Cladocera from bottom deposits as an indicator of changes in climate and ecological conditions

L. A Frolova

Institute of Geology and Petroleum Technologies, Kazan Federal University, Kremlevskaya str., 4/5, 420008, Russia

E-mail: Larissa.Frolova@kpfu.ru

Abstract. Diatoms, pollen, and remains of higher vegetation are used as indicator groups in paleoecological studies. Using certain groups of zoological indicators such as planktonic and benthic organisms (Ostracoda, Cladocera, Chironomidae) has recently become popular in paleolimnology and paleoecology. This study aims to estimate the possibilities, benefits, problems and prospects of Cladocera use in the composition of zoothanatocoenosis of lakes’ sediments as one of the biological indicators in paleoenvironmental studies and paleoreconstructions of abiotic conditions of the past.

1. Introduction

Cladocera is an ancient group of water organisms, which is known to have existed at least since the mid-Mesozoic era [1]. Most of the modern Cladocera were present in the Jurassic period (about 150 million years ago) during the existence of the supercontinent Pangaea [2]. Cladocera can be considered as a whole natural taxonomic unit of superorder or subclass within the Branchiopoda class, and its internal groupings as the rank of orders Ctenopoda, Anomopoda, Onychopoda and Haplopoda, which reflect a significant degree of their representatives’ divergence [1]. Difficulties with identifying the taxonomic resolution of Cladocera are associated with an insufficient knowledge of the systematics and its local fauna, the absence of reliable determinants and a very low number of professional experts working on systematics and faunal studies.

2. The method of sampling for paleolimnological or paleoecological analysis of Cladocera communities

It is recommended that sampling for paleolimnological or paleoecological analysis of Cladocera communities of surface sediments or short and long columns of bottom deposits be conducted in the middle (or deepest) part of the lake. Passive movement of Cladocera remains from different littoral substrates of the shore (for example, due to the presence of coastal slope and wind) and their mixing with the remains of pelagic Cladocera has been empirically identified on the basis of numerous studies [3, 4]. Thus, deposits formed in the central part of the lake are supplemented by fossil remains of Cladocera living in different parts and substrates of the lake. Moreover, the analysis of Cladocera communities, conducted by use of paleolimnological methodology, provides more complete information on the species composition in the water than using standard hydrobiological methods with regular numerous sampling during the growing season, since the composition of bottom sediments is...
represented by species living in different periods of the growing season. Using this method for obtaining information about Cladocera communities may be recommended for remote, accessible, unexplored water bodies, or reservoirs with a very short ice-free period, for instance, a relatively unknown Arctic and subarctic lakes [5, 6, 7].

3. Identification of Cladocera fossil remains

Today, systematics of this group is not completely developed, particularly at the level of species, subspecies, and morphs. Not all of Cladocera taxa can be easily identified to the taxonomic rank, required for research. Thus, the taxonomic ambiguity of some taxonomic units obstructs the ecological interpretation of paleoecological data on Cladocera [8].

In addition, there is currently no single, complete and universally recognized “standard” guide, which could be used as a starting point to identify fossil remains of Cladocera. Instead, each researcher collects crumbs of information about fossil Cladocera remains from various literature sources such as scientific articles, reports on research work, faunal summaries and illustrated identification keys.

The chemical composition of the Cladocera body is a determining factor of the fossil remains in deep-water sediments. Chitin, which forms the Cladocera exoskeleton, is a chemically inert material, but the chitin cover of species differs in composition and inclusions and has various thicknesses in different areas of the body; as a result, the quality of preservation of species and their body parts varies.

The holistic chitinous covers of planktonic crustaceans disintegrate after the death (or after the molting) of different parts of the exoskeleton such as carapace, postabdomen, postabdomen claws, mandibles, segments of antenna (only Copepoda) and headshields (only Cladocera), the identification of which is possible up to the different taxonomic ranks [5, 9]. Representatives of Chydoridae (species-rich group of benthic Cladocera, mainly living on the bottom or on macrophytes) and Bosminidae (planktonic group) families, all exoskeleton components of which are well preserved in samples, are the most valuable for the paleolimnological studies [10]. Their remains are usually preserved in great quantity and tend to reflect quantitative balance and production of species of real-zooplankton community. Not all representatives of 9 existing families of Cladocera [1] are saved equally well. For example, planktonic Daphniidae, a key component of aquatic ecosystems is not fully preserved, since their exoskeleton is too fragile to resist decomposition processes by microorganisms and fungi.

4. Cladocera in paleoecological research

Study of Cladocera initiated in Denmark at the end of the XVIII century and then was picked up by other countries of Northern Europe. The earliest references to Cladocera remains findings in bottom sediments of the lakes date to the late nineteenth century [2]. The accumulated scattered information has been systematized by D. G. Frey and that contributed to use of Cladocera as an indicator organism in paleoindication [11].

Classical approaches based the relationship between fossil animal communities and environmental conditions on the presence of certain types of indicators. But it is commonly understood that the ecological indicator value of some Cladocera species is apparently low as confirmed by numerous studies of fossil Cladocera [2, 6]. By identifying individual species we obtain an overview of structure and composition of the Cladocera community. In interpreting the composition of Cladocera communities in lake sediments it is important to understand regional relationships between the community composition and their habitats depending on environmental factors, which are responsible for modern distribution of various taxa, their abundance and the frequency of occurrence. The creation of a calibration database of modern Cladocera from surface sediments of a large number of lakes distributed along the environmental gradient of interest parameter (e.g., pH, trophicity) is one of the best and fastest ways of gathering information about environmental factors determining the composition of Cladocera communities in lakes. Each sample of surface sediment accumulates detailed information concerning the lake and its catchment area. Then the environmental parameters
most significantly affecting the Cladocera composition are highlighted by use of multivariate statistical analysis and specialized software.

Cladocera inhabit a variety of biotopes in lakes, mainly occurring on the border between the pelagic and coastal zones, among the rocks, sand, vegetation and on soft soils in the littoral zone. Changes in the proportions between fossil remains of planktonic and littoral species may reflect changes in the relationships between shallow-water and pelagic zones. Littoral Cladocera increase with an expansion of littoral zone, indicating the development of preferred biotopes [2]. But care must be taken in interpreting the ratio of planktonic and littoral species of Cladocera in bottom sediments, as these relationships are influenced not only by changes in the area of the lake and its separate zones, but also by a number of additional abiotic and biotic factors.

Some species of Cladocera prefer a certain type of habitat substrate. Cladocera are found both in the littoral and pelagic zones of the reservoir: the pelagic zone is dominated by representatives of families Daphniidae and Bosminidae, while in the littoral zone representatives of Chyadoridae dominate [12]. Phytophilic species, such as Pleuroxus truncatus, Syda crystallina, pelagic such as Bosmina, benthic such as Rhynchotalona, Monospilus, Chydrorus gibbus and others can be identified according to biotopes [13]. Most species of Chyadoridae inhabit the thickets, where their biomass sometimes is much greater than in open coastal areas, but some species prefer this type of habitat (Chydrorus gibbis, Pleuroxus uncinitus, Disparalona rostrata) [14].

Cladocera is very sensitive to any changes of trophic conditions in the reservoir, therefore they are used to study the eutrofication history of lakes, causes of which can be related to natural and anthropogenic factors [15]. Daphnia cristata, D. longiremus, Alonopsis, Limnosida, Holopedium, Bythotrephes are indicators of oligo- and mesotrophic conditions [16]. Increasing nutrient status in the water body contribute to a decrease in species diversity and significant changes in ratios between species. The decrease of species diversity primarily concerns phytophilous species of the family Chydroridae. At the same time, with the eutrophication in biocenoses the number of species such as Daphnia galeata, D. cuculata, Ceriodaphnia reticulata, Leptodora, Chydrorus gibbus, Leydigia appears to greatly increase [13].

The changes in Cladocera community composition in accordance with changing pH have been noted in some paleolimnological studies. The change of acid-base reaction towards an increase in acidity is accompanied by changes in structural and functional relationships in the plankton community, acid-sensitive species extinction, reduction in species richness, changes in total biomass production and Cladocera abundance. The decrease in species richness is noted in Norwegian lakes exposed to acidification, as a result of which acid-sensitive planktonic organisms such as Daphnia longispina, Bythotrephes longimanus, Leptodora kindtii and Bosmina longirostris were eliminated [2, 17].

Climate variables, primarily temperature parameters, are the most significant factors affecting quantitative measures — abundance and biomass of zooplankton [9], as well as the composition and structure of Cladocera communities zoobenthocoenos is according to studies in different parts of the world, including Russia [18], Finnish Lapland [19], Canada [20].

Several previous studies, as well as our data, confirm that lake depth is one of the most important abiotic factors affecting the composition of Cladocera communities [3, 18, 21]. For instance, subfossil Cladocera remains are used by paleolimnology to reconstruct changes in lake depth [22]. Small lakes are generally smaller in size, have uniform habitats and have a well-developed littoral zone in comparison with pelagic and profoundal parts of the lake [3]. A naturally determined increase in relative abundance of the littoral species in shallow lakes and an increase of pelagic species in deeper lakes were revealed as a result of our studies on a number of Yakutia thermokarst lakes [18].

A number of studies indicate a clear correlation between the main hydrochemical parameters (ionic composition, pH, specific conductivity) and Cladocera species composition. As a rule, we should expect a decrease in the diversity of fauna with rapidly changing values of these parameters [2].
5. Conclusions
The examples given above demonstrate the value of Cladocera community zoobenthos as indicators of the impact of various abiotic and biotic environmental factors affecting lake status, such as climate variation, changes in trophic status, water level, ionic composition, etc. Cladocera have been successfully used over the past decade to create transfer models on a line of parameters (temperature, depth, trophicity, etc.). Studies of communities of Cladocera remains from bottom sediments of lakes allow an increase in the use of this group of organisms as bioindicators, particularly for paleolimnological and paleoecological reconstructions, to highlight the theoretical aspects of community ecology and their biogeography [21, 23].

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