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MR&CT analysis of the qualitative and quantitative structure of macrozoobenthos in selected oxbow lakes of Northern Poland

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Abstract

Macrozoobenthos inhabiting six oxbow lakes in the basins of the Słupia, Łyna, and Vistula rivers was investigated during spring, summer, and fall 2002-2006. The researched reservoirs – re-opened, dredged, with a sluice, natural open, natural semi-open, and natural closed – differed in degree of succession and type of connection with the relevant river. In order to determine the dependency of macrozoobenthos structure on type of oxbow lake and season, multivariate regression and classification tree method (MR&CT), and indicator species analysis were applied.

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The tree obtained revealed that the natural, semi-open oxbow lake differed distinctly from the others and was a favorable habitat for Diptera (mainly – Chironomidae larvae), Bivalvia, and Gastropoda. The latter taxon turned out to be an indicator for summer, while Insecta and Bivalvia dominated in spring and fall. Meliorated oxbow lakes (re-opened, dredged, with a sluice) were characterized by balanced density of all the macrozoobenthos organisms and the lack of indicator taxa. In turn, high trophy was indicated by Oligochaeta abundant in natural open and natural closed oxbow lakes, and in a reservoir with a sluice.

INTRODUCTION

Rivers tend to change their course, and this is typically accompanied by fragments of rivers being cut off to create oxbow lakes. Isolated, they are susceptible to succession, and change from lotic into lenitic ecosystems. These processes usually entail eutrophication and a decrease in biodiversity, which result in a considerable abundance of phytoplankton, lower water transparency, and elimination of stenotopic organisms (Kajak 1959). Investigation of the qualitative and quantitative structure of hydrobionts reveals the foregoing processes and trophic state of an aquatic ecosystem. In highly eutrophic reservoirs, benthofauna is mostly dominated by Oligochaeta and Chaoboridae (Kajak 1998).

Distribution of macrozoobenthos is determined by a whole set of biotic and abiotic factors (Kajak 1988). Only a few reports have been published on the macrozoobenthos of the oxbow lakes of the rivers Warta (Hajduk & Hajduk 1984, Jezierska-Madziar et al. 2000). Wkra (Lewin 2001) in central Poland (Piechocki 2004). When it comes to studies on Polish Pomeranian rivers, only one report, setting out the macrozoobenthos properties of such bodies of water in the Słupia river basin, has been published as a preliminary for wider studies (Obolewski 2003).

Therefore, the objective of this study was a preliminary assessment of the qualitative and quantitative structure of macrozoobenthos inhabiting oxbow lakes. The lakes investigated possess varying trophic states and connections to rivers in northern Poland. The multivariate regression and classification tree method (MR&CT) was employed in this research.

MATERIALS AND METHODS

Seasonal sampling of macrozoobenthos was conducted during spring, summer and fall 2002-2005 in 6 oxbow lakes in the Słupia River Basin (re-opened Osokowy Staw – 2002/03, dredged Koński Staw – 2004/05), the Łyna River Basin (natural semi-open S2, natural open S5, natural closed S8 – 2004/05), and the Vistula River Basin (oxbow lake with sluice - 2002/03) (Fig. 1). In total, 154 samples of sediments were taken using an Ekman-Birge grab

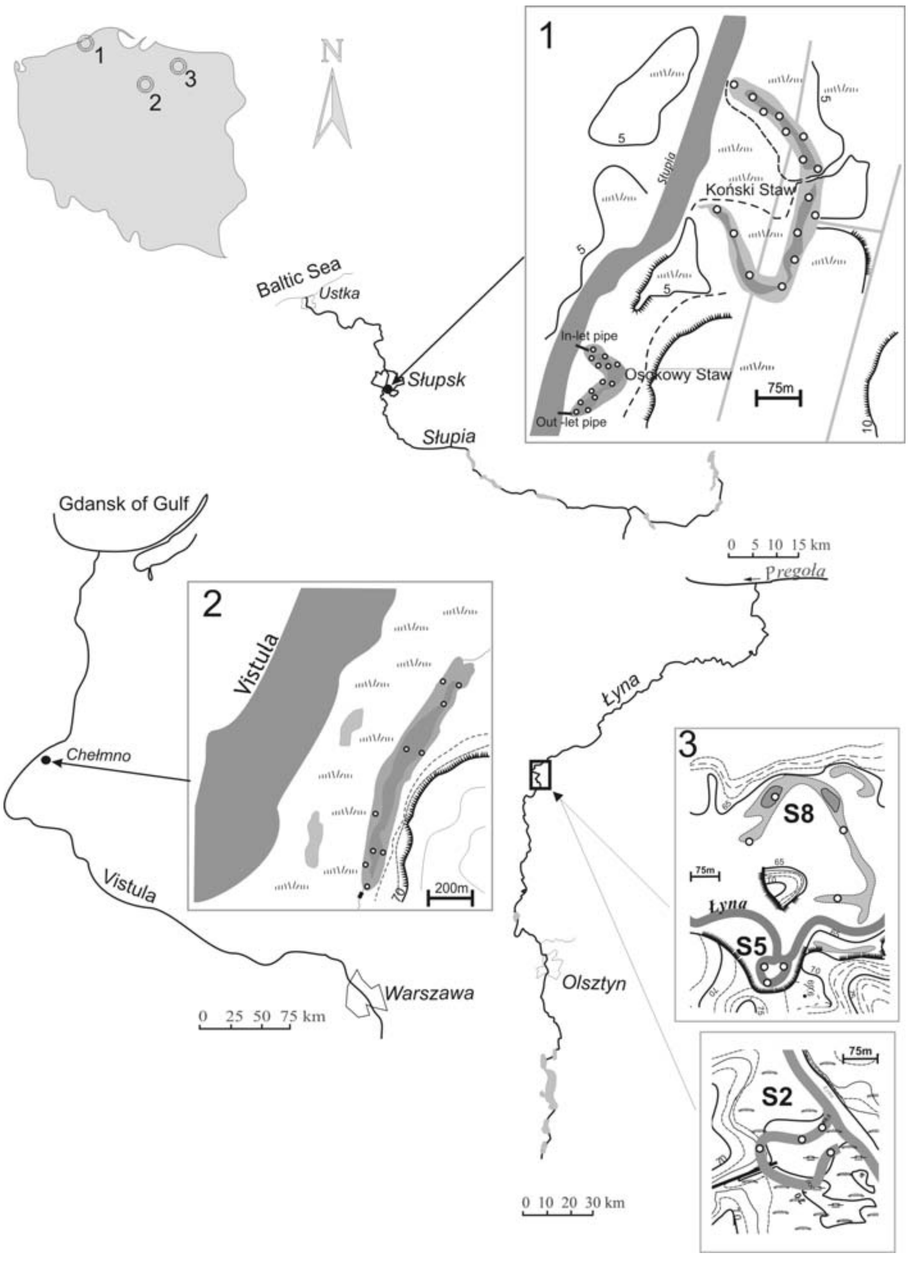

Fig. 1. Location of the studied oxbow lakes. 1 – dredged Koński Staw, re-opened Osokowy Staw on the Słupia River; 2 – sluice on the Vistula River; 3 – natural semi-open (S2), open (S5), and closed lakes on the Łyna River.

sampler (surface 225 cm^2). At each sampling site three subsamples were taken, and the sediments were sieved through a 0.5 × 0.0197 mesh size sieve and fixed in 4% formalin. Macrozoobenthos organisms were identified according to assemblage and their density was related to $1m^2$ of bottom.

The obtained data set was analyzed using multivariate regression and classification trees (MR&CT) (Breiman et al. 1984, De'ath and Fabricus 2000, De'ath 2002). This analysis results in a tree describing taxa assemblage and associated habitat. The overall fit of the tree is specified as relative error (RE; SSD – the sum of squared euclidean distances – in clusters divided by the SSD of the undivided data), and predictive accuracy is assessed by CVRE (Breiman et al. 1984, De'ath and Fabricus 2000). In this study, the finally selected tree was the most complex model within one standard error (1 SE) of the best predictive tree (Breiman et al. 1984), using 2000 multiple cross validations to stabilize CVRE. Taxa distinctive for a given cluster were identified using indicator values (indval), (Dufrene and Legendre 1997). The significance of taxon association with a particular cluster was assessed by a permutation test with 500 iterations. MR&CT analyses were carried out in R 2.1.1 (R Development core team, 2004) using the mvpart (Multivariate Partitioning) package, while indval analyses were performed with the labdsv (Dynamic Synthetic Vegephenomenology) package.

RESULTS AND DISCUSSION

Predictors in MR&CT analysis were categorical variables: type of oxbow lake (natural open, natural semi-open, natural closed, dredged, with sluice, re-opened). The obtained tree, with 3 splits and 4 terminal leaves (Fig. 2, Table 1), produced relative error RE=0.081 and cross-validated relative error CVRE=1.15, with a standard error of cross-validation SE=0.538.

In the original data set (node 1) the dominant taxa were Oligochaeta (mean density=269.2 indiv. m^{-2}) and Diptera (mean density=269.0 indiv. m^{-2}). A primary split separated the natural semi-open oxbow lake (right leaf) from the data set. This lake was characterized by very high density of Diptera (mean density=1666 indiv. m^{-2}; indval=0.85 – 80% Chironomidae larvae), Gastropoda (mean density=744 indiv. m^{-2}; indval=0.48), Bivalvia (mean density=70.3 indiv. m^{-2}; indval=0.36), and a total absence of Arachnida or Turbellaria representatives. The natural semi-open oxbow lake was a distinct type of habitat. A partial connection to the river creates conditions favorable to many organisms. More demanding representatives of Insecta (Plecoptera, Ephemeroptera) occur at the point of contact between the water of the oxbow lake and riverine water, while places with worse oxygenation are inhabited by Diptera, Megaloptera, Hetroptera, and Coleoptera (Drake 1984). Moreover,

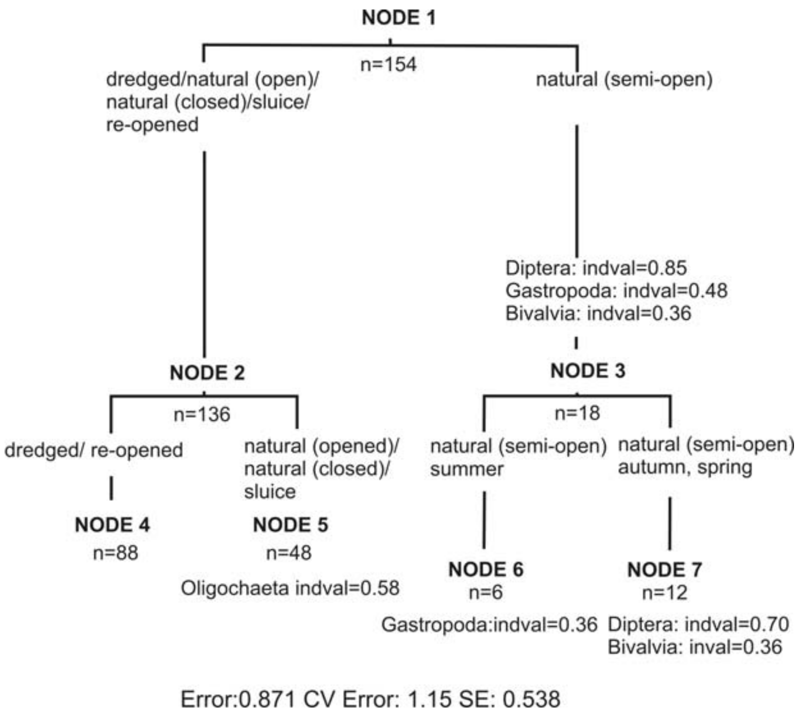

Fig. 2. Multivariate regression and classification tree. Error: Relative error; CV Error: cross-validated relative error; SE: standard error for cross validation; n – number of cases.

Table 1

Density of macrozoobenthos taxa in MR&CT nodes. Indicator species are in bold.

Macrozoobenthos taxa	Density [indiv. m^{-2}]						
	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7
Turbellaria	4.4	5.0	0.0	7.6	0.2	0.0	0.0
Oligochaeta	269.2	286.7	136.6	65.6	**692.0**	2.5	203.7
Hirudinea	17.7	14.7	40.3	16.0	12.3	7.4	56.8
Crustacea	87.8	94.6	36.2	130.7	28.5	0.0	54.3
Diptera	269.0	84.1	**1666.0**	60.9	126.6	244.4	**2377.0**
Arachnida	1.9	2.2	0.0	0.0	6.2	0.0	0.0
Gastropoda	33.8	28.4	**74.4**	30.7	24.2	**123.5**	49.9
Bivalvia	31.7	26.6	**70.3**	33.1	14.7	12.3	**99.2**

semi-open reservoirs are protected from the washing away of fauna by a strong river current. Gastropoda, with planctonic larvae, take advantage of this situation. Therefore Bivalvia and Gastropoda were indicator taxa for this type of reservoir. The inflow of riverine bioseston, and its sedimentation in a slower current, assure feed for filtrating Bivalvia (Piechocki 2004).

Node 2 was split into dredged and re-opened oxbow lakes (left leaf) - without indicator taxa, and with moderate macrozoobenthos density - and into reservoirs with sluice, natural open and natural closed (right leaf) - with a characteristic high density of Oligochaeta as an indicator taxon (mean density=692 indiv. m^{-2}; indval=0.58). Upsetting the biological balance in meliorated oxbow lakes induces destabilization of the biocenosis and rearrangements in the structure of hydrobionts (Obolewski 2006). Meliorated oxbow lakes form a new biological system with a different structure of benthofauna. Zoobenthos in open and periodically open oxbow lakes was dominated by the indicator taxon Oligochaeta. The structure of benthofauna, with abundant Oligochaeta and a low density of the remaining taxa, indicated the high trophy of these oxbow lakes (Kajak 1988). The density of Oligochaeta is determined by the water level and the age of alluvium (Kasprzak 1987). A lower water level in the drainage area favors this group of benthofauna. Oligochaeta feed on detritus inhabiting sediments, and in oxbow lakes this taxon finds a favorable habitat in thick layers of mud. That situation mostly takes place in closed oxbow lakes that are periodically connected with the relevant river, and also in open reservoirs, because of slime accumulation in meanders (Glińska-Lewczuk et al. 2005).

Node 3 was additionally divided into leaves representing the taxonomic structure of a natural, semi-open oxbow lake in summer (left leaf), and during spring and fall (right leaf). In both of these terminal nodes, Diptera was dominant, but indicative, with Bivalvia, for spring and fall (Diptera: mean density=2377 indiv. m^{-2}, indval=0.70 – 65% Chironomidae larvae; Bivalvia: mean density=99.2 indiv. m^{-2}; indval=0.36). However, Mollusca turned out to be an indicator taxon for summer (mean density=123.5 indiv. m^{-2}; indval=0.36). The indicator taxon, Diptera, transforms in summer; therefore its contribution to the macrozoobenthos structure was lower during this season. Bivalvia, too, were less abundant in summer, probably because of the worse oxygenation of the reservoir and fish pressure (Rasmussen 1988, Kajak 1998).

Indicator taxa analysis allowed for an interesting insight into macrozoobenthos structure. The index distinguished between ubiquitous taxa that dominated many groups in absolute density, and taxa that occurred consistently within single groups but had low density.

CONCLUSIONS

1. The qualitative and quantitative structure of macrozoobenthos was influenced by the type of oxbow lake. Season was an important predictor only for natural, semi-open oxbow lakes.
2. Oligochaeta was the indicator taxon for oxbow lakes that are naturally open, closed and periodically open (with a sluice). Oligochaeta indicates the high trophic status of these reservoirs.
3. A moderate density of all the macrozoobenthos taxa was characteristic for meliorated oxbow lakes.
4. Semi-open oxbow lakes turned out to be the most favorable habitat for macrozoobenthos, with the dominant role among these being played by Diptera (Chironomidae larvae) and molluscs.
5. The indicator value from indval analysis reveals the indicator taxa.

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