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DEVELOPING A MULTIMETRIC MACROINVERTEBRATE INDEX ON MOUNTAINOUS, SMALL AND MEDIUM SIZED WATER BODIES

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MAKROGERINCTELEN MULTIMETRIKUS INDEX KIDOLGOZÁSA HEGYVIDÉKI VÍZFOLYÁSOKRA

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ABSTRACT: According to the normative definition of the Water Framework Directive (WFD) the ecological quality assessment requires such a biological index that takes into account specific aspects of the biological quality elements, such as composition, abundance and has multimetric features. The specific goal of this study was to develop a multimetric index by following the intercalibration assessment method. In this case study we selected the 1st, 2nd and 3rd mountainous river types to elaborate such an index. The resulted index consist of four metrics: ASPT, Shannon diversity, Ephemeroptera and Plecoptera taxon number and the inverse of the ratio of littoral zonation preference. The index were tested against various chemical and landscape variables and found to be stressor specific and fulfils all criteria of the WFD and could also be used later in the official assessment process.

Key words: benthic invertebrates, biological quality assessment, EQR, WFD

KIVONAT: Az Európai Vízkeretirányelv (VKI) célja, olyan intézkedések elősegítése, melyek lehetővé teszik, hogy felszíni vizeink jó ökológiai állapotát elérjük 2015-re. Az ökológiai minősítés a VKI normatív definíciója alapján olyan indexeken alapul amely multimetrikus, a fajösszetétel, abundancia és diverzitás viszonyok is megjelennek benne. A tanulmány elsődleges célja az volt hogy a 1, 2 és 3 hegyvidéki típusú vízfolyásokra egy ilyen indexet kifejlesszünk. Az index négy biológiai metrikát tartalmaz az ASPT-t, Ephemeroptera és Plecoptera taxon számot, Shannon diverzitást és a littorális zonáció preferencia arányának inverzét. Az eredményül kapott indexet különböző kémiai és tájhasználati változóval teszteltük. Az általunk javasolt multimetrikus metrika stresszor-specifikus, teljesíti a WFD normatív követelményeit és megfelelő alapot jelent a későbbi minősítések során is.

Kulcsszavak: bentikus vízi gerinctelenek, biológiai vízminősítés, EQR, EU Víz Keretirányelv (VKI)

Introduction

The determination of the 'ecological status' required for the European Water Framework Directive (WFD) (COUNCIL OF THE EUROPEAN UNION 2000) is based on characterizing reference conditions for water bodies. The WFD classification scheme for water quality includes five status classes: high, good, moderate, poor and bad. 'High status' is defined as the biological, chemical and morphological conditions associated with no or very low human pressure. This is also called the 'reference condition' as it is the best status achievable - the benchmark. These reference conditions are type-specific, so they are different for different types of rivers, lakes or coastal waters so as to take into account the broad diversity of ecological regions in Europe. Assessment of quality is based on the extent of deviation from these reference conditions, following the definitions in the Directive. 'Good status' means 'slight' deviation, 'moderate status' means 'moderate' deviation, and so on. The definition of ecological status takes into account specific aspects of the biological quality elements

Hence the reference conditions are hard to find in our country the WFD allows the use of so called benchmark sites which includes the sites with the best available conditions. According to the normative definitions of the WFD to describe the biological elements the following attributes have to be considered: composition, abundance, the ratio of disturbance sensitive taxa to insensitive taxa and the diversity, the numerical equivalent of these attributes called biological metrics. Aggregation of these metrics simplifies management and decision making (KARR et al. 1986). Thus a multimetric approach with qualitative and quantitative data should be used to reflect different environmental conditions and aspects of the community the multimetric assessment (KLEMM et al. 2002). Multimetric Indices are frequently used in routine water management. (HUGHES et al. 1998; BARBOUR et al. 1999; KARR & CHU 1999)

In this article we continued the work described in VÁRBIRÓ et al (2010). In our previous work we developed a multimetric index for lowland running waters with small catchment area, that index have to renamed $HMMI_{sl}$ (which refers to small, lowland) because the original purpose of the authors was to establish a so called Hungarian Multimetric Index group which capable of the evaluation of all of the Hungarian river typology. In our present work we try to anwer two main questions, firstly how landscape variables could be used in the selection of the benchmark sites. Secondly by selecting the benchmark sites to develop the $HMMI_m$ (which refers to mountain type) index for the 1st, 2nd and 3rd mountainous Hungarian river types.

Methods

Selection of benchmark sites

For determining the benchmark sites, watershed-scale field vegetation data were obtained from MÉTA Database (Landscape Ecological Vegetation Database & Map of Hungary, (MOLNÁR et al. 2007, BÖLÖNI et al. 2007, www.novenyzetiterkep.hu). Vegetation-based landscape ecological indicators, as predictors of stream water quality were calculated from these data, according to suggestions of MOLNÁR and HORVÁTH (2008) and ORTMANN-AJKAI et al. (2010) (percentage cover of near-natural vegetation, number of near-natural habitat types, average habitat naturalness and cover of woody vegetation). In addition to this we select sites which were considered as their pollution loads were low. For this purpose we select the total nitrogen or total phosphorus parameter thresholds values were <200 ug l^{-1} following the good values of the Hungarian guidelines. Thus we could make two groups BS (Benchmark sites) and DS (Disturbed sites).

We focused on the 1, 2 and 3 official Hungarian WFD types. 46 samples were analysed, 112 biological metric and 33 environmental variables were tested. 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 this database. 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 BS 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 and must show a significant correlation either positive or negative to the stressor gradient. For selection of candidate metrics we calculated approximately 112 different metrics based on the ASTERICS (HERING et al. 2004, 2006) program. Technically we join the Hungarian macroinvertebrate database to the AQEM taxalist thus made us possible to calculate the indices inside the database.

At first the percentage cover of near natural vegetation (PNV) were plotted against chemical variables such as total Nitrogen (Fig 1.). We found significant correlations and therefore we could select the percentages which could be considered as natural so could serve as a benchmark level. This level was the 58 %.

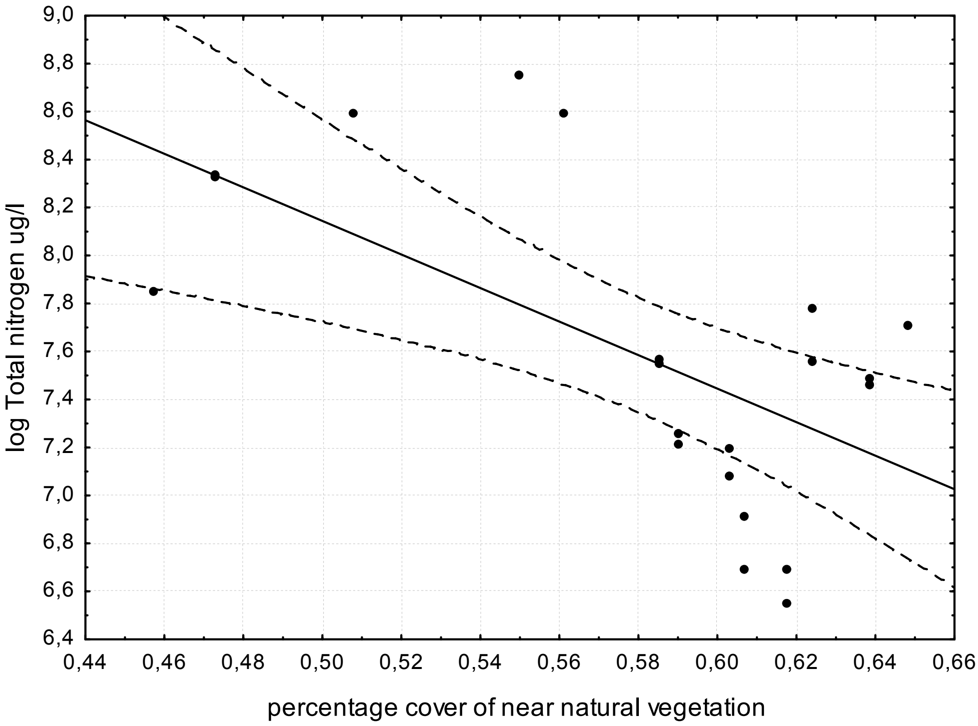

Fig. 1. The scatter plot of percentage cover of near natural vegetation vs. total nitrogen (logarithmized) (r^2 = 0,3804; r = -0,6168; p = 0,0029; y = 11,6409 - 6,9932*x).

As not all the sites were described by the PNV due to lack of relevant data we should found a biological metric which correlates with PNV and could be calculated for all the samples. We found that the Shannon diversity gives the most relevant correlation (Table 1., Fig 2.).

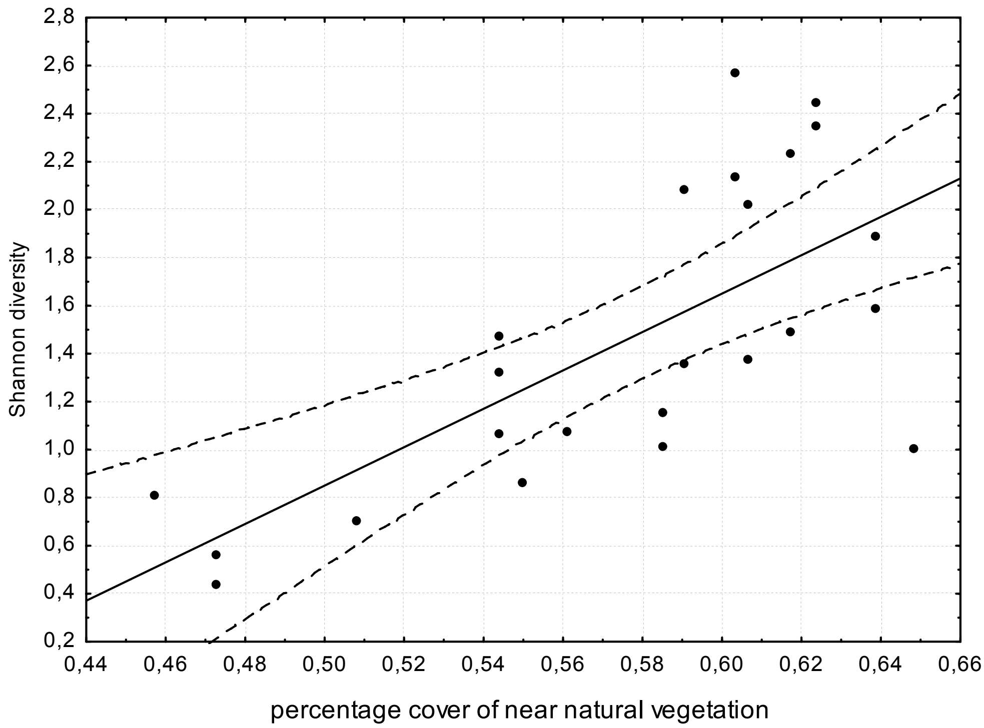

Fig. 2. The scatter plot of percentage cover of near natural vegetation vs. Shannon diversity index(r^2 = 0,4918; r = 0,7013; p = 0,0001; y = -3,1479 + 7,9967*x).

By applying linear correlation it was possible to divide the BS and DS and make two groups of the samples.

The resulted benchmark sites were characterized by descriptive statistics of chemical parameters and outliers were excluded.

The next step was to make a Mann – Whitney U test for the two groups by the 112 biological metric. The metric which does not gives significant differences between the two groups were excluded. This followed by making a correlation analysis between the biological metrics and the chemical variables. (Table 1.)

We selected only those metrics that have significant correlation with one of the chemical variables (total N, total P, NO2, NO3, PO4, alkalinity, conductivity and landscape variable such as PNV and forest area percentage on the watershed from Corine layer.

After having selected these candidate metrics they need to be evaluated for efficacy and validity. As 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 the best one of their kinds: At the end Shannon diversity (SH), Ephemera + Plecoptera taxon number, ASPT, Zonation preference of Littoral (% of scored taxa) were included in the multimetric index. Note that preference of Littoral correlates negatively.

Table 1. The correlation coefficients among the candidate metric values and various chemical pressures and landscape characteristics. * significant correlation at p<0,05 marked **bold**.

	Percentage cover of near natural vegetation	Forest area percentage on the watershed	Log NO_3	Log NO_2	Log ortoP	Dissolved oxigen	Log Total P	Log Total N	Conductivity
Total taxon number	**0,50**	0,28	**-0,50**	-0,38	-0,25	0,22	-0,02	-0,35	-0,43
ASPT	**0,41**	**0,56**	**-0,78**	**-0,54**	**-0,49**	0,36	**-0,54**	**-0,71**	**-0,72**
BMWP total score	**0,45**	**0,33**	**-0,56**	-0,37	-0,31	0,18	-0,08	**-0,41**	**-0,45**
Shannon diversity	**0,70**	0,24	**-0,65**	**-0,50**	**-0,67**	0,25	**-0,55**	**-0,48**	**-0,61**
EP taxon number	**0,68**	**0,50**	**-0,75**	**-0,63**	-0,40	0,25	-0,30	**-0,66**	**-0,72**
EPT taxon number	**0,63**	**0,57**	**-0,68**	**-0,52**	-0,29	0,32	-0,23	**-0,56**	**-0,66**
EPT%	0,24	**0,40**	**-0,56**	-0,38	-0,32	0,36	**-0,49**	**-0,60**	**-0,56**
Feeding habitat active filters (% of scored taxa)	0,23	-0,09	0,28	0,14	0,00	-0,33	0,03	0,33	0,35
RETI	**-0,54**	-0,10	-0,04	0,01	0,15	0,05	0,06	-0,06	0,08
Zonation preference of Littoral (% of scored taxa)	-0,33	**-0,67**	**0,64**	**0,44**	0,24	-0,15	**0,44**	**0,59**	**0,50**

Another important issue was the boundary setting. We followed the suggestions of the intercalibration guidelines (VAN DE BUND et al. 2009) and selected the comprehensive percentiles of the BS sites for the given metric. The high/good limit was set to the median of the BS sites; the good/moderate limit was the upper quartiles of the DS sites. The moderate/poor limit was the median of DS and the poor/bad was the lower quartiles of DS. After setting boundary limits they were normalized to the WFD EQR classes (namely-0.8, 0.6, 0.4, 0.2). Table 2.

Table 2. Class boundaries of the candidate metrics, the normalization equation.

	HIGH	GOOD	MEDIUM	POOR	Normalization equation
Shannon diversity (SH)	2,11	1,89	1,07	0,81	0,5927x - 2,115
EP taxon number (EP)	7,00	5,00	3,00	1,00	0,3987x - 0,0863
ASPT	4,88	4,62	4,27	3,88	0,1021x + 0,0639
Zonation preference of Littoral (% of scored taxa)(Li)	10	20	30	50	-0,0149x + 0,9086

The resulted index is called $HMMI_m$ (Hungarian Multimetric Macroinvertebrates Index for mountain type) and calculated as follows:

Eq. 1. Calculation of Hungarian Multimetric Macroinvertebrates Index $_{\text{mountain type}}$ ($HMMI_m$) where

$$HMMI_m = \frac{SH_{EQR} + EP_{EQR} + ASP\,T_{EQR} + Li_{EQR}}{4}$$

SH_{EQR} : Shannon diversity metric normalized EQR
EP_{EQR} :Ephemeroptera + Plecoptera taxon number metric normalized EQR
$ASPT_{EQR}$: ASPT metric normalized EQR
Li_{EQR} : Zonation preference of Littoral metric normalized EQR.

After calculating the $HMMI_m$ we had to check the stressor specific aspect of the index (Table 3.) and (Fig. 3, Fig 4.). This was checked against the total Nitrogen and the PNV values.

Table 3. The correlation coefficients among the index value and various chemical pressures and landscape characteristics. * significant correlation at p<0,05 marked **bold**.

	Percentage cover of near natural vegetation	Forest area percentage on the watershed	Log NO3	Log NO2	Log ortoP	Dissolved oxigen	Log Total P	Log Total N	Conductivity
HMMI	**0,71**	**0,64**	**-0,85**	**-0,66**	**-0,56**	0,30	**-0,54**	**-0,74**	**-0,83**

Summary

Several papers deal with the possible approaches of metric selection (Barbour et al. 1999; Karr & Chu 1999). The need of a well-constructed Multimetric Indices contain a suggested number of metrics from each type and therefore reflect multiple dimensions of biological systems (Karr & Chu 1999). The assessment method must be capable of indicating a general degradation of the benthic macroinvertebrate fauna, regardless, which factor is causing the degradation. The macroinvertebrate community of most streams in Europe is impacted by more than one stressor, such as organic pollution, habitat degradation and catchments use. General degradation mainly causes stagnation, which is reflected by a high percentage of littoral preferences. We were able to construct an index which concludes information about the abundance of sensitive taxa such as Plecoptera and Epemeroptera, stagnation indicators like littoral preference and diversity measures. The resulted index could be calculated easily fulfils the normative definitions of the WFD and based on the current quality of the Hungarian monitoring network.

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 should be used in the intercalibration process.

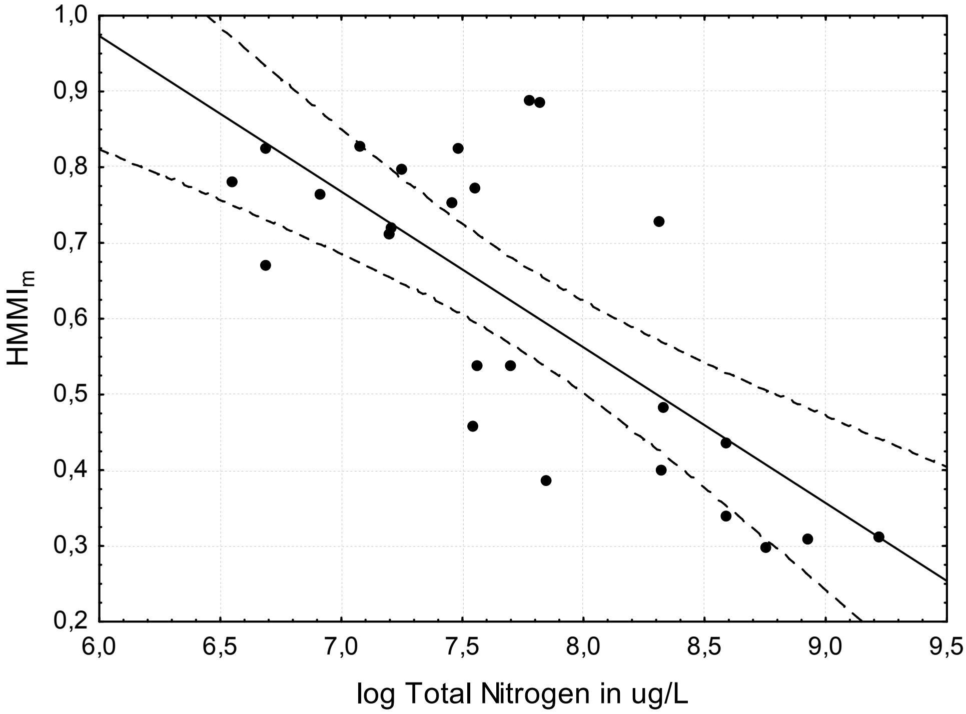

Fig. 3. The scatter plot of $HMMI_m$ vs. Total nitrogen (logarithmized) (r^2 = 0,5532; r = -0,7437; p = 0,00002; y = 2,207 - 0,2056*x).

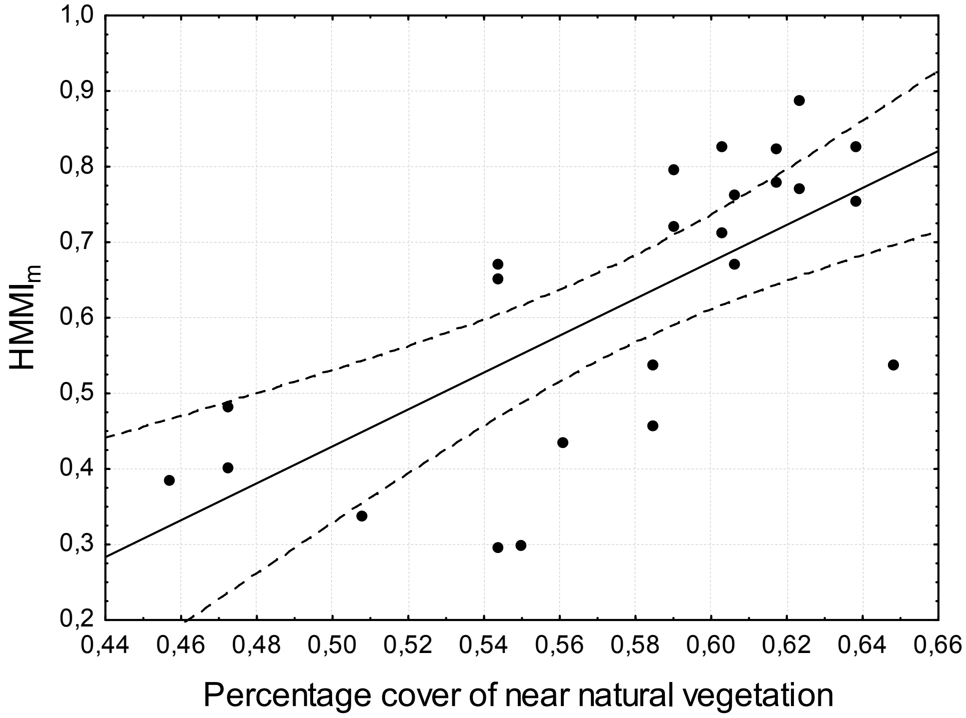

Fig. 4. The scatter plot of $HMMI_m$ vs. percentage cover of near natural vegetation (r^2 = 0,5004; r = 0,7074; p = 0,0001; y = -0,7914 + 2,4426*x).

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