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The utility of two marine community indices to assess the environmental degradation of lotic systems using fish communities

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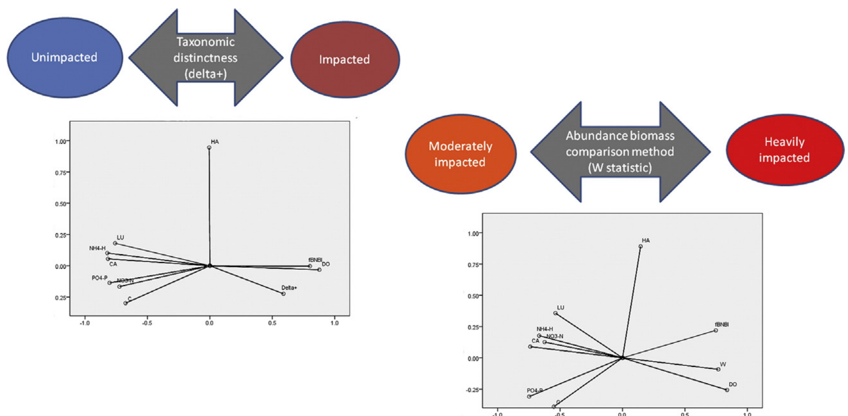
HIGHLIGHTS

- We tested the utility of two marine metrics to detect stress in lotic systems.
- The both tested indices are correlated with water and habitat quality gradients.
- The utility of TDI as a potential metric in bioassessment programs is limited.
- The ABC method could be proposed as a novel metric, but with certain limitations.

GRAPHICAL ABSTRACT



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ABSTRACT

Multimetric approaches are commonly used to evaluate the ecological status of aquatic ecosystems. However, it has been recommended that the sensitivity of existing methods be improved through the investigation of the potential of new metrics to detect environmental disturbances. In this study we tested the effectiveness of two community indices (Taxonomic distinctness index (TDI) and Abundance biomass comparison (ABC) method), primarily proposed for marine ecosystems, to identify sites with different levels of environmental degradation in lotic systems using fish community data. Fish samples were collected over the period 2003–2011 at 131 sampling stations. To generate water and habitat quality classes, a self-organizing map (SOM) based on environmental data was applied. Gradients over the SOM map were investigated for the values of the TDI and ABC indices. The results of this study reveal that the values of both the TDI and ABC indices are highly correlated with water and habitat quality gradients. However, despite the observed correlation, the utility of TDI as a potential metric in bioassessment programs is rather limited, due to its lack of discriminatory power. In contrast, the ABC method could be proposed as a novel metric, but can only be applied in type-specific multimetric approaches.
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1. Introduction

The main goal of water resources management is to restore or maintain the ecological integrity of aquatic systems. Monitoring biotic

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systems offers the most comprehensive indication of the ecological integrity of water bodies. Contrary to chemical measurements, which assume declining water resource conditions to have only been caused by chemical contamination, biological evaluation can diagnose chemical, physical and biological impacts as well as cumulative environmental impacts (Simon, 1999). To this regard, in 2000, the European Water Framework Directive WFD was introduced as the basis for water resources management in European Union countries (Pont et al., 2006). The WDF considers the biological assessment of water quality essential for successful implementation of a monitoring system. More precisely, according to the European WFD, the management of running waters and water quality assessment requires the use of an integrative assessment methodology for evaluating the ecological status of water bodies (EC, 2000). These requirements have frequently been achieved through the use of multimetric techniques. Such methods combine several stressor-specific indices, which are applied to different components of hydrobiocoenosis (Hering et al., 2006). A few of the multimetric indices proposed so far were developed to be applied in an entire region, e.g. Europe (EFI, FAME Consortium, 2004; EFI+, EFI+ Consortium, 2009), while the majority of them have been formulated to be applicable to a particular area or stream type (Angermeier and Davideanu, 2004; Aparicio et al., 2011; Breine et al., 2004; Oberdorff and Hughes, 1992; Stojković et al., 2014). To this regard, Stojković et al. (2014) proposed the first fish biotic index (fBNBI index) to reflect the regional-specificity of Serbian running waters, considering both the bioindicator properties of fish species and selected fish community metrics. However, improving existing methods and conducting research on new and promising metrics are highly recommended. Investigating new metrics involves exploring their potential to improve the existing bioassessments, which would then provide important information regarding the priority areas for restoration.

The potential use of fish guilds as a tool for assessing the ecological integrity of rivers has been well documented in many recent studies (Angermeier and Davideanu, 2004; Belpaire et al., 2000; Breine et al., 2004; Karr, 1981; Karr et al., 1986; Pont et al., 2006; Stojković et al., 2014). In addition, community indices condense information regarding the structure and composition of biota into a single metric, and are frequently used as a tool in monitoring environmental quality and assessing ecosystem sustainability. However, the applicability of some community indices, primarily defined for marine ecosystems, is still questionable when different groups of freshwater biota are used. More precisely, Clark and Warwick (1998) and Warwick (1986) proposed tools (Taxonomic distinctness index (TDI), delta+ and Abundance biomass comparison (ABC) method, W statistic) which used marine macroinvertebrates to diagnose environmental degradation. Both of them have been considered as convenient tools for evaluating environmental degradation in marine environments using fish communities (Hall and Greenstreet, 1998; Henriques et al., 2008; Rogers et al., 1999; Yemane et al., 2005). Many studies conducted by now, investigated the utility of the Taxonomic distinctness index to detect changes in lotic environments. However, those studies are mainly based on macroinvertebrates (Abellan et al., 2006; Heino et al., 2005, 2007; Marchant, 2007; Milošević et al., 2012). In contrast, there is little information on how the Taxonomic distinctness index is applicable to freshwater fish communities. The only attempt to test the usefulness of the TDI on freshwater fish communities so far was that of Bhat and Magurran (2006). However, in this study, the authors aimed to evaluate the utility of the measures of taxonomic diversity using fish community data from the tropical streams of the Western Ghats (India). On the other hand, the ABC method had been successfully applied to freshwater fish communities (Casatti et al., 2006; Coeck et al., 1993; Penczak and Kruk, 1999; Pinto et al., 2006), but with certain limitations regarding the minimum number of species caught in a particular sample (Penczak and Kruk, 1999; Stojković Piperac et al., 2015). However, there is no available data regarding the utility of ABC curves as a novel metric in bioassessment programs, especially for freshwater ecosystems.

Aquatic communities are capable of reacting predictably to different kinds of degradation (Wichert and Rapport, 1998). Among the potential indicators, fish assemblages are considered of particular interest since they are strongly dependent on the water and habitat quality, and they have long been used to quantify the effects of disturbance in the environment (Breine et al., 2004; Ganasan and Hughes, 1998; Hugueny et al., 1996; Karr, 1981; Kruk and Penczak, 2013; Oberdorff and Hughes, 1992; Stojković et al., 2014). Therefore, in this study we aimed 1) to test the variability of the delta+ index and W statistic along the water and habitat quality gradient in temperate regions, 2) to correlate the responses of the TDI and ABC indices with traditional freshwater indices and fBNBI along the quality gradient of lotic systems and 3) to evaluate the utility of the TDI and ABC indices as potential metrics for application in multimetric approaches based on fish community data.

2. Material and methods

2.1. Study area and sampling

In this study, we chose to analyze data from 131 sampling sites situated in central, western and south-eastern Serbia, covering 1/2 of the lotic systems in the country. More precisely, we collected data from 124 sites in two sub-drainages (Great Morava and Drina) of the Danube River basin, as well as 7 sites from streams belonging to the Aegean Sea drainage basin (Fig. 1). The sampling sites were chosen to encompass a wide range of water and habitat alteration, as well as different stream orders. The fish fauna was sampled over the period 2003–2011 during the same season (August–September). The electrofishing procedure was conducted at 131 sampling stations (Fig. 1), out of which 84 were sampled once, 41 twice, 3 three times and 3 four times during the investigated period. Since each sampling occasion was considered as a separate entity in data processing, the final data matrix consisted of 187 samples. Of the total number of samples, three were fishless and consequently excluded from further statistical analysis. The fish fauna was sampled using the Aquatech IG 1300 DC electrofisher (2.6 kW, 80–470 V). One electrofishing run was made in an upstream direction at each sampling site, and in order to obtain relative abundance and relative biomass, sampling was conducted: 1) in the same season (August–September), 2) making runs that were based on two types of unit effort (CPUE) (along 50 m of transect in wadeable streams, and along 200 m when drifting in a boat), 3) in accordance with Beklemishev's rule (Backiel and Penczak, 1989) to determine the minimum river bank length, which allowed us to record the greater part of the species living there and 4) by the same electrofishing crew to avoid any unnecessary influence on fish captures (Benejam et al., 2012). Part of the field campaign was conducted within fisheries management plans (Simić and Simić, 2006a, 2006b).

During the sampling campaign, the parameters defining water and habitat quality were measured for each sample in order to estimate the extent of anthropogenic disturbance. Water quality was expressed in terms of water conductivity (C) and dissolved oxygen (DO), measured by a WTW multi 340i probe, as well as the concentrations of ammonia nitrogen (NH4-H), nitrate nitrogen (NO3-N) and orthophosphates (PO4-P), estimated using the Shimatzu UV–Vis Spectrophotometer. In addition, habitat quality was characterized by three disturbance variables: hydrological alteration (HA), channel alteration (CA) and land use intensity (LU). According to the methodology of Angermeier and Davideanu (2004) and Stojković et al. (2014), each site was given a score of 1, 2, or 3 if slight, moderate, or severe alteration for each habitat disturbance variable was observed.

2.2. Data analysis

The taxonomic distinctness index (TDI) is a measure of diversity that records the phylogenetic relatedness of an assemblage and has already

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