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Population structure of three dominant *Calanus* species in North Water Polynya, Baffin Bay

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ABSTRACT: The population structures of *Calanus finmarchicus*, *C. glacialis* and *C. hyperboreus* were investigated in the recurrent polynya of the North Waters (NOW) in Baffin Bay during April–July 1998. Species were determined from samples collected by plankton nets of 300 μm and 200 μm mesh size. The highest concentration of all three species was found at the centre of study the area. *C. hyperboreus* was the most abundant species (44.54 ind. m^{-3}). *C. glacialis* was recorded up to 27.14 ind. m^{-3}, *C. finmarchicus* up to 5.63 ind. m^{-3}. *C. finmarchicus* was reproducing in the northern end of Baffin Bay. The life cycle for *C. glacialis* was estimated at 2 years, and that of *C. hyperboreus* to last at least 4 years.

Key words: Canadian Arctic, North Water Polynya, *Calanus* population.

Introduction

The North Water Polynya (NOW) is a recurrent polynya at the northern end of Baffin Bay (Melling *et al.* 2001). Polynyas, as large open areas of water in ice-covered regions (Ashijan 1995), may be of considerable importance to the overall fixation, cycling, and storage of carbon in the Arctic ecosystem, since primary and secondary production may increase in ice-free regions (Smith 1995). In areas surrounding the polynya, the interval between the break-up of the ice cover in mid-summer and the return of the polar light may be as short as 2 months. Hence the season of development of herbivores should start earlier than in non-polynya areas of the Arctic.

William Baffin first documented open water along the west coast of Greenland in 1616 (Dunbar and Dunbar 1972). In 1961, Grainger presented his description of *Calanus* species from the Canadian Arctic. All the previous expeditions to the NOW were too late and too short (Grainger 1963) or did not focus on the whole open water area (Buchanan and Sekerak 1982). The NOW project offered the opportunity to study the polynya from the early opening to mid-summer, when the polynya was almost at its largest.

The present work aims to describe populations of *Calanus* species in the northern parts of Baffin bay, with an in-depth focus on the *Calanus finmarchicus* population. The present study is based on the material collected from April to July 1998 in Baffin Bay at 5 stations.

Study area

The bottom topography of northern Baffin Bay is complex. Depths were only 400–500 m, with the exception of the north-south channel which in its centre reaches 700 m. Inflow to Northern Baffin Bay is attributed to Smith Sound to the north. Western inflow comes via Jones and Lancaster Sound and southern inflow is through Baffin Bay and Davis Strait (Fig. 1). Inflow of deeper Arctic Water is limited by shoals (250–200 m) at the Smith Sound, the entrance to Kane Basin, and by the Lancaster and Jones Sounds. Further to the south, the North Water opens into Baffin Bay, where average depths of 500 m gradually descend to a 2400 m basin in the central western portion of the bay. Water circulation in the region reflects its topography. Currents in the North Water (NOW) polynya are dominated by a strong southward flow of cold water and ice from the Arctic Ocean. In addition the West Greenland Current creates a modest flow of warmer water towards the polynya from the south-east. However this flow loses much of its warmer water towards the polynya from the south-east, and this flow loses much of its heat south of the polynya through re-circulation into and isopycnal mixing with the Arctic outflow (Melling *et al.* 2001).

The mechanisms causing the opening and maintainence of the NOW polynya is still debated and is believed to be dependent on both the atmosphere and the ocean conditions (Smith *et al.* 1990). A *sensible heat* polynya is formed at locations where the flux of heat from the ocean is sufficient to melt existing ice and inhibit the formation of new ice. At locations where persistent wind and current carry newly-formed ice away from a shoreline or stable ice- edge, a *latent heat* polynya is formed.

Materials and methods

Zooplankton was collected in the North Water Polynya (75°N–79°N) during the cruise of the R/V *Pierre Radisson* (7 April to 28 July, 1998). Mesozooplankton was sampled at five stations by *multi-net* (mouth opening 1 m^2, length 6 m, 200 µm mesh size) and ring-net (mouth opening 1 m^2, 300 µm). The bottom depth averaged from 600 m to 135 m. Nets were vertically towed from near bottom to the surface (Table 1). The zooplankton samples for the study were preserved in 4% bo-

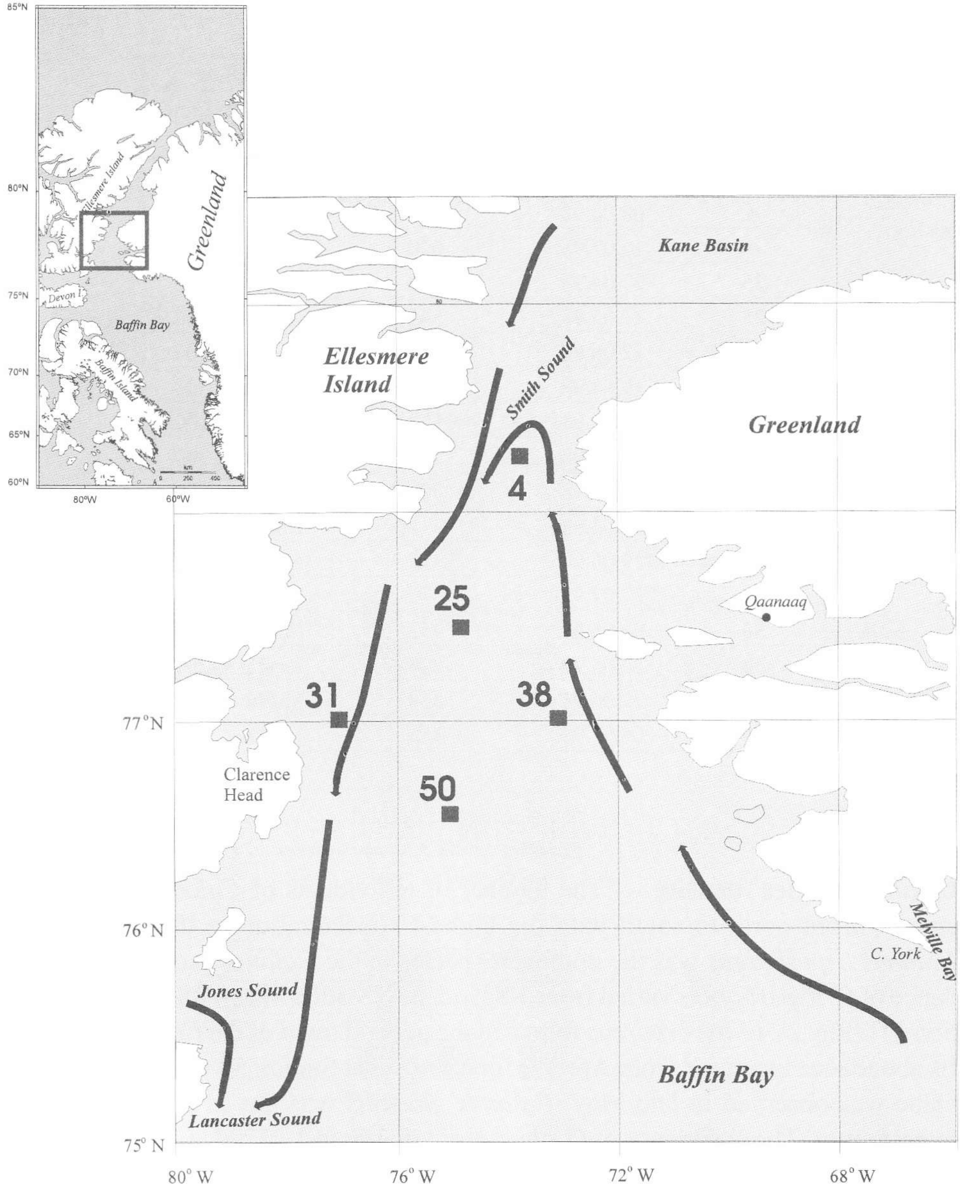

Fig. 1. Location of five moorings sites in northern Baffin Bay with the general cyrculation. Smith Sound is the main waterway between Baffin Bay and the Arctic Ocean(after Humfrey *et al.* 2001).

rax-buffered formalin and analysed for *Calanus* species. Counting and sorting of the samples was carried out at the Institute of Oceanology of the Polish Academy of Sciences. *Calanus* species were distinguished on the basis of the prosome length using data from Unstad and Tande (1991). Due to bad weather conditions in July at stations 25 and 31, no samples were taken there.

Table 1

Station	Data	Sampling depth [m]	Net tows, mesh size [μm]
4	13.04.98	550	Multinet, 200
4	13.05.98	540	Ring net, 200
4	08.06.98	550	Multinet, 300
4	11.07.98	600	Multinet, 300
25	17,04.98	660	Multinet, 300
25	17.05.98	545	Ring net, 200
25	12.06.98	637	Multinet, 300
31	19.04.98	300	Multinet, 300
31	23.05.98	180	Ring net, 200
31	15.06.98	250	Multinet, 300
38	02.05.98	300	Multinet, 300
38	25.05.98	331	Ring net, 200
38	19.06.98	315	Multinet, 300
38	17.07.98	470	Multinet, 300
50	04.05.98	452	Multinet, 300
50	26.05.98	226	Ring net, 200
50	22.06.98	450	Multinet, 300
50	06.07.98	450	Multinet, 300

Results

***Calanus* species' density** — The number of individuals of *Calanus* species increased from north to south with the highest concentration in the centre area. *Calanus hyperboreus* was the dominant species in the *Calanus* group. The abundance of *C. hyperboreus* varied from 3.82 ind. m^{-3} (Station 4) to 44.54 ind. m^{-3} (Station 31) (Fig. 2). *C. hyperboreus* followed the general trend of the *Calanus* species. Its abundance increased from April to June, except at Station 50 where the highest value was observed in late May. *Calanus glacialis* was not as numerous as *C. hyperboreus*. The abundance of *C. glacialis* varied from 1.21 ind. m^{-3} (Station 4) to 27.14 ind. m^{-3} (Station 31). At Station 38, situated in the western part of polynya, the abundance of *C. glacialis* at the beginning of study period was higher than that of *C. hyperboreus*. The highest abundance of *C. glacialis* was recorded at central stations. *Calanus finmarchicus* was not numerous compared with other *Calanus* species. The highest density (5.63 ind. m^{-3}) for this species was recorded at station number 50 in July.

Population structure of *Calanus* species — The population of *C. hyperboreus* was dominated by older stages (CIV, CV) and adults during the beginning of sampling period, with substantial numbers of CIV (Fig. 3). Stage IV constituted up to

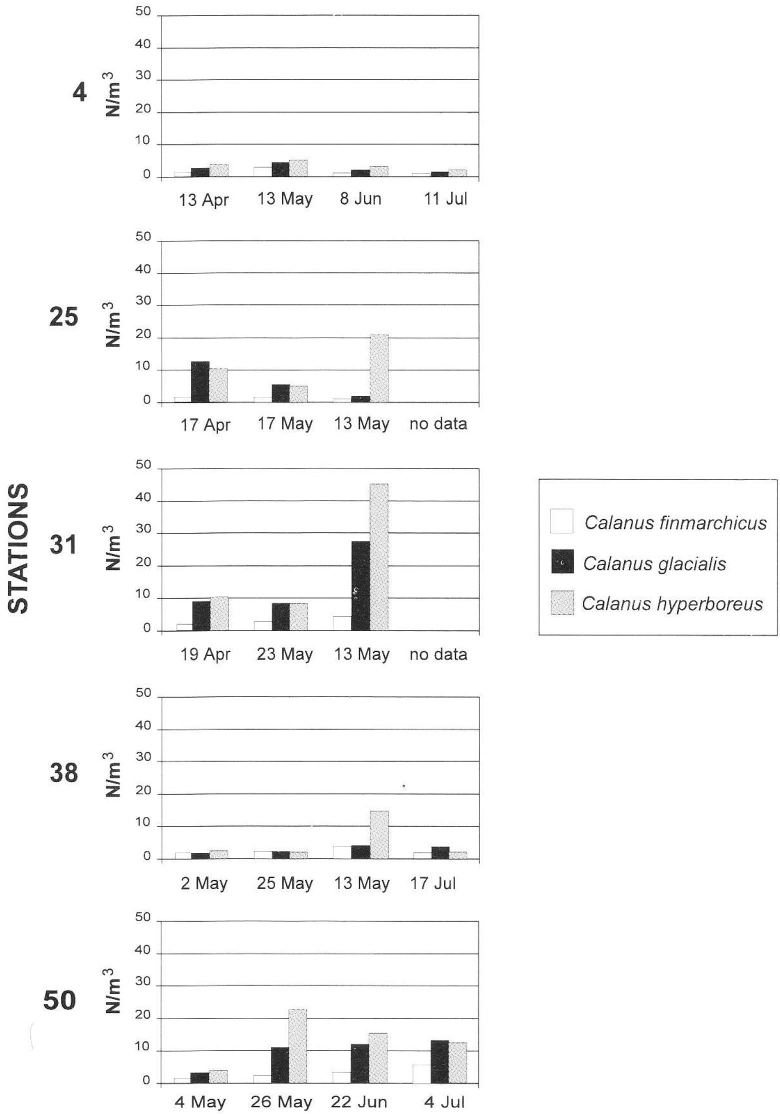

Fig. 2. Seasonal change in distribution of individuals *Calanus* species at sampling stations.

75% of abundance at Stations 38 and 60% at Station 50. Males made up 2–4% at Stations 4 and 31. At the beginning of this study CI and CII were absent or very scarce, except at Station 4 where CII constituted over 25% of the population. In the following months the young stages were observed in significant numbers at all stations. The highest abundance of *C. hyperboreus* CI was noted in May and of CII in June (Fig. 3).

The predominance of CIII and CIV of *C. glacialis* over CI and CII was noticed at all stations in the first month of our survey (Fig. 4). Development of young

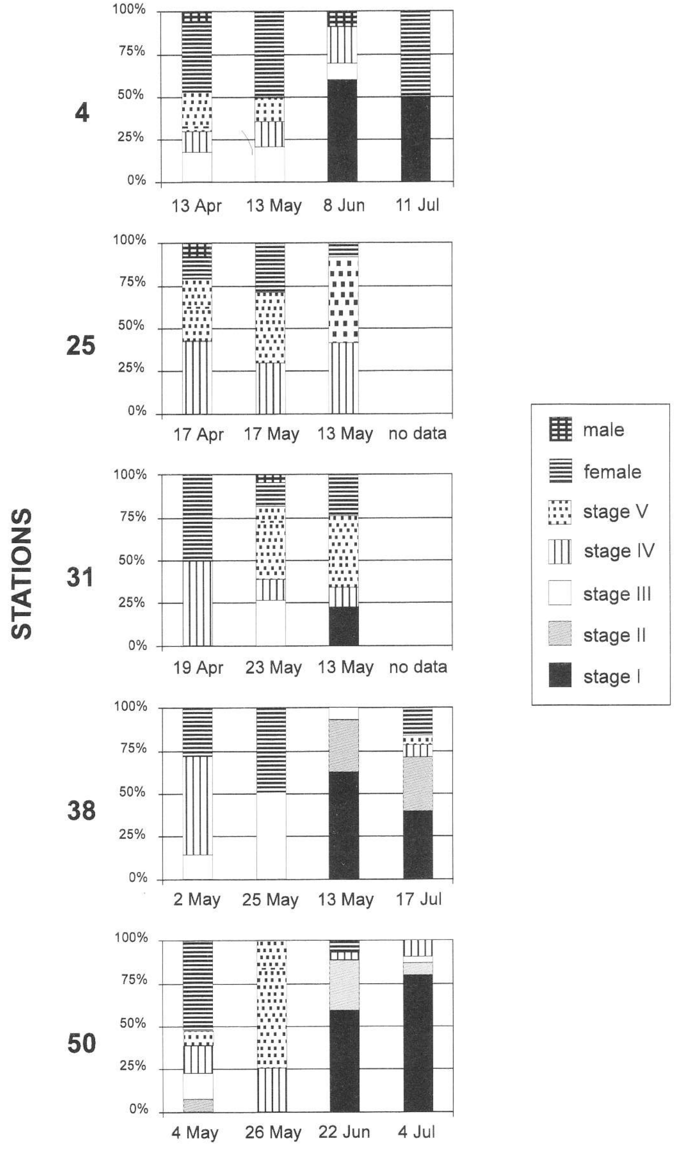

Fig. 3. Seasonal change in proportion of copepodit stages of *Calanus hyperboreus* at sampling stations.

stages (CI–CIII) followed a seasonal progression, reaching a maximum in June (99% and 90% at Stations 38 and 50, respectively). A rapid increase in CI numbers was observed in May at each station. At Station 50 they made up 60% of individuals. In June, CII was recorded in the significant percentages (20–30%). Only at Station 31 was this stage not observed.

Females and CIV of *C. finmarchicus* dominated at the beginning of the study period (Fig. 5). The percentage of females varied from 30% to 50% of the population,

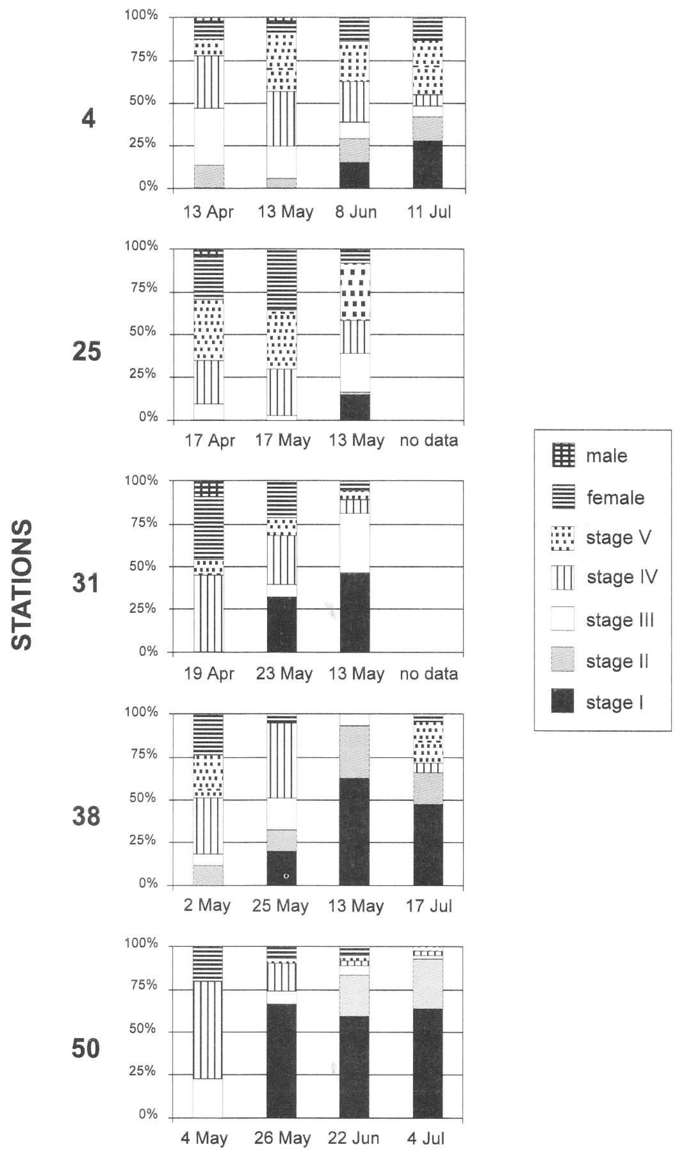

Fig. 4. Seasonal change in proportion of copepodit stages of *Calanus glacialis* at sampling stations.

with the highest concentration in the southern part of the study area (Station 50). Stage IV made up 10% at the most northern and southern stations and up to 60% in the central basin of the polynya. In the later period of this investigation CI and CII dominated the population structure of *C. finmarchicus.* The highest abundance of CI was noticed in June (up to 60%). An exception was the Station 50, where this stage reached the maximum in July (80%). Stage CII was not especially abundant at Stations 4 and 31, while at Stations 38 and 50 it reached 30% of the whole population.

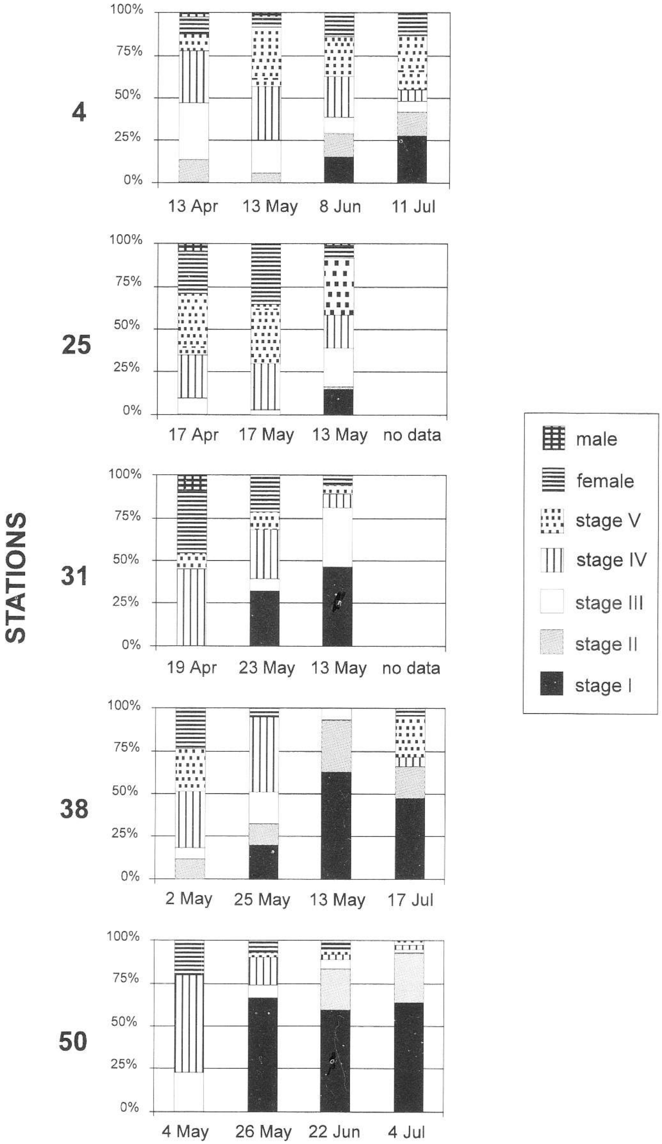

Fig. 5. Seasonal change in proportion of copepodit stages of *Calanus finmarchicus* at sampling stations.

Discussion

***Calanus* species' density** — *Calanus hyperboreus* is the dominant species in the Greenland Sea and Central Basin of the Arctic Ocean (Grainger 1963). Baffin Bay might belong to the areas with the highest concentration of this species (Hirche and Mumm 1992). The data obtained in this study confirm these observations. *C. hyperboreus* was the dominant species among all *Calanus* species in the North

Water Polynya in the April–July period. An interesting situation was observed at Station 38, which is under strong influence of the West Greenland Current, where *C. hyperboreus*, defined as an Arctic species (Buchanan and Sekerak 1982), dominated over Atlantic *C. finmarchicus*. A similar rare occurrence of *C. finmarchicus* in Baffin Bay was observed by Sameoto (1984). *C. hyperboreus* is regarded as a deep-water species (Klekowski and Węsławski 1991, Conover and Huntley 1991, Mumm 1993). However it is found in the region where bottom topography (in Smith Sound and Jones Sound) limit the inflow of the deep Arctic water and thus the inflow of this species. We assume that its occurrence in NOW might be caused by the migrations of overwintering population from the deep water to the upper layers (100–600 m) (Sømme 1934, Wiborg 1954), to which they might be transported from over topographical barriers.

Calanus glacialis is the dominant species together with *C. hyperboreus* in the western (Longhurst *et al.* 1984) and eastern parts of Baffin Bay (Sameoto 1984, Longhurst *et al.* 1984). *C. glacialis* is considered as an Arctic water species (Buchanan and Sekerak 1982) and the large numbers of it found at western station (31) could be explained by the strong influence of the Arctic surface waters at the station.

Calanus finmarchicus, a boreal-Atlantic species (Grainger 1963) is the least numerous *Calanus* species in NOW. Only at the beginning of the study period were the numbers of *C. finmarchicus* similar to *C. glacialis*, and this situation lasted only for a very short time (till May). The occurrence of *C. finmarchicus* as far as Smith Sound and Jones Sound, also noted by Grainger in 1961, may provide evidence for the presence of Atlantic waters driven by the West Greenland Current. Due to its ability to exist in wide temperature ranges (from 0°C to 22°C, Grainger 1963), *C. finmarchicus* is able to survive in the area where Arctic and Atlantic waters mix.

Population structure of *Calanus* species — Does *Calanus finmarchicus* reproduce in northern Baffin Bay? Grainger (1963) and Buchanan and Sekerak (1982) asserted that its reproduction success in this region is impossible, but that *C. finmarchicus* could survive in this water body for long periods. The time of investigation of these authors was from June to October, much later than our study. The major period of *C. finmarchicus* reproduction is very strongly related to the time of phytoplankton bloom (Niehoff and Hirche 2000), thus a large amount of the females recorded at the beginning of the cruise could spawn at that time. The high concentration of stage CI at Station 4 in June/July and the ability of both CI and females to survive in low temperatures (Sameoto 1984) suggest that reproduction may take place in the northernmost part of NOW. As the present investigation lasted only till July, the situation of the population in later months is not known. However, as CII, CIII, and CIV stages do not have as wide a tolerance for temperature as CV and adults (Sameoto 1984), we assume that the population may not survive during the winter period.

Evidence already exists that *C. glacialis* has a 1- to 2-year life cycle (Tande *et al.* 1985). This species is well capable of developing from eggs to CIII or CIV stage during its 1st year. This species overwinters as CV during its 2nd year in the Arctic (Hirche 1991, Tande *et al.* 1985), which suggests a 2-year life cycle in NOW as well. A similar life cycle is observed by Grainger (1965) in the Arctic Ocean and by Conover (Conover and Siferd 1993) in the Barents Sea. Conover and Harris (*unpublished data*) noted the reproduction of *C. glacialis* in the Canadian Arctic when ice was present. Smith *et al.* (1990), suggested that *C. glacialis* does not need a food supply for initial spawning. On the basis of this information we suspect that reproduction in NOW took place under ice, since a great amount in the CII stage was present at the beginning of the investigation period.

The size of *C. hyperboreus*, which is much larger in comparison to *C. finmarchicus* and *C. glacialis*, implies a much longer life cycle for this species (Scott *et al.* 2000). Its generation time is thought to vary between 1 and at least 4 years (Conover 1988, Conover and Siferd 1993, Hirche 1997). Sameoto (1984) defined at least a 2-year life cycle of *C. hyperboreus* in the eastern region of the Baffin Bay. Recently, Hirche (1997) proposed that *C. hyperboreus* develops to CIII stage during its 1st year and then overwinters as this stage. During the 2nd year the species develops to CIV, overwinters as this stage, then develops to CV in its 3rd year. The CV copepodites develop to adults during winter and then reproduce in the following spring, i.e. in the 4th year of their life. Since CIV stage was highly numerous in April in the NOW, we suspect that this species completes its life cycle in at least 4 years as well. The NOW population of *C. hyperboreus* seems to begin reproduction one month earlier than the other Arctic species, *C. glacialis*. Sameoto (1984) in Melville Bay and Grainger (1963) in the eastern region of Canadian waters found that the spawning period in the Arctic Ocean for this species occurs between January and March, which is due to the female's ability of spawning during the polar night (Conover 1988). Hence nauplii stages develop before the phytoplankton bloom (Grainger 1963) and the first copepodite stage has greater access to food supply.

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