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ECOLOGICAL CHARACTERISTICS OF 0+ FISH COMMUNITIES IN THE SHORE-ZONES OF THE MIDDLE NEMUNAS AND THE NERIS RIVERS

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Abstract. 5243 individuals of 0+ juvenile fish belonging to 20 species were caught in the Middle Nemunas. The following fish species predominated in the fish communities: bleak, roach, minnow, riffle minnow, chub, bitterling, and dace. In the Neris River, 6226 individuals of 0+ fish belonging to 22 species were caught. Such species as roach, dace, bleak, chub, gudgeon, riffle minnow, and barbel predominated over others.

While comparing the mean of density and the dispersion index of fish species, we can maintain that ecological conditions in the Neris River are suitable to lithophilous, lithophilous-phytophilous and psamophilous fish species. In the Middle Nemunas, there are enough biotopes suitable to lithophilous-phytophilous and psamophilous fish species, but lithophilous fish species are highly influenced by the environmental factors, and more sensitive species are eliminated (barbel). Correlation of the zooplankton and 0+ fish densities ($R^2 = 0.667$) shows, how important is the amount of forage resources for 0+ fish while determining the suitability of their development zone. There was also established the influence of organic pollution upon the 0+ fish communities: the greater is the pollution, the smaller is the share of reophilous fish species and the larger is the share of reolimnophilous fish species in them; the number of species of 0+ fish in communities is determined by the pollution and water yield of a river. A similar tendency is observed when the eutrophication of a biotope increases: the share of reophilous fish species decreases and the share of reolimnophilous fish species increases. All that allows us to determine causative relations between the pollution and degradation of biotopes, and structure of communities. The shares of 0+ roach and barbel juveniles, which correlate best with pollution and eutrophication of biotopes, are valuable indicators of the ecological status of rivers.
Key words: 0+ fish, river fish community, shore-zone habitat.

INTRODUCTION

Species-environment interrelations are the basis of the ecology of communities. They can be used as a model while investigating species-species relations. In the time scale of ecology and evolution, these interactions are obviously decisive (Harvey and Stewart, 1991). Reproductive adaptation of freshwater fish reflects needs of existence, that is why the investigations of species-environment relations reveal not only the importance of the environment to spawning, but the influence of the environment on the development of juvenile and adult fish as well (Kryzhanovsky, 1949; Copp, 1992 a). Since different fish groups need a whole complex of biotopes during their life cycle, fish communities are good indicators of their living environment and ecological integrity of large river systems. Reproductive and early stages of development are critical, and the conformity of fish requirements and the habitat determines the existence of populations (Schiemer, 1998). Thus 0+ fish are important indicators of the ecological status of rivers. Data on the ecology of 0+ fish are very important for implementation of river protection and restoration programs (Copp, 1992b).

The influence of the environment on Salmonidae fish in typical salmon rivers has been investigated most thoroughly. In rivers of other types, investigations were not so numerous, and they usually were concentrated on separate fish species and not on their communities. The number of ecological investigations of 0+ fish communities is still rather small. The attention was mostly paid to adult fish because of their smaller density, easier identification, etc. In not numerous investigations of 0+ fish, fish communities have been investigated in several biotopes or only several fish species have been analyzed. Investigations comprising species-environment interrelations in wider geographical context are still rarely carried out.

In Lithuania, only species-habitat relations of fish juveniles were investigated, and during these investigations only 0+ fish in the stage of fry and two-year-old or even older individuals were analyzed (Žiliukas, 1983; 1986; 1988; 1995; 1997). There were not any investigations carried out in Lithuania of 0+ fish communities alone.

The purpose of this work is to establish the changes of qualitative and quantitative parameters in 0+ fish communities in the shore-zones of the Middle Nemunas and Neris River in dependency upon micro (biotope, forage resources) and macro (pollution, yield) environmental factors and to evaluate causative interrelations of separate ecological groups of 0+ fish within a community.

Material and methods

The data were collected in six stations on the Middle Nemunas in June-July of 1996 and in thirteen stations on the Neris River in June-July of 1997. The stations were located in the section of the Nemunas River from Druskininkai to Birštonas and on the Neris River from the Lithuanian-Belarus border to its mouth approximately each 30-40 km (Fig. 1). 0+ fish was caught applying fish dredge (Aneer et al., 1992). Caught 0+ fish were submerged into 4% formalin solution, their species composition was determined basing on their definer (Koblickaja, 1981). Depth in the fishing sites did not exceed 1m. In each fishing site, there was measured the flow rate and determined the substrate and the covering of the bottom with vegetation in percents. For the analysis of results we applied the data

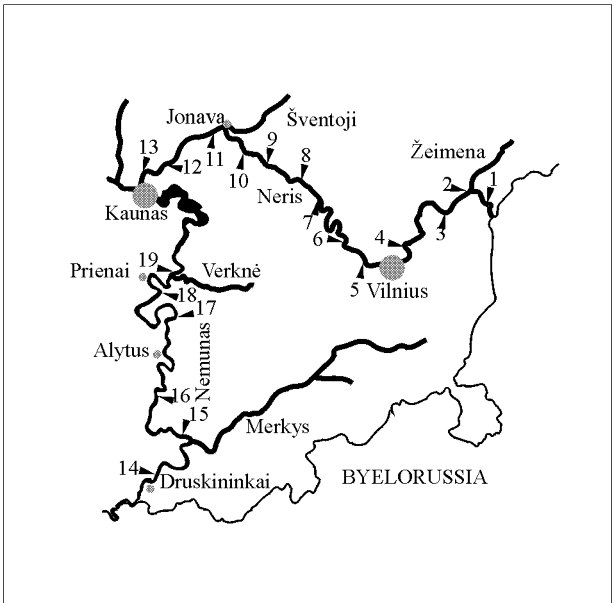

Figure 1. Research stations on the Middle Nemunas and Neris River

on water quality established by the Ministry of Environment: concentrations in water of general nitrogen, phosphorus, mineral nitrogen and PO_4-P, water yield, and BOD_7. For this article we applied the averages of the above-mentioned parameters from the research data collected in June and July. Four research stations in the Middle Nemunas (14, 16, 17, 18) and six in the Neris River (1, 4, 5, 10, 11, 13) were not far from the water quality sampling stations (Fig. 1).

The zooplankton biomass was determined by Pliuraitė, a research assistant of the Institute of Ecology of Lithuania (Kesminas, 1997).

Results and discussion

During the investigations, there were caught 11469 0+ fish individuals of 23 species in the Middle Nemunas and Neris River. In the six stations of the Middle Nemunas, there were caught 5243 individuals of 20 fish species. The specific diversity of 0+ fish varied within rather narrow scale, from 10 to 16 species (variance = 6, mean = 14). In the fish communities of the Middle Nemunas, 0+ fish of Cyprinidae family made the majority among 0+ fish species. 0+ fish individuals of bleak (20.4%), roach (14.6%), minnow (12.9%), riffle minnow (11.5%), chub (10.4%), bitterling (8.2%), and dace (5.4%) predominated there (Fig. 2A). Frequency of occurrence of many prevailing in communities 0+ fish species reached 100%, frequency of occurrence of minnow, and riffle minnow made 83%, and that of bitterling made only 67%. In addition to the latter predominating in communities fish species, there constantly were found 0+ individuals of pike, ide, asp, gudgeon, vimba and perch.

In the thirteen stations on the Neris River, there were caught 6226 individuals of 22 fish species. Unlike in the Middle Nemunas, the number of 0+ fish in the Neris River varied within rather broad scale: from 6 to 15 (variance = 8.83, mean = 11). In the communities of the Neris River, 0+ individuals of roach (21.4%), dace (15.2%), bleak (14.9%), chub (9.8%), gudgeon (7.0%), riffle minnow (5.3%) and barbel (4.8%) were prevalent (Fig. 2B). Unlike in the Middle Nemunas, where the frequency of occurrence of many fish species belonging to the main body of a fish community reaches 100%, only bleak was found in all the stations of the Neris River. The frequency of occurrence of other fish species was lower. Among 22 species of 0+ fish only 8 species were constantly met in the Neris River: roach, chub, ide, three-spined stickleback, gudgeon, bleak and riffle minnow.

While comparing the dispersion index of more abun-

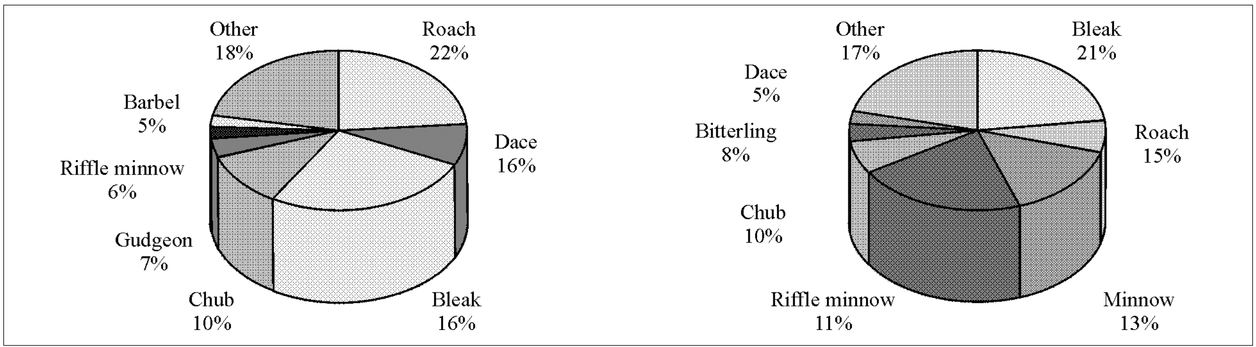

Figure 2. Species composition of 0+ fish (%) predominating in fish communities of the Middle Nemunas (A) and Neris River (B)

dant fish species density calculated in the Neris River with the mean density, it was established that the most frequently shoaling 0+ fish species were: roach, ide, vimba, silver bream, and bream (Figure 3A). 0+ individuals of vimba were most abundant below the Šventoji River where their share in fish communities varied from 6.1 to 17.4% (in other research stations it varied from 0 to 1.2%). The highest densities of 0+ roach and ide were established at the mouth of the Žeimena River where the share of roach varied from 35.8 to 75.9% (in other stations it varied from 0 to 9.1%), and the share of ide varied from 7.6 to 9.2% (in other stations it varied from 0 to 2.4%). 0+ individuals of silver bream and bream were more abundant in the lower reaches of the Neris River where their share in fish communities was also larger than in other sites. Vimba intensely migrate to spawn to the basin of the Šventoji River, and their migration above the mouth of the Šventoji River is less intensive (Kesminas et al., 1995). Roach and ide also migrate to spawn to the upper reaches of rivers (Virbickas T., 1998). Thus the shoal formation of 0+ fish of these species seems to be closely related with the migrations of spawners and their spawning sites. There are a lot of sites suitable for spawning of such phytophilous fish species as bream and silver bream in the Neris River. So they do not have to migrate up-river for spawning. The tendency of 0+ fish of these species to make shoals is more related to the lack of biotopes suitable to the spawners in the Neris River, which is rather shallow and rapid. Thus these species are more abundant in the lower reaches of the river where there are more deep pits and creeks. Such fish species as bleak, riffle minnow, dace, chub, gudgeon, barbel, three-spined stickleback and asp have the least expressed tendency of making shoals in the Neris River. Since in spite of active and passive distribution of 0+ fish downstream the river their occupied environment is similar to the spawning sites of the reproducers (Copp, 1992a), it is possible to evaluate the abundance of sites suitable for spawning and the state of the ecosystem according to the tendency of fish species to make shoals. So lithophilous, lithophilous-phytophilous, and psammophilous fish species find enough spawning sites, and the state of the ecosystem of the River Neris is good.

In the Middle Nemunas, stone loach, bitterling, minnow, riffle minnow, ide and roach show the strongest tendency to make shoals (Figure 3B). Roach is most abundant in the upper reaches of the Nemunas River (station 14), and ide is most abundant at the tributaries (station 19) where the share of these species in communities is much larger than in other sites. Perhaps the reasons why roach and ide make shoals in the Middle Nemunas are very similar to those in the Neris River. However, the tendency of stone loach, bitterling, and riffle minnow to make shoals in the Nemunas River is due to the lack of biotopes suitable for spawning of reophilous-lithophilous fish (minnow, riffle minnow, stone loach) in the ecosystem. In the Nemunas River, dace, chub, gudgeon, three-spined stickleback, and asp show the least expressed tendency to make shoals. All these species have no inclination to make shoals in the Neris River as well, but in the Middle Nemunas, unlike in the Neris, the number of lithophylous fish species (riffle minnow, minnow, stone loach) is limited by the environmental factors and more sensitive species are being eliminated (the share of barbel in the community makes only 0.1%). Thus the state of the ecosystem of the Middle Nemunas is worse than in the Neris River. While generalizing the acquired data, we may affirm that when the eutrophication of a river is increasing the number of biotopes suitable for lithophilous fish species is decreasing and lithophilous-phytophilous fish species also experience the environmental press. This fact is also proved by investigations of 0+ fish carried out in highly eutrophicated British rivers where gudgeon, dace, bitterling, and three-spined stickleback are most prone to make shoals (Copp, 1992b). In the Neris River and Middle Nemunas, these fish species are dis-

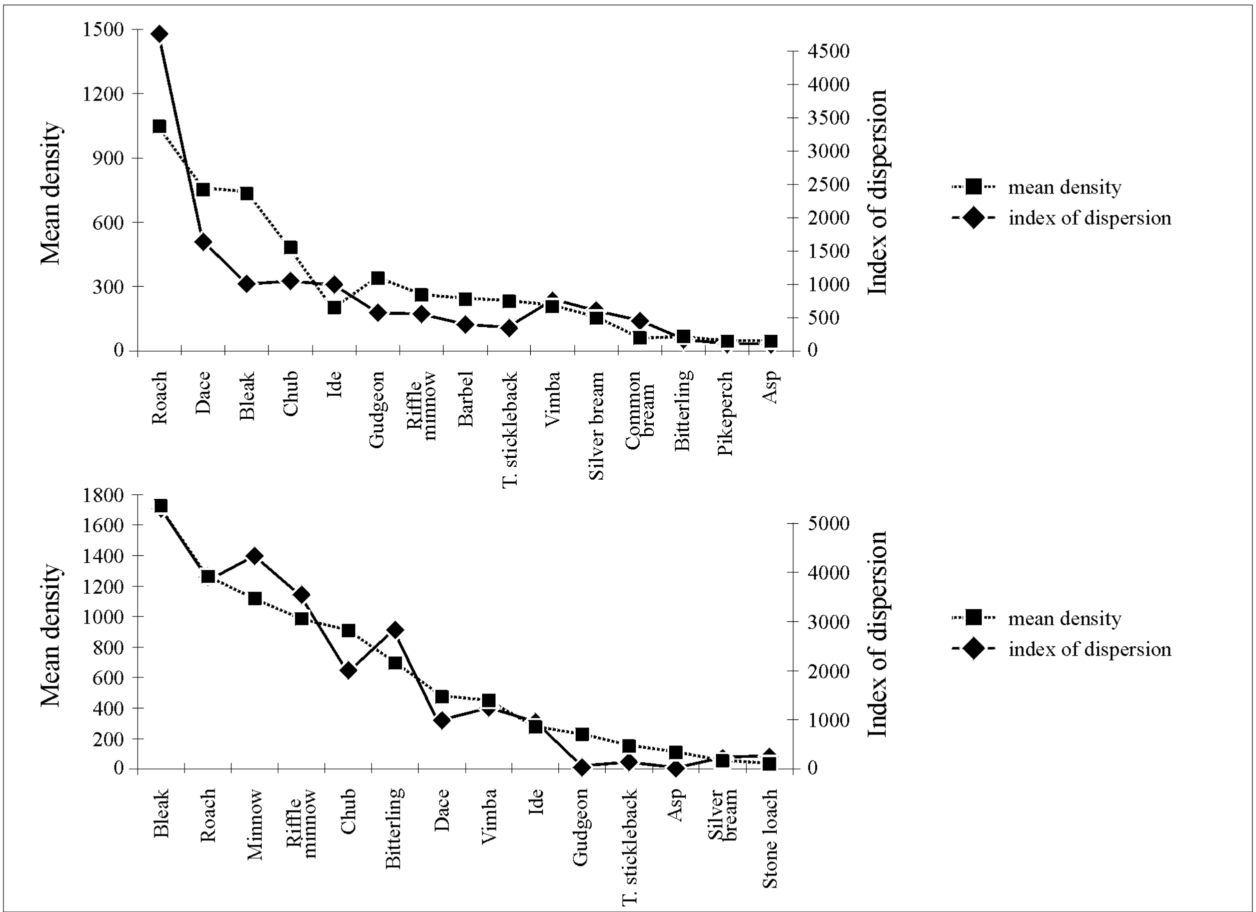

Figure 3. The index of dispersion and mean density of 0+ fish in the Neris River (A) and the Middle Nemunas (B)

tributed quite evenly (except bitterling).

In the investigated rivers, the density of 0+ fish varied from 1487 to 4290, but in some stations (in the Nemunas River below the mouth of the Merkys and in the Neris River below the mouth of the Žeimena) the density was much higher and reached 18300 and 38070 individ./100 m^2. Below the outfalls of clean cold-water rivers (the Merkys, Žeimena), conditions for the development of zooplankton are more favorable, since exactly in these places the highest values of the zooplankton biomass are registered (Fig. 4). Forage resources of 0+ fish make an important factor of suitability of the development zone (Keckeis, 1998), i.e. the density of 0+ fish depends on the amount of zooplankton. It can be expressed by the regressive equation of the influence of zooplankton upon the abundance of 0+ fish: $\ln N = 7.662 + 0.157B_{pl}$ (where B_{pl} is the biomass of zooplankton, N is the density of 0+ fish, $P < 0.001$, $R^2 = 0.667$, $n = 19$). The confluences of eutrophicated and clean rivers can form favorable spawning conditions for reproducers, which also should influence the density of 0+ fish. But favorable spawning conditions are more important for the abundance of 0+ fish only in their early ontogenesis. When the fish larvae start to feed intensively (after the resorption of yolk ducts), the amount of food becomes one of the most important factors determining the abundance of 0+ fish.

The correlation coefficients of the zooplankton biomass and 0+ fish density change depending upon the spawning period of fish. Fish species, which begin to spawn earlier, i.e. at lower temperatures of water (Virbickas J., 1986), have greater correlation coefficients than species, which start spawning later (Fig. 5). It can be explained by the fact that the methods of zooplankton withdrawal do not allow evaluating properly the biomass and abundance of Rotatoria, which are the main food for 0+ fish in their early stage of development. In later stages of development, 0+ fish start feeding on Cladocera and Copepoda crustaceans. That is why the density of 0+ fish of earlier spawners correlates better with the biomass of zooplankton. It is also proved by a high correlation coefficient (R= -0.91) between the temperature of water in the beginning of spawning, the density of 0+ fish of different species, and the correlation coefficients of the zooplankton biomass.

While comparing the number of species with the quality indices of rivers, it was established that the num-

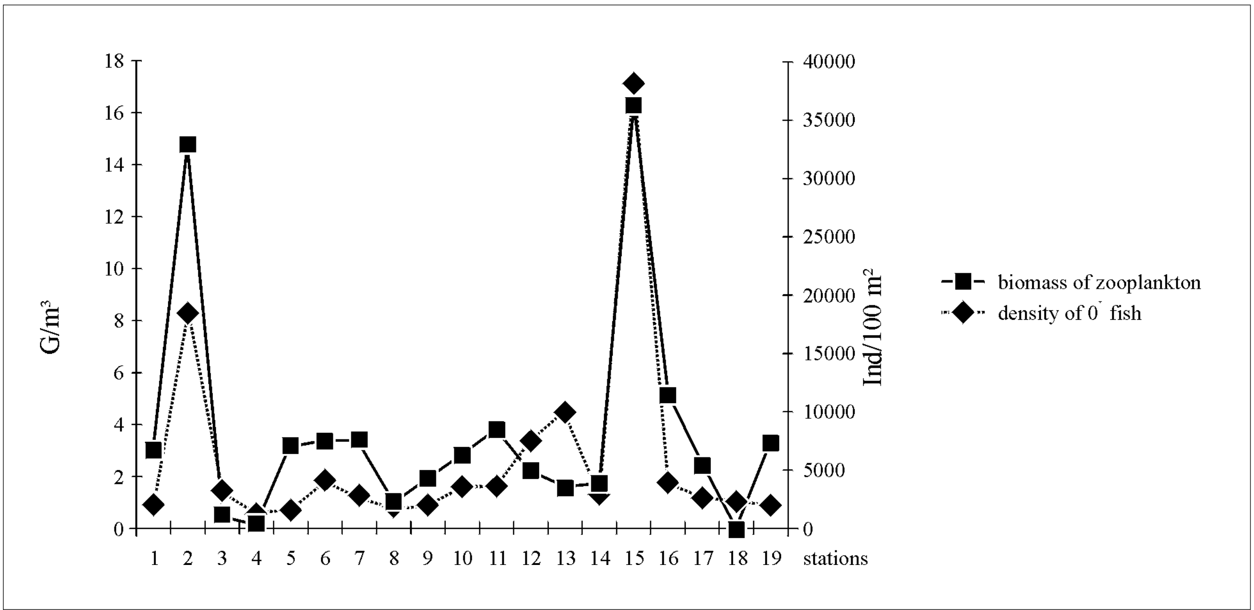

Figure 4. Density of 0+ fish and the biomass of zooplankton in the Middle Nemunas and Neris River

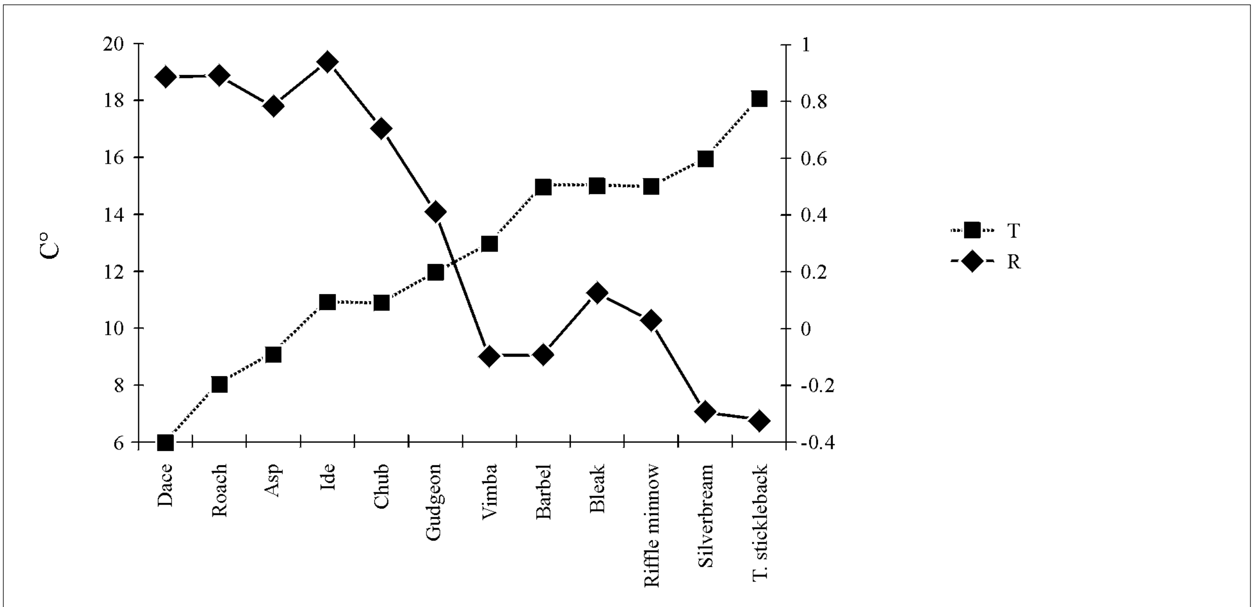

Figure 5. Minimal temperatures (T) suitable for spawning of different fish species and the correlation coefficients (R) of 0+ fish density with the biomass of zooplankton in the Neris River

ber of species had high positive correlation with the water yield of rivers (R = 0.75) and negative correlation with BOD_7 (R = -0.73) (Fig. 6). The dependency of the number of species upon these factors may be expressed with a regressive equation $N_S = 18.68 + 0.037\ Q_Y - 1.861\ BOD_7$ (where Q_Y is the water yield of a river, N_S is the number of species, $P < 0.01$, $R^2 = 0.761$, n = 10). A larger water yield and lower average BOD_7 determined a higher variety of the number of fish species in the Middle Nemunas (upon the average, up to 14 species in the research area).

While analyzing the influence of BOD_7 on the communities of 0+ fish, it was observed that the share of reophilous and reolimnophilous 0+ fish in communities depends upon the organic pollution of rivers. When the pollution increases, the share of reophilous fish species decreases and the share of reolimnophilous fish species increases. These dependencies can be expressed with the following equations of regression: $R_S = 1.799 - 0.187\ BOD_7$ (where R_S is the share of reophilous fish species in a community; $P < 0.01$, $R^2 = 0.62$, n = 10) and $RL_S = -0.737 + 0.174\ BOD_7$ (where

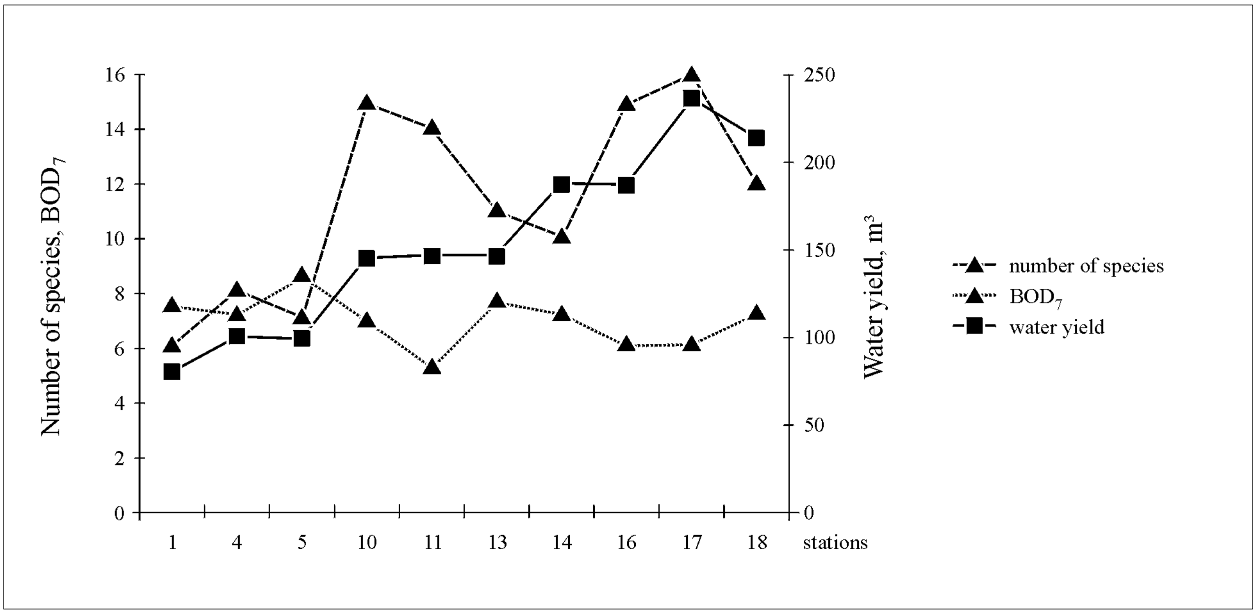

Figure 6. The number of 0+ fish species, BOD_7, and water yield in the Middle Nemunas and Neris River

RL_S is the share of reolimnophilous fish species in a community; $P < 0.05$, $R^2 = 0.53$, $n = 10$).

Large and quite rapid rivers are more resistant to the influence of environment, but the shore-zones of rivers are very sensitive to the changes of environment. Any change in the biotopes of the shore-zones of rivers evokes chain reaction. For instance, higher organic pollution stimulates the growth of water vegetation. Thriving water vegetation decreases the flow rate of a river in the shore-zone. When the flow rate of a river slows down, small deposits carried along begin to accumulate in its water more rapidly and the shore-zone biotope changes fundamentally in a very short time. Contrarily to adult fish, the dwelling biotopes of which are much broader and the stress of negative environmental factors on which is not so evident, minihabitats of 0+ fish undergo a very strong stress of environmental factors. Organic pollution of rivers affects the communities of 0+ fish and determines their decrease in abundance (Kubecka, 1998; Slavik, 1998). It is evident that the changes of shore-zone biotopes are closely related to organic pollution, and the degradation of biotopes, caused by it, is fatal to the communities of 0+ fish. It tells, without doubt, on the whole fish community, since the temporal and spatial accessibility of development zones is a decisive need of fish (Keckeis, 1998). In order to evaluate better the influence of environment on 0+ fish communities, the biotopes, where the 0+ fish were caught, were evaluated in grades (Table 1). While evaluating the biotopes, there were established the prevailing substrate, vegetation of the bottom (%), and flow rate (m/s).

According to the system of evaluation of biotopes, greater amount of grades falls to less eutrophicated biotopes. The negative correlation of biotopes and BOD_7 ($R = -0.57$) is very close to the reliability of 95%. The negative influence of pollution on the shore-zone biotopes of rivers is shown by the reliable positive correlation of biotopes with the share of reophilous fish and negative correlation with the share of reolimnophilous fish in fish communities, as the share of reophilous fish and reolimnophilous fish in communities correlate reliably with BOD_7. Thus, when the eutrophication of a biotope increases, the share of reo-

Table 1. Evaluation of biotopes in grades.

Grades	Vegetation coverage (%)	Flow-rate (m/s)	Prevailing bottom
0	100	0	Silt
1	≥ 80 < 100	0 ≤ 0.2	Sand, silt
2	≥ 60 < 80	> 0.2 ≤ 0.4	Sand
3	≥ 40 < 60	> 0.4 ≤ 0.6	Sand, gravel
4	≥ 20 < 40	> 0.6 ≤ 0.8	Gravel
5	< 20	> 0.8	Stones

philous fish decreases and the share of reolimnophilous fish species increases (Fig. 7). These dependencies can be expressed by the following equations of regression: $R_S = 15.11 + 4.831$ Bs (R_S is the share of reophilous fish species in a community, Bs is the sum of the grades in a biotope; $P < 0.001$, $R^2 = 0.56$, n = 19) and $RL_S = 83.35 - 5.079$ Bs (RL_S is the share of reolimnophilous fish species in a community, Bs is the sum of the grades of a biotope; $P < 0.0001$, $R^2 = 0.62$, n = 19). In the Neris River, the share of 0+ roach has the highest negative (R = -0.6) and the share of barbel has the highest positive correlation (R = 0.71) with the evaluation of the biotopes in grades, i.e. roach is the most resistant and barbel is the least resistant fish to eutrophication. Many foreign authors also have come to a similar conclusion. The predominating of roach in fish communities over other species can be interpreted as a partial indicator of the degradation of a hydrosystem (Copp et al., 1992), and barbel is one of the most sensitive indicators allowing to evaluate the lack of suitable biotopes and pollution in rivers (Copp, 1992b).

As we have established, pollution and biotopes determine the variety of species, quantitative composition

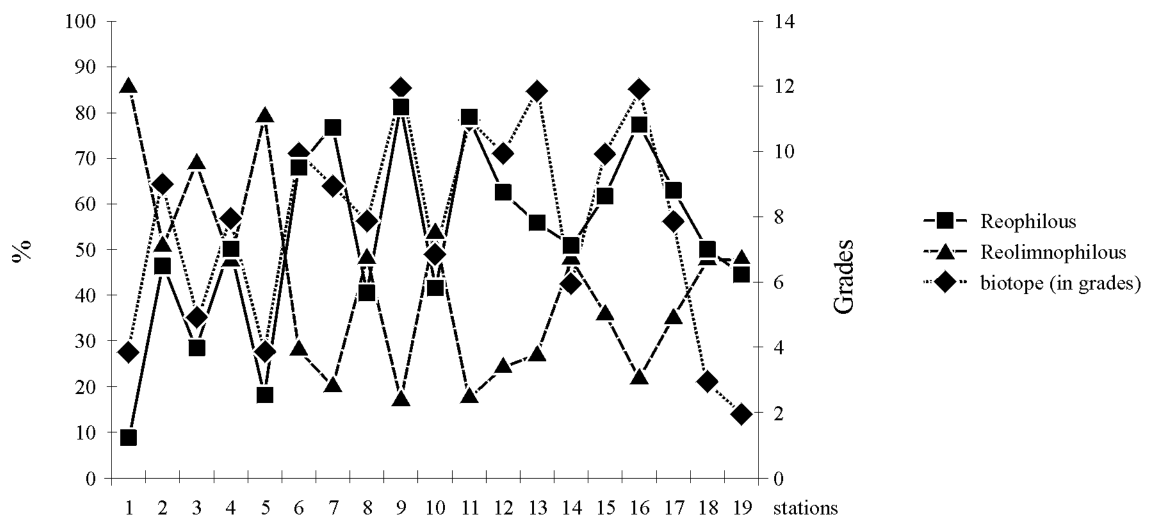

Figure 7. The shares of 0+ reophilous and reolimnophilous fish in the communities of the Neris River and Middle Nemunas depending on a biotope

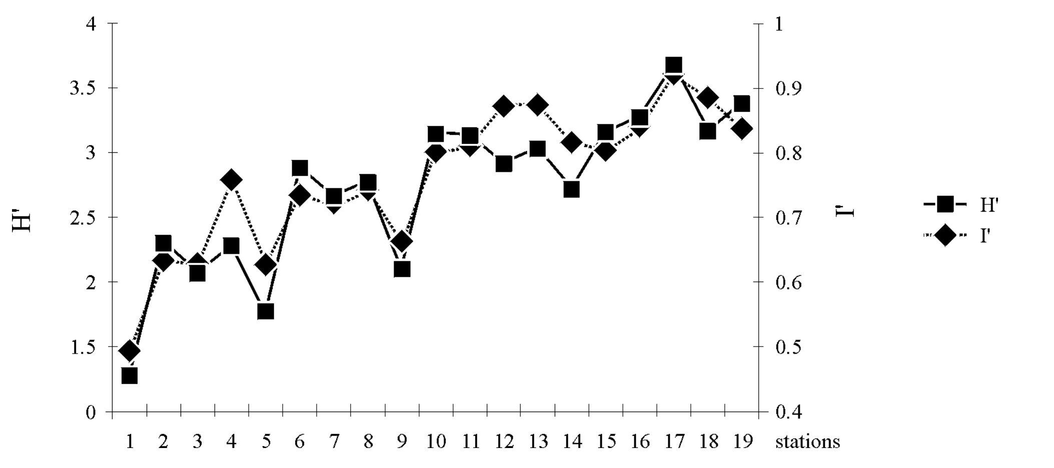

Figure 8. Indices of evenness (I') and diversity (H') of 0+ fish communities in the Neris River and Middle Nemunas

of communities, and it is natural that the index of the variety of species (H') characterizing communities and the index of the evenness of distribution of species (I') depend upon biotopes and pollution. Although H' and I' indices positively correlate with the evaluation of biotopes in grades and negatively with BOD_7, the coefficients of correlation are quite small and statistically unreliable, but the influence of pollution upon H' and I' indices can be founded indirectly. The index of the specific variety reliably positively correlates with the share of reophilous fish species ($R = 0.58$, $P < 0.01$) and negatively with the share of reolimnophilous fish species in fish communities ($R = 0.61$, $P < 0.01$). Therefore, the share of reophilous and reolimnophilous fish species influence H' and I' values in communities and depend on BOD_7 and a biotope.

While having summarized the data and results, we may assert that the worst ecological situation of 0+ fish in the Neris River is at the border of Lithuania-Belarus (station 1) and below Vilnius near Grigiškės (station 5). At these stations, the variety of fish species is poor, reolimnophilous fish species make over 80% in fish communities, and ecological indices of fish communities (H' and I') are much lower than in other stations (Fig. 8). The ecological state of 0+ fish in the Middle Nemunas is much worse than in the Neris River. It is a bit better below the mouth of the Merkys River (station 15) and above Alytus (station 16).

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Nemuno vidurupio ir Neries upės priekrantės 0+ amžiaus žuvų bendrijų ekologinė charakteristika

S. Stakėnas

Santrauka

Žuvų šiųmetukų bendrijos kaip geras gyvenamosios aplinkos ir didelių upių sistemų ekologinio vientisumo indikatorius yra vertingas ekologinio upės statuso indikatorius. Žinios apie 0+ žuvų bendrijų ekologiją svarbios upių ekosistemų apsaugos ir renovacijos programoms. Nepaisant to, Lietuvos upių, žuvų šiųmetukų bendrijų tyrimų dar nebuvo. Stengiantis bent dalinai užpildyti šią spragą nustatyti Nemuno vidurupio ir Neries upių priekrančių žuvų šiųmetukų bendrijų kiekybinių ir kokybinių parametrų kitimai priklausomai nuo aplinkos veiksnių, įvertinti žuvų šiųmetukų tarpusavio ryšiai bendrijose.

Nemuno vidurupyje sugauta 20 rūšių 5243 žuvų šiųmetukai. Bendrijose vyravo paprastoji aukšlė, kuoja, rainė, srovinė aukšlė, šapalas, kartuolė ir strepetys. Neries upėje sugauti 22 rūšių 6226 žuvų šiųmetukai, vyravo kuoja, strepetys, paprastoji aukšlė, šapalas, gružlys, srovinė aukšlė ir ūsorius.

Lyginant rūšių tankio dispersijos indekso ir tankio vidurkius galima teigti, kad Neryje litofilams, litofilams-fitofilams ir psamofilams ekologinės sąlygos tinkamos. Nemuno vidurupyje litofilai-fitofilai ir psamofilai nejaučia tinkamų biotopų stygiaus, tačiau litofilinės žuvys gana stipriai veikiamos aplinkos veiksnių, o jautresnės eliminuojamos (ūsorius). Zooplanktono biomasės ir šiųmetukų tankio koreliacija ($R^2 = 0,667$), patvirtina 0+ žuvų maisto kiekio svarbą nulemiant vystymosi zonos tinkamumą. Nustatyta organinio upių užterštumo įtaka žuvų šiųmetukų bendrijoms – didėjant užterštumui mažėja reofilų ir didėja reolimnofilų procentinė dalis; užterštumas ir debitas lemia šiųmetukų rūšių skaičių. Panaši tendencija, kai didėjant biotopo eutrofizacijai mažėja reofilų ir didėja reolimnofilų procentinė dalis, leidžia nubrėžti priežastinius ryšius tarp užterštumo, biotopų degradacijos ir bendrijų struktūros. Geriausiai koreliuojantys su užterštumu ir biotopų eutrofizacija kuojos ir ūsoriaus šiųmetukų dalis bendrijose yra vertingas ekologinio upės statuso indikatorius.

Apibendrinus duomenis ir rezultatus galima teigti, kad Neries upėje žuvų šiųmetukų bendrijoms blogiausia ekologinė situacija yra ties Lietuvos – Baltarusijos siena, bei žemiau Vilniaus ties Grigiškėmis. Šiose stotyse rūšių įvairovė skurdi, bendrijose reolimnofilai sudaro virš 80 %, žymiai mažesni nei kitose stotyse ekologiniai bendrijų indeksai (H’ ir I’). Nemuno vidurupio žuvų šiųmetukų bendrijų ekologinė būklė gerokai prastesnė nei Neries upės, kiek geresnė būklė žemiau Merkio žiočių ir aukščiau Alytaus.