Studia Quaternaria, vol. 29 (2012): 53–58.

ALGAL AND INVERTEBRATE MICROFOSSIL ASSEMBLAGES FROM LAKE SEDIMENTS IN THE RECONSTRUCTION OF PAST COMMUNITY DYNAMICS – PRELIMINARY INFORMATION

Zhanna Antipushina[1], Krystyna Szeroczyńska[2], Edyta Zawisza[2, 3]

[1] *Institute of Ecology and Evolution RAS, 119071 Russia, Moscow, Leninsky prospect 33, e-mail: zh.antipushina@gmail.com*

[2] *Institute of Geological Sciences, Polish Academy of Sciences, Research Centre in Warsaw Twarda 51/55, PL-00818 Warsaw, Poland, e-mails: kszerocz@twarda.pan.pl, ezawisza@twarda.pan.pl*

[3] *Instituto de Geofisica, Universidad Nacional Autónoma de México, Ciudad Universitaria, D.F., Mexico*

Abstract

This paper focuses on the usefulness of a palaeolimnological method called the joint algological and zoological analysis. The joint algo-zoological analysis involves counting all identifiable remains of the main algae groups (Bacillariophyta, Cyanophyta, Desmidiales, other Chlorophyta, *Trachelomonas* sp.) and invertebrate groups (Cladocera, Ostracoda, Chironomidae, *Chaoborus* sp., and other insects, Turbellaria, Bryozoa, Spongia and Testacida) in volumetric samples. We present results from recent sediments of Lake Glubokoe (Moscow region, Russia) as an example of the application of this method. We reconstruct the structure of phytoplankton, zooplankton and zoobenthos communities and their dynamics over the last 25 years. Our results support the validity of this method in the reconstruction of the structure of phyto- and zooplankton communities and their dynamics, information that may be lost when carrying out separate analyses for individual groups. Simplicity is another advantage of this methodology.

Key words: lake sediments, subfossil Cladocera, subfossil phyto- and zoo-organisms, thanatocoenosis, Late Holocene

INTRODUCTION

Lake sediments contain remains of many vegetal and animal groups accumulated during a long period of time. Algological, pollen, and zoological analyses are the most common methods used in classic palaeoecological studies, among them pollen, diatom, and cladoceran analysis (e.g. Fuji 1978; Brake, Davis 1983; Frey 1986; 1988) are the most well-known. These proxies are very useful for palaeoenvironmental reconstructions and historical biocoenology. Remains of other invertebrate groups, such as testacids (Kulikovskaya 1983), sponges (Hall, Herrmann 1980), Bryozoa (Crisman *et al.* 1986; Francis 2011), some insects, particularly Chaoboridae and Chironomidae (Hofmann 1988), and Ostracoda (Günther 1986) are also well preserved in lake sediments, as well as algae remains. They can also be used to evaluate qualitative changes in the trophic structure induced by productivity, climate, and human impact over the Holocene. Each of these methods only provides information about the dynamics of individual groups.

Within the framework of the Polish-Russian Join Research Project (2011–2013), we wanted to discuss and test the method of joint algological and zoological analysis, continuing the study of Korde (1960) and Smirnov (2010). The main objective of this study was to verify the potential of this method for the assessment of the complex structure of the algal and invertebrate coenosis.

STUDY AREA

Lake Glubokoe is located approximately 90 km northwest of Moscow (55°45'N, 36°31'E, Moscow region, Russia). The lake has a pear-like shape (Fig. 1), and is approximately 1200 m long and 850 m wide. It includes two subbasins: the larger one has a maximum depth of 33 m, and the smaller one 5 m. The inflowing water is supplied to the lake from ditches, temporary streams, and surface drainage. It is separated from farmlands and villages by a strip of forest with a width of approximately 3 km (Smirnov 1986). According to previous studies, the lake has a glacial origin (Scherbakov 1967). Lake Glubokoe has a mesotrophic status, confirmed by chemical water analysis (Kluev 2002) and results of destruction of organic sediments from various depths (Martynova 2002).

MATERIAL AND METHODS

Sampling and dating

Two sediment cores (12 cm and 45 cm in length, about 1 m distance) were taken from the central part of the smaller basin of Lake Glubokoe (55°45'537'' N, 36°30'472'' E) in March 2011, from a depth of 3.3 m by means of a gravity corer KC-Denmark Kajak. The cores studied were sliced at 1 cm intervals, and the samples were kept in a dark and cold

Fig. 1. Location of Lake Glubokoe (the coring site is marked with **X**).

place (about +4°C) until the analysis. Samples from the shorter core (12 cm) were used for the joint algo-zoological analysis. For this propose, 1 cm^3 was subsampled from each depth.

Samples from the longer core (45 cm) were used for ^{210}Pb dating in the Isotopes Dating & Environment Research Laboratory of the Institute of Geological Sciences, Polish Academy of Sciences in Warsaw. For this propose, 3 cm^3 of fresh, homogenised material was taken from each level. The ^{210}Pb activity of sediments was indirectly determined by alpha spectrometry measurement of ^{210}Pb (Ea =5.31 MeV, T1/2 = 138 days) activity (Flynn 1968). The activity of ^{210}Pb and ^{208}Pb was measured by means of an OCTETE PC alpha spectrometer produced by EG&G ORTEC. The constant rate of supply (CRS) model was used to calculate the sediment age (Appleby 2001). Based on the results obtained, the age–depth model for the surface sediments of Lake Glubokoe was developed.

Algo-zoological analysis

The algo-zoological analysis concerned 1 cm^3 of fresh sediment mixed in 10 ml of distilled water with no chemical preparation or colouring. We conducted the volumetric count of the samples. An automatic pipette with a fixed value of 0.1ml was used to place a drop of the solution on an object-plate. All the remains identified were counted with the application of a light microscope Olympus BX40. Each of the samples was counted in double repetition, i.e. we counted two slides (0.1 ml each) from each sample.

The joint algo-zoological analysis involves counting all the identifiable remains of the main algae groups (Bacillariophyta, Cyanophyta, Desmidiales, other Chlorophyta, *Trachelomonas* sp.) and invertebrate groups (Cladocera, Ostracoda, Chironomidae, *Chaoborus* sp. and other insects, Turbellaria, Bryozoa, Spongia, and Testacida). Diatoms were represented by silica cell walls, well preserved in the sediments. Remains of other algae were cellulose cell walls. Chitinous parts of Cladocera (shell, head shield, postabdomen, claw, mandible, tail spine, filtering combs, and ephippia) and aquatic larvae of insects (head shield, mandible, and parts of antennas) were well conspicuous in the sediments too. Remains of Turbellaria and Bryozoa were represented by cocoons and statoblasts, remains of sponges – by silica spines, and remains of Testacida (Rhizopoda) – by agglutinated (*Arcella* sp.) and/or inlaid shells (*Difflugia* sp.) (Fig. 2). All the results were converted into total number of remains per 1 cm^3 (concentration in 1 cm^3).

Once all the remains were counted, we separated the invertebrate remains into two main groups – Cladocera and Testacida – in order to reconstruct their quantitative dynamics.

RESULTS

^{210}Pb dating – preliminary results

According to the results of ^{210}Pb dating, the 45 cm profile was accumulated throughout the last approximately 141±18 years, which yields an average sedimentation rate of about 0.3 cm y^{-1} (M. Gąsiorowski, unpublished data). Assuming similar sedimentation rate between the cores, the top layer of sediment from the 12-cm profile was probably accumulated during the last 25 years (Table 1). However, this dating is only preliminary, as there were few anomalies, which will require further testing with gamma spectrometry.

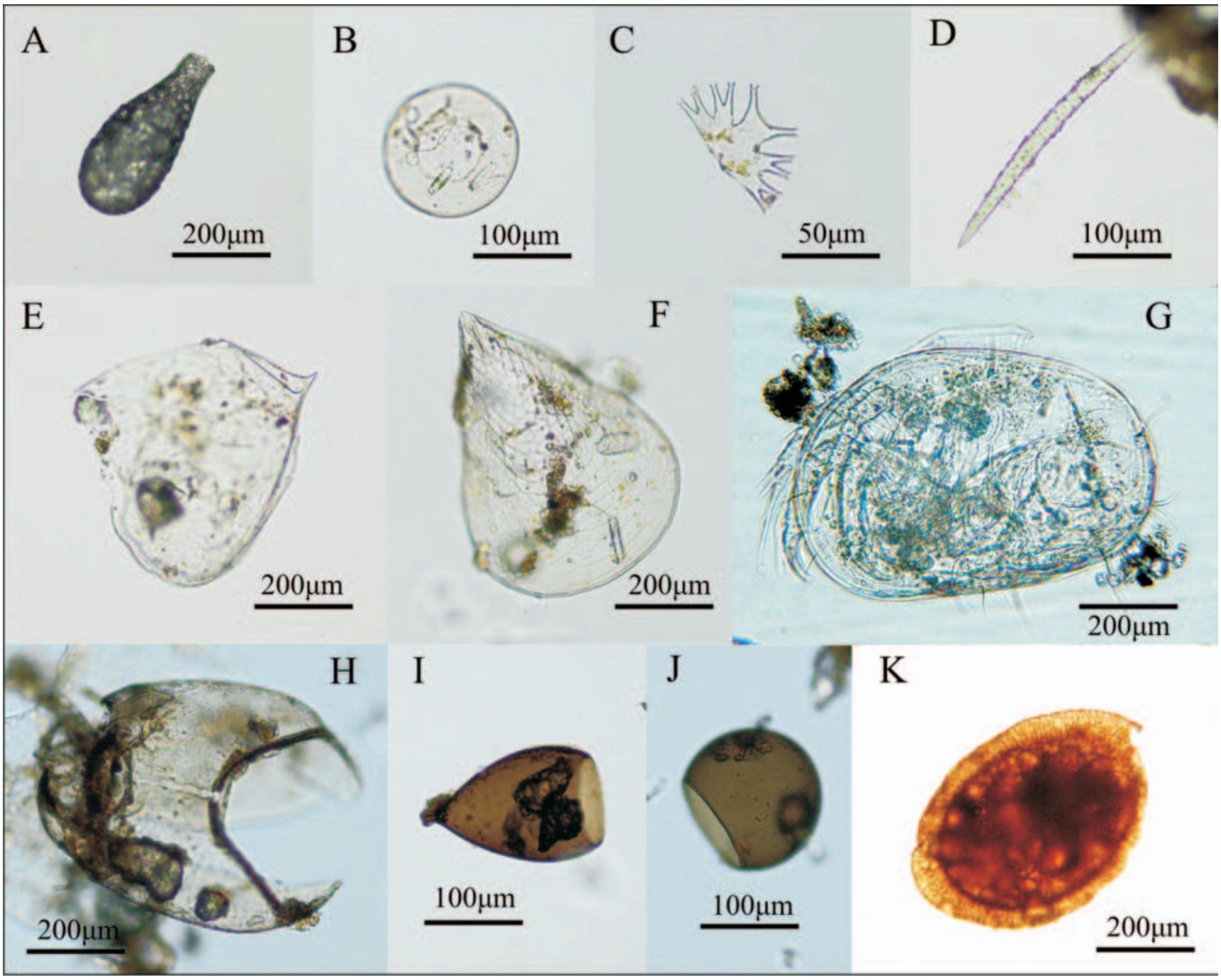

Fig. 2. Subfossil remains of common groups from sediments of Lake Glubokoe, where **A**, **B** – Testacida, **C** – Desmidiales, **D** – Spongia, **E**, **F** – Cladocera, **G** – Ostracoda, **H** – Chironomidae, **I**, **J** – Turbellaria, **K** – Bryozoa.

Results of joint algo-zoological analysis

The core analysed contained remains of diatoms, desmidiales, and other Chlorophyta, *Trachelomonas* sp., and invertebrate remains: Cladocera, Ostracoda, *Chaoborus* sp., Chironomidae and other insects, Turbellaria, Bryozoa, sponges, and testacids (Fig. 3). Cyanophyta remains were not found. As it was expected, algae were dominated by diatoms, and Cladocera were the dominant invertebrate group. This is a common situation for mesotrophic lakes (Smirnov 2010). Notably, the concentration of diatom remains increased in the upper part of the core, while the concentration of invertebrate remains increased downwards. Testacids were the subdominant group among invertebrates. Spines of sponges were also numerous, especially in the bottom part of the core. Remains of ostracods, Bryozoa, *Chaoborus* sp., and other insects were rare.

In the course of the joint algo-zoological analysis, we distinguished particular species among Cladocera and Testacida with a maximum possible accurancy. It was sometimes impossible to identify certain remains of Cladocera as well as Testacida at species level. For those remains, we used genus level identification: *Bosmina* (*Eubosmina*), *Alona* (large)

Table 1

Partial results of ^{210}Pb dating for the 45 cm profile (unpublished, M. Gąsiorowski)

Depth, cm	Age, years from present	Age, AD
0	0±0.9	2010
1	1±0.5	2009
2	2.8±0.5	2007
3	4.7±0.6	2005
4	6.3±0.6	2004
5	8±0.8	2002
6	10±0.8	2000
7	12±1	1998
8	14.4±1.5	1996
9	17±1.5	1993
10	20±2	1990
11	22±2	1988
12	24±2.4	1986
13	27±2.8	1983
14	30±2.8	1980
15	33±3.0	1977

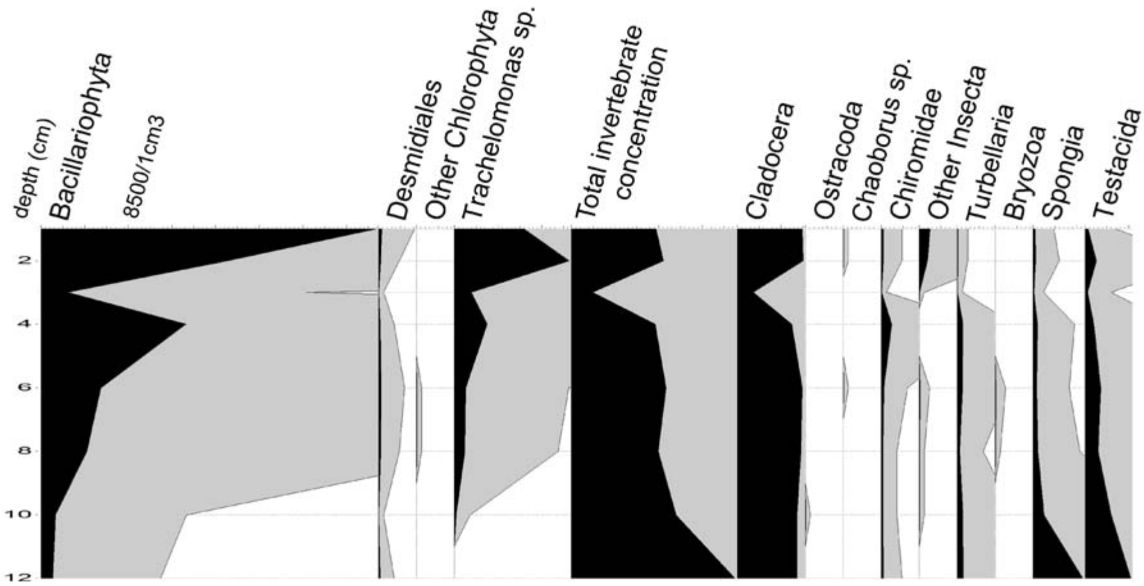

Fig. 3. Concentration of algae and invertebrate's remains in 1 cm^3 of sediments from Lake Glubokoe (the grey part shows the concentration in tenfold).

and *Alona* (small), *Camptocercus* sp., *Pleuroxus* sp., and *Difflugia* sp.

In total, remains of 19 Cladocera taxa belonging to four families and 7 taxa of Testacida were recorded in the sediments of Lake Glubokoe (Fig. 4). Remains of *Bosmina* (*Eubosmina*), *Bosmina longirostris*, and *Alona* (large) predominated. The concentration of remains of these species varied from 2000 to about 6000 per cm^3. Shells of *Difflugia globulosa* were the most dominant among Testacida, and the concentration of remains reached from 200 to 2000 per cm^3. The results demonstrated that the changes in both Cladocera and Testacida were synchronous in time.

The most distinctive changes in all of the groups studied (phyto- and zoo-organisms) in the core were observed at a depth of 10 cm, representing a year 1990 (±2) (Fig. 3). At this time, we noticed increasing numbers of algae and decreasing numbers of invertebrates. *Trachelomonas* sp. appeared among algae, and the concentration of Spongia and Testacida among invertebrates decreased. The total abundance of Cladocera was stable. Among Cladocera, however, the frequency of *B. longirostris* and *Alona* (large) decreased from a depth of 8 cm (year 1996 (±1.5) onwards in comparison with older sediments (Fig. 4A). At the same time, remains of *Daphnia* sp., *Leydigia* sp., and *Pleuroxus* sp. totally disappeared. A very similar tendency was also observed for the Testacida species composition (Fig. 4B). The most distinctive change was recorded for the frequency of *Difflugia globulosa*, which was a dominant species before but decreased in abundance at the depth of 8 cm. The second change in the core was recorded at a depth of 3 cm (appr. year 2005). At this time, a short-term decrease in the total abundance of algae as well as invertebrates was observed.

DISCUSSION AND CONCLUSIONS

The results of the joint algological and zoological analysis reflected the dynamics of the environmental conditions over the last 25 years. Approximately 20–25 years ago (in 1985–1990), the structure of the phyto- and zooplankton community corresponded to the period of water turbulence and better oxygen conditions. According to Korde (1960), the high concentration of sponges depends on high aeration, some flowage or water turbulence, high silicon concentration, and the absence of suspended mineral matter. The concentrations of testacids *Difflugia globulosa* and *D. gigantea*, which are related to oligotrophic or mesotrophic conditions (personal experience of Siemensma F., www.arcella.nl), were higher in this period. According to synoptic data (Korovchinsky 1999; Korovchinsky, Boikova 2009), summers were rainier before 1992. This contributed to an increase in nutrient runoff, water turbulence, and aeration. After 1992 summers became drier, and water turbulence and aeration decreased. Changes in the structure of the phyto- and zooplankton community (a decrease in concentration of sponges and two species of testacids: *Difflugia globulosa*, and *D. gigantea*) suggest that about 20–25 years ago, water turbulence and oxygen concentration were higher than nowadays.

In the upper part of the core the concentration of diatom remains increased, while the concentration of invertebrate remains decreased. This suggests the tendency of Lake Glubokoe to eutrophication over the last years, which was also indicated by hydro-chemical and phytoplankton parameters, as well as the indexes of relative number of Cladocera/Copepoda and Cladocera/Calanoida (Korovchinsky, Boikova 2009).

The water level was 10 cm lower in 2005 (Korovchinsky, Boikova 2009). At this time, a short-term decrease in the total abundance of algae and invertebrates was observed in the core. Maybe that water level decrease was more significant for the small basin of Lake Glubokoe.

The results based on phyto- and zoo-organism assemblages provided evidence of the environmental dynamics during the study period. We consider the method presented here very useful, particularly for the reconstruction of the

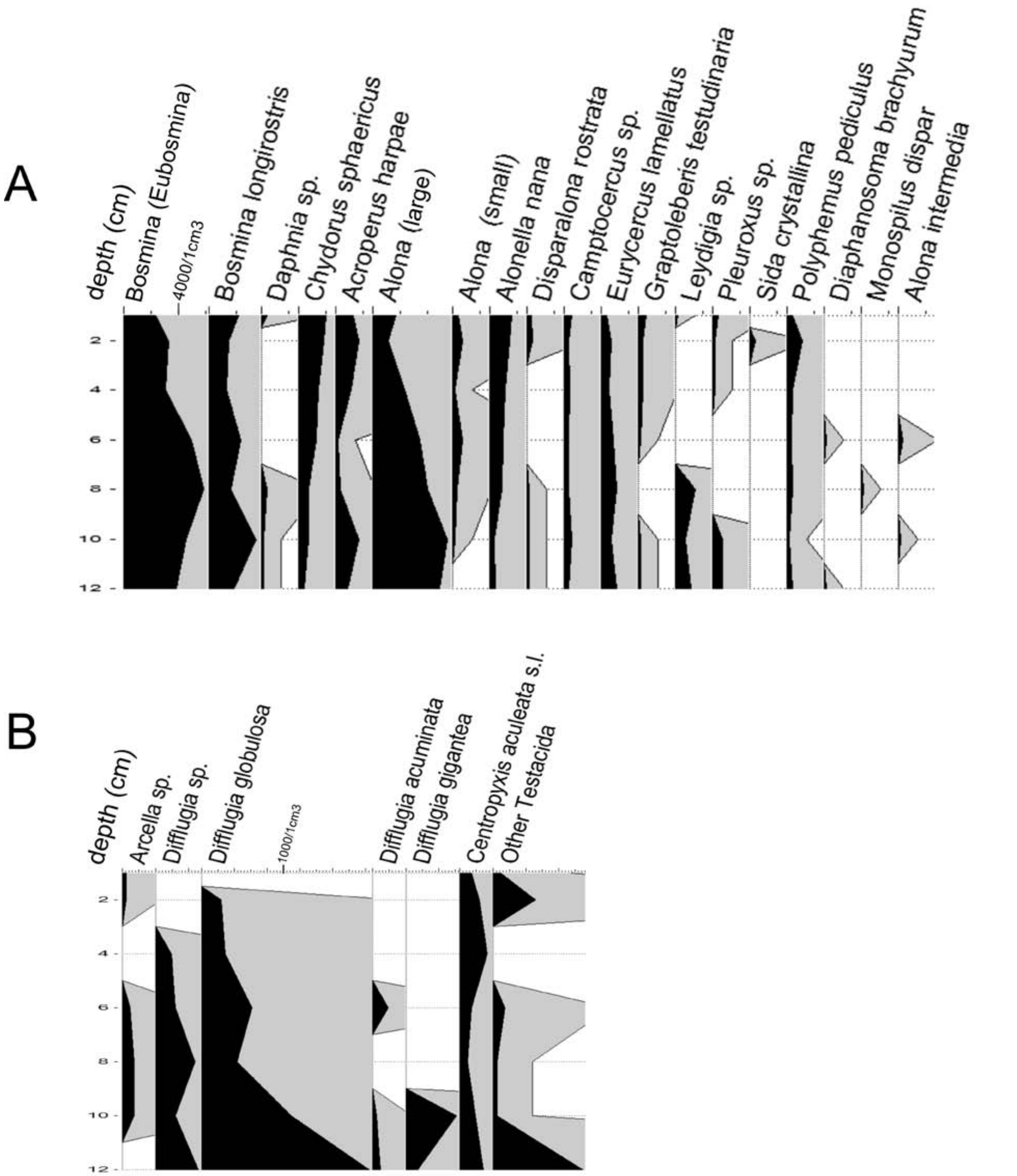

Fig. 4. Concentration of Cladocera (A) and Testacida (B) remains in 1 cm^3 of sediments from Lake Glubokoe (the grey part shows the concentration in tenfold).

general structure of phyto-and zooplankton communities and their dynamics. Separate analyses of individual groups provide more accurate data, but only regarding a single group. Information on the general structure of phyto- and zooplankton communities is lost. This method is especially informative when combined with data for individual groups, and therefore useful for the reconstruction of past lake ecosystems. "Interpretation from a single group of organisms are usually more suggestive than definitive, and without support from other evidence lead to open-ended unsatisfying conclusions" (Frey 1976). Already in the 1960s, Frey (1964) mentioned the necessity of simultaneous studies on all aquatic organisms inhabiting a given water body at the same time. Majority of the organisms leave traces of their presence in the form of remains in deposited sediments. Frey (1964) stated that through such remains, sediments contain an integrated record of not only the occurring limnological processes, but also extreme events in the watershed area, including those concerning the climate. In his review, he evidenced that only the global image provided by individual species of various groups allows for a full reconstruction of events. Based on the example of Lake Minnesota, Frey (1976) proved a significant effect of human economic activity on the development of various phyto- and zoo-rganisms.

An even more detailed analysis of the effect of human activity was carried out by Bas van Geel (1978). He analysed micro- and macrofossils in peat bog sediments from Germany and The Netherlands. Based on the analysis with a resolution of 1 cm, based on 70 determined fungal taxa, 25 animal taxa, and 4 algae, the author determined the climatic conditions occurring in the Holocene.

We justified the application of simultaneous algo-zoological analysis for studying both short and long periods. We applied this method for the period of the last 25 years and evidenced that it is a perfect method, not only providing a full image of the phytoplankton, zooplankton, and zoobenthos structure, but also permitting a faster reconstruction of events. This is particularly important in case monitoring data is lacking. In the era of quite extreme climatic events, data regarding changes in lakes (hydrological, trophy changes, etc.) are necessary for environmental protection and forecasting of future changes.

Therefore, the analysis of all aquatic organisms is a highly important element of performing a reconstruction. Each of them provides mutually supplementing information.

Acknowledgements

The authors are very thankful to Prof. N. N. Smirnov, Dr. A. A. Kotov, Dr. N. M. Korovchisky, Dr. M. Gąsiorowski, and Dr. M. Ketola for their help. The facilities of the Hydrobiological Station "Lake Glubokoe" are appreciated. The study was carried out under the agreement of the Polish-Russian Join Research Project (2011–2013), and supported by the Russian Foundation for Basic Research (projects No. 10-04-01568, 12-04-00655, and 12-04-31010), programs "Fundamentals of Biological Resources Management", "Origin and Evolution of the Biosphere", and "Wildlife".

REFERENCES

Appleby P.G. 2001. Chronostratigraphic techniques in recent sediments. In Last W.M., Smol J.P. (eds.), Tracking environmental change using lake sediments 1, 171–203. Kluwer Academic Publishers, Dordrecht.

Brake D.F., Davis R.S. 1983. Cladoceran and diatom indicators of past lake water conditions. Abstracts of 22nd Congress of the International Association of Limnology. 44. Lyon.

Crisman T.L, Crisman U.A.M., Binford H.W. 1986. Interpretation of bryozoan microfossils in lacustrine sediment cores. *Hydrobiologia* 143, 113–118.

Flynn W.W. 1968. The determination of low-levels of polonium-210 in environmental materials. *Analytica Chemica Acta* 43, 221–227.

Francis D.R. 2011. Bryozoan statoblasts. In Smol J.P., Birks H.J., Last W.M. (eds.), Tracking environmental change using lake sediments 4, 105–124. Kluwer Academic Publishers, New York.

Frey D.G. 1964. Remains of animals in Quaternary lake and bog sediments and their interpretation. (Ergebnisse der Limnologie), *Archiv für Hydrobiologie* 2, 1–114.

Frey D.G. 1976. Interpretation of Quaternary paleoecology from Cladocera and midges, and prognosis regarding usability of other organisms. *Canadian Journal of Zoology* 54, 2208–2226.

Frey D.G. 1986. Cladocera analysis. In Berglund B.E. (ed.), Handbook of Holocene palaeoecology and palaeohydrology, 667–692. John Wiley & Sons, Chichester.

Frey D.G. 1988. Littoral and offshore communities of diatoms, cladocerans and dipterous larvae, and their interpretation in paleolimnology. *Journal of Paleolimnology* 1, 179–191.

Fuji N. 1978. Pollen analysis of a 200-m core sample from Lake Biwa. *Verhandlungen der Internationalen Vereinigung für Theoretische und Angewandte Limnologie* 20, 2663–2665.

Günther J. 1986. Ostracod fauna of Duvensee, an ancient lake in Northern Germany. *Hydrobiologia* 143, 41–416.

Hall B.V., Herrmann S.J. 1980. Paleolimnology of the species of freshwater sponges (Porifera: Spongillidae) from a sediment core of a Colorado semidrainage mountain lake. *Transactions of the American Microscopical Society* 99, 93–100.

Hofmann W. 1988. The significance of chironomid analysis (Insecta: Diptera) for paleolimnological research. *Paleogeography, Paleoclimatology, Paleoecology* 62, 501–509.

Kluev N.A. 2002. Chemical analysis of water of Lake Glubokoe. In Korovchinsky N.M, Smirnov N.N. (eds.), Proceedings of Hydrobiological Staton "Lake Glubokoe" 8, 33–35. Grif i K, Moscow-Tula (in Russian with English summary).

Korde N.V. 1960. Biostratification and typology of Russian sapropels (original: Biostratifikaciya i tipologiya russkich sapropelei), 1–220. Academy of Sciences of USSR, Moscow (in Russian).

Korovchisky N. 1999. Studies on pelagic crustacean zooplankton of Lake Glubokoe in 1994–1998. *Arthropoda Selecta* 8, 55–58.

Korovchinsky N., Boikova O. 2009. The pelagic crustacean zooplankton of lake Glubokoe in 1999–2008 and some results of its long-term observations. In Korovchinsky N.M, Smirnov N.N. (eds), Proceedings of Hydrobiological Staton "Lake Glubokoe" 10, 39–50. Argus, Moscow (in Russian with English summary).

Kulikovskaya I.M. 1983. O faune rakovinnyh ameb (Rhizopoda, Testacida) ozera Glubokoe (original: Tecamoebas' fauna (Rhizopoda, Testacida) of Lake Glubokoe). In: Smirnov N.N. (ed.), Biocoenosis of mesotrophic Lake Glubokoe. 149–181. Moscow, Nauka press (in Russian).

Martynova M.V. 2002. Alterations of some sediment's properties with the increase of lake's depth. In Korovchinsky N.M, Smirnov N.N. (eds), Proceedings of Hydrobiological Station "Lake Glubokoe" 8, 20–32. Grif i K, Moscow-Tula (in Russian with English summary).

Scherbakov A.P. 1967. Lake Glubokoe (original: Ozero Glubokoe). 1–379. Nauka, Moscow (in Russian).

Smirnov N.N. 1986. Lake Glubokoe (Moscow region, Eastern Europe), general characteristics. *Hydrobiologia* 141, 1–6.

Smirnov N.N. 2010. Historical ecology of freshwater zoocoenosis (original: Istoricheskaya ekologiya presnovodnyvh zoochenozov), 1–232. KMK Press, Moscow (in Russian with English summary).

Van Geel B. 1978. A palaeoecological study of Holocene peat bog sections in Germany and The Netherlands, based on the analysis of pollen, spores and macro-and microscopic remains of fungi, algae, cormophytes and animals. *Review of Palaeobotany and Palynology* 25, 1–120.