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Cladocera species composition in lakes in the area of the Hornsund Fjord (Southern Spitsbergen) – preliminary results

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ABSTRACT

Key-words: *Cladocera species composition, Spitsbergen, lakes, Hornsund Fjord*

Species composition of benthic and planktonic Cladocera was analysed in four lakes and ponds located in the southern part of the Spitsbergen Island near the Fjord Hornsund. This is the first study to provide information on the species composition of the contemporary and subfossil Cladocera in this region. A total of eight Cladocera taxa were found in the sediments and waters of the lakes that have been chosen for the study. The sediments included remains of only five species, while seven Cladocera species were found in the zooplankton samples. The results imply that the lakes are subject to natural transformations driven by the fluctuating climate which was reflected by increasing the number of species, and in particular in the appearance of *Bosmina longirostris.* Absence of some littoral Cladocera species in the sediments (*e.g.*, small *Alona*, *Ophyroxus gracilis*), with simultaneous occurrence of these species in the water, may be a result of physical and chemical processes influencing the destruction and lack of preservation of the remains in the sediments.

RÉSUMÉ

Composition spécifique des cladocères des lacs d'une région du Fjord Hornsund (Sud-Spitzberg) – résultats préliminaires

Mots-clés : *composition spécifique des cladocères, lacs, Spitzberg, fjord de Hornsund*

La composition spécifique des cladocères des sédiments et des eaux de quatre lacs et mares de la partie sud de l'île de Spitzberg, à proximité du fjord Hornsund, a été analysée. Cette étude représente la première approche de la composition spécifique de cladocères subfossiles du sud du Spitzberg. Un total de huit taxons a été trouvé dans les sédiments et les eaux des lacs étudiés. Les sédiments ne contiennent que les restes de cinq espèces, alors que sept espèces de cladocères sont trouvées dans les échantillons de zooplancton. Les résultats obtenus suggèrent que les lacs étudiés sont sujets à des changements naturels traduits par un accroissement du nombre d'espèces et en particulier dans l'apparition de *Bosmina longirostris*, espèce qui n'avait jamais été observée dans les sédiments de tels lacs. Pour cette raison, la présence de nouvelles espèces dans les eaux des lacs étudiés constitue probablement une conséquence aux meilleures conditions climatiques (principalement thermiques) aux hautes latitudes. L'absence de certaines espèces de cladocères dans les sédiments, et la présence simultanée de ces espèces dans l'eau, peuvent être le résultat de processus physiques ou chimiques conduisant à la destruction et à l'absence de préservation de restes dans les sédiments.

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INTRODUCTION

Lacustrine sedimentary deposits provide a unique opportunity to study the dynamic of environmental and climate changes (Korhola and Rautio, 2001; Smol, 2008; Bjerring *et al.*, 2009). Lakes located at high latitudes are of particular interest to researchers. Arctic lakes are good sentinels of environmental changes caused by natural and anthropogenic factors because they respond very quickly to even slightest changes in the surrounding landscape and atmosphere (Douglas and Smol, 1999; Betts-Piper *et al.*, 2004). Aquatic organisms represent an important element of research in lakes, particularly the zoo- and phytoplankton. Cladocera represent one of the main component of the lakes zooplankton and because their shells preserve well in sediments they are often used as proxies to reconstruct past environmental conditions in these ecosystems (Jeppesen *et al.*, 2001; Kamenik *et al.*, 2007; Smol, 2008; Galbarczyk-Gąsiorowska *et al.*, 2009).

Most of the studies on contemporary and subfossil Cladocera in the high Arctic lakes have been conducted in Canada, Greenland, and Lapland (Brodersen and Anderson, 2000; Lauridsen *et al.*, 2001; Rautio *et al.*, 2003; Sarmaja-Korjonen *et al.*, 2006; Szeroczyńska *et al.*, 2007; Sweetman *et al.*, 2008; Nevalainen, 2009), while only few studies have been done in the Svalbard Archipelago (Birks *et al.*, 2004).

The main goal of our research was to describe species composition of modern and subfossil Cladocera in four lakes located in the southern part of Spitsbergen near the Fjord Hornsund. This information will be used in the future studies to determine the major factors that influence the trophic status of the lakes. The first results that have already been obtained suggest that the Cladocera species composition determined in the lakes studied differs significantly from those determined in other arctic regions. It probably results from various factors, such as: severe climatic conditions, the morphometry of the lakes, and the size and nature of catchments of the lakes. The results obtained also suggest significant changes occurring today (within the last few years) in the Cladocera species composition.

DESCRIPTION OF THE STUDY SITE

The current climate of Svalbard is arctic, with an average annual temperature of approximately −6 °C. The climate of the southwestern part of the Spitsbergen coast is somewhat more moderate than in the remaining part of the island. This area is under the influence of two water masses: the warmer West Spitsbergen Current and the colder Sorrkap Current (Swerpel, 1985). The average summer temperature for this area (June to August) is 4.6 °C, and the vegetation period last between 8 and 10 weeks. The coldest period is between January and April, with an average monthly temperature between −10 and −14 °C. The average precipitation for this region is $<$ 400 mm per year, with maximum rainfall during summer periods (July) (Brázdil *et al.*, 1988; Birks *et al.*, 2004; Nowiński and Wiśniewska-Wojtasik, 2006).

Two biological activity periods can be distinguished in lakes located in the high Arctic – the active and passive phase. The active phase is concurrent with the period of positive temperatures during the arctic summer when the hydrological network is functioning. The passive phase is related to the period of negative temperatures, and usually lasts from the middle of September to the end of May (Nowiński and Wiśniewska-Wojtasik, 2006; Wojtasik and Bryłka-Wołk, 2010). Generally, lakes on Spitsbergen are in the initial phase of limnological succession, characterised by very low production of organic matter (Nowiński and Wiśniewska-Wojtasik, 2006).

The four lakes (site 1 – lake constituting a drinking water reservoir for the Polish Polar Station, site 2 – lake located in the direct vicinity study site No. 1, site 3 – Lake Fugledammen, site 4 – Lake Revvatnet) that were subject of this study are located in the southern part of the Spitsbergen Island, west of the Polish Polar Station "*Hornsund*" in the vicinity of the Fjord Hornsund (77° 00′ N; 15° 33′ E; Figure 1).

The lakes are situated on post-glacial marine terraces commonly occurring at the coast. (Rakusa-Suszczewski, 1963; Giżejewski, 1994; Nowiński, 2005). During the summer the

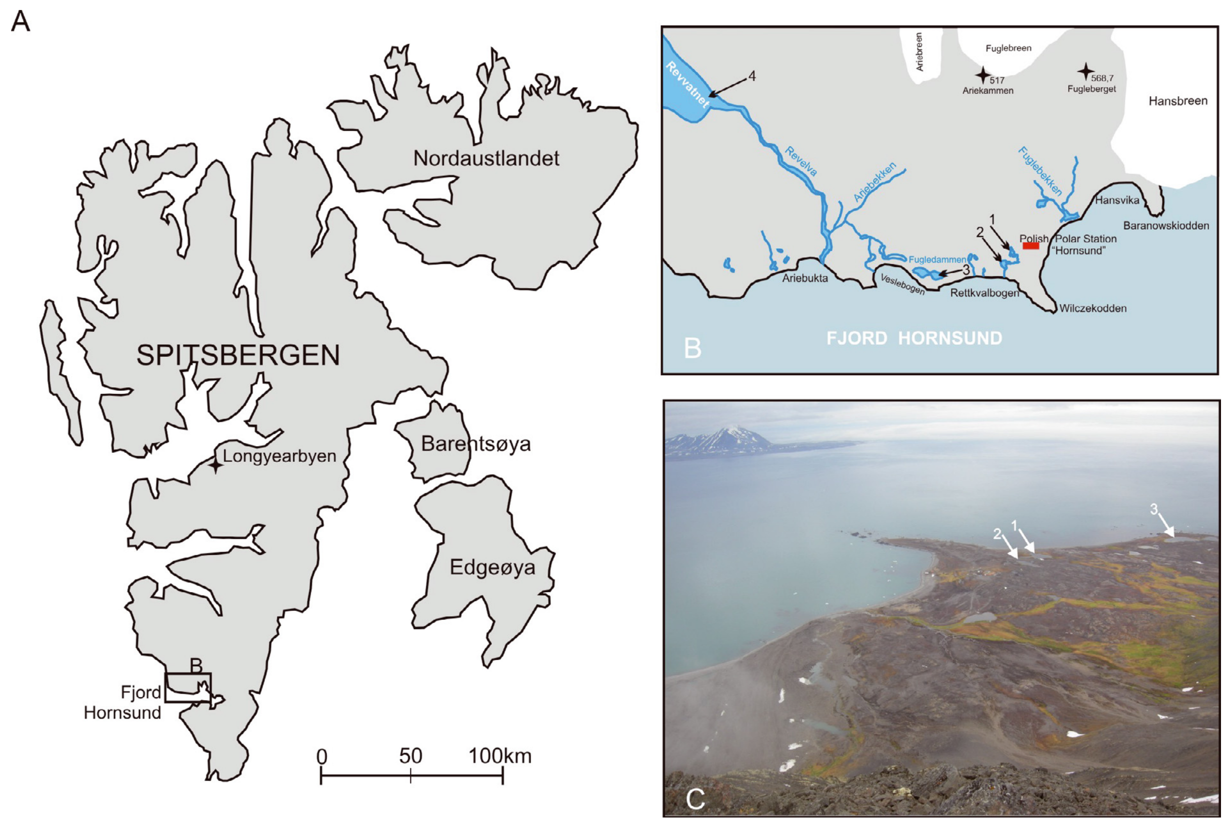

Figure 1
Location of the study lakes (Spitsbergen, Fjord Hornsund, Norway). (A) Location of the Fjord Hornsund. (B) Map of the northern part of the Fjord Hornsund with marked study sites (1, 2, 3, 4). (C) Photograph of the region of the Polish Polar Station ("Hornsund") with marked study sites (1, 2, 3).

Figure 1
Localisation des lacs étudiés (Spitzberg, fjord Hornsund, Norvège). (A) Localisation du fjord Hornsund. (B) Carte de la partie nord du fjord Hornsund avec indication des sites d'étude (1, 2, 3, 4). (C) Photo de la région de la station polaire polonaise (« *Hornsund* ») avec indication des sites d'étude (1, 2, 3).

Table I
Lithology and core length of the four study sites.

Tableau I
Lithologie et longueur des carottes des quatre sites d'étude.

Lake	Surface area	Depth of sampling site	Core length	Lithology
Study site No. 1 water intake	0.6 ha	110 cm	0–17 cm	Silts and medium sands
Study site No. 2	0.7 ha	80 cm	0–8 cm	Silts and algal mats
Study site No. 3 Fugledammen	2.3 ha	90 cm	0–18 cm	Silts and fine sands with pebbles of local rocks of up to 1.0 cm
Study site No. 4 Revvatnet	76 ha	110 cm (max. depth 38 m)	0–15 cm	Silts and gravels and coarse sands with pebbles of local rocks of up to 2.5 cm

average conductivity of the lakes' water is ~150 $\mu S \cdot cm^{-1}$, and the oxygen content is ~14.1 $mg \cdot dm^{-3}$. The average water temperature in the studied lakes at the beginning of August 2007 amounted to approximately 8.4 °C, and pH varied between 7.4 and 7.7.

The lakes No. 1 and No. 2 are small, shallow and do not contain fish. They are classified as polymictic lakes. Continuous water mixing is observed during the summer and ceases completely during the winter, when the lakes freeze down to the bottom (Nowiński and Wiśniewska-Wojtasik, 2006).

Lakes Fugledammen (No. 3) and Revvatnet (No. 4) are larger, deeper, and are inhabited by fish. They are subject to significant mixing, but smaller than lakes No. 1 and No. 2 (Table I). All the lakes are extremely oligotrophic, although their fertility increases during the summer period due to expansion of bird colonies along the coast (Wojczulanis-Jakubas *et al.*, 2008; Zmudczyńska *et al.*, 2009).

MATERIALS AND METHODS

In order to determine species habitat affinities, Cladocera samples were collected from each lake's water column and sediment surface in July and August 2007. At the same time, a total of four sediment cores were retrieved from the same locations for analyses of past environmental conditions. The zooplankton samples were collected using a plankton net with a 40-μm mesh, from the littoral zone of each lake, while the sediment cores were retrieved using a Kajak gravity corer and then sectioned into 1 cm slices. All samples were stored in plastic bags, transported to the laboratory on ice and preserved in alcohol until they could be processed. Lithologically, the sampled sediments were composed mainly of more or less organic fine-silts with sands and pebbles of local rocks (Table I).

The sediments of Lakes Fugledammen and Revvatnet were dated by means of the Pb-210 method (Quaternary Geochronology Laboratory in the Institute of Geological Sciences, Polish Academy of Sciences in Warsaw, Poland), but the obtain results are not suitable for age model and the determination of the rate and time of sedimentation.

The sediment samples were prepared for subfossil Cladocera analysis according to the method described by Frey (1986). Coarse-grained sediments (including medium sands and gravels) were not stirred in a magnetic stirrer to prevent mechanical damage to Cladocera remains. Because of the poor preservation and/or low concentrations of cladoceran remains in the sediment samples, it was impossible to conduct any quantitative analyses using the obtained data. Therefore, all the results described in this manuscript are qualitative, in nature. The cladoceran remains (head shields, shells, postabdomens, postabdominal claws, and ephippia) were counted. The identification of species was carried out according to Flössner (1972, 2000) and Smirnov (1996) for freshwater samples, and Szeroczyńska and Sarmaja-Korjonen (2007) for Cladocera remains.

Table II
Species composition of Cladocera from water and sediments in four study sites.

Tableau II
Composition spécifique des cladocères de l'eau et des sédiments des quatre sites d'études.

Species	Study site No. 1		Study site No. 2		Study site No. 3		Study site No. 4	
	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment
Chydorus sphaericus	+	+	+	+	+	+	+	+
Bosmina longirostris	+		+		+		+	
***Daphnia pulex* – group**			+	+	+	+		
Small *Alona* (*guttata*)	+							
Acroperus harpae	+			+		+		
***Eurycercus* sp.**					+	+		
Ophyroxus gracilis					+			
Chydorus arcticus						+		

RESULTS

A total of five taxa were identified in the core samples. These were: *Chydorus sphaericus* (Müller, 1776), *Daphnia-pulex* group Leydig 1860, *Acroperus harpae* (Baird, 1835), *Eurycercus* sp. Baird, 1843, and *Chydorus arcticus* (?) (Røen, 1987) (Table II, Figure 2). *Chydorus sphaericus* (Figure 2D) was the only taxon that appeared in sediments of all the lakes. The remains of *Daphnia pulex*-group and *Acroperus harpae* (Figure 2C) were recorded only in the sediments of lakes Nos. 2 and 3, while *Eurycercus* sp. (Figure 2B) and *Chydorus arcticus* (?) (Figure 2A) in lake No. 3. In Lake Fugledammen (study site 3), remains of Cladocera belonging to genus *Chydorus* were found, classified by the authors as *Chydorus arcticus* (Figure 2A), a species described by Røen (1987). Because only the remains of shells and no head capsules were found, the determination of the species as *Chydorus arcticus* is uncertain.

Arctic Cladocera species are often classified as pioneer species because they can withstand even the most unfavourable environmental conditions (*e.g.*, very low temperatures) and appear first in previously inhabited, often frozen aquatic ecosystems indicating the beginning of environmental change often cause by warming climate (Sarmaja-Korjonen *et al.*, 2003; Bennike *et al.*, 2004; Szeroczyńska, 2006).

Zooplankton samples collected from the water column included seven Cladocera species. Among these species, *Chydorus sphaericus* and *Bosmina longirostris* (Müller, 1785) occurred in all the studied lakes. The waters of lake No. 1 included species of *Acroperus harpae* and small *Alona* (*guttata*) Sars, 1862. Waters of lakes No. 2 and 3 contained species of the *Daphnia pulex*-group, which were also found in the lakes sediments (Table II).

DISCUSSION

The investigated lakes contained more Cladocera species in the water than in the sediment. The difference between species composition in the water column and sediment samples indicates recent changes in edaphic conditions and temperature. The only species occurring in both, sediment and water column was the cosmopolitan *Chydorus sphaericus* species. This species can tolerate broad changes in temperature and occurs in all types of lakes. *Bosmina longirostris,* which was exclusively recorded in the water column of all of the studied lakes, implies better edaphic condition. Occurrence of this species may indicate an increase of nutrients concentration in the water and probably an increase of water temperature (Locke and Sprules, 2000; Korhola and Rautio, 2001; Čeirāns, 2007; Sweetman *et al.*, 2010). Additionally, Wiktor and Wojciechowska (2005) showed that improved thermal conditions in Spitsbergen during the last few years triggered development of macroalgae (mostly Chlorophyta) in the local lakes, which increased the supply of nutritious substances. Lack of *Chydorus arcticus* – a low temperature-tolerant species (Røen, 1987; Bennike, 2000; Sweetman *et al.*, 2008), in

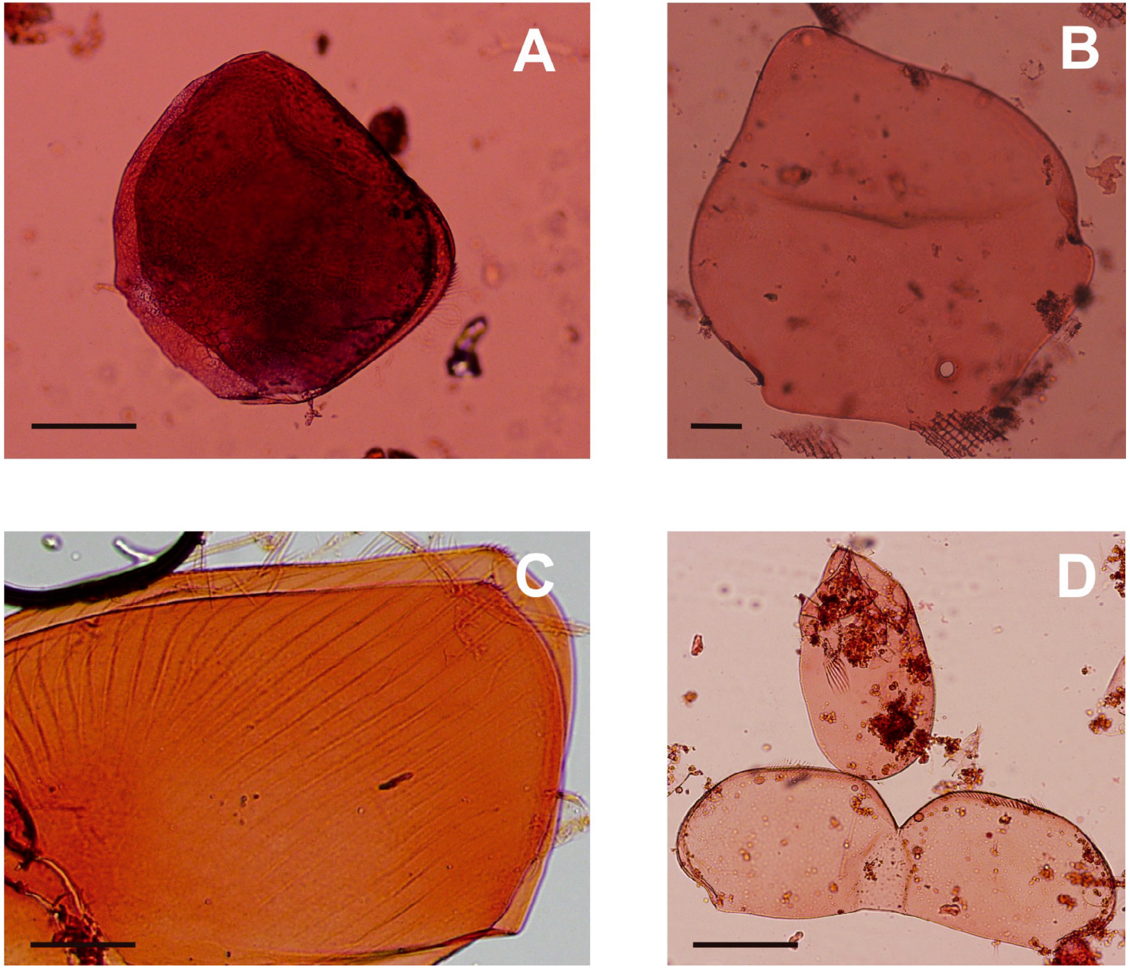

Figure 2
Examples of Cladocera remains found in lake sediments in the area of the Hornsund Fjord; the scale bar is 100 μm. (A) Chydorus arcticus *(?) – shell, lake Fugledammen (study site No. 3); depth −11 cm. (B)* Eurycercus *sp. – headshield, Lake Fugledammen (study site No. 3); depth −8 cm. (C)* Acroperus harpae *– shell; study site No. 2; depth 2 cm. (D)* Chydorus sphaericus *– headshield and shell, study site No. 1; depth −5 cm.*

Figure 2
Exemples de restes de cladocères trouvés dans les sédiments lacustres de la région du fjord Hornsund ; la barre d'échelle représente 100 μm. (A) *Chydorus arcticus* (?) – carapace, lac Fugledammen (site d'étude n° 3) ; profondeur −11 cm. (B) *Eurycercus* sp. – capsule céphalique, lac Fugledammen (site d'étude n° 3) ; profondeur −8 cm. (C) *Acroperus harpae* – carapace ; site d'étude n° 2 ; profondeur −2 cm. (D) *Chydorus sphaericus* – capsule céphalique et carapace, site d'étude n° 1 ; profondeur −5 cm.

the waters of the studied lakes may indicate increase of the average water temperature of the lakes due to the warming occurring in recent decades at higher latitudes.

Generally, the sediments of the Spitsbergen lakes included a small number of Cladocera species (Table II). The differences between the Cladocera occurring in the sediment and in the water are quite difficult to explain. Lack of certain species in the sediments, in spite of their occurrence in the water column, can be due to several reasons. One of which may be rapid destruction of the shells in the lake's bottom sediments. This process may be caused by a complete freezing of the lakes down to the bottom or physical damaging of the thin shells in sediments that are often composed of coarse-grained material. Another explanation of poor species preservation in sediments may be a large inter- and intra-annual temperature variability. We hypothesize that higher number Cladocera species in the water may be due to higher water temperature, which are probably a results of the climate warming observed in Arctic regions in recent years. A similar phenomenon was described by Sweetman *et al.* (2008) and Smol *et al.* (2005) in the case of lakes situated in the Arctic area of Canada. They found out that the migration of some species to high latitudes is related to the climate warming occurring in the Northern Hemisphere.

This pilot study suggests that more studies are necessary in the lakes on the Spitsbergen Island to improve our knowledge of Cladocera species distribution, composition and relationship to water quality. This knowledge is necessary before the studies of the past environmental conditions can begin.

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