

Scientific note

Stable isotope compositions of arctic copepods in the Greenland Sea in winter

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Abstract: Natural abundances of stable isotopes ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) were measured in copepods collected in the Greenland Sea in January 1999. Standing stocks of zooplankton dominated by copepods in the upper 200 m varied among 12 stations and marked zooplankton increases at 4 stations ($> 10 \text{ mg-dry weight m}^{-3}$) were observed around the marginal ice zone, although surface chlorophyll *a* concentrations at all stations were nearly zero. The isotopic compositions of copepods varied in the ranges of -22.2‰ – -20.6‰ in $\delta^{13}\text{C}$ and of 8.2‰ – 12.2‰ in $\delta^{15}\text{N}$, which were comparable with those collected in other polar waters. The enrichment factors (difference in $\delta^{15}\text{N}$ between copepods and POM) of about 3.2 suggest possible linkage between winter copepods and winter POM without algal populations.

1. Introduction

Information on the life of pelagic zooplankton, including copepods, in arctic and subarctic waters during winter has been limited, particularly for populations inhabiting seasonally ice-covered and marginal ice zones (MIZ). In the Antarctic Ocean, a considerable amount of calanoid and harpacticoid copepods were observed under the fast ice in Lützw-Holm Bay during winter (*e.g.* Tanimura *et al.*, 1984, 1996). Many Antarctic krill (*Euphausia superba*) were also collected using a light-trap under the fast ice in austral winter (Kawaguchi *et al.*, 1986). Nishino and Kawamura (1994) examined the foregut contents of Antarctic krill collected in the South Georgia area in winter to evaluate feeding habits related to overwintering strategy and emphasized their possible carnivorous feedings during winter.

The natural abundance of C and N stable isotopes can be useful in examining sources of these elements to consumers (*e.g.* Wada *et al.*, 1987). These isotope ratios in animals are generally related to those in their diets (DeNiro and Epstein, 1981). The stable nitrogen isotopic ratio ($\delta^{15}\text{N}$) of consumers is systematically heavier than those of their diets (Minagawa and Wada, 1984; Wada and Hattori, 1991). There have been some reports of stable isotope measurements from polar marine food web studies. Geographic gradients in stable carbon isotope ratios ($\delta^{13}\text{C}$) of arctic zooplankton have been observed in the Bering, Chukchi and Beaufort Seas (Dunton *et al.*, 1989; Saupe *et al.*, 1989). Causes of these geographic variations might be a consequence of the intrusion of different water masses including ^{13}C -depleted carbon (Dunton *et al.*, 1989; Saupe *et al.*, 1989). Frazer (1996)

reported that larval krill (*E. superba*) collected around the Antarctic Peninsula in early winter were depleted in ^{15}N ($<1\text{‰}$), primarily because of their herbivorous feeding on ice-associated food sources. Although the reported isotope values were quite variable, these data provide primary information on the lives of arctic and antarctic zooplankton in winter. Further investigations will have to focus on the overwintering mechanisms of these animals.

We present here preliminary data on $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values of arctic copepods collected in the Greenland Sea in January 1999, and evaluate the use of these values as indicators of copepod food sources during winter.

2. Materials and methods

Samples were collected from 12 stations located in the Greenland Sea and southwest Barents Sea in January 1999 during the R/V Ivan Petrov Cruise. Zooplankton samples were obtained using a NORPAC net (North Pacific Standard net; 180 cm in length and 0.3 mm in mesh size) in the upper 200 m of the water column. Each sample was preserved with formalin and divided into two aliquots, one for dry weight measurements (60°C, 12 hours) and the other for stable isotope determinations and microscopic observations. The present study does not consider the microscopic observations of zooplankton. Routine oceanographic surveys were made using a CTD/RMS for water temperature and salinity measurements, and water sampling. One liter of seawater was filtered through a GF/F glass fiber filter for determinations of chlorophyll pigments.

Copepods were recovered from net-collected samples and were washed of detritus before analysis. Since most copepods were smaller than 4 mm long, approximately same sized-individuals were pooled to obtain sufficient material for isotopic analysis. One sample consisted of at least 5 individuals (350 μg to 2 mg in dry weight). Each sample with copepods was exposed to chloroform methanol solution for removing lipids and was dried in an aluminum dish at 60°C for 12 hours. They were used for determinations of carbon and nitrogen stable isotopic compositions using an ANCA/GSL mass spectrometer (Europa Scientific Ltd). Results were expressed as conventional $\delta^{13}\text{C}$ or $\delta^{15}\text{N}$ values, where the ratio of the sample is compared to that of a standard,

$$\delta X(\text{‰}) = \left\{ \left(R_{\text{sample}} / R_{\text{standard}} \right) - 1 \right\} \times 1000.$$

X is ^{13}C or ^{15}N and R is $^{13}\text{C}/^{12}\text{C}$ or $^{15}\text{N}/^{14}\text{N}$. Standards were calibrated by PDB and atmospheric nitrogen. L-alanine ($\delta^{13}\text{C} = -21.5\text{‰}$, $\delta^{15}\text{N} = -5.3\text{‰}$) was used as a running standard for isotopic measurements. The reproducibility for one standard deviation was $\pm 0.1\text{‰}$ for $\delta^{13}\text{C}$ and $\pm 0.3\text{‰}$ for $\delta^{15}\text{N}$, respectively.

3. Results and discussion

Surface water temperature was warmer than 5°C in the southwest Barents Sea located north of Norway (Sts. 1, 2, 3 and 4) and lower than 0°C in the area west of Spitsbergen (Sts. 11, 8 and N4), where the sea surface was partly covered with ice (Table 1). The MIZ and packed ice zones were characterized by low salinity water (<34.5 psu) (Table 1). All chlorophyll *a* concentrations observed in the upper 100 m were less than 0.01 mg m^{-3} (Table 1), indicating scarcely distributed phytoplankton as well as ice-associated algae

Table 1. Location, temperature and salinity of surface water, concentrations of chlorophyll *a* (0–100 m), and averaged zooplankton standing stocks (0–200 m). Stable carbon and nitrogen values of copepods collected in the upper 200 m layers. Numbers in parenthesis indicates standard deviation.

Station	Latitude (N)	Longitude (E)	Temp. (°C)	Sal. (PSU)	Chlorophyll <i>a</i> (mg m ⁻³)	Zooplankton (mg m ⁻³)	δ ¹³ C (‰)	δ ¹⁵ N (‰)
St. 1	71:00	17:59	6.21	34.52	< 0.01	4.71	-22.2	11.9
St. 2	72:00	17:59	6.36	35.11	< 0.01	0.12	-21.6	12.2
St. 3	72:59	17:59	6.2	35.15	< 0.01	1.31	-21.5	9.4
St. 4	73:59	17:59	5.72	35.15	< 0.01	8.28	-20.6	9.9
St. 5	74:59	17:59	1.31	34.83	< 0.01	6.42	-20.8	11.0
St. X5	76:59	12:49	4.6	35.12	< 0.01	9.25	-20.6	10.7
St. 11	78:00	2:29	-1.63	34.26	< 0.01	5.15	-21.6	9.2
St. 10	78:58	0:27	3.4	34.87	< 0.01	15.81	-21.5	8.2
St. 8	79:00	4:58	-1.77	33.84	< 0.01	8.58	-21.7	8.8
St. N4	79:59	0:00	-1.69	34.16	< 0.01	32.23	-21.4	9.0
St. N2	80:00	4:58	2.44	35	< 0.01	14.23	-21.0	9.8
St. X10	80:57	4:11	0.84	34.96	< 0.01	12.06	-21.4	9.5
Mean						9.85	-21.3	9.9
Std						(8.49)	(0.5)	(1.3)

derived from floating ice in this region in winter.

Averaged zooplankton standing stocks in the upper 200 m water column were relatively lower in the sea north of Norway (< 5 mg m⁻³) compared with those in coastal areas west of Spitsbergen (> 5 mg m⁻³). In the northern-most stations around the MIZ (Sts. 10, N4, N2 and X10), marked increases of zooplankton were observed (> 10 mg m⁻³). Collected zooplankton were dominated by calanoid copepods. The meso-zooplankton (> 180 μm in length) standing stocks in late summer and early fall varied interannually in the range of 1.5 to 20 g-dry weight m⁻² in the Barents Sea (Skjoldal *et al.*, 1987). The largest zooplankton standing stock of this study obtained at St. N4 (32.23 mg m⁻³) can be calculated as a depth-integrated value (0–200 m) of 3.16 g-dry weight m⁻², which was comparable with those found in summer-fall periods (Skjoldal *et al.*, 1987). Copepods were abundant in the winter Greenland Sea, although the concentration varied among stations.

The isotopic compositions of copepods collected in the present study varied in the range of -22.2‰~-20.6‰ in δ¹³C values and of 8.2‰-12.2‰ in δ¹⁵N values (Table 1). The δ¹³C data were primarily comparable with those ranging from -22.8‰ to -20.9‰ collected in the northern Bering, Chukchi and western Alaskan Beaufort Seas during June–October (Saupe *et al.*, 1989). However, copepods sampled in the eastern Alaskan Beaufort and Canadian Beaufort Seas in June–October were relatively depleted in ¹³C (-26.7‰~-24.6‰) (Saupe *et al.*, 1989). These variations were probably caused by recycling of ¹³C-depleted carbon associated with the intrusion of upwelled waters in the southeastern Beaufort Sea (Dunton *et al.*, 1989; Saupe *et al.*, 1989). The geographical variation in δ¹³C values seems to be more pronounced than the seasonal difference in δ¹³C values. The relatively small geographic variation of δ¹³C values obtained in this study (Table 1) indicated that there was less evidence for different carbon sources to copepods. Goericke

and Fry (1994) showed that $\delta^{13}\text{C}$ values of POM (particulate organic matter dominated by phytoplankton) using historical data vary weakly with temperature in the world ocean, although large deviations were observed, especially at high latitude, primarily due to disequilibrium of CO_2 concentrations in the atmosphere and surface waters. No marked relationship between $\delta^{13}\text{C}$ values and surface water temperature was recognized within the relatively restricted sea areas of the present study (Table 1).

Although little is known about isotopic compositions of arctic copepods in winter, $\delta^{15}\text{N}$ values of *Calanus* spp. ($11.4 \pm 0.1\text{‰}$) collected in the western Beaufort Sea in February (Dunton *et al.*, 1989) generally agreed with those from the present Norwegian coastal stations (Sts. 1 and 2, Table 1). Hobson *et al.* (1996) collected many animal samples including copepods in the Northeast Water (NEW) polynya off northeast Greenland in June-July and used their isotope data to evaluate linkages between pelagic and benthic ecosystems. Based on the $\delta^{15}\text{N}$ enrichment factor (difference in $\delta^{15}\text{N}$ between prey and predator) of $+3.8\text{‰}$ (Hobson and Welch, 1992), they suggested the existence a direct pathway from POM with less ice algae to two dominant calanoid species (*Calanus hyperboreus* and *C. gracilis*) having $\delta^{15}\text{N}$ values in the range of 7 to 9‰ (Hobson *et al.*, 1996). It was supported by the comparison of $\delta^{13}\text{C}$ values between POM (*ca.* -28‰) and ice algae (*ca.* -18.5‰), the last of which were more enriched than those of copepod grazers (*ca.* -22.5‰) (Hobson *et al.*, 1996).

Comparative POM isotope data collected during the present cruise (Sato *et al.*, in preparation) were variable but were depleted in ^{15}N ($6.7 \pm 1.6\text{‰}$) relative to those of copepods ($9.9 \pm 1.3\text{‰}$, Table 1). An enrichment factor was also reported by Wada and Hattori (1991) as $3.4 \pm 1.1\text{‰}$. If the enrichment factors (Wada and Hattori, 1991; Hobson and Welch, 1992) can be applied to copepods in the Greenland Sea, the present enrichment value of $+3.2$ seemed to be the linkage between winter copepods and winter POM. No marked occurrence of phytoplankton (Table 1) and microheterotrophs (unpublished data) was found in sea water where zooplankton abundance increased. Thus these copepods might possibly be detritivorous.

Frazer (1996) reported isotopic compositions of larval krill (*Euphausia superba*) collected in winter along the west coast of the Antarctic Peninsula. The krill larvae in winter were generally enriched in ^{13}C ($> -27\text{‰}$) and depleted in ^{15}N ($< 1\text{‰}$) relative to those in summer months (Frazer, 1996). Frazer (1996) also showed that the isotopic compositions of larval krill in early winter ($\delta^{13}\text{C}$: $-24.9\text{‰} \pm 0.9$, $\delta^{15}\text{N}$: 2.7 ± 0.2) did not differ from those in late winter ($\delta^{13}\text{C}$: -24.7 ± 0.9 , $\delta^{15}\text{N}$: 3.3 ± 0.7), while the compositions of POM sampled in early winter ($\delta^{13}\text{C}$: -20.9 ± 0.0 , $\delta^{15}\text{N}$: -1.0 ± 0.1) significantly differed from those in late winter ($\delta^{13}\text{C}$: -32.0 ± 1.4 , $\delta^{15}\text{N}$: 6.35 ± 0.1) (Frazer, 1996). This suggested that seasonal shifts in isotopic compositions of larval krill did not result from changes in their diets and they could be primarily herbivorous prior to winter (Frazer, 1996). In contrast, foregut contents of krill collected in the South Georgia area during austral winter consisted of various fragments of crustacean zooplankton observed by detailed microscopic studies, indicating the existence of alternative carnivorous or detritivorous feeding modes (Nishino and Kawamura, 1994).

Our results show the possible utility of stable carbon and nitrogen isotope ratios in ecological studies on copepods. Although mechanisms that can alter isotopic compositions of copepods other than diets and overwintering behavior of arctic copepods in winter

remain uncertain because of insufficient data available, the enrichment value in $\delta^{15}\text{N}$ obtained in this study suggested the possibility of alternative detritivorous feeding of copepods during winter. Further information on isotopic variations of copepods and their food sources can provide insight into understanding and interpreting the feeding ecology related to overwintering strategies of arctic copepods.

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