Summary

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Large-scale assessment of planktonic organisms biodiversity in artificial water reservoirs in Poland

Zooplankton communities are excellent indicators of environmental changes due to their short life cycles, sensitivity to pollution and rapid adaptation to environmental changes. Because of these characteristics, they are suitable for comparative studies and predictions for describing the state of the environment.

The biodiversity of rotifers and planktonic crustaceans was studied in 31 artificial water reservoirs: dams, pit lakes (gravel, limestone, marl, pyrite) and waters localized in urban areas (fountains, ponds, dams, moats, fire protection ponds and urban pits). Samples were collected from 5 geographical regions scattered throughout Poland (Figure 1), with 2 sampling points from pelagic and littoral zones (depending on water reservoir morphometrics). Sampling continued for three years (2011-2013) in two periods: spring-summer and autumn-winter.

The aims of the research were as follows: a) evaluation of changes in the diversity of planktonic rotifers and crustaceans (evaluation of anthropogenic pressures, the degree of impoverishment), b) assessment of similarities of different aquatic ecosystems within regions and between regions.

Depending on the origin of the water reservoirs and their functions, a significant variability in both the physicochemical properties of the water and species composition, density and dry weight was shown.

In order to compare the anthropogenic reservoirs in terms of physicochemical parameters the authors used the Principal Component Analyses (PCA) and distinguished the following 3 groups of reservoirs: a) reservoirs with a higher concentration of PO_4^{3-} in water (regions I, II and III); b) reservoirs with higher concentrations of Cl^- and SO_4^{2-} in water (regions I, III and IV); c) reservoirs with a higher concentration of NO_3^- (region V). Pit-lakes were divided into: a) reservoirs characterized by high levels of SO_4^{2-} and PO_4^{3-} in water, as well as acidity and the lowest number of zooplankton species (region V- Kolorowe Jeziorka – pyrite pit-lake); b) pit-lakes (mainly excavation of chalk, limestone and gravel), having substantially lower values of conductivity, better oxygen saturation and lower values of concentration of SO_4^{2-} and PO_4^{3-} in water (regions I to IV). The most distinctive city reservoir was the pond in Park Kazimierz Wielki in Bydgoszcz, with its low concentration of O_2 (region II). Other city reservoirs had high concentrations of Cl^- and Ca_2^+ (regions I, III–V).

In the three studied categories of anthropogenic water reservoirs: dam reservoirs, pit- lakes (eg. gravel, limestone etc.) and city ponds (e.g. fountains, fire protection pond), a total of 134 rotifer, 49 cladoceran and 40 copepod species were found. They represented different species types including those which are widespread (e.g. *Keratella cochlearis*, *Eudiaptomus gracilis*, *Daphnia cucullata*) and characteristic for those geographical regions (eg. *Eubosmina thersities* – found in northern parts of Poland). There were also species characteristic of saline (*Alonella nana*) and acidified waters (e.g.*Cephalodella hoodi*) and species which are resistant to harsh environmental conditions (e.g. *Bosmina longirostris*). Some of the zooplankton species included: rare (e.g. cladocerans: *Scapholeberis rammeri*), indicators of a high trophic state index (e.g. rotifers: *Keratella tecta, Pompolyx sulcata*), characteristic of post-mining excavations e.g. acid reservoirs (e.g. rotifer: *Cephalodella delicata*), those enduring salinity of 30 ‰ (e.g. cladocerans: *Scapholeberis mucronata*) and one species which was introduced in the 20th century (cladocerans: *Daphnia ambigua*).

In order to assess the similarity of assemblages of zooplankton in different types of anthropogenic reservoirs we used Sörensen's coefficient. Both within the dam and pit reservoirs, two types of reservoirs can be distinguished on the basis of zooplankton assemblage (Sörensen index). The first group in dam reservoirs occurs in regions I, II and III, whereas the other group – in regions III, IV and V. In pit reservoirs, the first group included zooplankton assemblages in the piryte pit lakes, Kolorowe Jeziorka, in region V, whereas the other group – zooplankton from gravel, chalk and limestone pit reservoirs – in regions I–IV.

Comparing zooplankton assemblages from the city ponds did not result in a comparatively clearcut division of these reservoirs into groups.

The number of species in the dam reservoirs ranged from 33 to 67, in pit reservoirs – from 11 to 71, and in city reservoirs – from 16 to 59. The main factors influencing the number of species in dam reservoirs were their depth, presence or absence of a littoral zone, as well as trophic state and function of the water body. In the pit reservoirs the number of zooplankton depended on the geological structure of the bottom, physicochemical properties of water, as well as the presence or lack of a littoral zone. In the city reservoirs, in addition to geological structure, physicochemical properties of water and presence of a littoral zone, the most important factor accounting for the number of species was temporal stability of water bodies (e.g. temporal fountains vs permanent dams or city clay-pits).

The density and dry weight of the zooplankton varied among the taxonomic groups (rotifers, copepods and cladocerans) as well as among the investigated reservoirs. The highest densities of rotifers were found in cities: in the pond Park Kazimierza Wielkiego in Bydgoszcz (26 912 ind. L^{-1}), the dam Jezioro Zygmunta Augusta (7073 ind. L^{-1},) and the gravel pit Bagry Krakow (3306 ind. L^{-1}). In the same reservoirs the highest values of dry weight, up to 2 mg L^{-1}, were recorded. The highest density of cladocerans were found in the city dam-Park A. Mickiewicza in Łódź (3646 ind. L^{-1}), the dam reservoir Jezioro Zygmunta Augusta (1953 ind. L^{-1}) and the devonian limestone pit lake – Jeziorko Daisy (474 ind. L^{-1}). The highest values of dry weight were recorded in Park A. Mickiewicza in Łódź (31,165 mg L^{-1}), Siemiatyckie Zalewy dam reservoir (over 5 mg L^{-1}) and the limestone pit – Stara Kredownia (over 4 mg L^{-1}) . The highest densities of copepods were recorded in the city dam-Park A. Mickiewicza in Łódź (788 ind. L^{-1}), the Chańcza dam reservoir (720 ind. L^{-1}) and the devonian limestone pit lake – Jeziorko Daisy (396 ind. L^{-1}). In the same reservoirs the highest values of dry weight, up to 1 mg L^{-1}, were found.

Canonical Correspondence Analysis (CCA) was used to assess the impact of the environmental factors on zooplankton (dominant species of rotifers, cladocerans and copepods; Table 54 found in the dam reservoirs, pit-lakes and city ponds. In the dam reservoirs the most important physicochemical factors influencing the presence of the dominant species of rotifers and crustaceans were Na^+, Mg^{2+}, Ca^{2+}, NH_4^+, NO_3^-, Cl^-, PO_4^{3-}, F^-, CO_3^{2-}, SO_4^{2-} and conductivity. In the case of the pit-lakes, the most important physicochemical factors influencing the presence of the dominant species of zooplankton were K^+, Na^+, Mg^{2+}, Ca^{2+}, Cl^-, CO_3^{2-}, SO_4^{2-} conductivity. The most important physicochemical factors influencing the presence of zooplankton in city ponds were the concentration levels of O_2, pH, Li^+, Na^+, Cl^-, PO_4^{3-}, F^-, CO_3^{2-}, SO_4^{2-} and conductivity.

Biological diversity of zooplankton in the investigated reservoirs was tested using several biodiversity indices. The highest values of Margalef index diversity for zooplankton were found in all 3 types of reservoirs with well developed littoral zones. The index values ranged from 7.5 to 8.5 (water dam reservoirs from regions I, II and II; gravel pit lakes from regions II and III; city ponds from region I). The highest values of species diversity, Brillouin (H), Shannon-Wiener (H') and Simpson (I) indices, were found for zooplankton in dam reservoirs (with the Shannon--Wiener index (H') exceeding 2.5 in seven of these reservoirs). Among the pit-lakes, the indices had high values only for zooplankton in Owińska (gravel pit), which were comparable to those from zooplankton of the dam reservoirs. On the other hand, in the city ponds, high values

of zooplankton diversity were found only in two city dam reservoirs in Łódz (Park A. Mickiewicza and Zbiorniki Arturówek).

In general, the highest values of ecological indicators were reported for zooplankton in reservoirs in region III.

The authors hope that the results may be interesting not only for hydrobiologists and planktonologists concerned with water quality assessment and its protection but also for teachers and students at higher educational levels.