Evaluation of the diversity of microcrustaceans (Crustacea, Cladocera) using sediment samples collected from Lake Neito-Malto in Yamalo-Nenets Autonomous Okrug, Russia

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Abstract. Detailed layer-by-layer studying of fossil remains of organisms provides an insight into the historical development of biocenoses. This paper focuses on the fossil cladoceran remains obtained from the sediment archive of Lake Naito-3 (70°12'125" N 70°22'592" E) (Yamalo-Nenets Autonomous Okrug, Russia) in order to model its ecological transformations. A total of 17 cladoceran taxa, mostly belonging to the family Chydoridae, were identified. The dominant species was Bosmina longirostris (Müller, 1785) widespread in all horizons of the sediment core. Using the constrained cluster analysis, four stratigraphic zones were singled out.

1. Introduction

Arctic and Subarctic regions have attracted considerable interest of researchers at the recent years. Thought to be that high-latitude regions are play a strong role in climatic forcing, and may be particularly sensitive to climate change [1-2]. Paleoclimatic investigations allow us to clarify the study of the climate and environmental situation of particular regions and water objects in the past and to predict future changes, identify the development trends of the Earth's climate [3-4]. Cladocerans are very promising for studying climate change risks owing to their inherently predictive nature. They form a rich functional group of zooplankton in ecosystem modeling and are distributed all over the world [5-6].

This study investigates Neito-Malto (70°12'125" N 70°22'592" E) (Figure 1), a thermokarst blue lake on the Yamal Peninsula, Neito-Seyakha area. It covers the vastest area (more than 200 km^2) in the Neito lakes system and is the Yamal's second largest water body. The lake kettle has a round shape and extends 17.8 km from south to north, 16.5 km from west to east. The shoreline length totals 60 km. Despite its large size, the lake is shallow:

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average depth less than 3 m, maximum depth up to 21 m. The lake shallowness favors wind-induced mixing and cooling of waters. The shores are bluff, reaching 20–25 m in height (2–5 m in the southern area). The high shores are dissected by ravines and creek valleys. Moderate abrasion is present overall. Dissolved oxygen amounts to 158%, electrical conductivity of water is low (29 μS/cm), pH 6.2 [7-8].

2. Material and Methodology

The sediment core (total length 16 cm) for paleoecological analysis was taken from the deepest area of Lake Neito-Malto as part of the summer research expedition in 2020. The obtained core was cut into 1 cm thick segments. Each segment was used to investigate the subfossil cladoceran remains by A. Korhola and M. Rautio's method [9]. The dry sediments (2–5 g) were mixed with 10% KOH and heated to 75°C for 30 min. The suspended matter was then rinsed through 50 μm sieve. All samples were treated with ethanol to prevent decay, stained with safranin, and examined under an AxioLab A1 light microscope at 100–400× magnification.

The subfossil remains were identified to genus and species levels using the keys [10–18]. When planktonic crustaceans die, their chitinous body splits into various exoskeletal parts, such as carapaces, postabdomens, terminal claws of the postabdomen, mandibles, antennal segments (in Copepoda), and head shields (in Cladocera), all regarded as diagnostic features [9]. For each sample, 210 individuals from 15 sample segments were analyzed, on average.

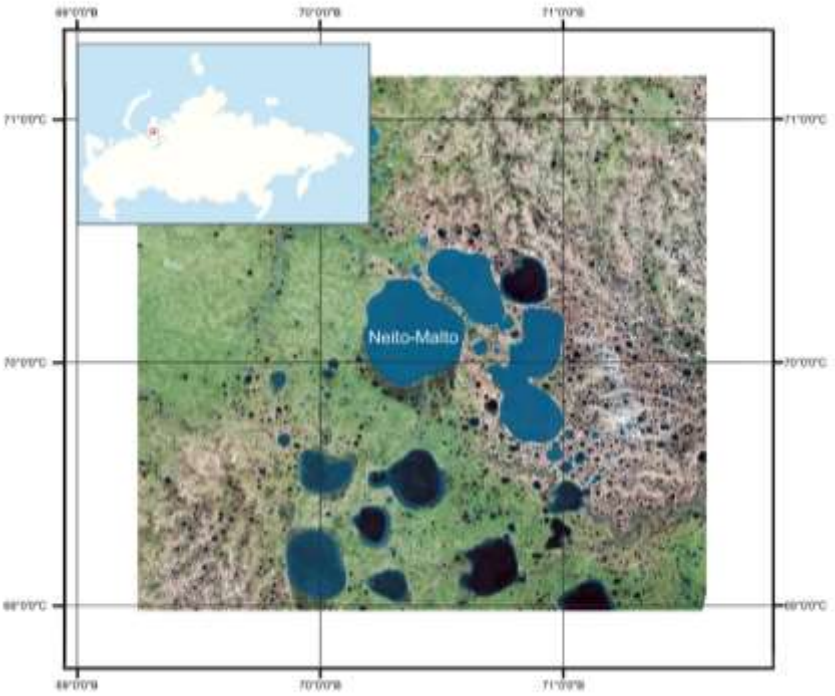

Fig. 1. Location of study area (Yamal Peninsula)

3. Results and Discussion

A total of 17 cladoceran taxa, mostly from the family Chydoridae, were registered in the zootanatocenoses of the lake. The families Bosminidae, Daphniidae, and Eurycercidae were represented by 5 taxa each. In the sediment core N3, the remains of 8594 cladoceran individuals were found. The average number of cladoceran individuals per sample segment was 210±5, with a minimum of 177 individuals and a maximum of 242 individuals. The concentration of subfossil cladoceran remains per 1 g of the dry sample segment weight varied from 38 to 173 ind./g (105±11 ind./g on average). The number of taxa in the core was from 3 to 11 (6 on average).

Along with cladocerans, the examined sample segments contained the remains of other invertebrates: Chyronomidae, Copepoda, and fragments of insects.

Throughout the entire core length, *Bosmina longirostris*, a small-sized species, turned out to be a superdominant (2752 ind., i.e., 87.23% of all recorded individuals) in the cladoceran assemblage. Other taxa were present in insignificant numbers. As it has long been established, bosmins and their remains are often numerous and, therefore, not rare findings. Although they occurred in the littoral zone as well, the pelagial zone was the area where they aggregated in extremely high numbers, thereby justifying the conclusion that the tanatocenosis of bosmins in Lake Neito-Malto is a pelagial group [19]. The superdominance of *B. longirostris* was observed, because there are areas with high depths in the lake under study. Other remains (much less numerous) were of *Bosmina (Eubosmina) longispina* (Leydig, 1860) (122 ind., 3.87 %) with the abundance changing throughout the sediment core and *Chydorus* cf. *sphaericus* (Müller 1785) (222 ind., 7.04 %) being eurytopic and widespread taxon.

Considering the ecological features of cladocerans, littoral taxa (71%), mostly Chydoridae, prevailed, while the planktonic (18%) and eurytopic (12%) taxa were less diverse. Based on the zoogeographical characteristics, the highest diversity was noted for the taxa confined to the northern areas, such as the Holarctic (58%) and Palearctic (25%). Cosmopolites were a few taxa (17%).

The Shannon–Weaver index indicating the water quality of the lake varied from 0.26 to 0.97 bit/ind. Its average value was 0.68±0.19 bit/ind., which is typical for polluted water bodies and associated with the low species diversity and absolute dominance of a single species. The Pantle-Buck saprobity index for the entire sediment core varied from 1.48 to 1.59 (1.53±0.01 on average), thereby reflecting the β-mesosaprobic conditions of the lake ecosystem.

The sediment core from the lake was divided into four stratigraphic zones using the constrained cluster analysis (CONISS) via Tilia software (Figure 2) [20].

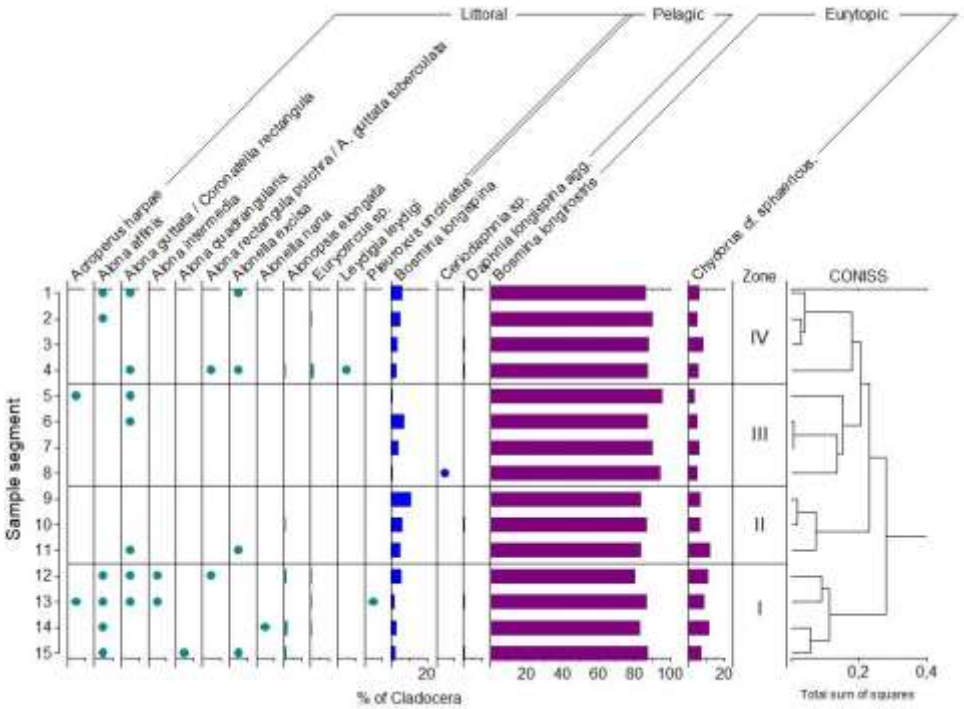

Fig. 2. Stratigraphic distribution of cladoceran taxa in the bottom sediments of Lake Neito-Malto (Yamal Peninsula), 2020.

Zone I comprised the horizon of 16–12 cm. A total of 14 cladoceran taxa were identified here. In the studied sample segments, the number of taxa varied from 7 to 11. The average number of cladoceran individuals was 201. The average concentration of subfossil cladocerans per 1 g of the dry sample segment weight was 89 ind./g. The abundance of individuals changed from 177 to 220, and their concentration per 1 g of the dry sample segment weight was from 73 to 123 ind./g. As the entire sediment core, this zone was dominated by *B. longirostris*, a eurytopic species reaching high abundance in the pelagial area. Furthermore, *C.* cf. *sphaericus* was characterized by its maximum abundance values (19 individuals on average in the studied samples) decreasing in the following horizons. Another representative of the family Bosminidae is B. *(E.) longispina* (6 individuals on average), which occupied a secondary position. The littoral taxa, mostly those from the family Chydoridae, were found as single individuals. However, they were most diverse within this horizon and included *Acroperus harpae* (Baird, 1834), *Biapertura affinis* (Leydig, 1860), *Alona guttata / Coronatella rectangula* (Baird, 1843), *Alona intermedia* (Sars, 1862), *Alona quadrangularis* (Müller, 1776), *Coronatella rectangula pulchra / Alona guttata tuberculata* (Baird, 1843), *Alonella excisa* (Fischer, 1854), *Alonella nana* (Baird, 1850), *Alonopsis elongata* (Sars, 1861), *Eurycercus* sp. (Baird, 1843), *Leydigia leydigi* (Leydig, 1860) and *Pleuroxus uncinatus* (Baird, 1850). Apparently, the littoral area was well-developed during this period, as compared with other horizons. Nevertheless, the pelagial zone still prevailed. The Shannon–Weaver index was 0.85 bit/ind. on average and varied in the range from 0.75 to 0.97 bit/ind., thereby indicating that the lake was polluted at these times. The low index values may be associated with the poor diversity of taxa in the lake community. The saprobity index varied from 1.48 to 1.53 (1.50 on average), which corresponded to the oligosaprobic conditions.

The minimum species diversity was recoded in zone II (12–9 cm), where 7 cladoceran taxa were identified (their number varied from 3 to 5 between the sample segments). The average number of cladoceran indivuduals in this horizon was 223, with the munimum and maximum values of 202 and 248 individuals, respectively. The average concentration of subfossil cladocerans per 1 g of the dry sample segment weight was 140 ind./g and varied from 123 to 160 ind./g. B. longirostris remained a dominant species (average number of individuals found 188, average concentration per 1 of the dry sample segment weight 140 ind./g). This zone is distinguished by a lowest diversity of littoral cladocerans. The ratio of the secondary species (*B. (E.) longispina* and *C.* cf. *sphaericus*) changes from the bottom to the upper part of the horizon in a completely opposite way. This may be due to some fluctuations in the trophicity and water level of the lake during the period under consideration. The Shannon–Weaver index (0.78 bit/ind. on average) shows that the lake was still polluted. Based on the saprobity index value (1.57 on average), the lake turned into β-mesosaprobic. A decrease in the species diversity was accompanied by the water quality impairment.

The horizon of 9–4 cm was designated as zone III. Here, a total of 7 cladoceran taxa were identified. In the examined sample segments, their number varied from 4 to 5. For this horizon, the average number of cladoceran individuals was 225, with the minimum and maximum of 204 and 236 individuals, respectively. The average concentration of cladoceran remains was 133 ind./g. The upper and bottom limits of this zone were characterized by the lowest abundance of *B. (E.) longispina* and a slight increase in the number of *B. longirostris*. Within the middle part of the horizon, their ratio changes in a diametrically opposite manner. However, *B. longirostris* retains its superdominant status. According to the average saprobity index (1.55), the lake remained β-mesosaprobic. The Shannon–Weaver index (0.46 bit/ind. on average) was minimum in this horizon.

The stratigraphic zone IV (4–0 cm) is characterized by an increase in the taxonomic diversity. A total of 11 taxa of subfossil cladocerans were identified here. The average number of cladoceran individuals was 196. The concentration of cladoceran remains per 1 g of the sample segment weight varied from 46 to 138 ind./g (73 ind./g on average). The littoral taxa became more numerous, but were represented by single individuals. *B. longirostris* was still a superdominant species (171 individuals on average). The abundance of *B. (E.) longispina* became insignificantly higher to the upper part of the horizon. *C.* cf. *sphaericus* appeared to be another secondary taxon. The Shannon–Weaver index was low (0.66 bit/ind. on average), which testifies that the lake was polluted. The average saprobity index (1.54) corresponds to the β-mesosaprobic conditions.

4. Conclusion

In the focus of this study is Neito-Malto, the largest lake of the Yamal Peninsula. This lake is of particular research interest due to the anthropogenic load that it has been exposed to, as well as because of the dramatic effects of the ongoing climate change on the northern regions. Furthermore, freshwater bodies of high latitudes are good indicators of both climate and ecological change of the environment.

The paleoecological analysis of the sediment core taken from the lake revealed low species diversity. A total of 17 cladoceran taxa were identified, many of them occurred as single individuals. *B. longirostris* was a stable superdominant throughout the entire sediment core. Its abundance changed only insignificantly. No considerable changes were registered in the taxonomic composition of subfossil cladocerans. Minor changes were detected in the number of *B. (E.) longispina* and *C.* cf. *sphaericus*, which may indicate some fluctuations in the water level and trophic status of the lake. The number of littoral taxa also changed – it

decreased in the middle part of the sediment core. The Shannon–Weaver index based on the abundance and taxonomic diversity values was low, which is due to the dominance of a single species. The Pantle-Buck saprobity index demonstrated β-mesosaprobity of the lake.

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