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IS SANDY BEACH OF THE LAKE AN ECOTONE? PSAMMON ROTIFERA IN A MESOTROPHIC LAKE KUC (MASURIAN LAKELAND, NORTHERN POLAND)

ABSTRACT: Is inshore, 2-cm layer of wet sand an ecotone? An attempt of this study is to answer the question by analysing characteristic patterns of a structure of rotifer communities inhabiting the psammolitoral zone. Psammon was sampled from sandy shore of a mesotrophic Lake Kuc (Masurian Lakeland, Poland), weekly from May to November 1996 and on one occasion in May 1998. Despite of extremely unfavourable conditions of their abiotic habitat, psammon rotifers of Lake Kuc were reaching occasionally extremely high densities. Seasonal dynamics of numbers and structure of psammon rotifer communities reflected variable character of their habitat. A course of the changes was similar in less variable higropsammon and extremely variable eupsammon. Patterns formed in psammolittoral – when illustrated with qualitative and quantitative features of psammon rotifer communities – fit definitions of an ecosystem, an ecotone, a part of a land/water ecotone, a microlayer in the ecosystem or a specific boundary zone in the lake ecosystem.

KEY WORDS: Psammon, Rotifera, lake, ecotone

1. INTRODUCTION

Classical ecology is based on a division of the biosphere to ecosystems build of biocoenoses and their abiotic environments. Transitory zone between biocoenoses of different types has been called an ecotone. Convention on Biodiversity signed at UNO Congress in Rio de Janeiro has rised the problem of diversity on various spatial scales, from landscapes to microsites. A quest for sites of special protective function became one of the results of the "biodiversity approach". Since that time much more attention have been paid to ecotones, i.e. boundary zones especially rich in species due to "contact effect". Since that time poorly hitherto known water and water-land ecotones have been studied more in details. And immediately the controversy has appeared around a question which aquatic sites are ecotones, and which are layers or "patches" inside the ecosystems. Whereas a littoral zone commonly defined as an ecotone between water and land ecosystems (de Haan *et al.* 1993, Kłosowski 1993, Raspopov *et al.* 1996 and many others), smaller parts of ecosystems are not given this definition. Despite of clearly transitory character, specific patterns and, at the same time, undergoing strong influences of both water and air environments, aquatic surface microlayer is not considered as an ecotone (Sodergren 1993), but just a microlayer being a part of a lake ecosystem – a kind of "air-pathway" through ecotones. On the other hand, according to Sabater and Vila (1992), Williams (1993), Brunke and Gonser (1997), Valett *et al.* (1997) hyporheic zone in streams fits the definition of an ecotone.

What is then this near-shore 2-cm deep layer of wet sand? An aim of this paper is to answer this question via analysis of characteristic patterns of a structure of rotifer communities inhabiting the zone.

In the opinion of Wiszniewski (1934) "a development centre of zoopsammon is a higropsammon zone, which in no case can be considered as a transitory step between water life, and life in further parts of beaches; the zone is peculiar in every respect". Wiszniewski (1934) distinguishes three zones in psammon, i.e.: hydro-, higro- and eupsammon. Hydropsammon inhabits the constantly submerged zone. Higropsammon inhabits a spray zone periodically washed with waves. Eupsammon lives in emerged zone – the zone with constantly desiccated surface microlayer and a moist deeper one.

2. MATERIAL AND METHODS

Psammon was sampled from sandy shore of a mesotrophic Lake Kuc (99 ha, max. depth = 28m; mean epilimnetic TP = 15 $\mu g\ l^{-1}$) situated in Masurian Landscape Park, Northern Poland), weekly from May to November 1996 and on one occasion in May 1998.

Sand samples were cut out by means of a sharp-edged cylinder with the opening size of 28 cm^2 and thickness of 2 cm. The samples were then transferred to glass containers and 6 times rinsed with clean water, which after sedimentation of sand grains (it takes *ca.* 10 seconds) was filtered through a plankton net of a mesh-size of 30 µm. Samples were taken in three replicates. The first subsample was analysed alive, next after fixing them with formalin. In most cases rotifer density was calculated per 100 cm^2.

Epilimnetic zooplankton was collected with a 5-liter sampler. The samples were condensed by filtering them through a 30-µm mesh net, and fixed immediately with Lugol's solution, and then (in a laboratory) with formalin.

The Shannon-Weaver, species-diversity index (Margalef 1957) was used:

$$D = \Sigma\text{–}{}^{n}i/N \log_2 {}^{n}i/N \qquad (1)$$

where: N = total numbers of rotifers; n_i = numbers of a species i.

3. RESULTS

Sandy beach habitats seem to provide rather unfavourable conditions for life. High daily fluctuations of temperature, high physical instability, small living space, low concentrations of oxygen and high – of chemical compounds – these are factors determining life of organisms in this habitat (Wiszniewski 1934). However, comparison of the numbers of rotifers inhabiting this zone (expressed in the same density units, i.e. per 1 litre of wet sand) with the numbers of them in communities found at the same time in epilimnion, which seems to be more favourable contradicts the above statement (Fig. 1). Densities of higro- and eupsammon rotifers are often two or even three orders of magnitude higher than that in pelagic communities.

A transect through the boundary "water/land" zone in Lake Kuc (Fig. 2) showed that – similarly to the results of Wiszniewski's (1934) studies, hydropsammon rotifers were markedly less abundant than rotifers inhabiting sand washed with waves. Species structure of hydropsammon rotifer communities was different than the structure in higro- and eupsammon communities as well. The hydropsammon community showed also higher species diversity. Species diversity index was 3.82 at the station 1 and it was decreasing towards the shoreline (st. 2 – 2.70, st. 3 – 2.72; st. 4 – 2.51). The community was dominated by species of the genera *Lecane* [*L. flexilis* (Gosse), *L. lunaris* (Ehrenberg), *L. psammophila* (Wiszniewski)], *Lepadella patella* (Müller), and species of the genera *Trichocerca* [*T. weberi* (Jennings), *T. myersi* (Hauer)]. The communities of higro- and eupsammon showed

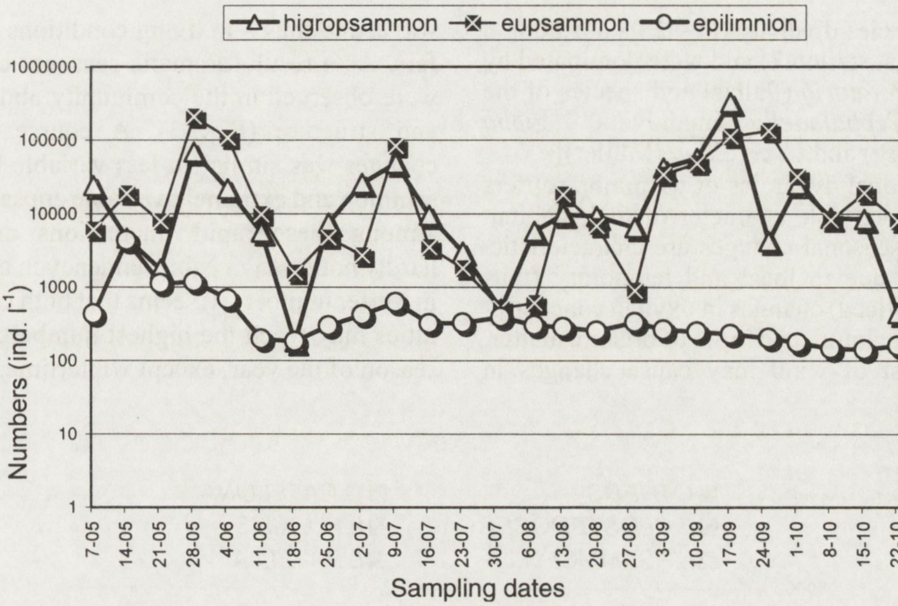

Fig. 1. Seasonal dynamics of numbers (ind. l^{-1} of water or wet sand) of epilimnetic and psammon communities of Rotifera in Lake Kuc in the year 1996.

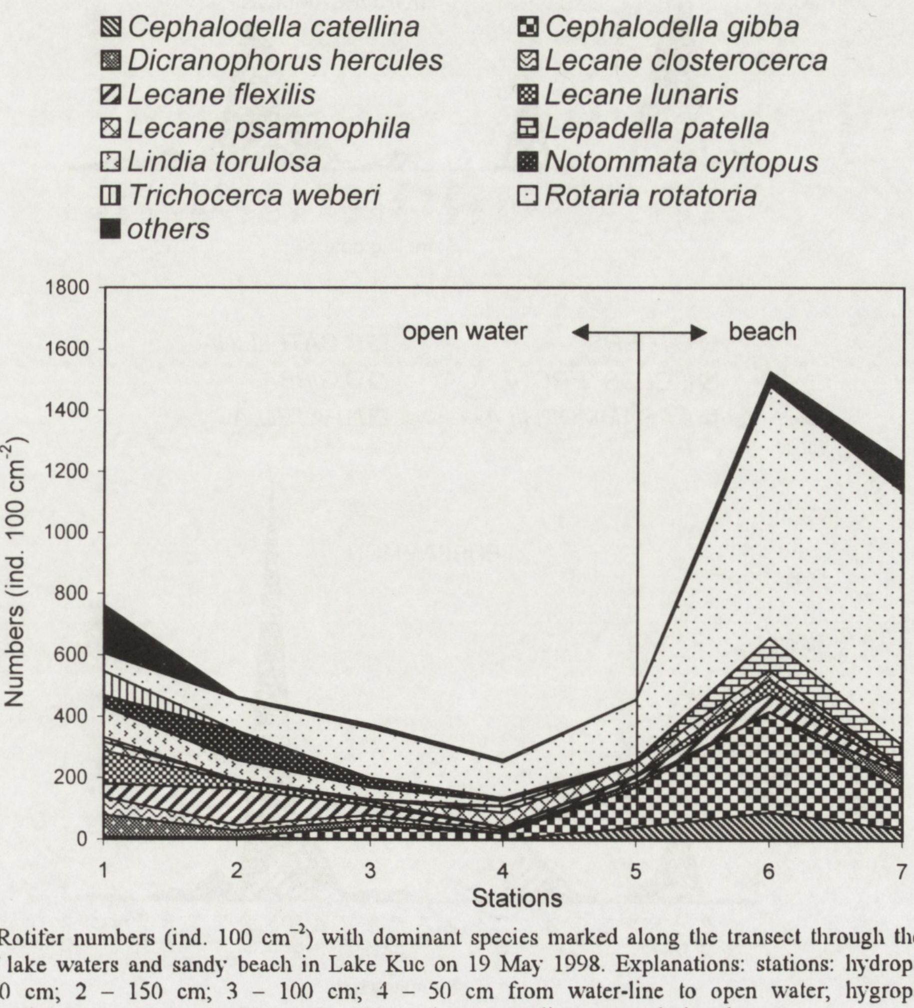

Fig. 2. Rotifer numbers (ind. 100 cm^{-2}) with dominant species marked along the transect through the contact zone of lake waters and sandy beach in Lake Kuc on 19 May 1998. Explanations: stations: hydropsammon: 1 – 200 cm; 2 – 150 cm; 3 – 100 cm; 4 – 50 cm from water-line to open water; hygropsammon: 5 – water-line; eupsammon: 6 – 50 cm; 7 – 100 cm from water-line, on sandy beach.

lower species diversity (D = 2.08 at station 6 and 1.80 at station 7) and were dominated by *Rotaria rotatoria* (Pallas) and species of the genus *Cephalodella* [mainly *C. gibba* (Ehrenberg) and *C. catellina* (Müller)].

Seasonal dynamics of psammon rotifers reflected variable character of their habitat. Distinct seasonal changes are characteristic, probably due to local and temporary (thus hardly noticed) changes in oxygen concentration, temperature and input of organic matter. Each gust of wind may cause changes in wave, and thus – in living conditions of rotifers. As a result, dramatic seasonal changes were observed in the community abundance and structure (Fig. 3). A course of the changes was similar in less variable higropsammon and extremely variable eupsammon. Among these rapid fluctuations one can hardly notice any visible tendency in changes in rotifer numbers. It seems that both communities may reach the highest numbers at any season of the year, except wintertime.

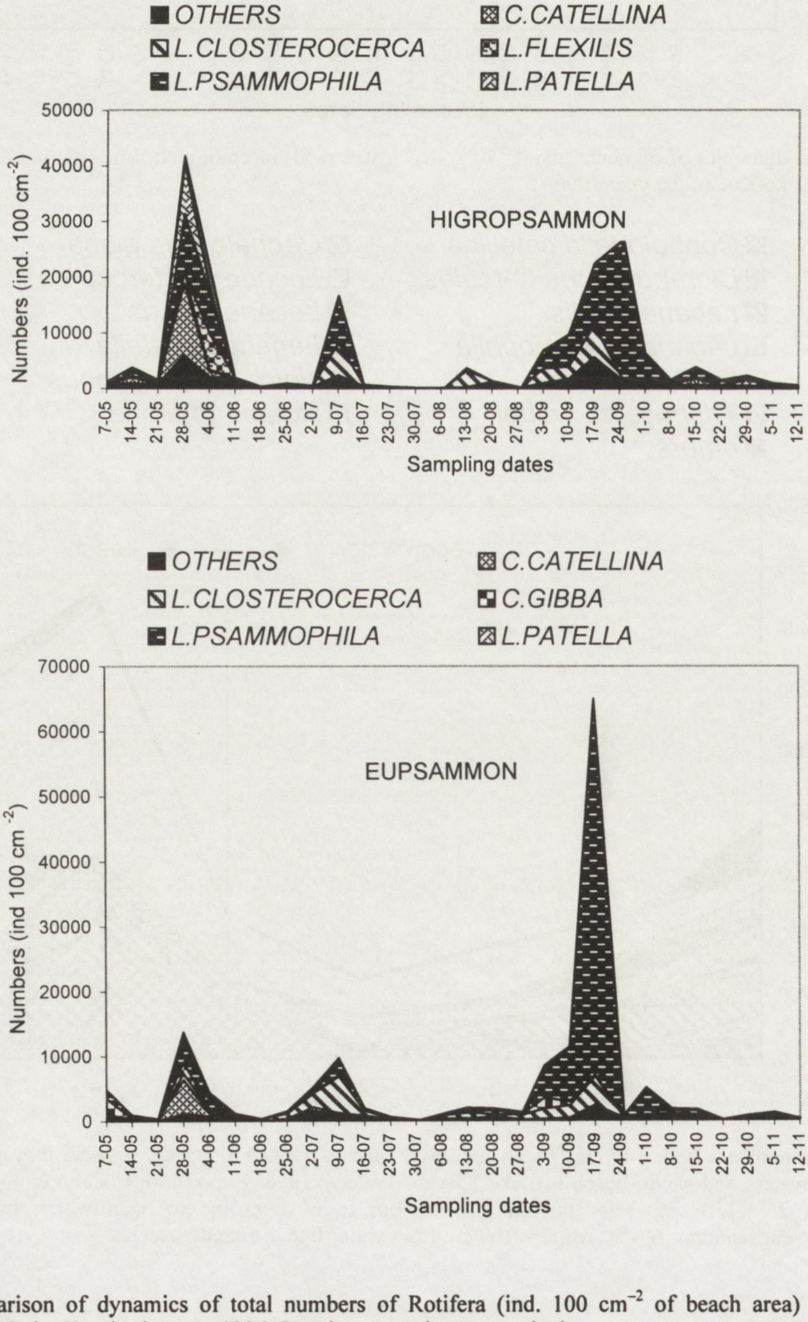

Fig. 3. Comparison of dynamics of total numbers of Rotifera (ind. 100 cm^{-2} of beach area) in higro- and eupsammon in Lake Kuc in the year 1996. Dominant species are marked

4. DISCUSSION AND CONCLUSIONS

Extremely high densities of psammon rotifer communities and, at the same time, relatively high their species diversity are phenomena difficult to explain, taking into account that the environment is permanently stressed by rapidly changing physical and chemical factors (Wiszniewski 1933, 1934). If wet sandy beach is an ecotone, then the phenomenon may be a "contact effect". However, this effect is a result of co-occurrence of species originating from neighbouring ecosystems and species typical for the ecotone. Such penetration of the sandy beach zone by littoral and pelagic species has not been observed. Perhaps that high species diversity with high abundance of psammon rotifers is a "stress effect". According to Connell's (1978) hypothesis of disturbances: environments moderately stressed – in contradiction to ones being under low or high stress – reach the highest diversities (Fabiszewski 1995).

A course of changes in species diversity along the trasect (Fig. 2) seems to confirm the above suggestion. The highest values of diversity were found in hydropsammon, thus an environment being under rather moderate stress in contradiction to extremely variable abiotic habitat of eupsammon. The latter community though very abundant was characterised by twice-lower species diversity index than hydropsammon. Environmental offer in psammolittoral zone is most certainly qualitatively poor as both habitat and food resources (detritus and bacteria) are little differentiated. It is however – at least periodically – quantitatively reach (Wiszniewski 1934). It can explain the extremely high abundance of psammon rotifers.

The above conclusion and Connell's (1978) hypothesis of disturbances may explain why eupsammon communities of rotifers are characterised by high densities and high species diversities at the same time.

Looking for an appropriate "address" of psammon rotifer communities one can consider at least five cases:

1. Psammolittoral is an ecosystem. Arguments: rotifer community is abundant and diversified. It consists of numerous species characteristic for the zone. A penetration of this environment by pelagic or littoral rotifers has not been observed, and there is not any evidence for such the penetration of water masses by psammon rotifers. Organisms beyond the zone are not incorporated into a complicated net of trophic interrelations. The net is build by autochtonous organisms as the zone is characterised by high primary production (Czernaś *et al.* 1991) and psammon rotifer community consists of algivores (e.g. species of the genera *Wierzejskiella*) and bacterivores (*Lepadella, Lecane)* as well as predators (*Dicranophorus*).

2. Psammolittoral is an ecotone. Arguments: the community is similar to communities inhabiting hyporheic-interstitial zone in rivers, which is commonly defined as an ecotone. Psammon communities of Rotifera, though specific for this habitat are dependent in their functioning on permanent input of organic matter from neighbouring ecosystems.

3. Psammolittoral is a part of "water-land" ecotone, i.e. of littoral – wetland zones. Arguments: the ecotone consists of lake macrophytes and their substratum. Communities like hydropsammon and eupsammon inhabit thin top layer of the panel fragment of this substratum. Wet sand of beach is then a fragment of a deep layer of an ecotone.

4. Psammolittoral is a layer in ecosystem and psammon is a stratocoenosis. Arguments: psammon consists of recurrent and highly specific set of rotifer species. This system is however remarkably dependent on other biocenotic systems (e.g. renewing food resources).

5. Psammolittoral is something specific – boundary (not transitory) zone similar to aquatic surface microlayer. Arguments: this thin layer is open to external influences. It is strongly dependent on lake ecosystem which derives to the zone both water and organic matter.

It seems that patterns of psammolittoral – when illustrated with qualitative and quantitative features of psammon rotifer communities – fit definitions of all above described systems. Thus the answer for the question asked at the beginning of the paper could be found as a result of precise statement of ecological terminology rather then continued studies of psammolittoral structure.

5. SUMMARY

Is inshore, 2-cm layer of wet sand an ecotone? An attempt of this study is to answer the question by

analysing characteristic patterns of a structure of rotifer communities inhabiting the psammolittoral zone.

Psammon was sampled from sandy shore of a mesotrophic Lake Kuc, weekly from May to November 1997 and on one occasion in May 1998.

Despite of extremely unfavourable conditions of their abiotic habitat, psammon rotifers of Lake Kuc were reaching occasionally extremely high densities. When expressed in the same units they were 23 orders of magnitude higher than those noted at the same time in pelagic waters (Fig. 1). Hydropsammon rotifer community was markedly less abundant and differed in species structure from the community inhabiting capillary water between sand grains (higro- and eupsammon) (Fig. 2). The hydropsammon community showed higher species diversity and was dominated by species of the genera *Lecane, Lepadella* and *Trichocerca*. The communities of higro- and eupsammon showed lower species diversity and were dominated by *Rotaria rotatoria* and species of the genus *Cephalodella*.

Seasonal dynamics of numbers of psammon rotifers reflected variable character of their habitat (Fig. 3). Dramatic seasonal changes were observed in the community abundance and structure. A course of the changes was similar in less variable higropsammon and extremely variable eupsammon.

Patterns of psammolittoral – when illustrated with qualitative and quantitative features of psammon rotifer communities – fit definitions of an ecosystem, an ecotone, a part of a land/water ecotone, a microlayer in the ecosystem or a specific boundary zone in the lake ecosystem. Thus the answer for the question asked at the beginning of the paper could be found as a result of precise statement of ecological terminology rather then continued studies of psammolittoral structure.

6. REFERENCES

Brunke M., Gonser T. 1997 – The ecological significance of exchange processes between rivers and groundwater – Freshwat. Biol. 37: 1–33.

Connell J. H. 1978 – Diversity in tropical rain forest and coral reefs – Science 199: 1302–1310.

Czernaś K., Krupa D., Wojciechowski I., Galek J. 1991 – Differentiation and activity changes of algal communities in the shore zone of mesotrophic Piaseczno Lake in years 1983–1985 – Ekol. pol. 39: 323–341.

De Haan H., Boschker H. Y. S., Buis K., Cappenberg T. E. 1993 – Functioning of land-water ecotones in relation to nutrient cycling – Hydrobiologia 251: 27–32.

Fabiszewski J. 1995 – Różnorodność gatunkowa w świecie roślin [Species diversity in the world of plants] – (In: Problemy różnorodności biologicznej [Problems of biodiversity], Eds: R. Andrzejewski, R.J. Wiśniewski) – Kom. Nauk. "Człowiek i Środowisko" PAN – Oficyna Wydawnicza IE PAN: 29–36. (in Polish)

Kłosowski S. 1993 – The shore vegetation in selected lakeland areas in northern Poland – Hydrobiologia 251: 227–237.

Margalef R. 1957 – Information theory in ecology – Gen. Sys. 3: 36–71.

Raspopov I. M., Andronikova I. N., Dotsenko O. N., Kurashov E. A., Letanskaya G. I., Panov V. E., Rychkova M. A., Telesh I. V., Tchernykh O. A., Vorontsov F. F. 1996 – Littoral zone of Lake Ładoga: Ecological state evaluation – Hydrobiologia 322: 39–47.

Sabater F., Vila P. B. 1992 – The hyporheic zone considered as an ecotone (In: Homage to Ramon Margalef; or Why there is such pleasure in studying nature, Ros J., Orat N. Eds.) – Barcelona, Spain, Univ. De Barcelona 10: 35–43.

Sodergren A. 1993 – Role of aquatic surface microlayer in the dynamics of nutrients and organic compounds in lakes, with implications for their ecotones – Hydrobiologia 251: 217–225.

Valett H. M., Dahm C. N., Campana M. E., Morrice J. A., Baker M. A., Fellows C. S. 1997 – Hydrologic influences on groundwater-surface water ecotones: Heterogeneity in nutrient composition and retention – J.N. Am. Benthol. Soc. 16: 239–247.

Williams D. D. 1993 – Nutrient and flow vector dynamics at the hyporheic/groundwater interface and their effects on the interstitial fauna – Hydrobiologia 251: 185–198.

Wiszniewski J. 1933 – O życiu w wilgotnych piaskach [On life in moist sands] – Wszechświat 1: 1–7. (in Polish)

Wiszniewski J. 1934 – Recherches ecologiques sur le psammon et specialement sur les Rotiferes psammiques – Arch. Hydrobiol. Ryb. 8: 149–165. (in French).

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