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RESEARCH ARTICLE

Seasonal dynamics of biotic indices in uncontaminated sites of Breksa River (South-Western Altai)

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River macroinvertebrate communities are distinguished by significant seasonal and interannual dynamics associated with variability of biotic and abiotic factors of their formation. Seasonal changes in composition and structure of bottom communities can have a significant impact on bioindication results because just these indicators are used in calculations of most biotic indices. The purpose of the study is to evaluate seasonal variability of biotic indices in the background section of Breksa River. In 2006–2009, macroinvertebrates were collected every month from April to October. To assess seasonal variability, we calculated biotic indices, which are most commonly used in ecological monitoring of rivers in different countries, i.e. the biotic index of Trent River, the Biological Monitoring Working Party Index (BMWP), Average Score Per Taxon Index (ASPT), the number of stoneflies, mayflies and caddisflies species (EPT), as well as the species richness and the Shannon diversity index. The maximum variability in the uncontaminated area of Breksa River falls on species richness indices, whereas the minimum one – on ASPT and TBI, which can be considered as priority indicators of habitat quality.
Keywords: bioindication; macroinvertebrates; seasonal dynamics; biotic indices; reference site

Introduction

The South-Western Altai is among the regions distinguished by high anthropogenic load (Olivier et al., 2006). Long-term operation of mining and metallurgical enterprises has led to degradation of its natural landscapes and pollution of water bodies (Bayandinova et al., 2017). To ensure the control over pollution and the conservation of aquatic ecosystems in the region, the program for the environmental monitoring of water bodies is needed. It is generally recognized that a macroinvertebrates-based bioindication is an important part of the environmental monitoring of mountain rivers (Bonada et al., 2006). Macroinvertebrates are characterized by a wide range of sensitivity to changes in the environmental conditions and have long life cycles (Bonada et al., 2006; Morse et al., 2007; Tipping et al., 2009). Biotic indices developed on the basis of structural characteristics of macroinvertebrates are used in the environmental monitoring of rivers in many countries.

Despite the widespread use of biotic indices for assessing the environmental transformation, seasonal dynamics of these indicators is one of the least studied issues (Sporka et al., 2006). A serious methodological problem in assessing the quality of running water with the use of macroinvertebrate community structure is the choice of indices minimally dependent on seasonal variability of their structural features. Of particular importance is the study of seasonal dynamics of indicators in the sites free from anthropogenic impact because it allows to identify natural variability of bottom communities and to set background values of the chosen indicators. The purpose of the study is to evaluate seasonal variability of biotic indices in the background section of Breksa River, and to develop the recommendations on their use when assessing the ecological state of rivers in the region.

Materials & methods

The study area lies in the mountain watercourses of the Ulba basin (the South-Western Altai). The South-Western Altai occupies the right bank of Irtysh River and comprises a system of mountain chains with separating ridges located at a height of 2,000-2,500 m above sea level. The peculiarity of the South-Western Altai relief structure is presented by intermontane troughs (Leninogorskaya, Zyryanovkaya, Katon-Karagayskaya, Narym-Bukhtarminskaya) filled with soft sediments of various thickiness that have undulating-morainic topography and folded by ancient glacial sediments. The studied river is located within the Leninogorskaya intermontane trough. The Breksa is typically mountain and featured by heavy spring floods induced by snowfield melting in the mountains. Breksa River is 21 km long with the water catchment area of 150 km^2. This small river of the South-Western Altai flows in East Kazakhstan Oblast'.

In 2006–2009, macroinvertebrates were collected every month from April to October. Quantitative samples of zoobenthos were taken by means of a hydrobiological scraper with the 18 cm cutting edge. In each sampling point, fivefold sampling was made from the ground surface of a 1 m strip; the catch area was 0.9 m^2. The samples were washed in a 250x250-μm hand net. Macroinvertebrates were selected in the Petri dish using a binocular and fixed in 4% formalin. In the lab, invertebrates were identified and weighted with the use of the analytical electronic balance ALJ 220-4 with readability of 0.1 mg. A total of 28 quantitative samples were collected.

To assess seasonal variability, we calculated biotic indices, which are most commonly used in ecological monitoring of rivers in different countries, i.e. the biotic index of Trent River (index Woodiwiss TBI), the Biological Monitoring Working Party Index (BMWP), Average Score Per Taxon Index (ASPT), the number of stoneflies, mayflies and caddisflies species (EPT), as well as the species richness and the Shannon diversity index (Semenchenko, 2004). Statistical analysis was performed in Statistica 6.0. The nonparametric Kruskal-Wallis (H) test was used to assess the statistical significance of differences, which were considered to be significant at $p < 0.05$.

Results and discussion

The benthic communities of Breksa River were characterized by a relatively high species richness. During the research period, 107 of macroinvertebrate species were found. The number of species was hardly seasonal and generally ranged within 15-25 species. The only exception fell on April and September–October, 2006 when species richness was the least for the whole period of investigations. The variability of species richness of zoobenthos was significantly less than that of abundance and biomass: the constant of variation of species richness in the background area did not exceed 52%, number and biomass - 93% and 110%, respectively (Table 1). Species composition is more stable in comparison with number and biomass. As compared with species abundance, seasonal changes in number and biomass were higher also in the Ob basin rivers- different in size, hydrological regime and location (Yanygina, 2017).

Table 1. Arithmetic mean values (M) and coefficients of biotic indices variations (V, %) for Breksa River upper city Ridder in 2006-2009

Indicator	2006 (n=7)		2007 (n=7)		2008 (n=7)		2009 (n=7)	
	M±SD	V, %	M±SD	V, %	M±SD	V, %	M±SD	V, %
ASPT	7.1±0.6	8.1	7.3±0.9	12.9	6.9±0.7	9.6	7.1±0.3	4.3
BMWP	104.3±56.2	53.9	107.9±10.5	9.7	159.0±25.3	15.9	154.6±15.0	9.7
TBI	8.9±1.2	13.7	9.3±0.5	5.3	9.7±0.5	5.0	10.0±0.0	0.0
H	2.6±0.7	26.8	2.7±0.8	31.1	3.3±0.5	14.0	2.8±0.5	17.9
EPT	10.0±5.8	58.0	10.3±1.4	13.4	14.3±3.7	25.8	14.0±1.5	10.7
S	14.6±7.6	52.1	14.7±1.0	6.5	23.1±3.1	13.5	22±2.6	11.7

Zoobenthos number and biomass in the background section of the Breksa showed essential variability. For instance, the constant of within-year variation in number reached 93%, biomass -110%. During the study season, two peaks in number drop were recorded, i.e. in April or May (in different years) and August or September. Despite the changes in seasonal dynamics of zoobenthos in different years, annual differences in zoobenthos number were statistically insignificant (the Kruskal-Wallis test H=3,58, p=0,31). After decrease in April-May, zoobenthos biomass was restored only by the end of summer reaching its maximum mainly in August (September, 2008). In autumn (in some years - in September or October), the second minimum of biomass was noted. Relatively high values of zoobenthos biomass in April 2008 and 2009 were most likely related with the pre-flood sampling. The increase in number and biomass of macroinvertebrates with the onset of the free-ice period and before a flood peak was also marked in rivers of the South-Eastern Altai (Yanygina, 2014). The decrease in number and biomass of zoobenthos in spring was probably due to flood occurrence in this period. In addition, the appearance of imago of relatively large size and large body weight happened that could also lead to extra biomass drop.

In general, average zoobenthos biomass for the analyzed period (2006-2009) was 4.6±1.9 g/m^2. It corresponds to the "moderate" class of productivity and characterizes this river section as alpha-mesotrophic (by the Kitaev scale).

Seasonal dynamics of biotic indices. During the study period, BMWP varied widely from 27 to 202 (Fig. 1). According to the data averaged over different years, the minimum values of the index were observed in October (111.5±40.4), whereas the maximum – in May (147.8±27.0). By and large seasonal dynamics of the BMWP index correlated with that of species number (Fig. 1).

Seasonal dynamics of the ASPT index was less pronounced; its values varied from 5.9 to 8.5 during the study period. In different years, it showed similar trends, i.e. its maximum occurred mainly in May (April 2009), while its minimum– in August–

September. The average values of this index differed insignificantly in various years (the Kruskal-Wallis criterion H=0.70, p=0.87).
Seasonal dynamics of the Woodiwiss biotic index (TBI) was the least pronounced; during the observation period, the index fluctuated mainly within the range of 9-10 points and to 7-8 points solely in 2006. Such a low variability of TBI is probably due to the relatively high diversity of stoneflies and mayflies in this area. Even in the period of certain species appearance, other species are constantly present in the community thus maintaining high index values throughout the year.

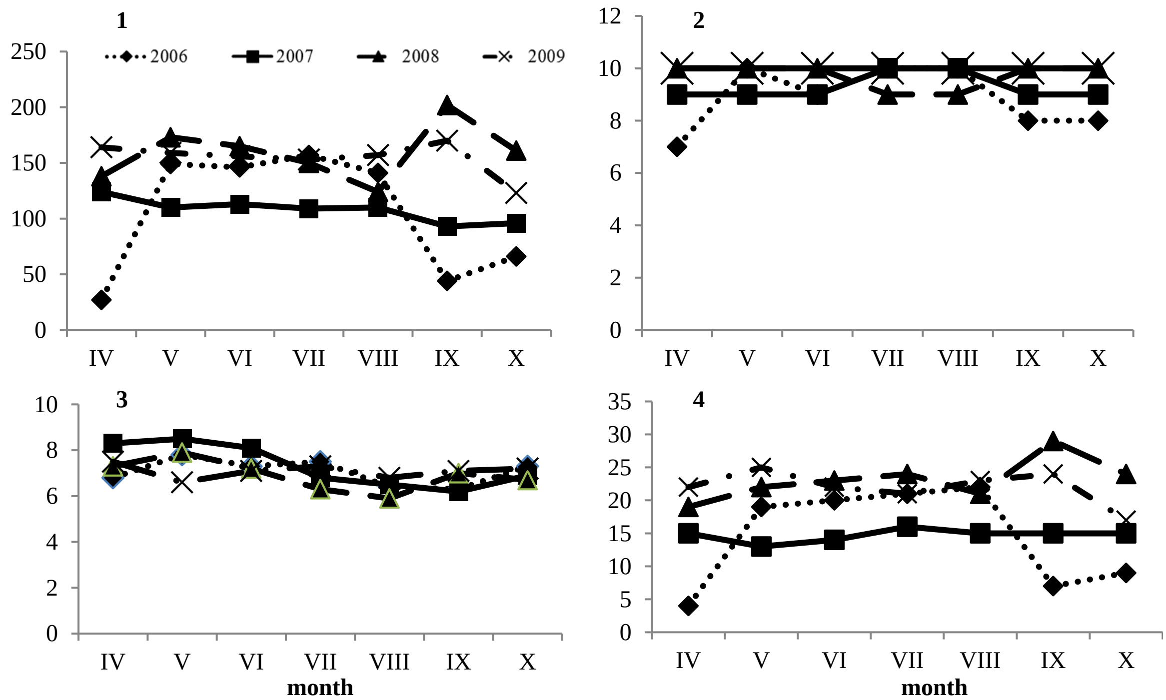

Figure1. Seasonal dynamics of BMWP (1), TBI (2), ASPT (3) and species richness (4) in Breksa River upper city Ridder (2006-2009)

River macroinvertebrate communities are distinguished by significant seasonal and interannual dynamics associated with variability of biotic and abiotic factors of their formation. Seasonality of life cycles in hydrobionts, various overgrowth of reservoirs by higher plants and algae fouling are major biotic factors of annual dynamics of bottom communities. The predominance of amphibiotic insects in benthic communities is typical for mountain streams of the Ulba basin. It is known that the appearance of adult amphibiotic insects is accompanied by the reduction in species richness, abundance and biomass of zoobenthos being a decisive factor in dynamics of benthic communities. Mountain rivers overgrowth by macrophytes is usually minor due to the predominance of unsuitable for higher plants rocky soils. Therefore, this factor is of little importance for lithophilic communities.
Among abiotic factors, temperature is critical for macrozoobenthos seasonal dynamics (Soulsby et al., 2001). On the one hand, it affects the duration of individual phases of life cycles of aquatic organisms (including dates of amphibiont appearance), on the other – it determines the peculiarities of hydrological regime of rivers. The temperature regime of mountain streams of different geographical location is determined by the balance of incoming heat (Sokolov, 1952); it depends on the climate in the area, the type of rivers alimentation, including the altitude of their catchments. The change in hydrological characteristics (i.e. flow velocity, water level, floodplain inundation area, the source of river alimentation, the nature of floods, stability of a low-period) influence greatly on seasonal dynamics of macroinvertebrate communities in streams of temperate latitudes (Yanygina, 2014). The hydrological regime of Ulba River is characterized by prolonged spring and summer floods with sharp rise in water levels and discharges started in April and lasted for 2-3 months.
Seasonal changes in composition and structure of bottom communities can have a significant impact on bioindication results because just these indicators are used in calculations of most biotic indices. The studies carried out in rivers in various world regions are evidence of considerable seasonal variability of some bioindication indices (Marchant, 1982; Doledec, 1989; Moretti, Callistoi, 2005; Sporka et al., 2006; Joshi et al., 2007; Wenn, 2008; Leunda et al., 2009; Álvarez-Cabria et al. 2010).
In our studies, variability of all biotic indices was lower than that of zoobenthos abundance and biomass. The greatest variability among biological indicators used in the assessment of ecological state of watercourses was noted for indices EPT (up to 58%), BMWP (up to 54%) and species richness (up to 52%) (Table.). The same indices also varied greatly in studies of other rivers of the Ob basin (Yanygina, 2014), Stupavsky Potok River (Sporka et al., 2006) and Taranaki River (Stark, Phillips, 2009). All these indicators are primitive and calculated as the sum of taxa number or as the sum of taxa tolerance values. ASPT is derived from BMWP and number of detected indicator taxa; this index was the least variable. Low variability is also noted for TBI.
Strong variability in number and biomass of zoobenthos in the background areas of the basin can induce variability of background biological indicators of water quality and thus cause errors in the hydrobiological indicators-based assessment of

ecological state of rivers. The analysis of seasonal dynamics of biotic indices at the background sites is necessary both for the selection of biological indicators (least exposed to natural variability) and for the identification of the most favorable period to be selected for the specimen collection.
Despite the importance of seasonal variability of biotic indices used for the improvement of bioindication accuracy, only few special studies have been performed (Sporka et al., 2006). The recommendations on choosing the sampling date during the period of maximum invertebrate diversity and with minimal effort are made intuitively. There are numerous criteria for selecting the sampling date, e.g. the maximum development of the flora and the fauna (June–September) (Manual..., 1983), the period of minimal appearance of amphibious insects (spring or early autumn) (Chesnokova, 2007), the maximum diversity of invertebrates (mid-June to late October) (DeShon, 1995) and the minimum water runoff (Barbour, 1999). Such recommendations often contradict one another and the available in situ data on the Ulba river basin. For instance, recommendations on making sampling in June, as the period of the maximum fauna development (Manual, 1983; DeShon, 1995), are not suitable for the rivers of the Ulba basin because of little number and biomass of zoobenthos; it contradicts the criterion of selection of the minimum runoff dates (Barbour, 1999) due to flood occurrence in this period.
It is obvious that the choice of the most optimal sampling period is specific for each region. For example, in the mountain rivers of the Far East it is recommended to sample zoobenthos from spring (after ice meltdown) to late autumn (Manual, 1983), in the rivers of state Indiana - from June to mid-November, in Ohio - from June 15 to September 30 (Biological Criteria, 2015), in the rivers of Slovakia - in early spring and autumn (Sporka et al., 2006), in new Zealand - in spring and winter (Stark, Phillips, 2009). For the rivers of the Ulba basin, such studies have not been conducted before. Our analysis results suggest perform the macroinvertebrates-based bioindication for Breksa River in April-May. This period is characterized by the maximum level of macroinvertebrate biomass and biotic indices values.

Conclusion

The benthic communities of Breksa River were characterized by a relatively high species richness. Zoobenthos abudance, biomass, species richness and BMWP index in the background section of the Breksa showed essential seasonal variability. Among the biological indicators used for the assessment of ecological state of watercourses, the minimum variability in the uncontaminated area of Breksa River falls on ASPT and TBI, which can be considered as priority indicators of habitat quality. The maximum level of macroinvertebrate biomass and biotic indices values in April-May were noted. This period is recommended to perform the macroinvertebrates-based bioindication for Breksa River.

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