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Short communications

DIEL VARIABILITY IN THE OCCURRENCE OF JUVENILE FISH IN THE SHALLOW LITTORAL ZONE: DO MACROPHYTES IMPACT THE STRUCTURE OF FISH ASSEMBLAGES?

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ABSTRACT. The aim of the research was to determine the diel variability of fish assemblage occurrence in aquatic vegetation which varied in both species composition and structure in the shallow littoral zone of a lake heated by power plant discharge waters. The fish were caught at three study sites of different habitats: dense, single-species aggregations of the macrophytes *Nuphar lutea* (L.) Sibth. & Sm. (NUL) and *Vallisneria spiralis* L. (VAS) as well as from fragments of the littoral zone overgrown with layers of *V. spiralis* (PVS). Eleven fish species representing five families were caught. The richest species composition was noted at the PVS site, although fish density was similar in all of the habitats. Two clear periods of fish activity occurred at all the study sites within the diel cycle.

Key words: JUVENILE FISH, MACROPHYTES, DIEL VARIATION, LITTORAL, HEATED LAKES

Due to its high water temperature and oxygen concentration, the shore zone provides highly advantageous conditions for the development of the eggs and juvenile stages of many fish species (Petr 2000). Littoral fish assemblages exhibit temporal and spatial variation in density and occurrence that depend on, among other factors, the presence and species composition of macrophytes (Weaver et al. 1997, Xie et al. 2001). Interdependencies among the coverage and species composition of macrophytes and the temporal and spatial density and occurrence of fish have been the focus of the efforts of many researchers (Keast 1984, Hosn and Downing 1994, Kapusta 2004, Lewin et al. 2004, Fitzgerald et al. 2006). However, the relationship between diel variation in fish occurrence in the littoral zone and the species composition and the abundance of macrophytes has not yet been investigated sufficiently.

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The aim of the present study was to determine the diel variation in fish occurrence in macrophyte aggregations that varied in species composition and structure in the shallow littoral zone of a lake heated by post-cooling waters discharged from an electric power plant.

Juvenile fish were caught using an experimental double-winged fyke-net with a leading wall (mesh size 1mm) in 24-hour cycles in June and July from 2001 to 2003 in Lake Licheńskie (central Poland, 52°18'N, 18°20'E). The fish were removed from the gear at three hour intervals and then sorted by species in the laboratory. The fish were caught in dense, single-species macrophyte aggregations, which were regarded as separate habitats, of *Nuphar lutea* (L.) Sibth. & Sm. (NUL) and *Vallisneria spiralis* L. (VAS) and the fragmented littoral zone overgrown with layers of *V. spiralis* (PVS). These study stations were characterized by similar depths, distance from the shore, and bottom sediment type (Table 1). During fishing, the physicochemical parameters of the water were also determined (temperature, oxygen content, water pH) in the surface zone of the habitat (<10 cm) and at the bottom.

TABLE 1

Habitat characteristics at the study sites (VAS – dense, single-species aggregations of *Vallisneria spiralis*; PVS – layered, single-species aggregations of *V. spiralis*; NUL – dense, single-species aggregations of *Nuphar lutea*)

	VAS (N = 32)	PVS (N = 16)	NUL (N = 16)	P
Aquatic vegetation type (%)				< 0.001
None	0	50	10	
Vallisneria spiralis	100	50	0	
Nuphar lutea	0	0	90	
Sediment type	sand, mud	sand	sand, mud	
Min. distance from bank (m)	5	3.5	3.5	
Mean depth (cm)*	50±23.9	45±21.8	50±25.2	ns
Temperature (°C)*	27.9±2.1	27.5±1.7	27.5±2.0	ns
Oxygen (mg O_2 dm^{-3})*	11.9±5.0	9.8±3.0	12.1±4.6	ns
pH*	8.34±0.37	8.31±0.41	8.43±0.36	ns

Variables represents categories (difference (P) compared with the Chi^2 test)
** – measurements are means ± SD (difference (P) compared with the Kruskal-Wallis test); ns – not significant differnces (P > 0.05).*

The fish species richness and density in the various habitats was analyzed with nonparametric variance analysis (ANOVA Kruskal-Wallis). Determining the goodness

of fit of the distribution of the variables (species richness, abundance, biomass) at the study sites over the diel cycle was done with the Chi^2 test after the data had been standardized. The comparison of the distribution of variables characteristic of the studied sites was performed with the Chi^2 test, while the differences between the mean values of the water physicochemical parameters were tested with Kruskal-Wallis ANOVA. The standardization of the data was based on transforming the original values so that the variables had a mean distribution of 0 and a standard deviation of 1. Thanks to this it was possible to compare the distribution of independent variables with the measurement units of the individual variables. The relation between the physicochemical parameters of the water and the diel variation of the fish species richness and density for each of the habitats was determined with multiple regression analysis. The analysis of remainders was applied to verify the statistically significant models.

A total of 896 fish specimens representing five families and 11 species were caught. Most of the fish were aged 1+ and 0+. The mean number of fish species caught in the various habitats varied significantly statistically (ANOVA Kruskal-Wallis, $H_{2.64}$ = 6.480, P = 0.039). The highest species richness was noted in the habitat of the PVS site. Throughout the entire study period 11 fish species were confirmed, among which bleak, *Alburnus alburnus* (L.), rudd, *Scardinius erythrophthalmus* (L.), and roach, *Rutilus rutilus* (L.) were the most abundant. In the dense, single-species macrophyte aggregations, however, lower ichthyofauna species richness was noted; there were eight fish species at the VAS study site while at the NUL site there were seven. In both instances the most commonly occurring species were rudd and roach. Heterogeneous littoral habitats provide advantageous conditions for the formation of varied fish assemblages, while littoral habitats comprised of one macrophyte species can limit the heterogeneity of the ichthyofauna (Valley et al. 2004). However, the spatial structure of submerged vegetation has a more substantial impact on the distribution and variation of juvenile fish assemblages than does the species richness of the macrophytes (Weaver et al. 1997). This hypothesis is confirmed by the results of studies conducted in the 1960s in Lake Licheńskie (Wilkońska and Żuromska 1978). These authors, who studied the diel variability of the occurrence of 0+ fish in habitats comprised of heterogeneous macrophytes, reported higher species richness and a different dominant species structure in comparison with the results of the current study.

The comparison of fish density in the littoral habitats under investigation did not confirm statistically significant differences between the mean number (ANOVA Kruskal-Wallis, $H_{2.64} = 1.280$, $P = 0.527$) and the biomass (ANOVA Kruskal-Wallis, $H_{2.64} = 2.805$, $P = 0.246$) of fish assemblages. Two distinct periods of fish activity were noted and were characterized by greater fish abundance and the higher biomass of the fish caught (Figs. 1 and 2). The first peak occurred in the morning hours from sunrise to 09:00. During the day there was a decline in the number of fish caught. Another increase, usually less pronounced than that of the morning, occurred in the evening hours with the maximum at 21:00, and in the case of the NUL site at midnight. The highest species richness noted in the fish assemblages was at this time of day; however, it was only possible to identify this peak at the PVS site (Fig. 3). The density distribution and species richness of the fish assemblages in all of the habitats was similar (Chi^2 test, $P > 0.05$). Changes in fish density in the littoral zone could have resulted from the varied effectiveness of the fishing gear deployed depending on light intensity or migration outside of the fishing grounds. Avoiding disadvantageous chemical, physical, and biological conditions and optimizing feeding are the main factors responsible for fish migration in the littoral zones of lakes (Gauthier and Boisclair 1997, Lewin et al. 2004). The heated waters that are discharged from the power plant into Lake Licheńskie disrupt its thermal regime (Zdanowski 1994). During the day the shallow littoral zone is further heated by solar radiation, which leads to increases of water temperature that exceed 32°C. This, in concert with considerable water oxygen saturation in the areas where there are dense aggregations of macrophytes (VAS, NUL), creates conditions that are not advantageous for fish. In consequence, some species avoid homogeneous fragments of the littoral macrophytes and most migrate during the day to zones with less dense macrophytes.

Regression analysis indicated repeatedly that a highly significant correlation between fish assemblage parameters and the physicochemical properties of the water and the time of day only occurred at the PVS study site. The number of species caught in one 24-hour period at the PVS site was very highly correlated with the time of day, the temperature of the surface water layer, and the oxygen contents at the bottom ($R^2 = 0.85$, $P < 0.0001$, $N = 16$). The abundance of fish at the PVS site increased as the surface water temperature decreased and the oxygen contents increased ($R^2 = 0.76$,

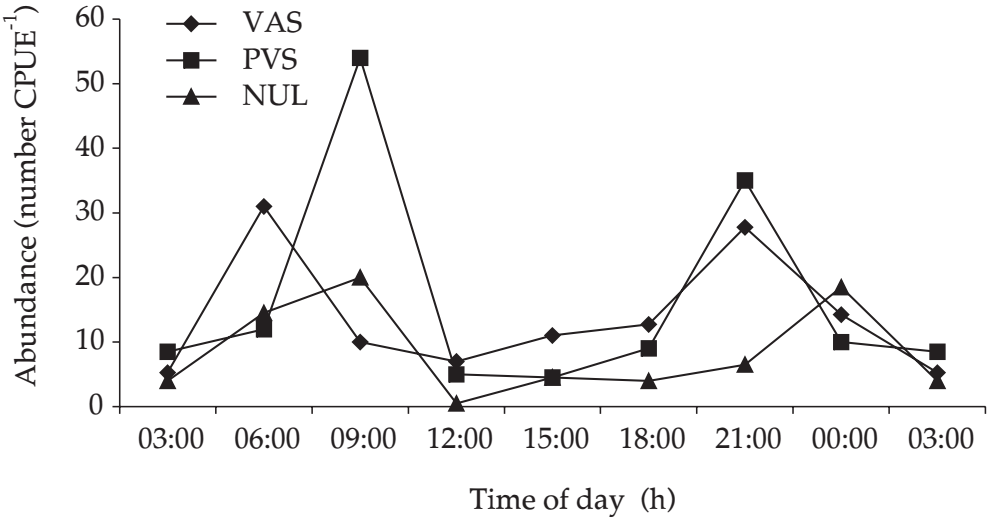

Fig. 1. Diel dynamics of variation in the mean abundance of fish (individual $CPUE^{-1}$) caught in a 24-hour period in the littoral zone of Lake Licheńskie (CPUE – number of fish caught during one experimental fyke-net retrieval; other notation as in Table 1).

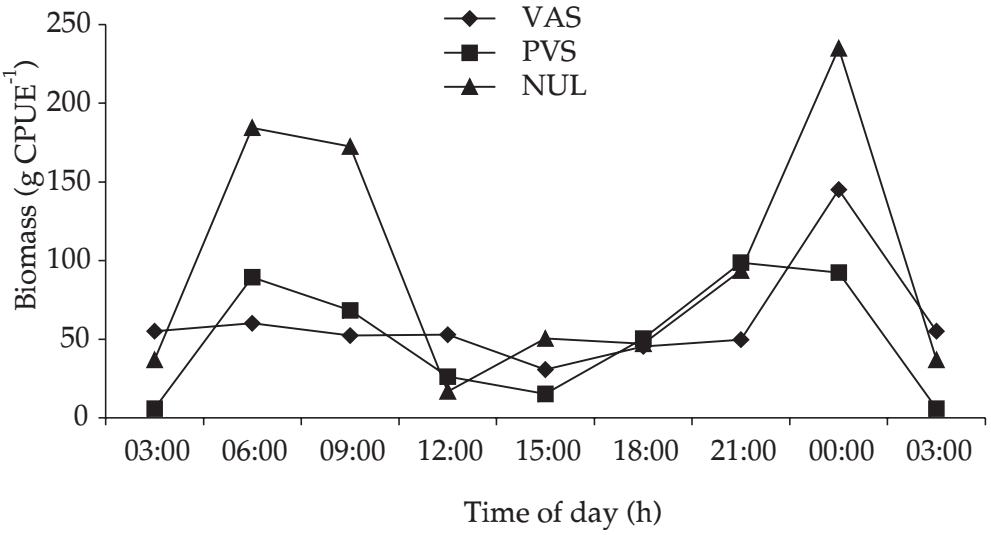

Fig. 2. Diel dynamics of the mean biomass of fish (g $CPUE^{-1}$) caught in a 24-hour period in the littoral zone of Lake Licheńskie (notation as in Table 1).

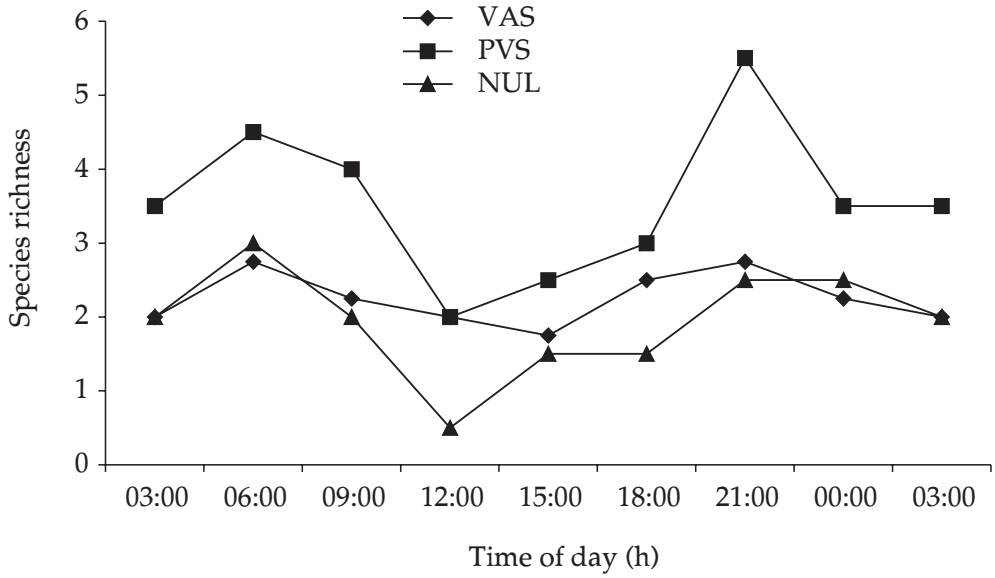

Fig. 3. Diel dynamics in the mean number of fish species caught in a 24-hour period in the littoral of Lake Licheńskie (notation as in Table 1).

$P < 0.0001$, $N = 16$). However, as the number of fish species occurring at the PVS site increased, so did their biomass ($R^2 = 0.72$, $P < 0.0001$, $N = 16$).

The spatial differentiation of the littoral zone structure has an impact on the species richness and composition of juvenile fish assemblages. Homogeneous habitats are characterized by poorer ichthyofauna species composition. One of the effects of greater habitat variety is greater fish assemblage variety. However, in the case of Lake Licheńskie, the paucity of ichthyofauna species in the single-species macrophyte aggregations could also have resulted from disadvantageous physical and chemical conditions. The reaction of the fish to the high water temperature and the substantial oxygen oversaturation in the shallow littoral zone dominated by *V. spiralis* was to migrate during the day to areas where the density of this macrophyte was lower.

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STRESZCZENIE

DOBOWA ZMIENNOŚĆ WYSTĘPOWANIA RYB JUWENALNYCH W PŁYTKIM LITORALU: CZY MAKROFITY MAJĄ WPŁYW NA STRUKTURĘ ZESPOŁÓW RYB?

Celem pracy było określenie dobowej zmienności występowania ryb w zróżnicowanych gatunkowo i strukturalnie zespołach roślinności wodnej w płytkim litoralu podgrzewanego jeziora. Ryby łowiono w obrębie trzech zróżnicowanych siedlisk (tab. 1): zwartych jednogatunkowych zbiorowisk makrofitów *Nuphar lutea* (L.) Sibth. & Sm. (NUL) i *Vallisneria spiralis* L. (VAS) oraz w fragmentach litoralu płatowato

porośniętych przez *V. spiralis* (PVS). Złowiono 11 gatunków ryb należących do 5 rodzin. Największym bogactwem gatunkowym charakteryzowało się siedlisko PVS, natomiast zagęszczenie ryb we wszystkich siedliskach było podobne. Na wszystkich stanowiskach wystąpiły dwie wyraźne pory aktywności ryb, które objawiły się zwiększeniem ilości (rys. 1) i biomasy (rys. 2) łowionych ryb. Homogeniczne siedliska fitolitoralowe charakteryzowały się stałym bogactwem gatunkowym zespołów ryb w ciągu doby, natomiast zróżnicowane przestrzennie siedlisko PVS wyróżniało się wzrostem bogactwa gatunkowego w godzinach porannych i wieczorem (rys. 3).