

ASSESSMENT OF THE EFFECTS OF MECHANICAL BOTTOM SLUDGE REMOVAL FROM LAKES DIDŽIULIS AND LENTVARIS (TRAKAI DISTRICT) BASED ON MACROZOOBENTHOS INDICATORS

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Abstract. Two lakes in Trakai district – Didžiulis and Lentvaris were heavily polluted in the past by discharges of municipal wastewater without proper treatment. This anthropogenic impact resulted in large amounts of bottom sludge in both lakes, high amounts of biogenic substances and deterioration of water ecosystems. In both lakes, methods of mechanical lake restoration were applied in 2008 by removing 80000 m³ of bottom sludge from the northern part of Lake Didžiulis and 60000 m³ of bottom sludge from the southern part of Lake Lentvaris. The objectives of this article are 1) to examine composition of local macrozoobenthos communities in both lakes prior and after sludge removal and 2) evaluate changes and trends of ecological status in restored parts of both lakes by using two most popular in Lithuania indices based on macrozoobenthos: Trent Biotic Index and Danish River Fauna Index.

Keywords: macrozoobenthos, lake restoration, mechanical sludge removal, biological indicators, Trent Biotic Index, Danish River Fauna Index.

1. Introduction

During the last decades, the flows of unbalanced, high amounts of nutrients from different anthropogenic pollution sources have led to intensification of the process of eutrophication in the lakes (Alkan *et al.* 2009). Respectively, increased biological productivity and urban sediment delivery resulted in accumulation of excess sludge at the bottoms of the lakes. The sludge contains high amounts of nutrients and poses risks of secondary pollution and further stimulation of the process of eutrophication (Zigmontiene and Zuokaite 2010). This chain leads to deterioration of the structure of limnosystem: although the primary productivity increases, the number of species decreases resulting in poor biodiversity and loss of stability in the ecosystem (Kilkus 2005).

Pollution abatement alone will not return most lakes to their former condition because nutrients and toxic materials are recycled from lake sediments. These processes maintain eutrophic conditions or continue to contaminate food webs, even though loading has been reduced or eliminated (Balevičius *et al.* 2007). However, a number of lake restoration methods have been designed that should lead to the recovery of an ecosystem to its pre-disturbance structure and function (National Research Council 1992). Mechanical bottom sludge removal is the most widely used method in Lithuania and it was applied in 2008 by removing 80000 m³ of bottom sludge from the northern part of

Lake Didžiulis and 60000 m³ of bottom sludge from the southern part of Lake Lentvaris in Trakai district. The two lakes were heavily polluted in the past by discharges of municipal wastewater without proper treatment.

Removal of the sludge from the bottom of a lake is expected to eliminate accumulated nutrients and accordingly reduce secondary pollution, slow down eutrophication process, reduce primary bioproductivity and lead to improved ecological status of the water body.

It is widely acknowledged that the assemblage of organisms living in the bottom of a water body and their response to anthropogenic impacts can provide an indication of past and current disturbances and may be used in the assessment of the ecological conditions of a given lake (Chapman *et al.* 1992). Assemblage of benthic macroinvertebrates (macrozoobenthos) is one of the mostly used and sometimes the only reliable biological indicator to assess ecological status of the bottom of a water body (Aplinkos apsaugos agentūra 2003). Macrozoobenthos includes aquatic invertebrate organisms living on the bottom or on submerged vegetation, with a size of 2-3 mm (Tumas 2002; Šatkauskienė 2004; Pliūraitė 2006). These organisms are widely spread in surface water bodies and are able to survive even most polluted environments. They represent abundant and ecologically important group of hydrobionts, playing a significant role in the processes of accumulation and decomposition of organic substances and nutrients, while their filtration potential highly influences biological

self-purification abilities of a water body (Bubinas and Vaitonis 2005).

There are numerous methods of the assessment of the water body status based on bioindicating qualities of macrozoobenthos, using benthic invertebrate fauna composition and abundance, the ratio of sensitive taxa to insensitive taxa and the diversity of invertebrate communities as criteria (Povilaitis and Querner 2008). The objective of this article is to examine composition of local macrozoobenthos communities in both lakes prior and after sludge removal and to apply two most popular in Lithuania indices based on macrozoobenthos: Trent Biotic Index and Danish River Fauna Index for evaluating changes and trends of ecological status in restored parts of the two lakes.

2. The study area

Lake Didžiulis is located in the northern-eastern part of Trakai district, by the highway Vilnius-Kaunas-Klaipėda. Nearest towns are Grigiškės and Lentvaris. Total area of the lake is 54.1 ha, its mean depth – 6.5 m, maximum depth – 18.5 m. Lake Didžiulis belongs to the Neris river basin. Fabrikas (Saidės) stream falls into the lake, while Malevanka stream flows out of it. Total basin area of Lake Didžiulis is 13.1 km². Until 2002, the lake was being polluted by discharges from Lentvaris-Trakai wastewater treatment plant, which had only primary mechanical treatment process. Practically untreated wastewater was being discharged into Fabrikas (Saidės) stream, which as mentioned above, falls directly into Lake Didžiulis. Biological wastewater treatment was introduced in the plant in 2002 and since then pollution loads to the lake have decreased significantly.

In order to remove excessive amounts of nutrients, which have accumulated in the bottom sludge of the lake, 80000 m³ of sludge was mechanically removed from the bottom of the northern part of Lake Didžiulis in 2008, by using excavators and a dredger with a pulp pumping capacity of 80 m³/h. The area of mechanical lake restoration is shown in Fig. 1.



Fig 1. Area of mechanical lake restoration (Lake Didžiulis)

Lake Lentvaris is located in the northern-eastern part of Trakai district, within the town of Lentvaris. Total area of the lake is 29 ha, mean depth – 9.7 m, maximum depth – 36.0 m. Lake Lentvaris belongs to the Neris river basin. Rivulet L-1 falls into the lake, while F-1 stream flows out of it. Total basin area of Lake Lentvaris is 87.7 km². The coasts of the lake are surrounded by urbanized areas of Lentvaris town. According to the official statistical data, 11800 inhabitants were living in this town in 2005. Until 2002, 79 % of the inhabitants were living in households not connected to the centralized wastewater treatment system and the lake was being polluted by untreated wastewater. However, households of 9327 inhabitants were connected to the rehabilitated Lentvaris-Trakai wastewater treatment plant in 2002 and since then pollution loads to the lake have decreased significantly.

In order to remove excessive amounts of nutrients, which have accumulated in the bottom sludge of the lake, 60000 m³ of sludge was mechanically removed from the southern part of Lake Lentvaris in 2008, by using excavators and a dredger with a pulp pumping capacity of 80 m³/h. The area of mechanical lake restoration is shown in Fig. 2.

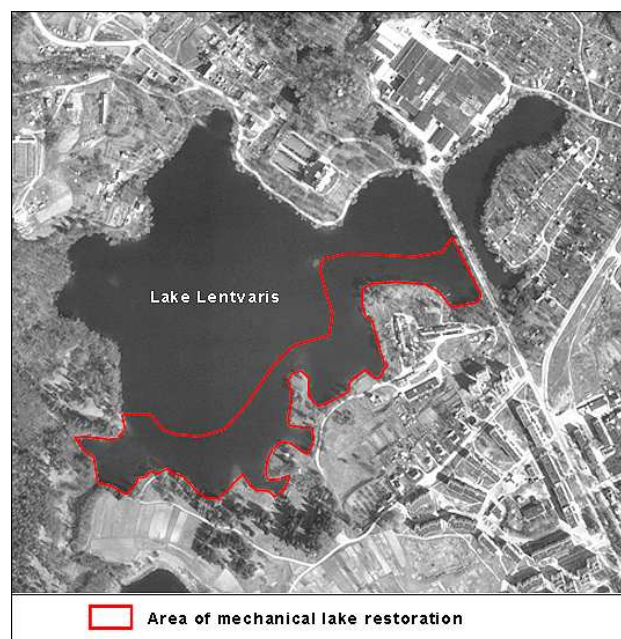


Fig 2. Area of mechanical lake restoration (Lake Lentvaris)

3. Materials and methods

The benthic communities were studied from May 2007 (just before lake restoration) to May 2009. Areas of mechanical restoration in both lakes were sampled by taking and combining eight benthic samples along the length of the whole area from all available habitats. Sampling methodology was based on the requirements provided in LAND 70-2005 “Water quality. Methodology for biological sampling. Sampling instructions for benthic macro invertebrates”. Samples were taken with a skimmer type hand-held sampler consisting of a handle and a mesh-frame with a width of 300 mm, a height of 300 mm and a length of 500 mm. Samples were washed in the field with the lake water through a sieve

of 0.25 mm mesh size, until particles of sludge and sand were washed off. Contents of the sieve were then poured into glass containers with the lake water and transported to the laboratory. Samples were analyzed by small portions in a flat-bottomed dish; living organisms were extracted using tweezers and preserved in 10 ml glass bottles with 96 % ethyl alcohol. Preserved contents were examined in Petri dishes, firstly by naked eye, afterwards by using a binocular stereo microscope with a 100x magnification. Benthic organisms were identified using identification manuals and divided into systematic groups relevant for Trent Biotic Index and Danish River Fauna Index.

Trent Biotic Index is based on the number of defined taxa of benthic invertebrates in relation to the presence of six key organisms found in the fauna of the sample site. The index is calculated by using the Woodywiss table, which ranks benthic organisms in order of tendency to disappear as degree of pollution increases. Identified groups (meaning any of the species included in the table) are expressed in three categories: “one species only”, “more than one species” and “all above species absent”. Depending on the number of taxonomic groups present and the key organisms

found, the index ranges from 10 (for clean water) to 0 (most polluted water).

Trent Biotic Index was further modified to reflect local Northern European and Scandinavian conditions by developing the Danish Fauna Index, which is determined on the basis of indicator taxa and the number of diversity groups in the total fauna sample and allows evaluating the quality class of a water body. The first step of assessing the quality class is done by assigning the sampled fauna to one of six indicator groups based on at least one specimen found in the hand-picked sample. Additionally, selected species belong to positive (e.g. *Baetidae*, *Nemoura*) or negative (e.g. *Erpobdella*, *Sialis*) diversity groups, which are added up and classified (four ranges in total) within the second step of assessment. Carrying-out of both steps leads directly to one of seven quality classes, ranging from fauna class 7 (“unimpacted”) to fauna class 1 (“very strongly impacted”).

4. Results

The results of analysis of combined samples from the areas of mechanical lake restoration in each of the two lakes are provided in Table 1 and Table 2.

Table 1. Abundance of benthic organisms in combined samples of Lake Didžiulis

Taxa		Abundance in combined sample (2007.05.13)	Abundance in combined sample (2008.05.17)	Abundance in combined sample (2009.05.02)
Phylum/class/order	Family/genus/species			
<i>Oligochaeta</i>	<i>Oligochaeta</i>	8	14	-
<i>Hirudinea</i>	<i>Helobdella stagnalis</i>	-	4	-
<i>Hirudinea</i>	<i>Erpobdella octoculata</i>	5	2	-
<i>Hirudinea</i>	<i>Glossiphonia concolor</i>	-	2	-
<i>Hirudinea</i>	<i>Theromyzon tessulatum</i>	-	2	-
<i>Ephemeroptera</i>	<i>Caenis macrura</i>	-	3	-
<i>Ephemeroptera</i>	<i>Caenis robusta</i>	-	24	-
<i>Ephemeroptera</i>	<i>Caenis horaria</i>	-	-	65
<i>Mollusca</i>	<i>Anisus sp.</i>	-	1	-
<i>Mollusca</i>	<i>Unio pictorum</i>	1	-	-
<i>Mollusca</i>	<i>Radix auricularia</i>	-	-	1
<i>Mollusca</i>	<i>Coretus corneus</i>	-	-	1
<i>Odonata</i>	<i>Erythromma najas</i>	2	5	-
<i>Odonata</i>	<i>Platycnemis pennipes</i>	2	-	-
<i>Odonata</i>	<i>Gomphus vulgatissimus</i>	-	-	2
<i>Odonata</i>	<i>Leucorrinia dubia</i>	-	-	6
<i>Odonata</i>	<i>Epiteca bimaculata</i>	-	-	2
<i>Trichoptera Leptoceridae</i>	<i>Athripsodes aterrimus</i>	-	12	-
<i>Trichoptera Leptoceridae</i>	<i>Athripsodes pupae</i>	-	5	-
<i>Trichoptera Leptoceridae</i>	<i>Mystacides longicornis</i>	-	2	-
<i>Trichoptera Polycentropodidae</i>	<i>Plectrocnemia conspersa</i>	-	4	-
<i>Trichoptera Polycentropodidae</i>	<i>Polycentropus flavomaculatus</i>	-	2	-
<i>Trichoptera Limnephilidae</i>	<i>Anabolia soror</i>	13	-	-
<i>Trichoptera Limnephilidae</i>	<i>Limnephilus flavicornis</i>	-	-	9
<i>Trichoptera Limnephilidae</i>	<i>Limnephilus rhombicus</i>	-	-	8
<i>Trichoptera Limnephilidae</i>	<i>Limnephilus stigma</i>	-	-	12
<i>Trichoptera Molannidae</i>	<i>Molanna angustata</i>	-	-	13
<i>Diptera</i>	<i>Chironomidae</i>	11	35	280
<i>Diptera</i>	<i>Chironomus plumosus</i>	-	-	120
<i>Diptera</i>	<i>Chironomus pupae</i>	-	9	-
<i>Diptera</i>	<i>Chaoborus sp.</i>	-	4	-
<i>Heteroptera</i>	<i>Sigara sp.</i>	-	3	-

Table 2. Abundance of benthic organisms in combined samples of Lake Lentvaris

Taxa		Abundance in combined sample (2007.05.13)	Abundance in combined sample (2008.05.17)	Abundance in combined sample (2009.05.02)
Phylum/class/order	Family/genus/species			
<i>Oligochaeta</i>	<i>Oligochaeta</i>	22	5	8
<i>Hirudinea</i>	<i>Helobdella stagnalis</i>	6	6	-
<i>Hirudinea</i>	<i>Erpobdella octoculata</i>	5	6	-
<i>Hirudinea</i>	<i>Glossiphonia complanata</i>	1	-	-
<i>Crustacea</i>	<i>Asellus aquaticus</i>	6	-	-
<i>Ephemeroptera</i>	<i>Baetis spp.</i>	21	-	-
<i>Ephemeroptera</i>	<i>Caenis horaria</i>	17	-	-
<i>Ephemeroptera</i>	<i>Ephemera vulgata</i>	15	6	13
<i>Ephemeroptera</i>	<i>Caenis robusta</i>	-	9	-
<i>Ephemeroptera</i>	<i>Centroptilum luteolum</i>	-	-	2
<i>Mollusca</i>	<i>Bithynia tentaculata</i>	9	8	-
<i>Mollusca</i>	<i>Bithynia leachi</i>	-	4	4
<i>Mollusca</i>	<i>Radix auricularia</i>	-	2	-
<i>Mollusca</i>	<i>Pisidium amnicum</i>	-	2	-
<i>Mollusca</i>	<i>Valvata naticina</i>	-	7	-
<i>Mollusca</i>	<i>Lymnaea stagnalis</i>	-	2	-
<i>Mollusca</i>	<i>Lymnaea ovata</i>	2	-	-
<i>Mollusca</i>	<i>Dreissena polymorpha</i>	25	24	17
<i>Mollusca</i>	<i>Unio pictorum</i>	1	-	-
<i>Odonata</i>	<i>Ischnura elegans</i>	3	6	-
<i>Odonata</i>	<i>Platynemis pennipes</i>	-	1	-
<i>Odonata</i>	<i>Gomphus vulgatissimus</i>	-	-	1
<i>Trichoptera Leptoceridae</i>	<i>Athripsodes cinereus</i>	7	18	4
<i>Trichoptera Leptoceridae</i>	<i>Mystacides longicornis</i>	-	15	-
<i>Trichoptera Limnephilidae</i>	<i>Anabolia soror</i>	3	6	-
<i>Trichoptera Limnephilidae</i>	<i>Anabolia nervosa</i>	-	-	5
<i>Trichoptera Limnephilidae</i>	<i>Limnephilus flavicornis</i>	4	4	-
<i>Trichoptera Limnephilidae</i>	<i>Limnephilus fuscicornis</i>	1	-	-
<i>Trichoptera Limnephilidae</i>	<i>Limnephilus politus</i>	1	1	-
<i>Trichoptera Limnephilidae</i>	<i>Limnephilus rhombicus</i>	2	-	4
<i>Trichoptera Limnephilidae</i>	<i>Limnephilus puppae</i>	3	-	-
<i>Trichoptera Limnephilidae</i>	<i>Halesus interpunctatus</i>	-	3	-
<i>Trichoptera Molannidae</i>	<i>Molanna angustata</i>	-	2	-
<i>Trichoptera Polycentropodidae</i>	<i>Plectrocnemia conspersa</i>	-	3	-
<i>Trichoptera Polycentropodidae</i>	<i>Polycentropus flavomaculatus</i>	-	4	-
<i>Diptera</i>	<i>Chironomidae</i>	14	38	14
<i>Diptera</i>	<i>Chironomus pupae</i>	8	-	-
<i>Diptera</i>	<i>Syrphidae</i>	2	-	-
<i>Heteroptera</i>	<i>Sigara sp.</i>	-	3	-
<i>Arachnidae</i>	<i>Hydracarina</i>	6	10	-

Table 3. Values of Trent Biotic Index (TBI) and Danish River Fauna Index (DRFI) in lakes Didžiulis and Lentvaris (in the areas of mechanical lake restoration)

Index	2007.05.13 Before restoration	2008.05.17 After restoration	2009.05.02 After restoration
Lake Didžiulis			
Trent Biotic Index (TBI)	5	9	6
Danish River Fauna Index (DRFI)	3	4	3
Lake Lentvaris			
Trent Biotic Index (TBI)	9	9	7
Danish River Fauna Index (DRFI)	4	4	5

Each table reflects identification of benthic organisms according to the systematic groups relevant for Trent Biotic Index and Danish River Fauna Index and contains abundance in combined sample before restoration works (2007.05.13) immediately after restoration

(2008.05.17) and a year after restoration (2009.05.02). According to the abundance of indicative organisms, values of Trent Biotic Index and Danish River Fauna Index were calculated for each combined sample from both lakes. These results are provided in Table 3.

5. Conclusions

1. As it is seen from the results provided in Table 3, an immediate increase in Trent Biotic Index (from 5 to 9) was detected in Lake Didžiulis after restoration, while Danish River Fauna Index increased slightly, from 3 to 4. However, no changes were identified neither in values of Trent Biotic Index nor Danish River Fauna Index before and after sludge removal in Lake Lentvaris.
2. A year after restoration of Lake Didžiulis, there was a regressive decrease in Trent Biotic Index value (from 9 to 6) and Danish River Fauna Index dropped back to pre-restored value of 3. Curiously, a year after restoration the value of Trent Biotic Index in the restored part of Lake Lentvaris decreased from 9 to 7, while value of Danish River Fauna Index has slightly increased from 4 to 5.
3. It can be overly concluded that neither of the indices based on macrozoobenthos (Trent Biotic Index and Danish River Fauna Index) showed continuous positive effects of mechanical bottom sludge removal and the obtained results indicate only a short term positive fluctuation in one of the lakes with a quick regress and no changes or even slight further deterioration in the second lake.
4. Finally, although the results from a three year study show some general trends, they also identify an obvious need for further and more detailed research in this field.

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