Ecological Indicators 90 (2018) 171–178

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Diversity and zooplankton species associated with certain hydroperiods and fish state in field ponds

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ARTICLE INFO

Keywords:
Biodiversity
Trophic status indicators
Water regime
Fish impact
Rotifers and crustaceans
Small water bodies

ABSTRACT

Human-induced impact on the biocoenoses in small water bodies within field landscape, aquatic ecosystems undergoing habitat loss, is not only restricted to trophic increase. Ponds are often used for amateur fish production, mainly carp and crucian carp. In addition, in order to limit the growth of aquatic vegetation alien fish species to native fauna, grass carp, are frequently introduced. Only temporary ponds remain entirely free of such manipulations. Therefore, changes in diversity and the occurrence of specific species can be expected in ponds representing different scenarios of fish predation FP and water regime WR.

In order to establish conditions responsible for zooplankton occurrence in field ponds subjected to FP (three categories of ponds: fish-free; low fish stocking; high fish stocking) and WR (two categories of ponds: permanent vs. temporary), material was collected from the open water of six neighbouring ponds, thirteen times in 2009, covering the spring, summer and autumn. A total of 134 zooplankton taxa was recorded with rotifers (94 taxa) prevailing taxonomically over cladocerans (24) and copepods (16). A tendency of certain taxa and species diversity to group along a gradient of WR and FP was observed. Higher species diversity was attributed to fish-free ponds, partly depending on the higher contribution of macrophyte-dominated areas, which are known to support a high variation of organisms. Two groups from among the most frequent species that indicated temporary ponds were: 1/littoral-associated (e.g. *Lepadella ovalis*, *Chydorus sphaericus*) in fish-free ponds and 2/large-bodied mainly pelagic (e.g. *Eudiaptomus gracilis*) in low-fish ponds. Fish ponds that were of permanent character, however, had lower species richness, with a high frequency of typically eutrophic taxa such as *Brachionus angularis*, *Keratella cochlearis* f. *tecta* or *Trichocerca pusilla*. However, they were also a source of rare species such as *Brachionus falcatus*, *Lecane tenuiseta*, *Ceriodaphnia dubia* that occurred exclusively in these ponds compared to natural fish-free ponds, which were remnants of lost species richness. This in turn increased overall zooplankton richness in the regional aspect. Thus, the co-occurrence of temporary ponds along with fish-production targeted permanent ponds may lead to a rise in zooplankton biodiversity on a local scale. We assume therefore that not only patterns of zooplankton biodiversity but also the occurrence of particular species can be treated as a useful indicator of FP and WR in small water bodies and are crucial for conservation purposes and management of aquatic systems at regional and landscape levels.

1. Introduction

Natural depressions, filled with permanent or temporary water, belong to typical features of the landscape of northern and central Europe. The hydrology of ponds is usually determined by precipitation and evaporation but also on sources of fluvial and underground water (Golus and Bajkiewicz-Grabowska, 2017; Lischeid et al., 2018). Both hydrological types of ponds, temporary and permanent (Wiggins et al., 1980), are aquatic ecosystems that support high biodiversity and contribute to increasing overall heterogeneity (Mętrak et al., 2014; Kuczyńska-Kippen and Joniak, 2016). However, agricultural areas, predominating in this part of Europe, are prone to severe human-induced impacts (Serrano et al., 2017) which can be reflected in the structure of biocoenoses (Kozak et al., 2017). Firstly, this can be connected with the increase of the trophic state of water. Improper management in the watershed of a pond leads to a worsening of water quality (Joniak et al., 2009; Klimaszyk et al., 2015; Dondajewska et al., 2017). In order to protect as well as prevent ecological deterioration of ponds and stability of trophic conditions, maintenance of a buffer zone created by shrubs and trees around the pond is advisable. Secondly, manipulation with biotic factors, which strongly affect the structure of the inhabiting organisms (Habdija et al., 2011; Basińska et al., 2014), is

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https://doi.org/10.1016/j.ecolind.2018.03.016
Received 19 October 2017; Received in revised form 6 March 2018; Accepted 8 March 2018

crucial in the case of ponds which are small, shallow and have a restricted water volume. Among fish species that typically occur in small water bodies are crucian carp (*Carassius carassius* Linnaeus, 1758) (Piironen and Holopainen, 1988), lake minnow (*Rhynchocypris percnurus* Pallas, 1814) (Wolnicki et al., 2008; Radtke et al., 2011) as well as roach (*Rutilus rutilus* Linnaeus, 1758), rudd (*Scardinius erythrophthalmus* Linnaeus, 1758) and perch (*Perca fluviatilis* Linnaeus, 1758) (Brylińska, 1991). In Poland, ponds of a relatively constant level of water are often used for the purpose of amateur fish production, mainly carp (*Cyprinus carpio* Linnaeus, 1758) and crucian carp.

In addition, in order to limit the growth of aquatic vegetation specific fish species are introduced. Fish examination in Polish water bodies (Prejs and Jackowska, 1978; Prejs, 1984) revealed that roach and rudd belong to important consumers of plant material. However, alien species to native fauna, such as grass carp (*Ctenopharyngodon idellus* Valenciennes, 1844), are also frequently introduced into the ponds (Pípalová, 2006; Krupska et al., 2012). Only water bodies which are temporary remain entirely free of such manipulations with ichthyofauna. The presence of fish is known to have a particularly strong effect on the structure of crustaceans, particularly large-bodied forms such as daphnids (Williams and Moss, 2003). Thus, domination of planktivorous fish may induce a decrease of cladocerans and an increase in rotifers (Kozak et al., 2015; Dondajewska et al., 2017). Not only planktivore type but also the fish-stocking biomass can be decisive for plankton dynamics and community structure (Attayde and Menezes, 2008). The increase of rotifers in the presence of fish may be due to two factors. Rotifers, which can be suppressed by cladocerans in two ways – through exploitative competition for shared and limiting food resources as well as through mechanical interference (MacIsaac and Gilbert, 1989; Kuczyńska-Kippen, 2001a), may benefit in their absence resulting from fish predation on microcrustaceans. Moreover, rotifers are known to develop well in highly eutrophic waters with high fish biomass (Telesh, 1993; Ejsmont-Karabin, 2012) where they have increased access to detritus-originated bacteria.

Water level fluctuations, which are also known to be responsible for supporting pond diversity (Antón-Pardo et al., 2016), may be a part of normal water regime variation. This can be observed as diurnal, seasonal and/or long-time (multiyear) variation. Such natural changes are typical for temporary ponds, whose water level may change due to processes referring to the water cycle such as evaporation or precipitation and as runoff. The long-term fluctuations make small water bodies prone to disappearance resulting from e.g. water deficits (Wolnicki et al., 2008). Bazzanti et al. (2003), examining temporary ponds in Italy, found that the annual hydrologic cycle was the main factor that contributed to differentiation in the macroinvertebrate community between temporary and permanent ponds and other abiotic factors were of lower impact. Moreover, Kuczyńska-Kippen et al. (2009), who investigated macrophyte cover and zooplankton communities in three seasons (spring, summer and autumn) during one vegetative period, found that along with the lowering of the water level structural changes in hydrobiota, especially in the case of submerged vegetation, were recorded. This emphasizes the potentially strong impact of hydroperiod on organisms inhabiting small water bodies. Moreover, experimental study on temporary pond ecosystems has also indicated that besides predation, demographic constraints due to wetland drying play a key role in structuring zooplankton communities (Zokan and Drake, 2015). Changes in the water level may not only influence the richness of the zooplankton community but also its composition. In 19 temporary freshwater ponds of the Doñana National Park (SW Spain) representing three hydroperiod categories most taxa were widely distributed, however, some species were restricted to only one hydroperiod (Serrano and Fahd, 2005). Therefore, it is very important to recognise the richness pattern of zooplankton inhabiting small and shallow aquatic systems, along with environmental drivers influencing diversity and species distribution, so as to provide information necessary for conservation purposes and management.

As the examined water bodies were under pressure of two very strong ecological forces we hypothesized that ponds of similar origin, situated within the same area and of similar catchment conditions greatly contribute to the increase in local biodiversity owing to two very important processes: level of predation (FP) referring to variation in fish levels and different water regime (WR).

The specific purpose of the study was to detect patterns in zooplankton diversity and structure of particular species and to relate these patterns to various hydroperiods WR (the ponds were assigned to two WR categories: temporary and permanent ponds) and varying levels of fish stock FP (the ponds were assigned to three FP categories: fish-free ponds; ponds with low fish stocking; ponds with high fish stocking) in six neighbouring ponds situated in the same type of catchment area. In order to distinguish species typical for ponds with various FP and WR we used data from intensive seasonal monitoring of natural agricultural ponds.

We also decided to verify the strength of both structuring forces (FP and WR) on zooplankton diversity and the occurrence of specific species.

Because the location of small water bodies in the agricultural landscape is often connected with anthropogenic eutrophication (Serrano et al., 2017) we assumed that species that are indicators of high trophic conditions will have the highest frequency in our ponds situated within the field landscape.

2. Material and methods

2.1. Study site

Six water bodies, located within the pastoral catchment area of the Gniezno Lake District (Żnin District, Kujawsko-Pomorskie), were examined for zooplankton and environmental parameters. Each pond was monitored thirteen times in 2009, covering the three seasons: spring, summer and autumn. The research material was collected in periods with presence of water (Table 1).

2.2. Characteristics of studied water bodies

Characteristics of location, morphological features of ponds and dates of sample collection are presented in Table 1. The ponds are located on a moraine plateau composed of poorly permeable clays. For this reason their water regime is determined mainly by the atmospheric exchange of water, i.e. by precipitation. They are not connected with the river network. Three of them P2, P3 and P4 had greater direct catchments compared to small water bodies P1, P5 and P6.

Two ponds were entirely free of fish, while in four ponds various fish stocking levels were observed throughout the study period. Apart from grass carp, which consumes aquatic plants (Krupska et al., 2012), the ponds were inhabited by planktivorous tench, and omnivorous common carp and crucial carp (Tonn et al., 1994; Adámek et al., 2003). During the study period (between sampling dates 3 and 4; Table 1) one of the ponds (P1) was additionally stocked by new fish species (F1, F2, F4; Table 1). Management of ponds was the responsibility of private owners, hence the changes in the quantity and quality of stocking in pond P1 occurred during the study period.

As macrophytes are known to modify habitat conditions (Takamura et al., 2003; Špoljar et al., 2012) and very strongly affect zooplankton occurrence (Kuczyńska-Kippen, 2001b; Habdija et al., 2002; Basińska et al., 2010) we only took into consideration the open water zones. However, particular ponds had different macrophyte cover. In four ponds phytocoenoses of helophytes (*Typha latifolia*, *Sparganium erectum*, *Iris pseudacorus, Juncus effusus*) were present, in four nymphaeids (*Persicaria amphibia*, *Potamogeton natans*) and in two ponds elodeids (*Ceratophyllum submersum*) and pleustophytes (*Lemna minor*, *L. trisulca*) (Table 1).

Moreover, as literature describes the strong impact of type of