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ORIGINAL RESEARCH ARTICLE

Effect of physicochemical parameters on zooplankton in the brackish, coastal Vistula Lagoon

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Summary This paper analyzes whether physicochemical properties significantly influence the occurrence of zooplankton in a brackish reservoir. The studies were carried out on the Vistula Lagoon in August and September from 2006 to 2009 at 32 research sites. The environmental conditions in the Vistula Lagoon varied widely. At the time of the investigation, 17 species of rotifers, six species of Cladocera, and ten species of Copepoda were noted, and the total density of plankton fauna ranged from 145 to 765 ind. dm^{-3}. Statistical analysis demonstrated a significant correlation between the occurrence of some zooplankton species and certain environmental parameters, whereas the sampling sites were grouped according to study years. The zooplankton systems recorded at the research sites in 2006 constitute the most disparate group. Thus, it can be concluded that physicochemical properties might significantly impact both individual species (depending on their environmental demands) and entire zooplankton clusters.

1. Introduction

The instability of environmental conditions is a typical feature of brackish waters such as estuaries or lagoons (Cognetti and Maltagliati, 2000). Changes in abiotic factors are reflected in the biochemical activity of both vertebrates and invertebrates. These factors determine the rate of metabolic transformations, the efficacy of immune systems, and reaction patterns of bodies to stressors (Kinne, 1964; Roddie et al., 1984).

Studies to date of the Vistula Lagoon have focused on the physicochemical characters of the water (Nawrocka and Kobos, 2011; Paturej and Kruk, 2011; Witek et al., 2010), the biota composition of the pelagic zone (Dmitrieva and

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Semenova, 2012; Psuty and Wilkońska, 2009), or the bottom area of the lagoon (Rychter et al., 2011; Warzocha et al., 2016).

Zooplankton is one of the most important biotic elements that impact all functional aspects of aqueous ecosystems including food chains and trophic networks, energy flow, and the circulation of matter. They occupy a central position in pelagic zone food webs (Lampert, 1997). The occurrence and distribution of plankton fauna depend on a number of factors such as climate change, habitat physicochemical properties, and biotic factors (Ahmad et al., 2011; Alexander, 2012; Cottenie et al., 2001; Rajagopal et al., 2010; Richardson, 2008). Environmental factors are also important elements; for instance, water temperature impacts the growth and development of organisms and can influence their mortality (Hall and Burns, 2001). Different species show varied tolerances to increases or reductions in temperature ranges, and particularly sensitive individuals are eliminated by them (Andrulewicz et al., 2008; Tunowski, 2009). In addition, salinity has a significant impact on organisms, because it requires them to adjust the saline concentrations in their bodies to the surrounding environment. Changes in salinity are the direct cause of some species disappearing and others occurring (Ojaveer et al., 2010). Environmental factors can also prompt organisms to migrate in order to avoid unfavorable environmental conditions, i.e., excessively high or low salinity. Variations in salinity can also contribute indirectly to food shortages and, consequently, they impact zooplankton abundance (Perumal et al., 2009). Water pH can also have an impact on zooplankton; low pH causes reduced zooplankton abundance, as well as decreased biodiversity and the loss of some species (Dehui, 1995; Ivanova and Kazantseva, 2006; Yamada and Ikeda, 1999), whereas alkaline conditions that accompany high primary production favors the growth and abundance of zooplankton (Bednarz et al., 2002; Mustapha, 2009). The availability of light determines the distribution of producers, and this indirectly impacts the diversity and distribution of animals. It also influences the vertical migration of plankton that require a specific intensity of light for many physiological processes. Light also exerts an indirect impact on other physical factors such as temperature and water color (Andrulewicz et al., 2008). Oxygen dissolved in water, which is required for the survival of all aquatic organisms, is another important abiotic factor. Oxygen deficiencies can directly influence organism mortality. In addition, indirect influences are observed through predator—prey interactions since hypoxia influences mobile species to change their horizontal or vertical distribution (Decker et al., 2004). Many authors (Kudari and Kanadami, 2008; Paturej, 2005, 2006; Pinto-Coelho et al., 2005; Wang et al., 2007; Yildiz et al., 2007) claim that the trophic status of a reservoir, i.e., the availability of nutrients, significantly impacts the structure and abundance of zooplankton. When trophic conditions are modest, large, herbivorous forms (Calanoida copepods, large water fleas) dominate, while in fecund waters small detritivore forms and predatory organisms (Cyclopoida copepods, small water fleas, rotifers) occur abundantly (González et al., 2011).

The objective of the study was to determine whether physicochemical properties such as water temperature, salinity, pH, and water transparency, particulate matter, oxygen concentration, nutrient concentrations, and chlorophyll *a* significantly impacted zooplankton occurrence.

2. Material and methods

The study was conducted in the Polish part of the brackish Vistula Lagoon located in the southern part of the Baltic Sea. The lagoon is a broad, shallow reservoir with an average depth that does not exceed 2.6 m and a surface area of 328 km^2 (Chubarenko and Margoński, 2008). Salinity ranges from 0.5 to 6.0 PSU depending on the intensity of freshwater and brackish water inflows (Kruk et al., 2012). Samples were collected at the end of the summer season in August and September from 2006 to 2009 from 32 sampling sites (Fig. 1).

The zooplankton was collected either with a Ruttner sampler or a 10 dm^{-3} bucket at shallow, coastal sites. The biological material (30 dm^{-3}) was concentrated on an Apstein plankton mesh (with a 30 μm net size), fixed with Lugol solution, and preserved in 4% formalin. The zooplankton was examined microscopically and classified into one of three groups of planktonic animals: Rotifera, Cladocera, or Copepoda. The abundance of planktonic fauna was also determined. The zooplankton structure was estimated using the dominance and stability indicators proposed by Kasprzak and Niedbała (1981).

Measurements of physicochemical environmental factors were taken simultaneously with plankton sampling. Water transparency was determined with a Secchi disk and temperature, oxygen concentration, salinity, and pH were measured in situ with a HACH HQd Field Case oxygen probe (RUGGED) and a WTW Multi 350i probe. Particulate matter were determined with the direct weighing method (Hermanowicz et al., 1999). Chemical analyses were performed on unfiltered water samples to determine total phosphorus, orthophosphates, ammonium nitrogen, nitrate nitrogen, total nitrogen, and chlorophyll *a*. Pheophytin was determined in a laboratory as soon as possible after sampling. Ammonium nitrogen was determined spectrophotometrically with the indophenol method according to PN-C-04576-01:1976. Nitrate nitrogen (V) was measured colorimetrically with phenol disulphonic acid according to PN 73/C-04576/08-1973. The concentration of total nitrogen was determined as the sum of nitrate nitrogen and Kjeldahl's nitrogen measured with Kjeldahl's method (Golterman and Clymo, 1969). Total phosphorus and orthophosphates were determined with the

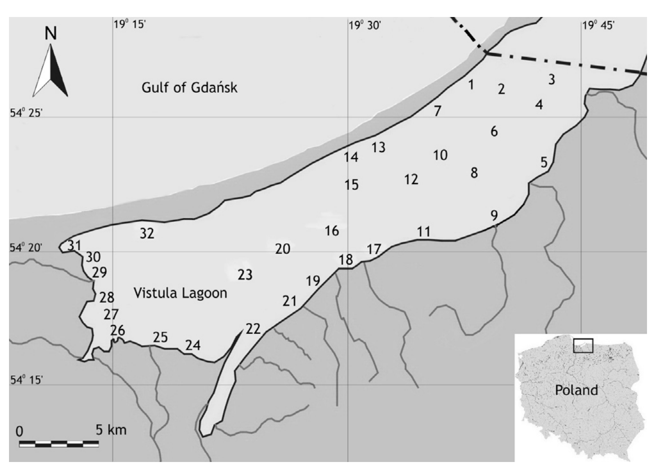

Figure 1 Location of the research sites on the Vistula Lagoon.