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Seasonal and Spatial Variation in the Fish Assemblage in the Lowland Kośna River, Łyna River System, Poland

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Abstract: The aim of this study was to identify spatial and temporal changes in species structure and abundance of fish in a small river in northern Poland. Electrofishing was conducted at eight sites in the upper and middle sections of the Kośna River and its tributaries. A total of 2,619 fish belonging to five families and 17 species were caught. The most numerously represented were the sunbleak (*Leucaspius delineatus*), the gudgeon (*Gobio gobio*) and the bleak (*Alburnus alburnus*). Fish density fluctuated from 1.7 to 283 ind./100 m^2. A significant dependence was noted in the seasonal density structure of the fishes. The highest mean fish density was noted in spring and the lowest in summer. The fish species richness fluctuated from one to 12 at the sites and was similar in all months but differed among the main river and its tributaries. Species richness, total density and Shannon-Wiener index were higher at sites in the lower section of the Kośna River. The results of the study provide evidence on the significance of spatial distribution of appropriate habitats and the corresponding fish species.

Key words: fish distribution, species richness, biodiversity, functional organisation, habitat

Introduction

Understanding spatial and temporal patterns of biodiversity is one of the principal topics in ecology (Magurann 1988), including riverine fish ecology and conservation biology (Erős et al. 2008). River systems exhibit great spatial variety and identifying the scales on which riverine fishes replace one another is of key importance for understanding and forecasting how fish assemblages develop (Czeglédi et al. 2016). Diverse environmental conditions significantly impact the development of their structure. Seasonal hydrological changes influence distribution and quality of aquatic resources and biotic structure. Habitat availability is the primary contributing factor to the structure of fish assemblages in river ecosystems (Erős & Grossman 2005, Mueller & Pyron 2010). Environmental properties and structure are important factors determining riverine fish assemblages and fishes exhibit a variety of responses to changing morphological conditions (Smokorowski & Pratt 2007), availability of suitable habitats (Radinger &Wolter2015) and connections among them (Aadland 1993, Dębowski 2004). Fishes can rapidly minimise competitive interactions by dispersing, which suggests that even over short periods of time, mechanisms that shape fish assemblage structure can differ depending on the ontogenetic ability to disperse, seasonal migrations and habitat availability in particular years (Fitzgerald et al.

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2017). The structure of fish assemblages in temporal lowland rivers is also determined by fish life cycles. Some fish species undertake long migrations to spawning grounds and hydrology influences the dispersal of larval, juvenile (Bolland et al. 2015, Lechner et al. 2016) and adult stages (Radinger & Wolter 2014, Alexandre et al. 2016). Water flow fluctuations are not as pronounced in small rivers that flow through lakes and less is known about seasonal changes in fish assemblages there.

Lowland rivers in pristine conditions provide rich habitats for many fish species. Location, physiography of the terrain and biotic and abiotic factors determine the occurrence of fish species in natural environments (Smokorowski & Pratt 2007). Anthropogenic activities have a range of impacts on fish habitat conditions, often resulting in the gradual disappearance of fish species with specific requirements or declines in their population numbers, which has been observed in the north-eastern Poland in recent years (Terlecki et al. 2004, Kapusta et al. 2012). Anthropogenic geomorphological and hydrological changes are known to impact the structure and dynamics of fish inhabiting rivers (Cowx & Welcomme 1998, Marzin et al. 2013).

The aim of the study was to identify seasonal and temporal changes in species structure and density of fish in a lowland river flowing in the Lakeland region.

Materials and Methods

Study area

The Kośna is a fourth order river, a tributary of the Pisa Warmińska River (Pregoła River basin, Baltic Sea drainage basin). Its length, including the lakes through which it flows, is 47 km. The surface area of its drainage basin is 420.2 km^2, and the mean annual flow is 2.94 m^3 s^{-1}. Its largest tributaries are streams that flow from Lakes Małszewskie and Purdy. The study was conducted at eight locations in the upper and middle stretches of the river and its largest tributaries (Fig. 1, Table 1). Four stations were in the upper section of the river (S1-S4), while the second four were in the lower stretch of the river (S5-S8). Some amelioration works were carried out as the 1970 in the upper part of the river (S1-S4). The lower section of the river meandered through forests and meadows.

Fish sampling

Fish were caught from May to October 2014, using the single-pass fishing method with an Electra catch WFC7 generator (1 kW, 230-300 V, 2-5 A, 50-100 Hz; Electracatch International, Ireland). The stations were selected so that they represented characteristic sections of the stream. . All individuals were identified to species level and counted in the field to determine fish species structure and density (ind. 100 m^{-2}). Morphometric descriptions were done in the field at each sampling station and basic physicochemical water parameters were also measured (conductivity, oxygen saturation, water temperature). Observations in the field provided information on the distribution and proportion of substrates, allowing us to quantify the spatial heterogeneity of sampling sites. At each site the proportion of sand, gravel, rocks and others cover projected horizontally was visually estimated after fish collection (Simonson et al. 1994). The occurrence of silt was assessed separately.

Data analysis

The fish assemblage structure at each station in different months was characterised based on biocenotic domination, constancy and Shannon-Wiener indices. All of the fish species confirmed were sorted by reproductive guild (Balon 1975) and characterised according to habitat preferences (Schiemer & Waidbacher 1992, Aarts & Nienhuis 2003).

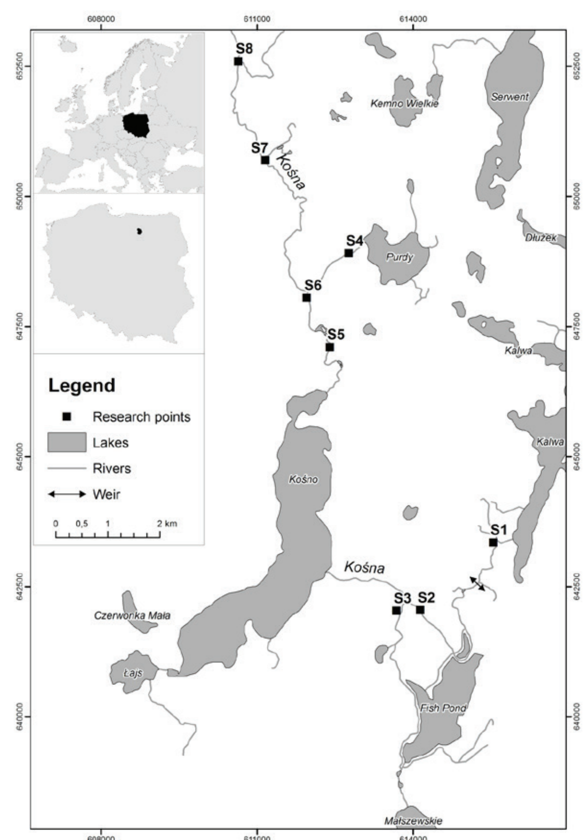

Fig. 1. Location of the study area in the Kośna River. Squares indicate sampling sites located on the surveyed streams.

Seasonal variance in physicochemical water parameters, riverbed morphometry and fish assemblages were analysed with non-parametric ANOVA (the Kruskal-Wallis test). Spatial variance of fish assemblages was determined through analyzing data from stations located upstream from Lake Kośno (S1-S4) and in the lower section of the Kośna River (S5-S8). These two groups of stations were compared with the Mann-Whitney U test. Principal Component Analysis (PCA) was used to determine dependencies among variables that characterise fish assemblages and environmental parameters. Cattell's scree test was used to determine the number of significant factors that explain the percentage of overall variance. Hierarchical cluster analysis with the agglomerative Unweighted Pair Group = with Arithmetic Mean (UPGMA) method based on the Bray-Curtis dissimilarity measure was applied to compare the fish assemblages structure at each station; this analysis was performed using the MultiVariate Statistical

Table 1. Characteristics of the sampling stations in the Kośna River.

Station	S1	S2	S3	S4	S5	S6	S7	S8
Altitude (m)	136.8	123.8	124.1	123.0	122.0	121.4	119.9	119.8
Station length (m)	150	150	120	120	200	150	500	750
Mean width (m)	3	2.5	3	2	15	15	10	20
Mean depth (m)	0.4	0.4	0.7	0.4	0.5	0.4	0.8	0.5
Sand (%)	75	60	90	95	75	80	90	100
Gravel (%)	10	25	10	0	15	20	10	0
Rocks (%)	5	10	0	0	10	0	0	0
Other (%)	10	5	0	5	0	0	0	0
Silt (%)	5	0	95	65	20	20	40	95
Emergent vegetation (%)	10	100	100	100	100	100	100	100
Hiding places[1]	G,K	K	ZR	G,K	K,ZD	K,ZD	K,G,ZD,ZR	ZR,ZD
Shade(%)	90	40	5	70	60	20	20	30
Riverbed type[2]	NM	RM	R	R	NM	NM	NM	N

[1] Hiding places: G – branches, K – roots, ZD – fallen trees, ZR – overhanging vegetation;
[2] Riverbed type: N – natural, NM – natural meandering, R – regulated, RM – regulated meandering.

Table 2. List of fish species confirmed in the Kośna River. Habitat preferences: R – rheophils, Eu – eurytopic fish, L – limnophils. Reproductive guilds: Ff – phytophils, Fl – phytolithophils, Ps – psammophils, Ar – ariadnophils, Os – ostracophils, Lf – lithophils.

Family/Species	Habitat preferences	Reproductive guilds	Domination (%)	Frequency of occurrence (%)
Cyprindae				
Leucaspius delineatus	Eu	Ff	35.0	21.7
Gobio gobio	R	Ps	13.3	65.2
Alburnus alburnus	Eu	Fl	11.1	30.4
Rutilus rutilus	Eu	Fl	9.7	73.9
Blicca bjoerkna	Eu	Fl	6.1	43.5
Rhodeus amarus	Eu	Os	4.3	43.5
Tinca tinca	L	Ff	0.8	56.5
Scardinius erythrophthalmus	L	Ff	0.8	34.8
Leuciscus cephalus	R	Lf	0.6	26.1
Abramis brama	Eu	Fl	0.1	4.3
Leuciscus idus	R	Fl	>0.1	4.3
Percidae				
Perca fluviatilis	Eu	Fl	1.8	56.5
Esocidae				
Esox lucius	Eu	Ff	2.6	69.6
Cobitidae				
Cobitis taenia	Eu	Ff	6.5	73.9
Misgurnus fossilis	L	Ff	0.3	26.1
Gasterosteidae				
Gasterosteus aculeatus	Eu	Ar	6.9	30.4
Pungitius pungitius	Eu	Ar	0.2	8.7

Table 3. Species richness, mean density (ind. 100 m^{-2}), Shannon-Wiener index of fish assemblage samples of streams in Kośna River.

Station	Mean density			Species richness			Shannon-Wiener index		
	May	Aug	Oct	May	Aug	Oct	May	Aug	Oct
S1	39.3	4.7	0.0	3	1	0	0.42	0.23	0
S2	25.3	6.7	7.3	6	2	6	0.62	0.35	0.73
S3	99.2	1.7	8.3	7	2	4	0.3	0.3	0.47
S4	11.7	4.2	3.3	5	2	3	0.58	0.29	0.45
S5	283.0	47.0	255.0	9	12	11	0.24	0.87	0.51
S6	70.0	38.0	126.7	9	8	9	0.7	0.71	0.57
S7	33.4	21.2	17.0	12	11	8	0.84	0.75	0.6
S8	42.1	10.7	8.5	10	8	7	0.7	0.73	0.56

Table 4. Mean values (± standard deviation) of environmental and biological parameters.

Parameters	Upper reaches sites (S1-S4)	Lower reaches sites (S5-S8)	P value
Biological data			
Species richness	3.4 ± 2.19	9.5 ± 1.68	0.000
Shannon-Wiener index	0.4 ± 0.19	0.6 ± 0.17	0.007
Density (ind. 100 m^{-2})	17.6 ± 28.04	79.4 ± 94.34	0.003
Cyprinids density (ind. 100 m^{-2})	13.8 ± 27.69	62.3 ± 84.92	0.002
Others density (ind. 100 m^{-2})	3.8 ± 2.50	17.1 ± 26.59	0.214
Environmental data			
Width (m)	2.4 ± 0.86	15.0 ± 3.69	0.000
Depth (m)	0.4 ± 0.18	0.5 ± 0.17	0.092
Temperature (°C)	14.0 ± 5.84	14.8 ± 4.69	0.990
Dissolved oxygen (%)	48.7 ± 24.57	68.5 ±11.49	0.022
Conductivity (µS cm^{-1})	357.9 ± 139.15	343.3 ± 12.93	0.603
Sand (%)	80.0 ± 15.81	86.2 ± 11.09	0.661
Gravel (%)	11.2 ± 10.31	11.2 ± 8.54	0.985
Boulder (%)	3.7 ± 4.79	2.5 ± 5.00	0.738
Silt (%)	41.2 ± 46.43	43.7 ± 35.44	0.771

Package (MVSP, Kov. Comp. Serv. 1985-2009). Statistical analyses were performed with Statistica 12 (StatSoft Inc. USA) and Canoco for Windows v. 4.5 (Ter Braak & Šmilauer 2002).

Results

Fish assemblage structure

A total of 17 species and 2,619 individuals were collected from the Kośna River and its tributaries; they belonged to five families (Table 2). All of the species were native to Poland. Family Cyprinidae was represented by 11 species and was the most dominant among different families. Three species (*Leucaspius delineatus*, *Gobio gobio* and *Alburnus alburnus*) accounted for about 59% of all of the collected species. The frequency of occurrence of six fish species was greater than 50% (Table 2). Eleven fish species belonged to the eurytopic group and three each were rheophiles and limnophiles. In terms of reproduction, species belonged to six guilds. Six species were phytophiles and phytolithophiles, while two were ariadnophiles and psammophiles, ostracophiles and lithophiles were represented by one species.

Spatial and seasonal variability

Significant seasonal variability was noted in the fish density structure (Kruskal-Wallis test, $P < 0.05$; Table 3). Fish density fluctuated from 1.7 to 283 ind. 100 m^{-2}. The highest mean fish density was noted in May (mean 75.5) and the lowest in August (16.8). The lowest mean fish density was noted at station S4 (6.4 ind. 100 m^{-2}), while the highest was at station S5 (195 ind. 100 m^{-2}). The mean fish density in the tributaries was significantly lower than in the Kośna River (Mann-Whitney U test, $P < 0.01$).

The species richness at stations fluctuated from

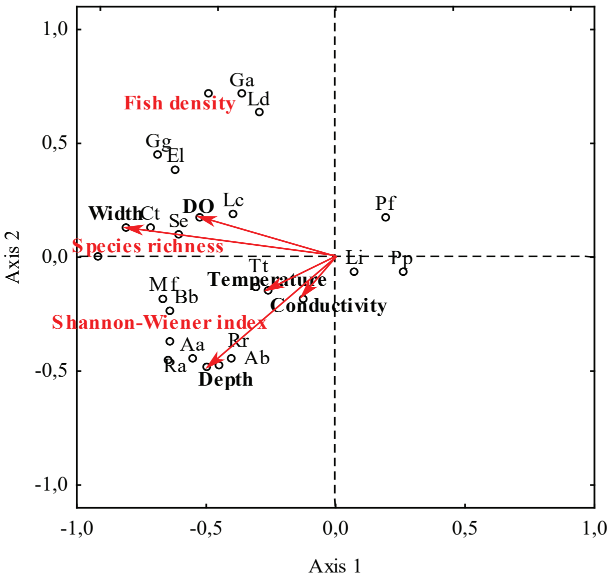

Fig. 2. Principal Component Analysis ordination of fish assemblage and environmental variables for all sampling sites. Environmental variable vector length denotes correlation strength, while vector direction denotes the relationship with different species and parameters characterizing fish assemblages. Species and parameters characterizing fish assemblages that are in the same direction as the environmental variable vectors are positively correlated with them, while those that are in the opposite direction are negatively correlated. The species and parameters characterizing fish assemblages that are perpendicular to the vector are not correlated with this variable. Axes 1 and 2 explain 44.3 and 18.1 % of the total variance, respectively. Aa – *Alburnus alburnus*, Ab – *Abramis brama*, Bb – *Blicca bjoerkna*, Ct – *Cobitis taenia*, El – *Esox lucius*, Ga – *Gasterosteus aculeatus*, Gg – *Gobio gobio*, Lc – *Leuciscus cephalus*, Ld – *Leucaspius delineatus*, Li – *Leuciscus idus*, Mf – *Misgurnus fossilis*, Pf – *Perca fluviatilis*, Pp – *Pungitius pungitius*, Ra – *Rhodeus amarus*, Rr – *Rutilus rutilus*, Se – *Scardinius erythrophthalmus*, Tt – *Tinca tinca*, DO – dissolved oxygen.

1 to 12 with a mean of 6.5 (SD = 3.65). In October, station S1 was completely dry, which is why there were no fish there. The mean species richness was similar in all months (Kruskal-Wallis test, $P > 0.05$), but it did differ significantly among the tributaries (3.4) and the Kośna River (9.5; Mann-Whitney U test, $P < 0.01$). The Shannon-Wiener index indicated that fish biodiversity ranged from 0.23 to 0.87 at a mean of 0.52 (SD = 0.22). The mean values of the biodiversity index were similar in all months (Kruskal-Wallis test, $P > 0.05$), but they differed significantly among the tributaries (0.40) and the Kośna River (0.65; Mann-Whitney U test, $P < 0.01$).

Stations located upstream from Lake Kośno differed substantially in riverbed width (Table 4). Species richness, Shannon-Wiener, total fish density and cyprinid density were all significantly higher at the stations in the lower stretch of the Kośna River (Mann-Whitney U test, $P < 0.05$). The density of the other fish species was higher at stations in the lower section of the Kośna River but these differences were not statistically significant. Only water temperature changed significantly throughout the seasons in the studied rivers (Kruskal-Wallis test, $P < 0.05$). The remaining parameters characterising riverbed morphology and physicochemical water properties did not differ significantly (Kruskal-Wallis test, $P > 0.05$).

PCA revealed two axes that together accounted for 62.7% of the total variation in fish assemblages among sites and seasons (Fig. 2). Axes 1 and 2 accounted for 44.3 and 18.1% of the total variation, respectively. The species richness of fish assemblages (0.910), the abundance of *C. taenia* (0.727), *G. gobio* (0.732), *E. lucius* (0.651) and river width (0.801) were positively correlated with Axis 1, while fish density (-0.688) and the abundance of *L. delineatus* (-0.640) and three-spined stickleback (*Gasterosteus aculeatus*) (-0.631) were negatively correlated with Axis 2.

Discussion

Fish assemblage composition

Fish species richness patterns in the rivers were strongly influenced by the spatial scale of the current observations (Oberdoff et al. 1995). On a local scale, biological factors, i.e., predation (Jackson et al. 2001) or competition (Grenouillet et al. 2002), and physical factors, i.e., habitat differentiation (Wolter et al. 2016), water quality (Kruk 2007), temperature, hydrological regime and riverbed morphology (Erős et al. 2003), shape species richness patterns and fish assemblage structure. On a local scale, physical factors determine species richness in transformed environments, while biological factors are more important under stable environmental conditions (Oberdoff et al. 1995). Obviously, local fish species richness is also affected by factors that have impacts on larger spatial and temporal scales.

The species richness of fish assemblages in small rivers ranges from several to several dozen species belonging to only one or several taxonomic, habitat or reproductive groups (Okur & Yalcin-Ozdirek 2008, Higgins 2009, Kapusta et al. 2012). During the study in the Kośna River, the fish caught belonged to different taxonomic, habitat and reproductive groups. In total, 17 species belonging to five families, three habitat groups and six reproductive guilds were identified. Neither the number of identified species nor their affiliation to specific habitat groups or reproductive guilds was especially impressive. This is probably associated with the size and character of the habitat of this small river and its partial anthropogenic transformation. Relatively low fish species richness is noted in lowland Polish rivers, especially in stretches that have been transformed (Marszał et al. 2014). Comparable is the number of species occurring in similar Central European lowland streams (Hajdú et al. 2013, Kruk et al. 2017) and is linked to this group of fishes that have developed high tolerance to variable environmental conditions (Mann 1996).

Spatial and seasonal variation

Many fish species change their feeding habits (Nunn et al. 2012) and choose different habitats during ontogenesis (Wolter et al. 2016). Some fish species are opportunistic with reference to the habitats they choose and the composition of their diets, which, when environmental variability is noted, leads to similarities in their ecological roles in fish assemblages. It is noteworthy that the environmental variability observed in the present study was not that pronounced and this impacted the functional organisation of the fish assemblages. The present study indicated that species structure differentiation and assemblage structure was associated with riverbed width and water oxygenation, while mean river depth and water conductivity had a smaller impact. In the studied small lowland rivers, environmental conditions associated with riverbed morphology and physicochemical water parameters did not change substantially spatially or temporally. Despite this, considerable changes in species structure and fish assemblage density were noted.

The greatest variability, both seasonal and temporal, was noted in fish density, the highest values of which were in spring and the lowest in summer. This was probably associated with the spring spawning period when a greater number of species was identified and the spawning migrations they undertook. It is possible that this was also associated with fluctuations in water levels in these small streams, especially in such a dry year. Seasonal changes in fish density in small streams were also observed by other researchers (Pires et al. 1999, Okur & Yalcin-Ozdirek 2008, Higgins 2009), as were spatial changes that depended on abiotic and biotic environmental factors, especially those regarding stream width and depth (Smokorowski & Pratt 2007, Higgins 2009). Weiperth (2014) observed similar changes, both temporal and spatial, in juvenile fishes in small Danube River tributaries. In addition to seasonal changes in fish density in Kośna River, significant spatial changes were also noted in fish density. Especially large were the differences between the stations located in tributaries and in the lower section of the main river. At station S3 fish density could have been affected by the existing fish ponds or the lake below this site.

Seasonal variation in fish species structure and density impacts the results of assessments of river ecological status based on fish fauna (Sutela et al. 2017). Awareness of the fact that local fish assemblages are shaped by factors that change in many spatial and temporal scales, has improved our understanding of the organisation of fish assemblages and this has simplified predicting features such as species richness and fish assemblage structure. Our study has revealed that even in a small river system spatial and temporal variation in the species structure of fish assemblages is significant.

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