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The zooplankton communities of small water reservoirs with different trophic conditions in two catchments in western Slovakia

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ABSTRACT

Our study summarizes data from six small water reservoirs in West Slovakia and analyzes the occurrence of zooplankton groups in relation to physico-chemical and catchment variables. The reservoirs are in two different catchments – of the Morava and Váh rivers. A total of 103 species were identified; 64 crustaceans (in both the pelagic and littoral zones) and 39 planktonic Rotifera in the pelagic zones. Significant differences were observed in species richness, abundance and biomass of planktonic crustaceans: 48 species were characteristic of the Váh catchment, while 53 were found in the Morava catchment. The density of zooplankton in the three reservoirs of the Váh River catchment ranged from 102 ind L^{-1} to 21,488 ind L^{-1} and the zooplankton biomass ranged from 0.12 mg L^{-1} to 103.29 mg L^{-1}. The density of zooplankton in three Morava River catchment reservoirs ranged from 2 ind L^{-1} to 3928 ind L^{-1} and the zooplankton biomass ranged from 0.1 mg L^{-1} to 27.3 mg L^{-1}. The differences were found to be related to catchment (altitude and catchment affiliation), chemical (BOD5, DO) and biological (Chromophyta, Chlorophyta) factors. Eutrophication of reservoirs in the Váh catchment was mainly due to agriculture and fish management, resulting in high nutrient concentrations. Species richness showed an unimodal response to BOD_5 and N-NH_4 with near optimum low values, 4.6 and 0.19 respectively. The relationship to oxygen content reflects preferences for less eutrophic waters and species richness tended to decrease with increasing DO and to decrease with increasing nutrient content.

Introduction

The small water reservoirs are built for irrigation, flood protection and water supply (Baxer 1977; Bauer et al. 2010). Natural and man-made ponds still represent at least 30% of the global surface area of the standing freshwater resource, despite their extensive loss in some countries (The Pond Manifesto 2008). Potentially, such small water reservoirs can assume the environmental role of natural ponds, pools or lakes. Ponds and shallow lakes are, collectively, exceptionally rich in terms of biodiversity (Chmielewski et al. 1997; Williams et al. 2004; Fahd et al. 2009) but they have only recently been recognized as important habitats (Biggs et al. 2005). In comparison with pools and ponds, small reservoirs are larger and thus temporally more stable. On average, local species richness in lentic systems tends to increase from small and temporary water bodies to larger and more permanent systems (De Bie et al. 2008; Davies et al. 2008). They are also valuable in protecting surface water quality in agricultural landscapes because their hydrocoenoses clear the polluted waters draining into such reservoirs from agriculture and settlements. The effects of water chemistry (e.g. phosphorus, alkalinity, pH) on biodiversity have been extensively studied (e.g. Jeppesen et al. 2000) and some studies have suggested the relative importance of other environmental variables such as lake (pond) morphology, hydrology, food availability (Devetter 1998), nutrient enrichment and fish (Stenson 1982; Telesh 1993) and land use (Karatayev et al. 2005). More recently, the question of what affects the size structure or taxonomic structure of the zooplankton community has also been explored (Dodson et al. 2000, 2009; Boix et al. 2008; Havens and Beaver 2011). Vakkilainen et al. (2004) studied some interactions within the food web and the response of zooplankton to nutrient enrichment and fish in shallow lakes.

Small water reservoirs are relatively numerous throughout the world, especially in Romania (Gastescu and Breier 1973), Spain (Margalef 1976) and in Britain (Biggs et al. 2005) are more studied. Some 200 have been built in Czechoslovakia alone since 1950 (Brňák 1980), mainly for irrigation or flood protection, together with fish farming and/or for recreation. Therefore previous studies have focussed mainly on seasonal changes in plankton communities (Hrbáček et al. 1966; Vranovský 1985; Brandl et al. 1989), phytoplankton and fish predation (Desortová et al. 1977; Kořínek et al. 1987; Hochman et al. 1988, 1989; Seda et al. 2000) or self-purification problems (Illyová and Štefková 1995). Most studies of zooplankton in reservoirs have been concerned with large, deep reservoirs (Hudec and Hucko 2000) and medium-sized reservoirs

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(Hudcovicová and Vranovský 2000) but there are only a few studies that have investigated the zooplankton communities of small reservoirs (e.g. Hudec 1992; Timková and Hudec 1997).

This work aimed to assess the planktonic communities of six small reservoirs and the main factors driving changes in their composition (e.g. human impact, chemical and physical factors). The main objectives were (i) to provide the first description of zooplankton communities in terms of their composition structure, abundance and biomass, because these are the first such records for these reservoirs; (ii) to determine the impact of anthropogenic enrichment on the species richness and diversity of the planktonic crustaceans of the reservoirs; (iii) to identify key natural and human drivers of zooplankton community structure and dynamics.

Methods

Site description

Six small water reservoirs with different trophic levels, belonging to two catchments, of the Váh River and the Morava River, were chosen for our study. All the dams were constructed by blocking a stream, initially because of their potential for irrigation requirements and as flood protection. Fish farming is now also part of their function. The area of lowlands and highlands in western Slovakia is characterized by quite intensive agricultural industry and by dense village settlements. The reservoirs are situated on either side of the Small Carpathian Mts (West Slovakia) and on this basis they can be divided into two groups:

The Váh River catchment reservoirs

Dol'any (16 ha; N 48°24′11; E 17°24′50), Suchá nad Parnou (31.2 ha; N 48°24′47; E 17°24′20) and Dolné Dubové (12 ha; N 48°30′08; E 17°35′39), are situated in an agricultural plain at up to 200 m a.s.l. The water of imputes is polluted by domestic sewage. The reservoirs are surrounded by agricultural fields and are strongly affected by human activities, especially by drawdown effect, because they are used periodically for irrigation. Dolné Dubové reservoir is regularly stocked with carp. The Dol'any reservoir comes under the Ramsar Convention on wetlands (Klementová and Juráková 2003), but since 2009 intensive fish farming has been carried out there (according to oral communication from local fishermen). Besides the dominant carp (*Cyprinus carpio*) and pike (*Esox lucius*), other fish species were recorded (*Abramis brama*, *Carassius gibelio*, *Ctenopharyngodon idella*, *Perca fluviatilis*, *Scardinius erythropthalmus* and *Silurus glanis*). Poor littoral vegetation had developed in these reservoirs: Dol'any – littoral – *Phragmites* sp., *Iris* sp., riparian – *Najas marina*, *Persicaria lapathifolia*, *Chenopodium glaucum*, *Ch. rubrum*, Suchá nad Parnou – *Iris* sp., *Polygonum amphybium* and Dolné Dubové – *Bartachium* sp., *Rumex* sp., *Iris* sp., *Phragmites* sp.

The Morava River catchment reservoirs

Kuchyňa (12 ha; N 48°24′07; E 17°09′56), Lozorno (35 ha; N 48°19′30; E 17°04′08) and Vývrat (10 ha; N 48°26′00; E 17°10′11), are on the west side of the Small Carpathian Mts (Slovakia) at altitudes up to 260 m a.s.l. The reservoirs are not under such strong anthropic pressure as the first group since their inlets flow through a protected area. Vývrat is actually used as sport fishing reservoir. The reservoirs Kuchyňa and Lozorno fall under the Ramsar Convention on wetlands (Klementová and Juráková 2003) and both these water bodies have good facilities for recreation. Richly developed aquatic macrophytes covers the littoral zones of these reservoirs: Kuchyňa – *Phragmites* sp., *Eleocharis* sp., *Typha* sp., Lozorno – *Ceratophyllum demersum*, *Myriophyllum spicatum*, *Elodea nuttallii*, *N. marina*, *Potamogeton nodosus* and Vývrat – *Potamogeton lucens*, *Chara globularis*, *Lemna minor*, *Phragmites australis*, *Carex* sp.

Sampling and data collection, data analysis

Water for chemical analyses, phytoplankton and zooplankton samples were taken from pelagial sites; complete qualitative planktonic crustacean samples were collected from two littoral locations. Zooplankton samples were taken in September and November 2008; and in April, May and August 2009, between 11 and 14 h from the deepest site of the reservoir (from the dam). The samples for qualitative analyses of zooplankton were taken from the pelagial and from the littoral zone with a vertical tow of a plankton net (60–70 μm mesh size) from the bottom. Quantitative samples were taken with a Patalas-type plankton sampler by collecting 20 L from the water column and concentrating the zooplankton using a phosphor–bronze sieve (40–50 μm mesh size) and preserving the zooplankton in formalin. Zooplankton density (ind L^{-1}) was assessed in a 1-mL Sedgewick-Rafter chamber. Biomass (mg L^{-1}) was established as wet weight calculated from the mean recorded body lengths and from the body length/biomass ratio using tables compiled from several bibliographic sources by Vranovský (unpublished). Species dominance (%) was set as the relative proportions of species to the densities of Crustacea and Rotifera respectively. The mean Shannon biodiversity index H′ (Hammer et al. 2001) was used to express species diversity of planktonic crustaceans inhabiting different study sites.

Qualitative phytoplankton samples were taken with a Patalas-type plankton sampler from the open water zone and microscopic analyses were carried out using fresh samples after sample concentration by centrifuge. Parameters: pH, dissolved oxygen content (DO), oxygen saturation (DO %), temperature (*t*) and conductivity were measured directly in the field using a multiparameter meter (Hanna HI 9828). Some chemical variables – BOD_5, total nitrogen (TN), ammonium ($N\text{-}NH_4$), nitrate ($N\text{-}NO_3$), total phosphorus (TP), and phosphate ($P\text{-}PO_4$) were analyzed according to Hrbáček et al. (1972). Chlorophyll-*a* (Chl_*a*) concentration was measured using the ISO Standard method (ISO 10260:1992).

The data were statistically analyzed in two ways. Species density data from the open water were summarized into a species matrix comprising the relative abundances (%) of planktonic crustaceans (Cladocera and Copepoda) and Rotifera. To reveal the relationships between zooplankton and environmental parameters canonical ordination (CANOCO program, Ter Braak and Šmilauer 1998) was used. To determine the distribution pattern (linear or unimodal), the species data matrix was first analyzed by Detrended Correspondence Analysis (DCA). According to the length of the gradient, Redundancy Analysis (RDA) was chosen as the direct gradient analysis. The environmental matrix for open water samples consisted of three groups of variables: 'natural' (catchment affiliation, altitude), 'physico-chemical' (pH, DO, DO%, *t*, conductivity, TN, $N\text{-}NH_4$, $N\text{-}NO_3$, TP, $P\text{-}PO_4$, BOD_5) and 'biological' variables (Cyanophyta, Chromophyta, Chlorophyta, Euglenophyta, Chl_*a*). A variation partitioning procedure permitted a distinction between the effects of individual groups of predictors on the zooplankton communities. Within every group of variables, stepwise RDA, with a forward selection procedure, was used to select a partial model with the combination of environmental variables that best explained the variation in the species matrix. Thus, the total variation in the invertebrate data matrix was partitioned into four components: the component explained by (i) catchment variables; (ii) physico-chemical variables; (iii) biological variables and (iv) unexplained variation. A model with temporal constraints was selected with seasons as covariables, to filter out the influence of the temporal pattern. Catchment variables enabled assessment of the 'natural' gradient of the studied reservoirs, as they reflect differences among