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CURRENT ISSUES IN ECOLOGICAL WATER QUALIFICATION: DEVELOPING MULTIMETRIC MACROINVERTEBRATE INDEX ON LOWLAND, SMALL AND MEDIUM SIZED WATERCOURSES – A CASE STUDY

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AZ ÖKOLÓGIAI VÍZMINŐSÍTÉS AKTUÁLIS KÉRDÉSEI: MULTIMETRIKUS INDEX KIALAKÍTÁSA ÉR JELLEGŰ VÍZFOLYÁSOK ESETÉBEN – ESETTANULMÁNY

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ABSTRACT: The environmental objectives of the European Water Framework Directive (WFD) are to prevent, protect and enhance the status of aquatic ecosystems, explicitly to maintain or achieve the so-called 'good ecological status' for all surface waters by 2015. The macroinvertebrates as one of the key biological elements has an important role on the ecological status of small and medium-sized rivers on the lowland. Although as for the normative definition of the WFD requires such a biological index that takes into account specific aspects of the biological quality elements, such as composition and abundance and has multimetric features, in Hungary in case of macroinvertebrates we are lack of this index. The aim of this study was to develop a multimetric index by following the intercalibration assessment method. In this case study we selected the 16th, 17th and 18th official Hungarian river types, as these are the most common in our region. The resulted index is stressor specific and fulfils all criteria of the WFD and could also be used later in the official intercalibration process.

Key words: macroinvertebrates, multimetric index, EQR, WFD

KIVONAT: A hazánkban is bevezetett Európai Vízkeretirányelv (VKI) célja, olyan intézkedések elősegítése, melyek lehetővé teszik, hogy felszíni vizeink jó ökológiai állapotát megőrizzük, ill. elérjük 2015-re. A vízi makroszkopikus gerinctelenek csoportja a VKI szempontjából kiemelt fontosságú biológiai elem. Habár a VKI normatív definíciója alapján ezt az élőlénycsoportot olyan indexszel kellene minősíteni, amely multimetrikus és például a fajösszetétel és abundancia viszonyok is megjelennek benne, jelenleg nem rendelkezünk ilyen indexszel. A cikk célja az volt hogy a területünkön leggyakrabban előforduló 16-os, 17-es és 18-as folyóvíz típusokba tartozó vizek esetében a VKI interkalibrációs ajánlásai alapján kifejlesszünk egy multimetrikus indexet. Az eredményül kapott index stresszor-specifikus és megfelelő alapot jelent a későbbi interkalibrációs eljárások során is.

Kulcsszavak: makroszkopikus vízi gerinctelenek, multimetrikus index, EQR, vízkeretirányelv (VKI)

Introduction

The European Water Framework Directive (WFD) sets uniform standards in water management in the European Union by the development of integrated and coordinated river basin management plans for all European water bodies (COUNCIL OF THE EUROPEAN UNION 2000). The environmental objectives of the WFD are to prevent further deterioration and to protect and enhance the status of aquatic ecosystems, explicitly to maintain or achieve at least 'good ecological status' for all surface waters by 2015. The determination of the 'ecological status' is based on characterizing reference conditions for water bodies. To describe the biological elements the following attributes have to be considered: composition, abundance, the ratio of disturbance sensitive taxa to insensitive taxa, etc. The WFD enforces a re-orientation of monitoring procedures towards an integrative approach. This paper describes a development of a multimetric index based on macroinvertebrates. Aggregation of metric scores simplifies management and decision making so that a single index value is used to determine whether action is needed. (KARR et al. 1986). No single biological metric can reflect all features required by the normative definitions of the WFD, i.e. taxonomic composition and abundance, disturbance sensitive taxa and presence/absence of major taxonomic groups, diversity). As a consequence, a multimetric approach with qualitative and quantitative data should be used to take into account these various criteria reflecting different environmental conditions and aspects of the community the multimetric assessment (BARBOUR et al. 1992, 1999; KLEMM et al. 2002). Multimetric indices have more advantages than simple single indices, such as diversity indices (FORE et al. 1994), but neither has superior to the other (GERRITSEN 1995). In the United States, Multimetric Indices are frequently used in routine water management (HUGHES et al. 1998; BARBOUR et al. 1999; KARR and CHU 1999)

In this study we try to include all four metrics types such as, Composition/abundance metrics, Richness/diversity metrics, Sensitivity/tolerance metrics and Functional metrics into a multimetric index for describing the ecological quality of the lowland small and medium size river types.

Currently in Hungary we try several single indices such as BMWPhu (JUST et al. 1998) or QBap (SZILÁGYI et al. 2006) or Sapropic index but these are unsuitable from the WFD point of view because they are not fulfils all the required normative definitions and may fall on the intercalibration process which should be finished by 2011. Therefore our work could show a good example of the development and assessment of the multimetric approach.

Methods

Selection of least disturbed sites

Naturally, it was not possible to determine real reference sites for the selected stream types, since the landscape has generally been exploited for centuries and no sound reference conditions were set up by Hungary earlier. Therefore we select sites which were considered as their pollution loads were low. For this purpose we select the BOD parameter which was suggested by the work of HERING et al. (2006). The thresholds values were <2 BOD mg l^{-1} following the reference values of the Hungarian guidelines. Thus we could make two groups LDS (Least disturbed sites) and DS (Disturbed sites).

In this paper we focused on the 16, 17 and 18 official Hungarian WFD types. 87 sampling sites and 125 samples were analysed. We used exclusively the data of the monitoring network of the Environmental Inspectorates, because the assessment and water management plans should also be based on these databases. The sampling, sorting and identification of the samples were based on the AQEM multihabitat sampling method. Samples were pre-selected in the field (to preserve fragile organisms) and transferred to the laboratory where final sorting was done. Samples were preserved in 70% ethanol solution. All chemical analyses were done using international standards (ISO). Prior to the analyses, we have standardised the abundance of each taxa to individuum per square meters. Correlation of stressor gradients and metrics were made by Pearson' product moment correlation. The comparison with the different metrics in the LDS and ND sites was made by Mann-Whitney U Test.

Results

An ideal metric has got low natural variability, provide a response that can be distinguished from natural variation, and is interpretable. A candidate metric's result must show a significant correlation to the stressor gradient. This correlation can be positive or negative, either across the whole stressor gradient or measured for a part. For selection of candidate metrics we calculated approximately 200 different metrics based on the ASTERICS (HERING et al. 2004) program. Technically we join the Hungarian macroinvertebrate database to the AQEM taxalist thus made us possible to calculate the indexes inside the database. At first measures with a narrow range of values or with many outliers and extreme values were excluded by box-plot analysis. The next step was to make a correlation analysis between the biological metrics and the chemical variables. We selected only those metrics that have significant correlation with one of the chemical variables (total suspended solids-TSS, Biological oxygen demand- BOD, Chemical oxygen demand- COD, NH4-N, NO2-N, NO3-N, PO4-P, alkalinity, conductivity and Na%). After having selected these candidate metrics they need to be evaluated for efficacy and validity.

This means that inappropriate metrics have to be eliminated from the process. Metrics have to be considered as inappropriate if they do not allow discrimination between anthropogenic influences and natural variability. This has been tested by comparing metrics in the LDS and DS sites by Mann-Whitney U Test. Where we have not found significant differences, the metrics have been excluded (Fig. 1).

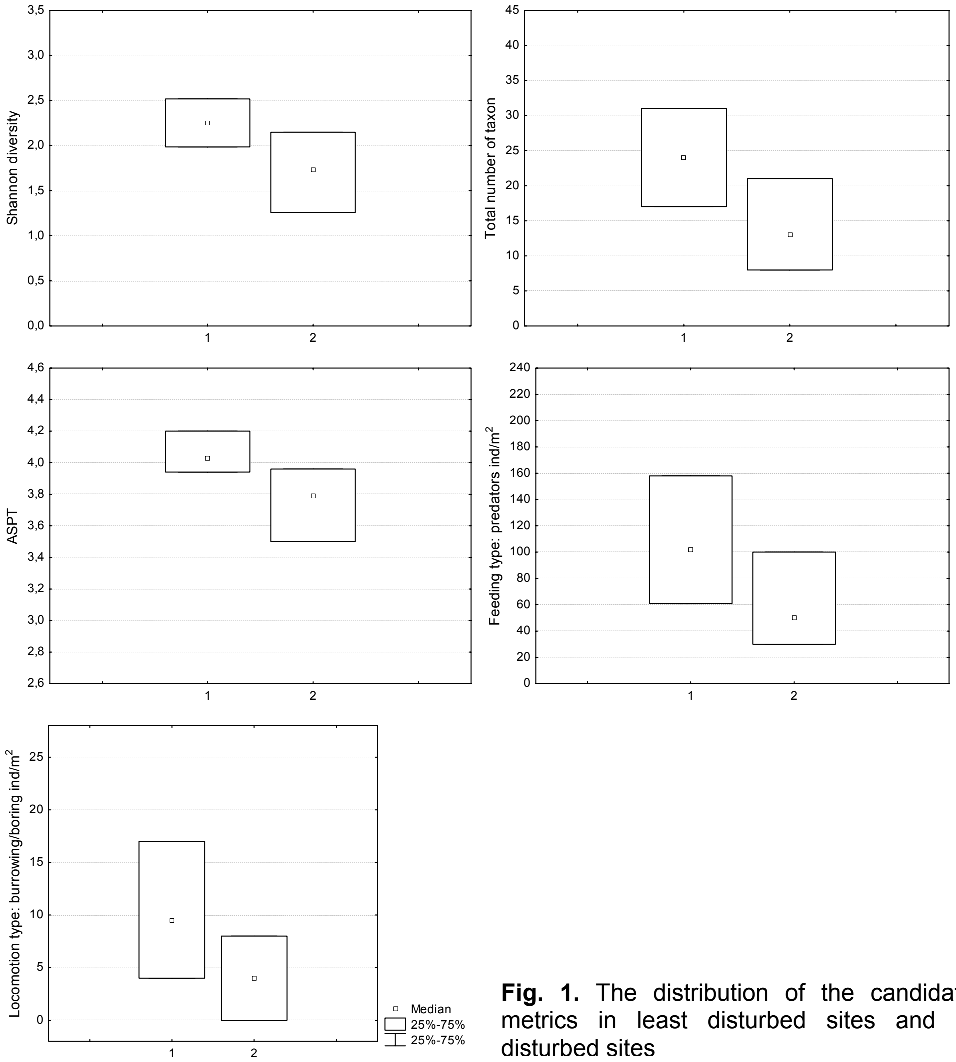

Fig. 1. The distribution of the candidate metrics in least disturbed sites and in disturbed sites

Moreover, different types of metric should be considered (composition/abundance metrics, richness/ diversity metrics; sensitivity/tolerance metrics; functional metrics). Following the selection process the metrics included in the multimetric index were: Shannon diversity (HS), Total taxon number, ASPT, Feeding type predators abundance (ind m^{-2}), Locomotion type: burrowing/boring abundance (ind m^{-2}).

Another important issue was the boundary setting of the different EQR categories. As no reference conditions and reference values were available we follows the suggestions of the intercalibration guidelines (VAN DE BUND et al. 2009) and selected the comprehensive percentiles of the LDS sites for the given metric. The high/good limit was set to the medium of the LDS sites; the good/moderate limit was the lower quartiles of the LDS sites. The remaining limit values were determined by equal classes between the good/moderate and the minimum values of the selected metrics. After setting boundary limits they were normalized to the WFD EQR classes (namely-0.8, 0.6, 0.4, 0.2). Table 1.

Table 1. Class boundaries of the candidate metrics, the normalization equation and its R^2

	POOR	MEDIUM	GOOD	HIGH	Normalization equation	R^2
Shannon diversity(HS)	0,77	1,38	1,99	2,25	$0{,}273\ x^{1{,}244}$	0,9913
Total taxon number (TT)	7,00	12,00	17,00	24,00	0,0354 x - 0,0316	0,9924
ASPT	3,09	3,52	3,94	4,03	$0{,}0008\ x^{4{,}8993}$	0,9821
Feeding type: predators abundance (ind m^{-2}) (Pred)	21,00	41,00	61,00	102,00	0,3853 Ln(x) - 0,9923	0,9898
Locomotion type: burrowing/boring abundance (ind m^{-2})(BB)	1,33	2,67	4,00	9,50	0,3121 Ln(x) + 0,1172	0,9825

Thus this makes us possible to calculate the multimetric index. The resulted index is called HMMI (Hungarian Multimetric Macroinvertebrates Index) and calculated as follows:

$$HMMI = \frac{HS_{EQR} + TT_{EQR} + ASPT_{EQR} + \mathrm{Pr}ed_{EQR} + BB_{EQR}}{5}$$

Eq. 1. Calculation of Hungarian Multimetric Macroinvertebrates Index (HMMI) where
HS_{EQR}: Shannon diversity metric normalized EQR
TT_{EQR}: Total taxon number metric normalized EQR
$ASPT_{EQR}$: ASPT metric normalized EQR
$Pred_{EQR}$: Feeding type predators abundance metric normalized EQR
BB_{EQR}: Locomotion type burrowing/boring metric normalized EQR

The discrimination between anthropogenic influences has been tested for LDS and ND sites also to validate the index suitability. Fig 2.

After calculating the HMMI we had to check the stressor specific aspect of the index (Table 2.) and (Fig. 3). We found also significant correlation between BOD, the nitrate formats, Na % and alkalinity.

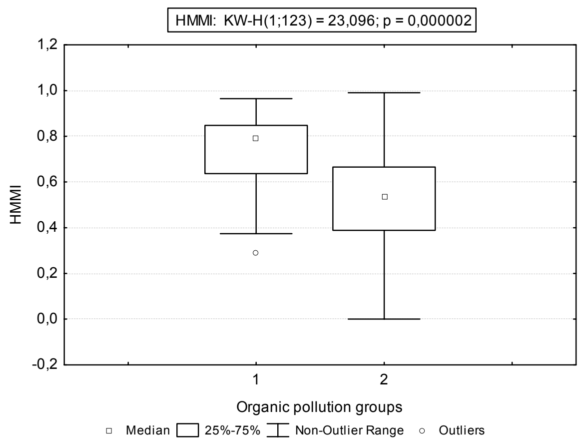

Fig. 2. The distribution of the monitoring sites in the least disturbed sites and in disturbed sites according to their EQR status by the HMMI index.

Table 2. The correlation coefficients among the index values and various chemical pressures. * means significant correlation at p<0,01

	logCOD	TSS	alkalanity	Na %	logNH4-N	logNO2-N	logNO3-N	logBOD
HMMI	-0,14	-0,18	0,27*	-0,36*	-0,08	-0,47*	-0,35*	-0,26*

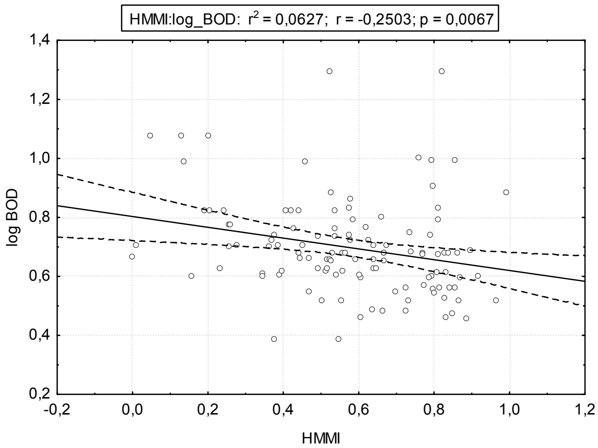

Fig. 3. The scatter plot of HMMI vs. BOD (logarithmized) the correlation is significant at p<0,01

Summary

Numerous papers describe the possible approaches to metric selection (e.g. HOLLAND 1990; BARBOUR et al. 1999; KARR and CHU 1999). Further selection criterion was the taxonomic resolution needed for the metric (order/family vs. genus/species level), which should be achieved by the national monitoring network.

The well-constructed Multimetric Indices contain a suggested number of metrics from each type and therefore reflect multiple dimensions of biological systems (KARR and CHU 1999). This procedure makes it more comparable and ensures that different aspects of the community and also can be easily interpreted, which is regarded as a main advantage of this type of bioassessment. Nevertheless it is a valuable tool for assessing various types of freshwater ecosystems, since they integrate different stressors and different components of the community.

During the construction of the index we followed the guidelines of HERING et al. (2006). By this process it was possible to make such a multimetric index that is WFD compliant and suitable for the quality of the current monitoring activities and could use in intercalibration process.

The distribution of the sampling sites into different quality classes can be seen on Figure 4.

Although in this paper we focused only a small part of the Hungarian river types but following the main idea of our study it is possible to give similar multimetric indexes to the other types as well.

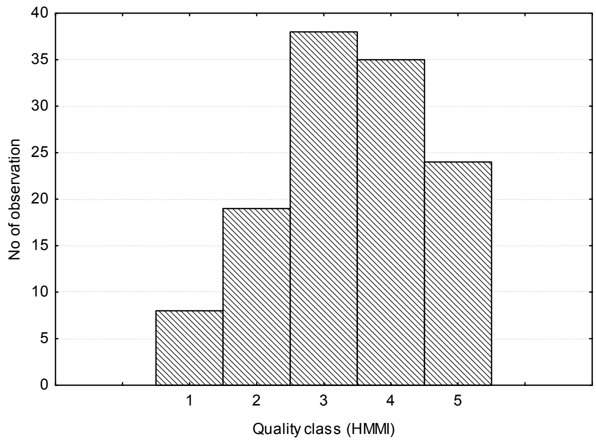

Fig. 4. The amount of the monitoring sites in the different quality classes, according to the HMMI (1-Bad, 2-Poor, 3-Medium, 4-Good, 5-Excellent)

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