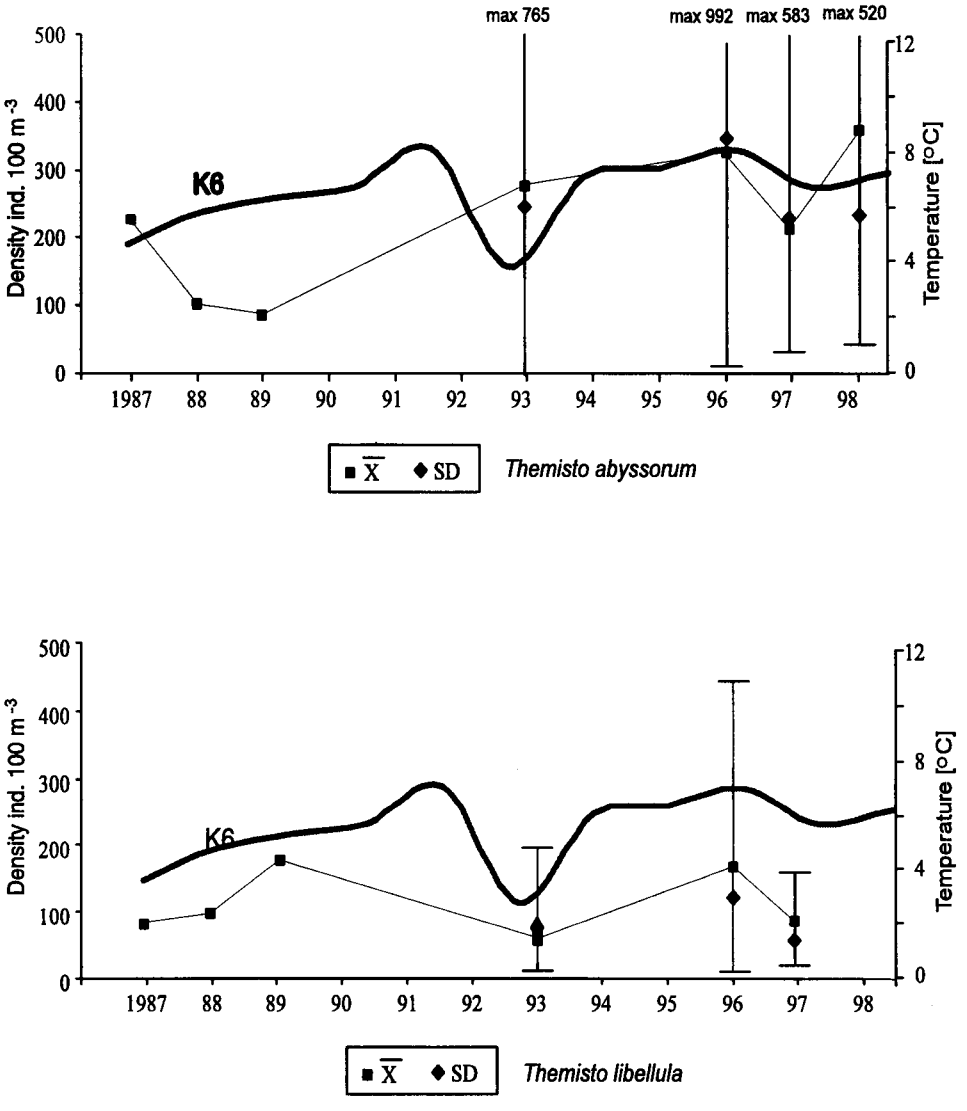

Fig. 4. Average, minimal, and maximal densities of the *Themisto* species found in the sampling areas. Data from 1986–89 after Kwaśniewski (1994). K6 – temperature in July at 0 to 10 m depth (after Piechura and Walczowski 1996).

in 1993. In 1996 individuals from 2 to 4 mm length were dominant. In 1997 the dominant class was individuals from 4.1 to 6.0 mm long (Fig. 3). The year-to-year fluctuations of density of both *Themisto* species were not correlated with each other (Fig. 4).

The parametric test Mann-Whitney was carried out and the V-test showed no statistical differences between number of *Themisto* in examined years ($p > 0.05$), but there were statistical differences between stations ($p = 0.05$).

Table 1

Density (ind.m^{-3}) of *Themisto abyssorum* and *T. libellula* in the research years; [– no data].

Species	Year	Stations																						Average	
		A1	A4	C2	C4	D4	E2	E4	G4	H1	H4	H9	I2	I4	J4	K2	K4	L4	M4	N2	N3	N4	N6	Horn-sund	density [ind.100m^{-3}]	biomass [mg 100m^{-3}]
Themisto	1993	–	32	178	20	–	390	10	–	–	–	–	234	484	–	120	144	–	–	220	280	–	–	–	192.00	151.30
abyssorum	1996	847	160	–	100	293	–	–	280	49	–	20	–	400	320	–	880	16	46.5	992	–	80	–	–	320.23	66.60
	1997	–	14	–	279	–	–	140	128	–	30	–	–	–	–	–	131.1	–	154	–	–	–	80	30	109.57	81.10
	1998	–	458.9	–	254	–	–	310	140	–	–	–	–	715.2	–	–	600	–	37	–	–	–	–	–	359.30	65.60
Themisto	1993	–	0	0	6	–	0	0	–	–	–	–	0	0	–	2	4	–	–	0	62	–	–	–	6.73	59.90
libellula	1996	40	0	–	0	0	–	–	0	0	–	0	–	0	448	–	40	16	0	144	–	0	–	–	49.14	131.50
	1997	–	0	–	0	–	–	0	0	–	0	–	–	–	–	–	11.1	–	120	–	–	–	144	0	25.01	69.60
	1998	–	0	–	0	–	–	0	0	–	0	–	–	–	–	–	0	–	0	–	–	–	0	–	0	0

Table 2

Densities of pelagic amphipods (*Themisto* spp.) reported in the existing literature.

Maximal densities of *Themisto* spp. reported in the literature [ind.100 m^{-3}]	Water stratum [m]	Area, season	Author	Sampling gear	Species
150; 50	0–230	North Atlantic, May–Nov.1982–92	Koszteyn *et al.* 1995	nets, WP–2, Bongo	*T. abyssorum, T. libellula*
200	0–100	Arctic Ocean, 1987–91 summer	Mumm *et al.* 1998	multinet, Bongo	*T. abyssorum*
118	0–500	North–East Atlantic, July 1973	Williams and Robins 1980	WP–3	*Themisto compressa**
1100	0–20	Kongsfiorden, summer 1996	Węsławski *et al.* 2000	Tucker trawl	*T. abyssorum, T. libellula*
2500	40–50	Forbisher Bay, Feb.–Aug. 1981–85	Percy 1993	plankton nets	*T. libellula*
110	0–600	North Atlantic, 1993–95 summer	Dalpadado *et al.* 1998	pelagic trawl	*T. libellula*

* before the revision by Schneppenheim and Weigmann-Haass (1986) this species was named *Parathemisto gaudichaudii*.

Discussion

The presence of *T. libellula* at the southernmost station A1 near the coast of Norway in 1996 confirms rare observations of this species in the area of Finmark (Stephensen 1940).

The density and distribution of *T. libellula* in the investigated years is similar to the data obtained by Koszteyn *et al.* (1995) and Dalpadado *et al.* (1998), who found this species in higher quantities of 110 to 2500 ind. 100 m^{-3} (North Atlantic, summer 1993–1995).

The density of *T. abyssorum* observed in this work is similar to that reported in existing literature (Węsławski and Kwaśniewski 1990, Kwaśniewski 1994, Koszteyn *et al.* 1995). Higher values were noted by Percy (1993) and Węsławski *et al.* (2000). Probably this results from the different type of plankton nets used (Table 2). Mumm *et al.* (1998) noted high values of *T. abyssorum* abundance – 200 ind. 100 m^{-3} (Arctic Ocean, summer 1987–1991). The values of biomass of both species were very similar and ranged from 59.9 to 151.3 mg 100 m^{-3}.

Population composition of both species in the summer shows domination of the youngest individuals. This might be an effect of the slow WP-2 net and escape reaction, since *Themisto* commonly reach over 20 mm in length (Percy 1993). The structure of population observed in 1993 suggests that the development of populations has been delayed, as all development phases were present and the young stages were scarce. This delay might have been the result of a cold year. In 1996 the season was warmer, and a lot of young stages were observed. In the studied period only individuals up to 12 mm were observed. According to Klekowski and Węsławski (1991), individuals of this species reach lengths up to 20–28 mm.

Despite the different water masses and year-to-year climatic differences, the biomass of *Themisto* varied only within a narrow range. Both species are organisms with relatively long life spans, up to 3–5 years for *T. libellula* (Vinogradov *et al.* 1982, Koszteyn *et al.* 1995); hence interannual reproduction variability can be buffered by the animals' long life span. This suggests the stable position of hyperiid amphipods in the Norwegian Sea trophic food web.

The results of the present work show that interannual differences in number and biomass of investigated amphipods does not change significantly. The absence of *T. libellula* in 1998 is an exception. Hydrographic changes influence the phenology of the investigated species -- the acceleration of *Themisto* development is a consequence of higher water temperature in 1996. A similar situation was noted in the phytoplankton community, which does not evidence a direct correlation between climate and the number of cells (Markowski and Wiktor 1998).

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Streszczenie

Materiał pobrano podczas rejsów r/v *Oceania* na Spitsbergen w latach 1993 i 1996–98 z poligonu badawczego znajdującego się pomiędzy 12°–15° E i 73°–78° N. Do poboru materiału użyto siatki WP-2 z gazą filtrującą 200 µm, pobrany materiał konserwowano 4% formaliną. Uzyskano dane dotyczące ilości *T. abyssorum* i *T. libellula* w badanym obszarze.

Nie stwierdzono istotnej korelacji pomiędzy zagęszczeniem badanych gatunków, a temperaturą wody, czy zimowym indeksem NAO.

Dla *T. abyssorum* średnia biomasa (sucha masa) wynosi od 65,6 mg × 100 m^{-3} w 1998 do 151,3 mg × 100m^{-3} w 1993, a dla *T. libellula* od 59,9 mg × 100 m^{-3} w 1993 do 131,5 mg × 100 m^{-3} 1996.

Zagęszczenie populacji *Themisto* sp. wykazywało duże wahania, lecz średnia biomasa na stacjach była bardzo stabilna. Wyniki te wskazują na stabilną pozycję badanych gatunków w ekosystemie Morza Norweskiego i Barentsa i co za tym idzie, ważną rolę w sieci troficznej.