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Ichthyological integral indices, the history of development and possible application on rivers in Serbia

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***Abstract*:**
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Based on a literature review, the different approaches in the water quality assessment using fish communities in freshwaters are summarized. Fish assemblage indicators, developed throughout the world, were reviewed and the main differences in methodologies, number of metrics and values are summarized. We have drawn attention to the methods used for designing a fish-based index with a particular focus on original developments in North America and its adaptations in many different regions and habitat types. The main obstacles for ecological assessment are scarce ecological information and the problem with the classification. The lack of knowledge is especially true for species assemblages in the relatively unexplored river basins of Europe, e.g. The Balkans peninsular.

Key words: biotic indices, fish, multimetric approach, water quality assessment

Introduction

Monitoring the ecological status of aquatic systems is in use by water resource managers worldwide. Historically, aquatic systems were assessed primarily through chemical measuring, providing a snapshot of water quality conditions. The anthropogenic capacity to alter the natural world usually overcomes our ability to assess the impacts of these alterations on the biological inhabitants within the water ecosystems (Simon, 1999).

Fish are an unavoidable element for such assessments because of their biological and socioeconomic status. Fish are considered as a reliable indicators in water quality assessment for various reasons: fish are present in most surface waters; the identification of species is relatively easy; the sensitivity to disturbance is well known for many species; as well as their responses to environmental stressors; different species represent distinct trophic levels; fish occupy a variety of habitats in rivers; diminished growth and recruitment are easily assessed and reflect exposure to stress (FAME CONSORTIUM, 2004). However, there are a few disadvantages: manpower needs - a three person crew is required to effectively and safely sample fish communities; migration of fish may provide misleading data; overlapping the effects of overfishing with pollution effects may lead to erroneous conclusions (Grabarkiewicz & Davis, 2008; Simić & Simić, 2009)

Various fish-based indices have been developed worldwide for assessing the ecological status of rivers. Most of them include a reference condition approach and appropriate biological variables or metrics (Noble & Cows, 2007; Roset et al., 2007), describing the fish assemblage attributes and quantifying the impact of anthropogenic activities on the biota.

The Index of Biotic Integrity (IBI) was initially developed by Dr. James Karr for the purpose of evaluating and describing the condition of small warm water streams in central Illinois and Indiana (Karr, 1981). As the IBI became widely used, different versions were developed for different regions and ecosystems. New versions, generally, retained most of the original metrics but the some of them have been modified for application in a particular region or type of stream.

The aim of this paper is to compare different approaches for assessing the ecological condition using fish communities. Likewise, we want to propose the most applicable metrics for rivers in Serbia.

Material and methods

The comparison was made between different methods used for designing a fish-based index according to a literature review from a period 1981-2009. The different approaches, used in North America, according to Karr (1981), Leonard & Orth (1986), Moyle et al. (1986), Hughes & Gammon (1987), Miller et al. (1988), Steedman (1988), Simon (1991), Lyons (1992), Simon & Lyons (1995), Lyons et al. (1996), Overton (2001), Teels et al. (2004), Barbour et al. (2002), Niemela & Feist (2000), were described. In addition, different modifications of IBI applied for water quality assessment in Europe (Belliard et al., 1999; Breine et al., 2004; Angermeier & Davideanu, 2004; FAME CONSORTIUM, 2004; Lenhardt et al., 2009) were compared.

The original version had 12 metrics that refer to fish species richness and composition, number and abundance of species, trophic organization and function, reproductive behavior, fish abundance, and condition of individual fish (**Tab. 1**). Karr (1981) proposed a rating system for each metric based upon the degree of deviation (5 (none to slight), 3 (moderately) and 1 (significantly)) from the appropriate ecoregional reference conditions. The metrics were scored and summed to arrive at an index ranging from 60 (best) to 12 (worst). Metrics, which are defined in original version of IBI (Karr, 1981) and envisaged for Illinois area, have been changed for application in many different regions worldwide. In every other version (Karr, 1981; Leonard & Orth, 1986; Moyle et al., 1986; Hughes & Gammon, 1987; Miller et al., 1988; Steedman, 1988; Simon, 1991; Lyons, 1992; Simon & Lyons, 1995; Lyons et al., 1996; Overton, 2001; Teels et al., 2004; Barbour et. al., 2002; Niemela & Feist, 2000), list of metrics has been modified according to features of target region (**Tab. 1**). Some of them are commonly used such as: total number of fish species, % individuals as omnivores, % individuals with anomalies; but most of them was adjusted according to assemblage of investigated area (Noble & Cows, 2007).

Results and discussion

According to the metrics from the list above and its variations, it can be concluded that each of them assess the same aspect of functional community but in a different way. Before making a choice which metrics are more appropriate, it should be drawn attention to their applicability in the investigated area. The potential metrics have to be changed in a predictive manner according to anthropogenic influence. Likewise, they have to be sensitive to stressors and to provide the response that can be discriminated from natural variation (Noble et al., 2007).

The utilization of the fish-based indices in Europe is less widespread than in the United States of America. Recently, scientists in France, Belgium and Romania have endeavored to adjust IBI for usage in their own countries (Vidal, 2008). Belliard et al. (1999) have suggested 10 metrics for water quality assessment in France, applying them on the Seine River. In Belgium, from the total of 28 candidate metrics, nine had been selected (Breine et al., 2004). In Romania, Angermeier & Davideanu (2004) made distinction between hilly and montane region, and have chosen 7 metrics for each region to include in preliminary multimetric indices (PMIs).

Karr's (1981) original IBI was also adapted in Serbia. This version related to lentic system, analyzed changes in the fish assemblage compared to sediment deposition in the reservoir. It contains 10 suitable metrics (Lenhardt et al., 2009).

In each of these four versions, scoring system was used but with different scores applied. Belliard et al. (1999) kept the original scoring system (Karr, 1981) using score values: 5, 3, 1 for slightly, moderately and the most impacted, respectively. In the second case, IBI score of an investigated site is the mean of scores for all metrics, and varies between 0 and 5. In dependence of the final IBI score, a given site will be classified in an appropriate water class according to Water Framework Directive (Breine et al., 2004). Values for metric scoring classes in Romania were assigned for each metric at each site as 3, 2, 1 for

Table 1. Metrics of the original IBI and other versions used for designing IBI in different regions

Category	Metrics of the original IBI (Karr, 1981)	Version of metrics used in different regions
Species richness	Total number of species	1. Total number of native species (Karr et al., 1986, Leonard & Orth, 1986, Moyle et al., 1986), Hughes & Gammon, 1987, Miller et al., 1988, Steedman, 1988, Simon, 1991, Lyons, 1992, Simon & Lyons, 1995, Lyons et al., 1996, Teels et al., 2004) 2. Salmonid age classes (Moyle et al., 1986, Hughes & Gammon, 1987)
Species composition	Number of darter species	1. Number of darter and ***sculpin species (***Steedman, 1988) 2. Number of sculpin species (Hughes & Gammon, 1987) 3. Number of benthic species (Karr et al., 1986, Leonard & Orth, 1986, Moyle et al., 1986, Hughes & Gammon, 1987, Miller et al., 1988, Steedman, 1988, Simon, 1991, Lyons, 1992, Simon & Lyons, 1995, Lyons et al., 1996) 4. Number of darter species, excluding tolerant species (Gatz & Harig, 1993)
	Number of sunfish species	1. Number of sunfish species, including genus Micropterus (Karr et al., 1986, Simon, 1991, Hoefs and Boyle, 1992, Lyons, 1992) 2. Number of cyprinid species (Hoefs and Boyle, 1992) 3. Number of sunfish and trout species (Steedman, 1988) 4. Number of water column species (Miller et al., 1988, Oberdorff & Hughes, 1992) 5. Number of headwater species (Simon, 1991)
	Number of sucker species	1. Number of sucker and cyprinid species (Hoefs and Boyle, 1992) 2. Number of sucker and catfish species (Steedman, 1988) 3. Number of minnow species (Hughes & Gammon, 1987, Simon, 1991, Hoefs and Boyle, 1992)
Tolerance guilds	Number of intolerant species	1. Number of amphibian species (Moyle et al., 1986) 2. % Individuals as brook trout (Langdon, 1989) 3. Number of trout species (Moyle et al., 1986, Simon, 1991) 4. Number of sensitive species (Karr et al., 1986, Leonard & Orth, 1986, Moyle et al., 1986), Hughes & Gammon, 1987, Miller et al., 1988, Steedman, 1988, Simon, 1991, Lyons, 1992, Simon & Lyons, 1995, Lyons et al., 1996)
	% Individuals as green sunfish	1. % Individuals as common carp (Hughes & Gammon, 1987) 2. % Tolerant species (Karr et al., 1986, Leonard & Orth ,1986, Moyle et al., 1986), Hughes & Gammon, 1987, Miller et al., 1988, Steedman, 1988, Simon, 1991, Lyons, 1992, Simon & Lyons, 1995, Lyons et al., 1996) 3. % Introduced species (Hughes & Gammon, 1987) 4. % Individuals as common roach (Oberdorff & Hughes, 1992)
Trophic guilds	% Individuals as omnivores	1. % Individuals as omnivores and herbivores (Overton, 2001) 2. % Individuals as generalists (Karr et al., 1986, Leonard & Orth, 1986, Moyle et al., 1986), Hughes & Gammon, 1987, Miller et al., 1988, Steedman, 1988, Simon, 1991, Lyons, 1992, Simon & Lyons, 1995, Lyons et al., 1996)
	% Individuals as insectivorous cyprinids	1. % Individuals as insectivorous (Hughes and Gammon, 1987, Simon, 1991, Miller et al., 1988, Lyons, 1992, Hoefs and Boyle, 1992, Oberdorff and Hughes, 1992) 2. % Specialized insectivores (Leonard & Orth ,1986) 3. % Individuals as benthic insectivorous (Teels et al., 2004)
	% Individuals as piscivorous	1. % Catchable salmonids Karr et al., 1986, Leonard & Orth ,1986, Moyle et al., 1986), Hughes & Gammon, 1987, Miller et al., 1988, Steedman, 1988, Simon, 1991, Lyons, 1992, Simon & Lyons, 1995, Lyons et al., 1996) 2. % Pioneering species (Karr et al., 1986, Leonard & Orth ,1986, Moyle et al., 1986), Hughes & Gammon, 1987, Miller et al., 1988, Steedman, 1988, Simon, 1991, Lyons, 1992, Simon & Lyons, 1995, Lyons et al., 1996)

Abundance	Number of individuals	1. Density of individuals (Karr et al., 1986, Leonard & Orth ,1986, Moyle et al., 1986), Hughes & Gammon, 1987, Miller et al., 1988, Steedman, 1988, Simon, 1991, Lyons, 1992, Simon & Lyons, 1995, Lyons et al., 1996) 2. Biomass of fish (Hughes and Gammon, 1987)
Reproduction and condition	% Individuals as hybrids	1. % introduced species (Karr et al., 1986, Leonard & Orth ,1986, Moyle et al., 1986), Hughes & Gammon, 1987, Miller et al., 1988, Steedman, 1988, Simon, 1991, Lyons, 1992, Simon & Lyons, 1995, Lyons et al., 1996) 2. % simple lithophils (Simon, 1991, Lyons, 1992, Hoefs and Boyle, 1992) 3. Number of late maturing species (Teels et al., 2004) 4. Percentage of species with multiple age groups (NCDEHNR, 1997)
	% Individuals with anomalies	1. Percent of individuals with heavy infestation of cysts of the parasite Neascus (Steedman, 1988)

slightly, moderately and the most impacted, respectively (Angermeier & Davideanu, 2004). Finally, in Serbia, for each metric, data were sorted into quartiles, according to Long & Walker (2005). A site had score of 1 where the observed value for the metric fell below the first quartile threshold. A score of 5 was attributed to those sites for which the observation occurred above the fourth quartile. Sites with the observation values falling within the second and third quartiles scored 3.

European fish index (EFI) has been developed as a result of European Union project, named FAME (Development, Evaluation and Implementation of the Standardized Fish-based Assessment Method for the Ecological Status of European Rivers). Generally, EFI is based on a predictive model that derives reference condition for the each site and quantifies the deviation between predicted and observed condition of the fish fauna (FAME CONSORTIUM, 2004). EFI employs 10 metrics (Table II.) and their response to human pressures has been already known. Theoretical values are predicted for each metric using environmental variables by means of a multilinear regression model. In order to quantify a level of degradation, the residuals, calculated as difference between observed and predicted metric values, are used. The ecological status is expressed as an index ranging from 1 (high ecological status) to 0 (bad ecological status).

It has been recommended that EFI should not be applied in areas where a fish fauna significantly deviates from those of the tested regions e.g. rivers of the south-eastern part of Europe (FAME CONSORTIUM, 2004).

In order to adjust IBI for application on rivers in Serbia, a great amount of ecological information is required for each species, which is the base for their classification in ecological guilds. The election of metrics is essential to make IBI strong enough to represent the condition of the river ecosystems in Serbia. We have suggested the preliminary list of metrics (Table III.) which can be potentially used in Serbia.

The total number of species represents a reliable indicator of the target population condition. Healthy ecosystem contains a great number of species (Karr et al., 1986). However, invasive and introduced species should be considered as a separate metric, because of their negative influence on the status of natural populations. According to Fame (FAME CONSORTIUM, 2004), metrics, which refer to tolerance guilds, are represented as a number of intolerant species and a number of tolerant species. In addition, FAME proposed to employ metrics related to reproductive requirements: relative abundance of lithophilic species and density of the phytophilic species. The evaluation of these characteristics is based on the fact that the increase of habitat degradation reduces the possibility of finding a specific substrate for spawning. The percentage of species with multiple age groups simultaneously may assess suitability of habitat conditions for reproduction and the degree of reproductive success.

From the parameters related to the assessment of trophic structure, the percentage of: omnivorous individuals; specialized insectivores; obligate piscivores can be applied as the appropriate metrics. This recommendation can made a difference between species specialized for the certain type of food from those within a wide spectrum.

Each species has its own specific requirements according to the habitat type (reophilic, limnophilic and euritop). According to Karr (1981), species are divided in two groups: the species which lives nearby the bottom and the species which lives in the water column (Percidae, Centrarchidae, respectively). This kind of division,

Table 2. Metrics used by European fish index (EFI) and their response to anthropogenic influence

Selected metrics	Response to anthropogenic influence
1. Density of the insectivorous species	Decrease
2. Density of the omnivorous species	Increase
3. Density of the phytophilic species	Increase
4. Relative abundance of lithophilic species	Decrease
5. Number of benthic species	Decrease
6. Number of rheophilic species	Decrease
7. Relative number of intolerant species	Decrease
8. Relative number of tolerant species	Increase
9. Number of species migrating over long distances	Decrease
10. Number of potamodromous species	Decrease

Table 3. Preliminary list of metrics for application on rivers in Serbia

Selected metrics	Response to anthropogenic influence
1. Total number of native species	Decrease
2. Total number of alien species	Increase
3. Number of intolerant species	Decrease
4. Number of tolerant species	Increase
5. % Individuals as omnivores	Increase
6. % Individuals as specialized insectivorous	Decrease
7. % Individuals as obligate ***piscivorous***	Decrease
8. Number of rheophilic species	Decrease
9. Number of euritop species	Increase
10. Percentage of species with multiple age groups	Decrease
11. % Individuals with anomalies	Increase

beside habitat type, takes trophic requirements into account and introduces the problem of stratification in shallow waters. Therefore, it would be recommented more suitable metrics such as: number of rheophilic species (specialized of habitat type), and number of euritop species (tolerant of habitat type). Metrics related to migration guilds are not acceptable for applying on rivers in Serbia, because there are very few species which can be classified as diadromous (Acipenseridae and Clupeidae). The total number of individuals, as a rule, should be reduced with increasing the environmental degradation. In some instances, although the environmental conditions are degraded, the number of individuals increase in term of abundance. Increased abundance of individual species is an outcome of their tolerance to the changes in the environment. Percentage of diseased fish, the presence of tumors and other abnormalities, in most cases has low value or it is absent, but may have a great importance for identifying areas with high concentration of toxic substances.

Conclusion

Classification of fish into ecological guilds is a prerequisite for the development of an IBI. Regional modifications of IBI are based on a different metrics which are employed. Choice of metrics requires the great ecological knowledge of the local fish population. The chosen list of metrics should be suitable for the target fish assemblage and strong enough to detect changes in functioning community. Formulation of an index, such as Index of Biotic Integrity in Serbia, based on fish assemblages, and its affiliation to the already existing Balkan Biotic Index (Simic & Simic, 1999), based on macrozoobenthos, may contribute to the development of a new approach in the environmental condition assessment. Such a comprehensive assessment, including a majority of freshwater biota, may lead to the formulation of an advanced strategy for conservation of ecosystem health.

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