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The structure of juvenile fish communities in the lower reaches of the Nemunas River

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During the investigations into shoreline juvenile fish communities of the lower reaches of the Nemunas River carried out in 1999, 2003 and 2006, 22 species belonging to six families were caught at ten stations. *Cyprinidae* was the most dominant family, constituting 67.8% of the total communities, followed by *Gasterosteidae* (21.4%) and *Percidae* (9.9%). According to the occurrence frequency, *Rutilus rutilus, Alburnus alburnus* and *Perca fluviatilis* were attributed to constant species. Other fish belonged to the groups of common, rare or accidental species. During the whole research period communities were dominated by *A. alburnus, Gasterosteus aculeatus* and *R. rutilus*, which together on average made up 62.9% of the total number of the caught fish. The relative abundance of valuable fishes (vimba, asp, pikeperch) was low. In comparison with the study period of 1975–1980, the decrease in the dominance of gudgeon (*Gobio gobio*) was quite obvious. Significant differences were established in fish density between May, September and October (Wilcoxon test, $p < 0.05$), whereas the richness of species was not of great variety ($p > 0.05$). Great species diversity indices (H', J') and mean annual density show that the ecological state of juvenile fish communities in the lower reaches of the Nemunas River is comparatively good, though they are considered moderate according to the mean values of metrics of Lithuanian Fish Index (LFI).

Key words: fish community, shoreline, ecological guilds, frequency, species richness, diversity, density, Lithuanian Fish Index, state

INTRODUCTION

Analysis of fish community structure is widely considered as an integrative indicator of the ecological state of water bodies (Kar, 1981). The aspects of the fish community that contribute to the community structure are species composition, species diversity, abundance, size structure and trophic composition (De Leeuw et al., 2003). The abundance of juvenile fish serves as an adequate indicator of the state of fish supply with regard to the entire population of the given species. As it was indicated by Кузнецов (1975), Жукинский (1986) and others (Penaz et al., 1978; Fausch et al., 1990; Kesminas, Virbickas, 1999), fish are very sensitive and responsive, particularly at the early stages of their development, so they can be used for bioindication of water bodies (Жилюкас, 1986; Slavik, Bartoš, 1997; Jurajda et al., 2002).

The biology of adult fish in the Nemunas River basin has been investigated quite thoroughly. However, the data on species composition and abundance of juvenile fish, which are very important indicators of fish resources (Правдин, 1966), are insufficient. Before 1970 there were only a few works (Гярулайтис, Миштаутайте, 1967; Вольскис, 1970) dealing with some biological aspects of juvenile fish. A more active research on biocenological aspect of juvenile fish in the Nemunas River basin has been done since 1975 (Жилюкас, Жилюкене, 1976; Жилюкас, 1983, 1986, 1993, 1995; Žiliukas, 1999, 2000; Žiliukas, Žiliukienė, 2006; Милерене, Гярулайтис, 1995; Stakėnas, Svecevičus, 1998; Stakėnas, 2002; Kesminas ir kt., 2008).

The purpose of this study was to evaluate species richness, distribution, diversity, equitability, density and ecological state of juvenile fish communities.

STUDY AREA

The Nemunas River is the fourth longest river in the basin of the Baltic Sea and the biggest river in Lithuania. Its length amounts to 937 km. The Nemunas drainage basin area is 97924 km^2. The Nemunas River from the source to 475 km flows through the territory of Belarus, from 457.7 km to

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111.9 km and from 13.2 km to the mouth – through the territory of Lithuania. The Nemunas marks off the border between Lithuania and Belarus and between Lithuania and Kaliningrad region (Russia). The Nemunas flows into the Curonian Lagoon, a half-closed lagoon of the Baltic Sea. 47.5% of the Nemunas basin area belongs to Lithuania (Kilkus, 1998; Jablonskis ir kt., 1993).

The approximate amount of 21 km^3 of water flows into the Curonian Lagoon during a year. A sudden rise in the water-level is typical during spring floods, relatively low and stable water level is characteristic in summer, and small floods occur in autumn and winter.

According to its physical-geographical and hydrological characteristics, the Nemunas River can be divided into three sections: I (upper reaches) – from the source to the Katra River mouth, II (middle reaches) – from the Katra to the Neris River mouth, and III (lower reaches) – from the Neris to the Curonian Lagoon.

The mean river slope is 20 cm/km. The width of the river bed fluctuates from 250 to 300 m, and in the shallows – till 500 m.

The Nemunas River upstream Kaunas city was dammed up in 1959 to prevent Kaunas from flooding and to use hydropower for electricity production.

In the lower reaches of the Nemunas River about half of the pollution arises from agriculture and half from the cities. For many years the biggest polluters have been Sovietsk, Neman (Kaliningrad region, Russia), Kaunas and Jurbarkas (Lithuania).

In recent years, when waste water treatment plants were built, pollution of the Nemunas River has decreased. Now, nitrogen and phosphorus levels are 2–3 times lower in comparison with the period 10–12 years ago (Kesminas, Repečka, 2005).

During the whole research period, the velocity of the current ranged from 0.38 to 0.85 m/s, discharge – from 167 to 685 m^3/s, temperature – from 8.1 to 18.3 °C, amount of suspended solids – from 3 to 25 mg/l. pH values ranged from 7.6 to 8.9. Mean oxygen saturation was relatively high (76–131%). Concentration of oxygen consuming substances (measured as BOD_7) exceed the highest allowable concentration (HAC) downstream Kaunas. In 1999, 2003 and 2006 BOD_7 varied between 1.6 and 12.8 mgO_2/l. HAC for BOD_7 in Lithuania is 2.3 mgO_2/l. Concentration of phosphates was 0.002–0.130 mgP/l (HAC for phosphates is 0.08 mgP/l). Concentration of nitrites ranged from 0.001 to 0.022 mgN/l (HAC for nitrites is 0.02 mgN/l) (Lietuvos upių ..., 2000, 2004, 2007).

Ten study sites (Fig. 1) were selected for research in the lower reaches of the River Nemunas between Kaunas and Rusnė. Specific characteristics of different sites are presented in Table 1.

MATERIALS AND METHODS

The data were collected in 1999, 2003 and 2006 (in May, September, October each year) at the same ten study sites (small shallow backwaters) situated on the right bank of the lowland Nemunas River. These sites differed from each other in the structure of habitats. The plain cover of the bottom made it possible to use seine nets. The advantages of using seine nets are low selectivity (Kubečka, 1996) and easy manipulation during the catch. Control catches in the shore-

Fig. 1. Location of study sites in the lower reaches of the Nemunas River

Table 1. **Characteristics of sampling sites. Explanations: m – mud, s – sand, g – gravel**

Parameters	Stations									
	1	2	3	4	5	6	7	8	9	10
Km from mouth	199	191	178	167	122	81	70	48	38	13
Mean length (m)	15	10	25	10	14	6	8	6	5	10
Mean width (m)	20	15	10	15	10	11	20	15	12	20
Mean depth (m)	1.0	0.8	0.85	0.65	0.5	0.9	0.95	0.85	0.70	0.70
Structure of bottom	m > s	s > m	g, m	s	s	s	s > m	s > m	s > m	g, s
Vegetation coverage (%):	70	30	60	0	0	20	30	10	30	75
Hydrophytes Filamentous algae	60	20	40	0	0	10	20	10	20	30

line zone of the river were conducted with a beach seine (8 m in length, mesh size 8 mm, height 1.5 m) in the centre of which a bolting cloth with the 1.5 mm-mesh was fixed. The number of replicate samples was two in each study site. Overall, ninety catches were carried out in 1999, 2003 and 2006.

Juvenile fish were fixed in 4% formaldehyde and identified later at the laboratory. In each catch, species composition, abundance and biomass of juvenile fish were determined. Then, in order to compare the data, we calculated the density for the unit of the area where catches were conducted (100 m^2). The main part of the control catches consisted of 0^+ and 1^+ juvenile fish, the other part containing more mature fish.

The determination of the species composition of the juvenile fish community was performed according to Коблицкая (1981) and categorised into ecological guilds according to (Bukelskis et al., 1998; Virbickas, 2000).

Mature fish of some species (gudgeon (*Gobio gobio*), ruffe (*Gymnocephalus cernuus*), bleak (*Alburnus alburnus*), three-spined stickleback (*Gasterosteus aculeatus*), nine-spined stickleback (*Pungitius pungitius*), bitterling (*Rhodeus sericeus*), spiny loach (*Cobitis taenia*) were also found in catches. The latter often dwell together with juvenile fish in the same habitats.

The dominance was expressed as the percentage of the corresponding species in the total number of individuals captured during the whole study period.

The frequency of occurrence for each species (V, %) was calculated according to the formula (Иоганзен, Файзова, 1978):

$$V = a_i / A \times 100\%, \quad (1)$$

where a_i is the number of collected samples when some particular species was caught; A is the total number of all samples collected during the study period.

Species structure of the community was expressed through species diversity indices (H' – Shannon's species diversity index; J' – Sheldon's equitability index; Shannon, Weaver 1949; Sheldon 1969):

$$H = \sum_{i=1}^{S} pilog2pi, \quad (2)$$

$$J' = H' / \log_2 S, \quad (3)$$

where S is the total number of all caught species; p_i – the share of i-species in the abundance of all the caught species. The Wilcoxon test was used to compare species diversity and density in juvenile fish communities between study years. To assess the ecological state of juvenile fish community Lithuanian Fish Index (LFI) was calculated according to the formula (Kesminas ir kt., 2008):

$$LFI = (NR_1 + NR_2 + \ldots + NR_n) / n, \quad (4)$$

where $NR_1 \ldots NR_n$ – are proportion of metric values of different ecological guilds with standard values; n – the number of metrics of different ecological guilds.

The assessment of ecological state was based on (LFI) deviation from standard value (0–1) scale. Five integrity classes (LFI > 0.93 – high, LFI = 0.93–0.71 – good, LFI = 0.70–0.4 – moderate, LFI = 0.39–0.11 – poor, LFI < 0.11 – bad) of river fish communities were distinguished**.** The statistical analysis of the data was performed with the programme Statistica 6.0.

RESULTS AND DISCUSSION

A total of 12,364 juvenile fish representing 6 families and 22 species were collected in 1999, 2003 and 2006. The species list, mean annual density and standard deviation are given in Table 2. *Cyprinidae* was the most dominant family, constituting 67.8% of the total communities, followed by *Gasterosteidae* (21.4%) and *Percidae* (9.9%) (Fig. 2). The proportion of *Cobitidae*, *Esocidae* and *Gadidae* families was only 0.9% in abundance.

Shallow shoreline sites, inlets and bays are the main habitats for most species of juvenile fish. They serve as feeding grounds and provide protection from predators. Juveniles find conditions for development and growth optimal there. For that reason, their distribution in the shoreline zone is aggregate (Кузнецов, 1975; Penaz et al., 1978; Slavik, Bartoš, 1997).

Totally, we recorded 22 species of juvenile fish in 1999, 2003 and 2006. During the research of adult fish in the shoreline zone of the Nemunas River (Манюкас, 1962) recorded 24 species.

Long-term investigations into the juvenile fish communities at the lower reaches were also conducted in 1975–1980 (Жилюкас, 1986). 25 fish species were caught then.

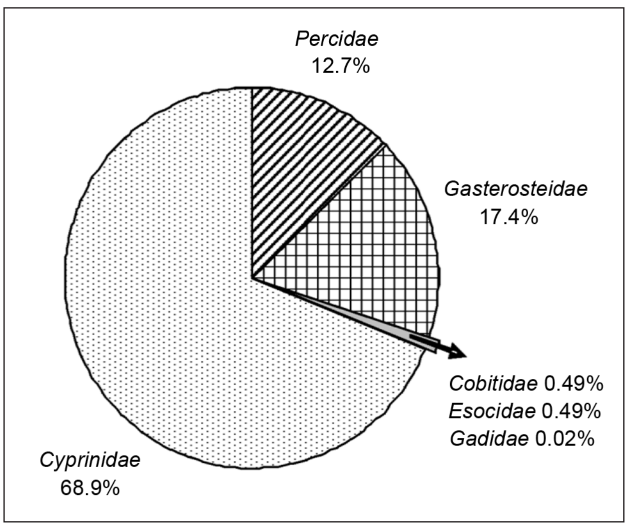

Fig. 2. Family composition of the juvenile fish communities in the lower reaches of the Nemunas River

Table 2. **Species list and density of juvenile fishes in the lower reaches of the Nemunas River (R – reophilous, RL – reolimnophilous, L – limnophilous)**

Family and scientific name	Common name	Ecological guild	Density, ind. / 100 m²	
			Mean	SD
Esocidae				
Esox lucius L.	Pike	RL	0.84	1.87
Cyprinidae				
Rutilus rutilus (L.)	Roach	RL	28.37	32.02
Leuciscus cephalus (L.)	Chub	R	4.33	9.62
Leuciscus leuciscus (L.)	Dace	R	12.44	25.58
Leuciscus idus (L.)	Ide	RL	0.22	1.24
Scardinius erythrophtalmus (L.)	Rudd	L	1.60	12.85
Aspius aspius (L.)	Asp	R	2.31	5.92
Leucaspius delineatus (Heck.)	Sunbleak	L	0.21	1.53
Gobio gobio (L.)	Gudgeon	R	12.83	30.03
Alburnus alburnus (L.)	Bleak	RL	47.71	61.05
Blicca bjoerkna (L.)	Silver bream	L	3.40	11.25
Abramis brama (L.)	Bream	L	7.48	18.99
Vimba vimba (L.)	Vimba	R	2.97	7.51
Rhodeus sericeus (Bloch)	Bitterling	RL	1.39	3.79
Carassius auratus gibelio (Bloch)	Golden carp	L	0.32	1.77
Cobitidae				
Cobitis taenia L.	Spiny loach	RL	0.89	2.16
Gadidae				
Lota lota (L.)	Burbot	RL	0.05	0.31
Percidae				
Perca fluviatilis L.	Perch	RL	10.90	15.52
Sander lucioperca (L.)	Pikeperch	L	0.24	1.13
Gymnocephalus cernuus (L.)	Ruffe	L	12.04	38.61
Gasterosteidae				
Gasterosteus aculeatus L.	Three-spined stickleback	RL	31.29	70.92
Pungitius pungitius (L.)	Nine-spined stickleback	RL	0.42	2.17

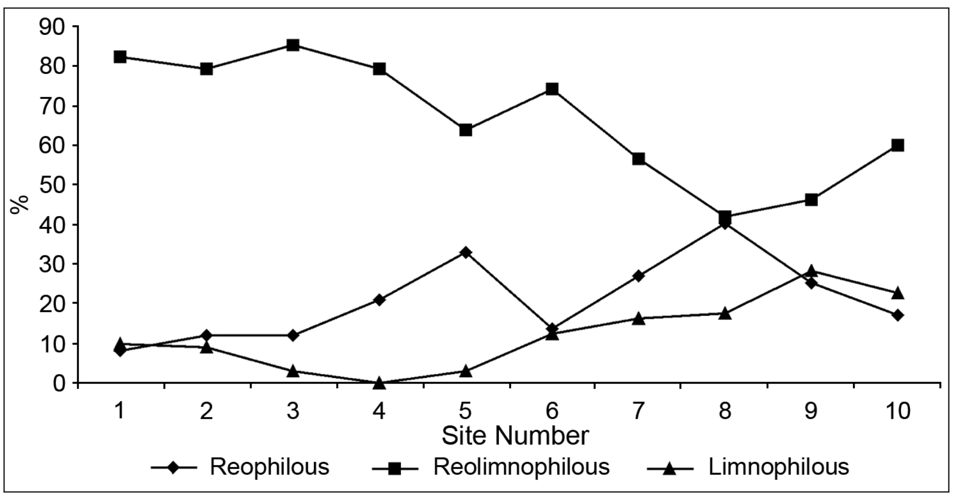

Fig. 3. Dynamics of juvenile fish species of different ecological guilds in the lower reaches of the Nemunas River

Juvenile fish species were divided into three ecological guilds: reophilous, reolimnophilous and limnophilous (Table 2) according to their aquatic habitats.

The dynamics of juvenile fishes of different ecological guilds along the river gradient during the study periods are shown in Fig. 3. Reolimnophilous species were overwhelmingly dominant at all study sites according to the relative abundance of juvenile fish.

With regard to occurrence (Fig. 4), the most frequent species (V > 70%) were *R. rutilus, A. alburnus* and *P. fluviatilis*, while *G. aculeatus, G. gobio, Leuciscus leuciscus, G. cernuus* and *Leuciscus cephalus* were common (V = 40–70%). Other fourteen species fell into the group of 'rare' and 'accidental' species. This ecological parameter partially shows the ability of the species to adapt to the living conditions and depends on the total abundance of fish (Penaz et al., 1978; Песенко, 1982). Moreover, fish are good indicators of ecomorphological conditions of the habitat (Wolter, Vilčinskas, 1997; Schmutz, Jungwirth, 1999).

The dominant species *A. alburnus*, *G. aculeatus*, *R. rutilus* constituted 62.9% of the total catch (Fig. 5). The juvenile fish community structure in the rivers is affected by three main abiotic factors: speed of the current, depth of the river, and characteristics of the bottom (Penaz et al., 1991; Stakėnas, 2002). In terms of these parameters, the study sites of our research are the most appropriate for the juveniles of the carp fish species (Gorman, Kar 1978; Garner, 1997). In 1999, 2003 and 2006 *A. alburnus*, *R. rutilus* showed a high degree of dominance in juvenile fish communities of the lowland Nemunas River. Compared to the study period of 1975–1980, the decrease in the dominance of *G. gobio* was quite obvious. In the period of earlier investigations the relative abundance of *G. gobio* in the shoreline juvenile community made up 12% on average, while in 1999, 2003 and 2006 the average of this parameter dropped to 6%.

Species richness in juvenile fish communities varied from 3 to 14 species. The mean species richness varied from 6.6 in 2003 to 8.0 in 2006. The mean diversity index (H') ranged from 1.73 in 1999 to 2.25 in 2006 and mean equitability index (J') – from 0.62 in 1999 to 0.78 in 2006 in the lower reaches of the river (Fig. 6).

A fish community consists of a great number of species differing from each other in the dynamics of their abundance. Each community possesses some particular structure. Species diversity is considered the main index of the species structure of a community that can be evaluated by information indices (Константинов, 1986).

It has been established that the more equal the distribution of species according to their relative abundance in a fish community, the higher is the species diversity in it (Pielou, 1975; Whittaker, 1975).

The density of juvenile fish communities at the study sites ranged between 35 and 574 individuals per 100 m^2.

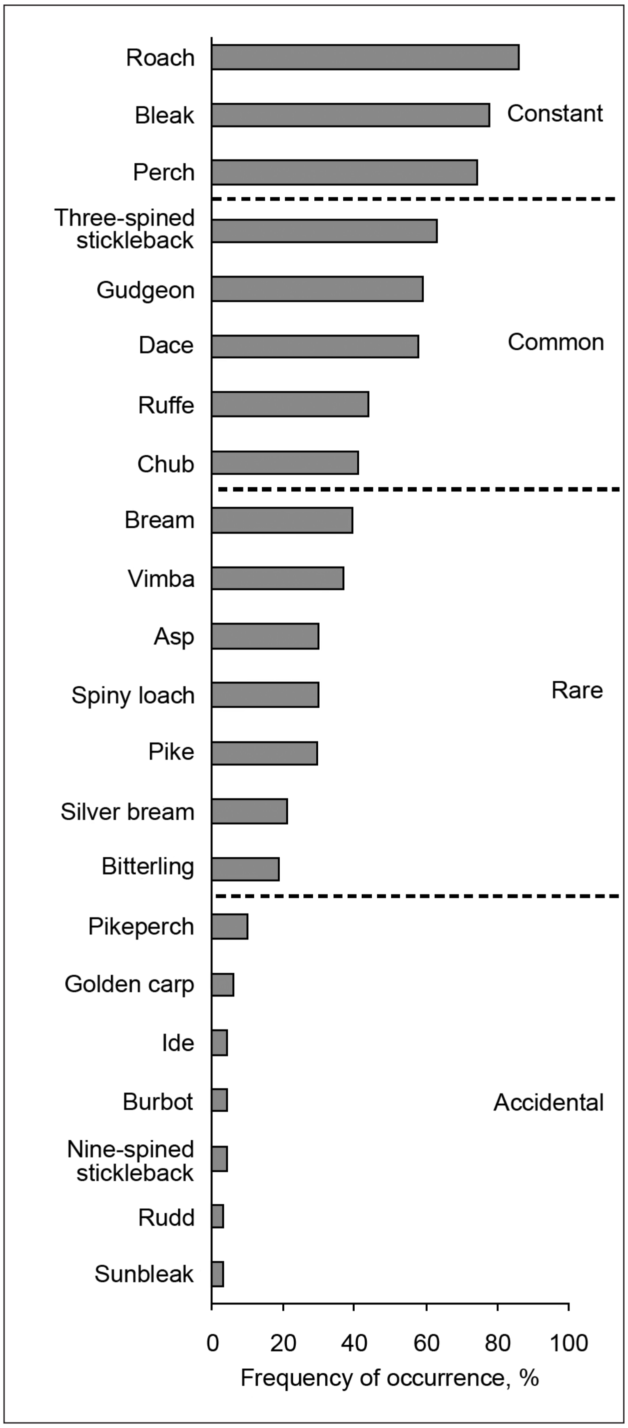

Fig. 4. Frequency of occurrence (V), % of various juvenile fishes in the lower reaches of the Nemunas River

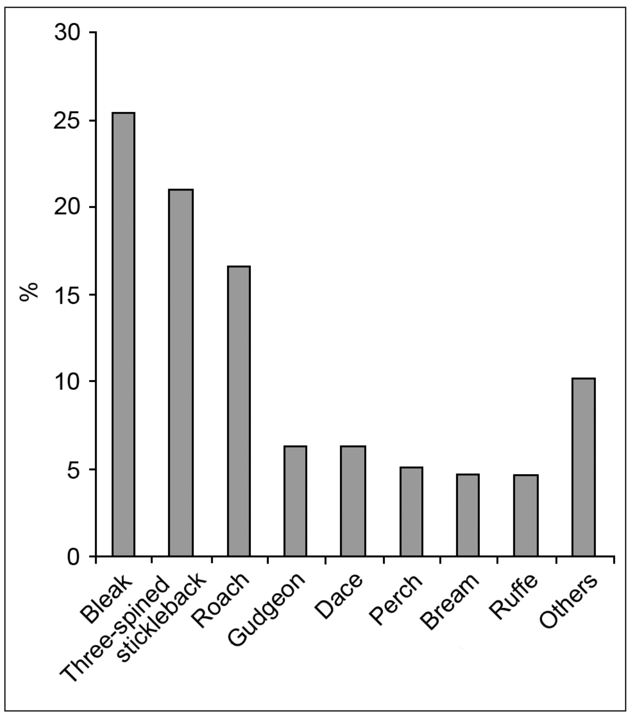

Fig. 5. Total dominance of the juvenile fish species in the lower reaches of the Nemunas River

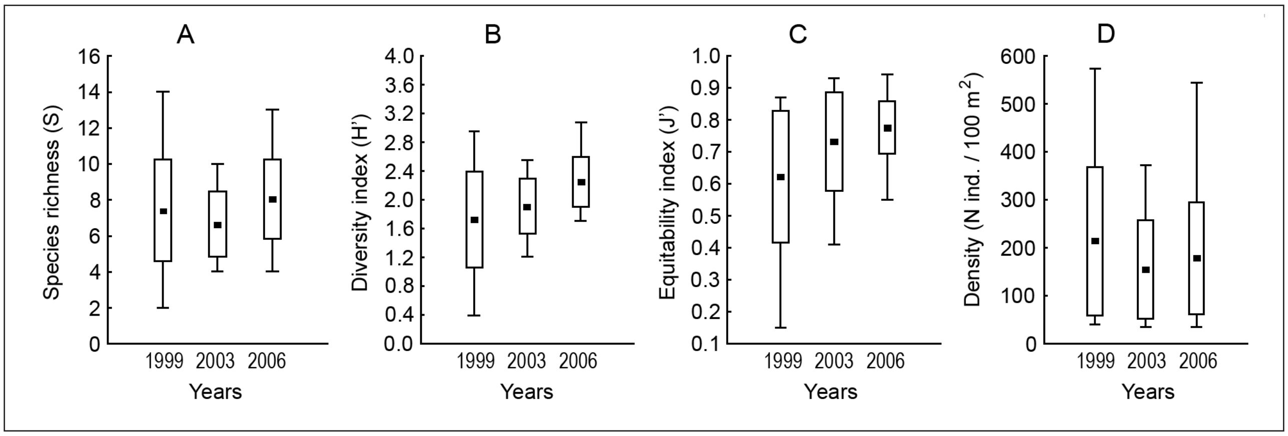

Fig. 6. Species richness (*A*), diversity index (*B*), equitability index (*C*) and density (*D*) of juvenile fish communities in the lower reaches of the Nemunas River in 1999, 2003 and 2006 (n = 30). The box represents the mean; the column represents the SD; the vertical bar represents the range

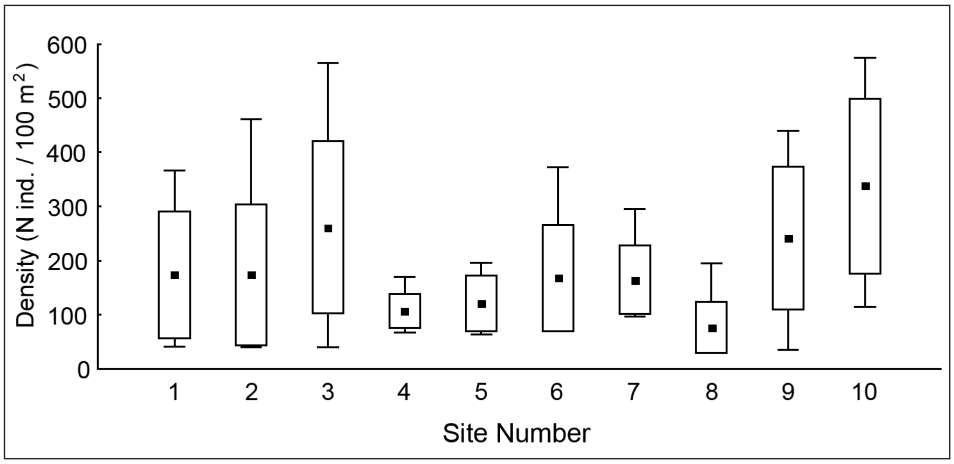

Fig. 7. Dynamics of density (N ind. / 100 m^2) of juvenile fish communities in the lower reaches of the Nemunas River (n = 9). The box represents the mean; the column represents the SD; the vertical bar represents the range

The highest density was recorded at study site 10, the lowest – at study site 8 (Fig. 7). It is obvious that the density of fish species varies on a large scale. The research showed that only three species (*A. alburnus, G. aculeatus* and *R. rutilus*) had the greatest densities: 47.71, 31.29, and 28.37 ind./100 m^2 respectively (Table 2). The density of the juvenile fish community is a significant ecological indicator enabling a better estimation of the ecological state of a water body. This parameter can be influenced not only by the depth of the river, the speed of the current, and the bottom characteristics, but also by water flora. In 1999, 2003 and 2006 the highest fish density was recorded at the study sites with abundant submerged vegetation (study sites 3, 10). According to Bartošova, Jurajda (2001), the absence of vegetation and other shelters in shoreline habitats may lead to high predatory pressure causing a decline in the quantity of young fish. Furthermore, the concentration of fish in the rivers can be influenced by seasonal dynamics as well (Marriner et al., 1976; Jurajda et al., 1998; Pires et al., 1999). Overall species richness and density was greater in September, followed by October and May (Fig. 8). Notable differences in fish density were determined in May, September and October (Wilcoxon test, $p < 0.05$), whereas the species richness was not of great variety ($p > 0.05$). Thus, the change of concentration of juvenile fish in the course of a year is evident in all the biggest investigated rivers in the Nemunas basin (Жилюкас, 1983). Perhaps, the impact of gradients of temperature and abundance of zoobenthos (Pliūraitė, 2001) predetermines the increase of juvenile fish density in the bays in autumn. The same regularity was observed earlier in different water bodies (Dolinskij, 1983; Nellbring, 1985; Thorman, Wiederholm, 1986).

The ecological state of the lowland Nemunas River juvenile fish communities calculated according to different guilds reflected that the value of metrics varied from subject to anthropogenic impacts (Kesminas ir kt., 2008). Each metric provides information about the state of juvenile fish communities. The mean of the ratings of these metrics together characterizes underlying biotic integrity of the sampling site. The values of LFI of the juvenile fish communities of the lower Nemunas River are presented in Table 3.

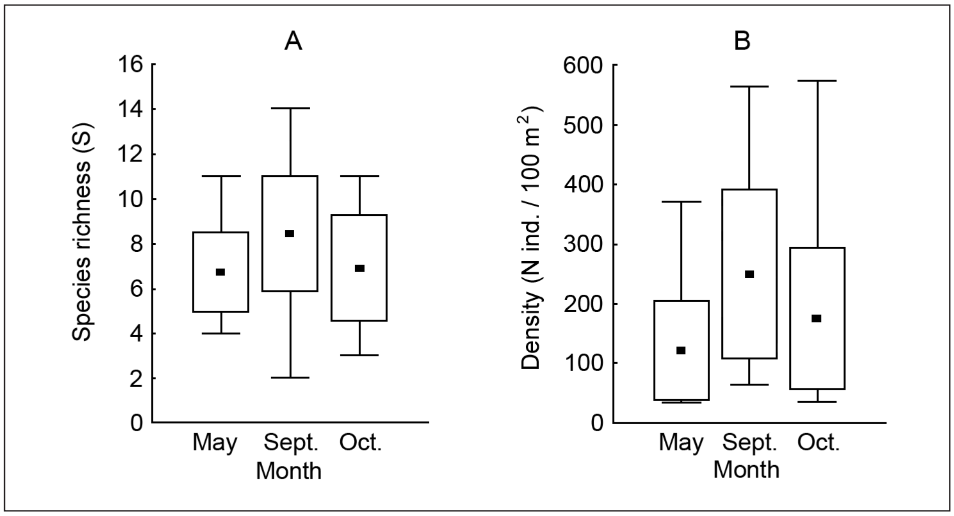

Fig. 8. Seasonal changes in species richness (*A*) and density (*B*) of juvenile fish communities in the lower reaches of the Nemunas River (n = 30). The box represents the mean; the column represents the SD; the vertical bar represents the range

Table 3. **The values of standard, present and gauge transformed to 0 (bad state) – 1 (high state) scale, used for calculation of Lithuanian Fish Index (LFI) of the lower reaches of the Nemunas River juvenile fish communities**

Metric	With anthropogenic impact: declining (↓) / rising (↑)	Standard value	Juvenile communities	
			Present value	Gauge (0–1)
Intolerant N%	↓	18	0.7	0.038
Lithophilic N%	↓	33	10.6	0.320
Lithophilic sp%	↓	39	22.7	0.582
Rheophilic N%	↓	46	21.7	0.471
Tolerant N%	↑	37	77.1	0.363
Tolerant sp%	↑	18	36.4	0.776
Omnivorous N%	↑	53	80.43	0.416
Mean:		34.86	35.63	0.424
Ecological state:				moderate

Our results suggest that the juvenile fish communities at various study sites of the lower reaches of the Nemunas River exhibit different qualitative and quantitative composition according to their preference of environments. Taking into consideration species richness, values of species diversity indices (H' and J') and density, we may assert that the ecological state of juvenile fish communities of less polluted sites of the lowland Nemunas River is comparatively good, while according to the mean value of LFI, the mentioned fish communities are moderate in terms of ecological state.

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ŽUVŲ JAUNIKLIŲ BENDRIJŲ STRUKTŪRA NEMUNO ŽEMUPYJE

Santrauka

1999, 2003 ir 2006 m. tyrinėjant Nemuno žemupio žuvų jauniklių priekrantines bendrijas 10 stočių buvo sugautos 22 rūšys, priklausančios 6 šeimoms. Žuvų jauniklių bendrijose pagal gausumą ženkliai vyravo karpinių (*Cyprinidae*) šeima (67,8 %). Toliau sekė dyglinių (*Gasterosteidae*) (21,4 %) ir ešerinių (*Percidae*) (9,9 %) šeimos. Tuo tarpu vijūninių (*Cobitidae*), lydekinių (*Esocidae*) ir menkinių (*Gadidae*) šeimos iš viso tesudarė 0,9 % nuo visų sugautų žuvų skaičiaus. Pagal aptinkamumo dažnį pastovios rūšys buvo kuoja, paprastoji aukšlė ir ešerys. Kitos žuvys priklausė įprastinėms, retosioms ir atsitiktinėms rūšims. Tyrimų metu bendrijose vyravo paprastoji aukšlė, trispyglė dyglė ir kuoja, kurios kartu sudarė vidutiniškai 62,9 % nuo visų sugautų žuvų skaičiaus. Vertingų žuvų rūšių (žiobris, salatis, sterkas) santykinis gausumas buvo mažas. Palyginus su 1975–1980 m. atliktais tyrimais, nustatytas ženkliai sumažėjęs gružlių populiacijos santykinis gausumas. Nustatyti žuvų bendrijų tankio gegužę, rugsėjį ir spalį patikimi skirtumai (Wilcoxon test, $p < 0,05$), tuo tarpu pagal vidutinį rūšių skaičių bendrijos mažai tesiskyrė (Wilcoxon test, $p > 0,05$). Pagal rūšinės įvairovės (H', J') indeksus ir tankį Nemuno žemupio žuvų jauniklių bendrijų ekologinė būklė yra palyginti gera, nors pagal Lietuvos žuvų indeksą (LŽI visų rodiklių vidurkį) – vidutinė.

Raktažodžiai: žuvų bendrija, priekrantė, aptinkamumo dažnis, struktūra, rūšių įvairovė, ekvitabilumas, tankis, Lietuvos žuvų indeksas, būklė