Sea ice, depth and the onshore-offshore gradient in zooplankton community in the south-eastern Beaufort Sea in the fall

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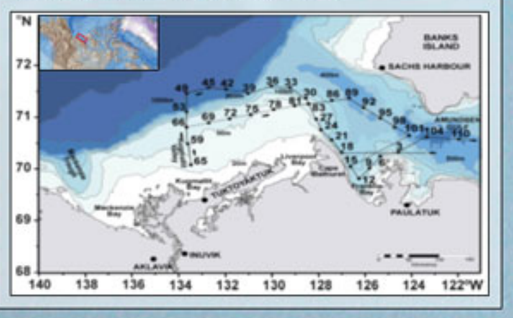
ABSTRACT

The reduction in sea ice cover caused by global warming will have severe repercussions on arctic marine ecosystems and biogeochemical fluxes. Various processes involved in the regulation of dissolved and particulate organic carbon on the extensive arctic continental shelves can be attributed to mesozooplankton. In order to reach a better comprehension of the effects of increased sea ice variability on biogeochemical cycles in the context of climatic warming, it is necessary to understand the dynamics of biogenic carbon in the upper water layers. At a regional scale, this requires knowledge of zooplankton community ecology, especially the distribution patterns of the different classes of zooplankton (Wassmann, 1998). The present study used multivariate techniques and Indicator Species Analysis to investigate patterns in zooplankton community structure on the Mackenzie Shelf and adjacent domains in autumn 2002. Cluster analysis and non-metric multidimensional scaling revealed three distinct community groups. Group 1 occupied the Mackenzie shelf and Franklin Bay, and off-shelf groups 2a and 2b occurred respectively in the cape Bathurst polynya and Beaufort slope. Eight copepod taxa dominated at >95% the zooplankton samples. *Pseudocalanus sp.* contributed predominantly to the three clusters discrimination and was the only significant species indicator for group 1. *Oithona similis*, *Oncaea borealis*, *Metridia longa* and *C. hyperboreus* were all indicators for Group 2a. Depth of station and duration of reduced ice conditions (<50% ice concentration) during the production season were strongly correlated with the zooplankton assemblage distribution patterns. The abundance of *Pseudocalanus sp.* was positively correlated with duration of reduced ice conditions while the abundances of species indicators for the Group 2b were negatively correlated with this same parameter. Under climatic warming, reduction of ice cover on the Arctic shelves is predicted to affect zooplankton distribution patterns to the potential benefit of *Pseudocalanus*.

MATERIALS AND METHODS

Study area

Fig. 1. A grid of 36 stations covered the Amundsen Gulf, Franklin Bay, middle and outer Mackenzie Shelf, and Beaufort continental slope at the limit of the ice pack. Sampling on board the CCGS *Pierre Radisson* ranged from 22 September to 14 October 2002.



Sampling

At each station, a sampler comprising four 1 m^2 aperture plankton nets (two 200-µm mesh nets and two 500-µm) was towed from the bottom to the surface to collect integrated samples of zooplankton. A CTD Rosette cast provided continuous vertical profiles of salinity and temperature as well as water from different depths for Chl a concentration measurements.

Weekly percent ice cover in a 25x25 km grid centred on each sampling station was calculated from satellite data provided by the National snow and Ice Data Center

Data analyses

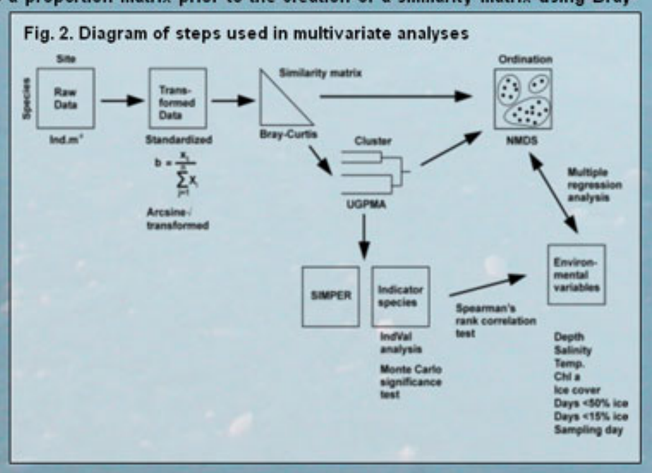
A "species abundance" X "site" matrix was analysed by cluster analysis and non-metric multidimensional scaling (NMDS) ordination to explore patterns in zooplankton community structure. Due to the broad range of depths sampled, the initial matrix was first transformed into a proportion matrix prior to the creation of a similarity matrix using Bray-Curtis similarity index.

Both a similarity of percentages (SIMPER) analysis and an Indicator Species analysis (IndVal) were used to identify the taxa responsible for the differences among the groups revealed by the cluster analysis.

A multiple regression analysis, comparing the scores derived from the NMDS plot with various environmental factors, was conducted to verify which of these may have the greatest influence on the zooplankton distributions.

A Spearman's rank correlation test between abundances of indicator species defined by the IndVal analysis and environmental variables was carried out to verify which of the latter might explain the species distribution patterns.

Fig. 2. Diagram of steps used in multivariate analyses



RESULTS

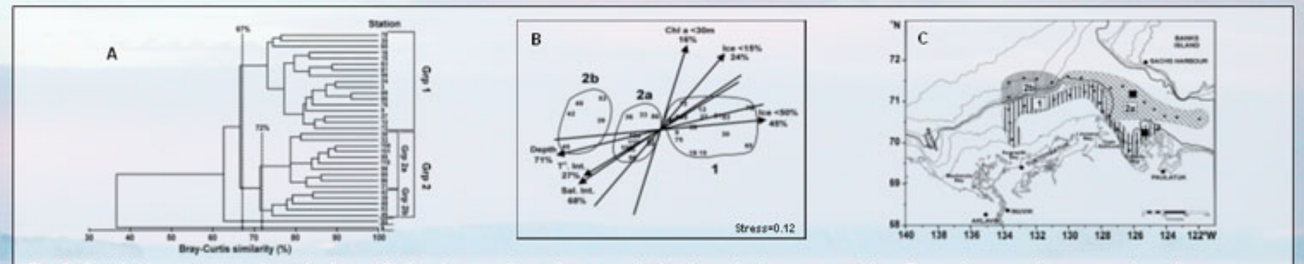


Fig. 3. Distribution patterns of zooplankton. (A) Dendrogram from cluster analysis of zooplankton composition. Two primary and two secondary clusters are identified. (B) NMDS ordination of sampling sites with superimposition of the zooplankton groups identified in Fig. 3A. Significant multiple regressions between ordination scores and environmental parameters are shown as well as the proportion (%) of the variance in the biotic data explained by the parameter. (C) Geographical distribution of station groups determined by cluster analysis. ■ = outlier.

Table 1. Ranking of taxa according to their relative contribution to the multivariate dissimilarities between pairs of groups defined by cluster analysis.

Group	1	2a
2a	1) *Pseudocalanus sp.* 2) *Oncaea borealis* 3) *Metridia longa* 4) *Cyclopina sp.* 5) *Microcalanus pygmaeus*	
2b	1) *Pseudocalanus sp.* 2) *Microcalanus pygmaeus* 3) *Cyclopina sp.* 4) *Metridia longa* 5) *Oithona similis*	1) *Pseudocalanus sp.* 2) *Cyclopina sp.* 3) *Microcalanus pygmaeus* 4) *Oithona similis* 5) *Spinocalanus longicornis*

- A Shelf zooplankton community group (Grp 1) and an off-shelf assemblage (Grp 2) were first distinguished by the cluster analysis. A further partition of group 2 gave the polynya zooplankton assemblage (Grp 2a) to the east and the slope group (Grp 2b) to the west. The NMDS plot, with a low stress value=0.12, validated this separation into three groups.
- Depth of station explained 71% of the variation in the data, followed closely by integrated salinity. However, the latter parameter was strongly correlated with depth (Spearman r_s=0,92; p<0.0001).
- Time with less than 50 % ice concentration during the production season also displayed highly significant multiple correlation with the NMDS configuration. Moreover, the angle between the direction of this parameter and the main axis of groups differentiation was the smallest.
- *Pseudocalanus sp.* was the taxon that contributed the most to the partition between all three groups.

Fig. 4. Site clusters revealed by the cluster analysis in Fig. 3, with associated significant indicator species from the IndVal analysis. Indicator values are in parenthesis. Numerically dominant taxa are in bold.

- The numerically dominant *Pseudocalanus sp.* was the only significant indicator of the shelf group 1.
- Eighteen taxa were indicative of the off-shelf zooplankton community (group 2).
- Ten taxa were significant indicators of the polynya group. Among these were the dominant *Metridia longa*, *Calanus hyperboreus*, *Oncaea borealis* and *Oithona similis*.
- The slope group had seven significant indicator taxa, but no numerically dominant ones among these.

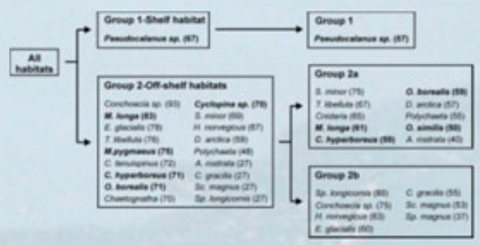


Table 2. Spearman's rank correlation coefficients (r_s) between environmental variables and integrated abundance of taxa selected for their dominant and/or indicator status. Number of sampling sites compared (n) =32. [a]Significance at the p<0.01 level; [b] significance at the p<0.001 level; [c] significance at the p<0.0001 level.

Variable	Species												
	Ps	Os	Ob	Ml	Mp	Ch	Cy	CH	Tl	Sm	Eg	CO	Sl
Station depth	-0.375	0.159	**0.645**[c]	**0.781**[c]	**0.724**[c]	**0.461**[a]	**0.692**[c]	**0.479**[a]	**0.552**[a]	**0.476**[a]	**0.661**[c]	**0.799**[c]	**0.465**[a]
Water temperature (integrated)	-0.360	-0.197	0.165	0.261	0.318	0.101	**0.480**[a]	0.404	0.104	0.242	0.210	**0.534**[a]	0.426
Chlorophyll a (integrated to 30m)	0.226	0.214	0.251	0.070	-0.218	0.256	-0.076	-0.124	0.197	0.204	-0.254	-0.210	-0.435
Duration <50% ice concentration	**0.438**[a]	0.039	-0.109	-0.279	**-0.500**[b]	-0.089	**-0.467**[a]	-0.278	-0.305	-0.314	**-0.447**[a]	**-0.594**[b]	**-0.505**[a]
Duration <15% ice concentration	0.375	0.113	-0.035	-0.097	-0.305	-0.010	-0.088	0.051	-0.040	0.035	-0.368	-0.417	-0.426

- The abundance of *Pseudocalanus sp.* was positively correlated with duration of reduced ice conditions whereas abundances of species indicative of the slope group showed a negative correlation.

CONCLUSIONS

- Three distinct zooplankton community groups were identified by multivariate analyses. Groups 1, 2a and 2b occurred respectively on the Mackenzie Shelf and Franklin Bay, in the Cape Bathurst polynya, and on the Beaufort slope.
- Depth and time of reduced ice conditions during the production season were strongly correlated with the zooplankton assemblages distribution patterns. This suggests that they are important factors in the structuring of the fall zooplankton communities in the south-eastern Beaufort Sea.
- The dominant *Pseudocalanus sp.* was the main contributor to the groups differentiation and was the only significant species indicator of the shelf group.
- Time of reduced ice cover may exert a positive control on the abundance of *Pseudocalanus sp.* Hence, the predicted reduction in sea ice cover should affect zooplankton distribution patterns to the potential benefit of *Pseudocalanus sp.*

REFERENCE

Wassmann, P., 1998. Retention versus export food chains: processes controlling sinking loss from marine pelagic systems. Hydrobiologia, 363 (1-3): 29-57