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# The variability of macrophyte metrics used in river monitoring

Krzysztof Szoszkiewicz[1], Janina Zbierska, Ryszard Staniszewski, Szymon Jusik

*Department of Ecology and Environmental Protection*
*Poznań University of Live Sciences*
*ul. Piątkowska 94, 61-691 Poznań, Poland*

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## Abstract

The study aimed at estimating the reliability of river classification based on macrophytes under differentiated habitat conditions. The studies were carried out between 2002 and 2005, within the EU STAR project and two other local projects. Factors taken into consideration included: shading, habitat modification, and lengths of the survey sections. Polish lowland watercourses were surveyed. The analyzed streams represented a wide range of degradation. Several macrophyte-based metrics were evaluated, including major European systems (MTR, IBMR, TIM, MI, RI) and diversity metrics (number of species, Shannon diversity index, total cover). The reaction of the macrophyte-based metrics examined to habitat factors was compared. It was proved that some of the metrics appeared to be resistant to different sources of variability, thus confirming their usefulness for river monitoring.

[1] Corresponding author: *kszoszk@au.poznan.pl*

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## INTRODUCTION

The Water Framework Directive (WFD) requires Member States to implement ecologically-based classification systems for the monitoring of surface waters (Directive 2000/60/EC). Methods for estimating ecological quality status for the purpose of the WFD are still under development, and there is an urgent need for research on biological indicators and for testing the potential of classification systems. Macrophytes are regarded by the WFD as one of the key groups of biota suitable for biomonitoring freshwaters and for ecological classification purposes. Currently, several freshwater bioassessment systems have been developed in Europe, e.g. in Great Britain (Holmes et al. 1999), Germany (Schneider et al. 2000, Schaumburg et al. 2004) and France (Haury et al. 1996, 2002).

This study aims to estimate the reliability of macrophyte-based ecological status classification for rivers. Variation in the estimation of the ecological quality of a water ecosystem depends on many factors, such as field sampling, personal judgement, and the selection of reference sites (Clarke 2000, Clarke et al. 2002). Several aspects influencing uncertainty in estimation of the ecological quality of rivers were considered during the STAR project (Staniszewski et al. 2006), and these aspects were further examined in relation to rivers in Poland. This study was designed to assess the variation of macrophyte-based metrics due to the influence of variable shading and hydromorphological degradation, and the different length of the survey section. The aim of the study was to estimate the reliability of river assessment based on macrophytes due to differentiated sources of variability.

## MATERIALS AND METHODS

Studies on macrophytes were undertaken in Polish lowland rivers between 2003 and 2006. Field surveys were carried out according to STAR guidance for the field assessment of macrophytes (Dawson 2002). This is closely related to the Mean Trophic Rank (MTR) methodology (Holmes et al. 1999). Taking the botanical survey as a basis, besides MTR scores, several other metrics were calculated. These included: IBMR - Indice Biologique Macrophytique en Rivière (Haury et al. 2002), TIM - Trophäe-Index Macrophyten (Schneider et al. 2000), MI - Macrophyte Index (Melzer 1999), RI - Reference Index (Schaumburg et al. 2004) (without the non-structural algae module), the number of species and Shannon diversity index (Shannon & Weaver 1949), and total macrophyte cover.

The macrophyte assessment included all submerged, free-floating, amphibious and emergent vascular plants, as well as mosses, liverworts and

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filamentous algae. During the field survey, macrophytes were recorded which were attached or rooted in parts of the river bank that are likely to be submerged for more than 85% of the year. The presence of each species within the standard MTR survey river length (100 m) was recorded together with their percentage cover using the MTR nine-point scale (Holmes et al. 1999).

To estimate the variability of macrophyte metrics caused by different factors (shading, hydromorphological degradation, and different length of survey section), a series of experiments were conducted during the field surveys. These experiments were based on comparisons of matched pairs of river sites which were differentiated in one of the tested features.

The sensitivity of the macrophyte indices to shading (caused mainly by trees growing along rivers) was estimated by surveying 29 matched pairs of sites where two stretches were within several hundred meters of each other, one being unshaded and one being shaded. The two matched sites had very similar environmental conditions in terms of water depth and width, current velocity, hydromorphological conditions and substrate. The absence of tributaries between two stretches was checked.

Thirty-one matched pairs of sites (hydromorphologically degraded and unmodified) were selected to test the impact of physical modifications of the river channel (e.g., bridges, reinforcements, regulations) on the hydromorphological score. The two sites within each pair were selected to be within 1 km of each other, but representing different classes of hydromorphological degradation.

To estimate the influence of the survey section length on scores of the macrophyte metrics, 35 sites were surveyed over distances of the water course of 50 m, 100 m, and 500 m.

To compare the impact of different sources of variation (shading, hydromorphological degradation, and different length of survey section) on macrophyte-based indices, the share of total variance due to different factors was estimated. To estimate this, the variance (the SD squared) of each metric's values caused by each factor was divided by the total variance amongst all the values of that metric. The significance of the revealed variance was tested using the Wilcoxon Matched-Pairs Signed-Ranks Test (Siegel & Castellan 1988). This is a nonparametric test to estimate whether the parts of a pair differ in size and does not require a population with a normal distribution. Testing three survey distances was undertaken also in pairs – first, the difference between 50 m and 100 m, and then between 100 m and 500 m was tested separately. Statistical analyses were based on a matrix with 10% of outlier values removed.

## RESULTS

The series of experiments undertaken showed that macrophyte metrics react differently to particular sources of variance. Comparison between shaded and unshaded sections showed that light availability was a very important factor that strongly modified taxonomical composition. Among the analyzed macrophyte-metrics, a very strong change of abundance (total cover) and diversity (Shannon-Weaver index) was found when pairs of sites were compared. It was estimated that 99% and 98% of the total variance, respectively, was attributed to this source of variation. The exposure to light was also very important for the number of species and the RI index, whereas four other indices were not strongly changed by this factor. The statistical test confirmed the significance of shade in the case of total cover, number of species, and the Shannon-Weaver index (Fig. 1) and RI index (Fig. 2). Differences of MTR, IBMR, TIM and MI between shaded and unshaded sections were not significant (Table 1).

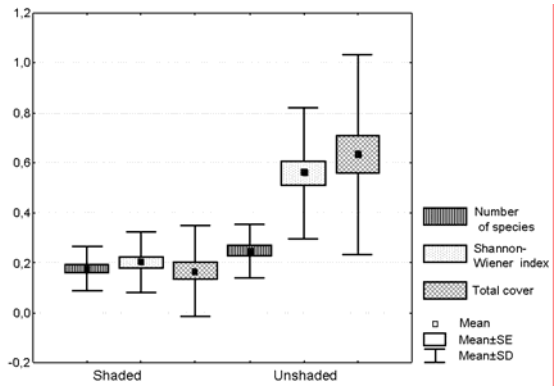



**Fig. 1.** Impact of shade on the number of species in the Shannon-Weaver index and total cover.

**Table 1**

Wilkoxon test for matched pairs.

| Index | Length | Morphology | Shade |
|---|---|---|---|
| Number of species | **0.001*** | 0.103 | **0.001*** |
| Shannon-Weaver index | **0.001*** | **0.001*** | **0.001*** |
| Total cover | **0.007*** | **0.046*** | **0.001*** |
| IBMR | 0.098 | 0.068 | 0.206 |
| MTR | 0.635 | 0.481 | 0.888 |
| TIM | 0.768 | 0.940 | 0.145 |
| MI | 0.204 | 1.000 | 0.948 |
| RI | 0.327 | 0.733 | **0.011*** |

* significant differences ($p<0.05$)

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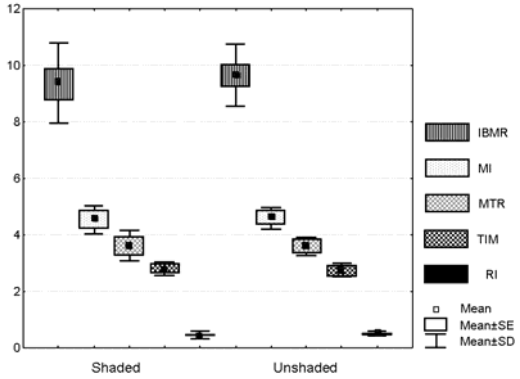



**Fig. 2.** Impact of shade on macrophyte metrics (IBMR, MI, MTR, TIM and RI).

All analyzed metrics reacted in the similar way to hydromorphological degradation (Fig. 3). The strongest reaction was indicated by MI (50% of the total variance) and TIM (47%). These metrics appeared most sensitive to this factor. The largest resistance to hydromorphological degradation was shown by MTR (28%). The statistical test confirmed the significance of

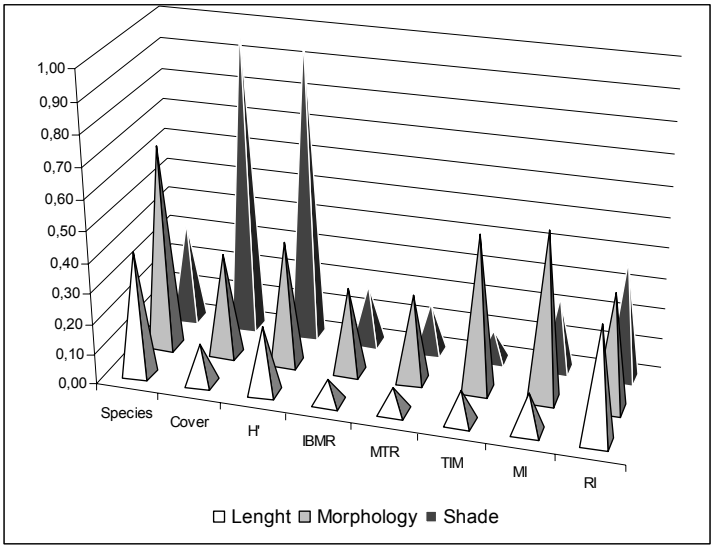



**Fig. 3.** Estimated share of total variance for selected indices due to the different length of the survey section, variable morphology, and shading.

hydromorphological degradation in the case of total cover and the Shannon-Weaver index (Fig. 4). Differences between values of other metrics as regards modified and natural section, although influencing strongly the total variance, were not significant (Fig. 4, 5), because the effect of the factor was not regular in terms of the direction of the change in the tested pairs.

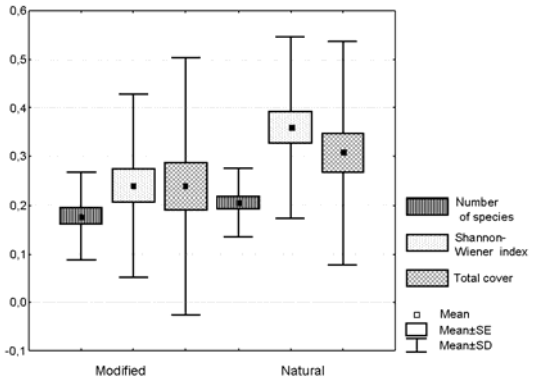



**Fig. 4.** Impact of hydromorphological modifictions on the number of species in the Shannon-Weaver index and total cover.

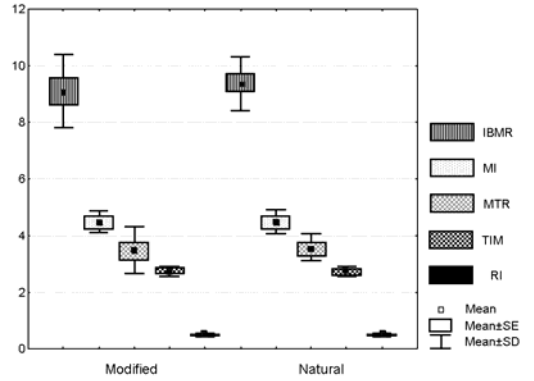



**Fig. 5.** Impact of hydromorphological modifictions on macrophyte metrics (IBMR, MI, MTR, TIM and RI).

Macrophyte metrics react differently to the distance of the survey stretch (Fig. 3). This factor most strongly influenced the number of species index. The reaction of the Shannon-Weaver index and total cover to this factor was also quite large. The significant reaction of these three indices was confirmed

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statistically. The strong effect of the length of the survey distance on RI was also detected, but due to the general high variability of this index, the impact of this factor appeared to be insignificant (Fig. 6, 7).

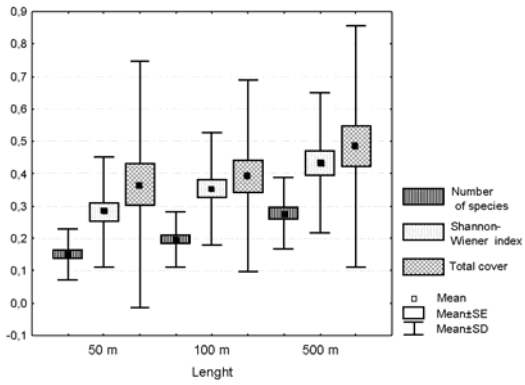



**Fig. 6.** Impact of length of the survey section on the number of species in the Shannon-Weaver index and total cover.

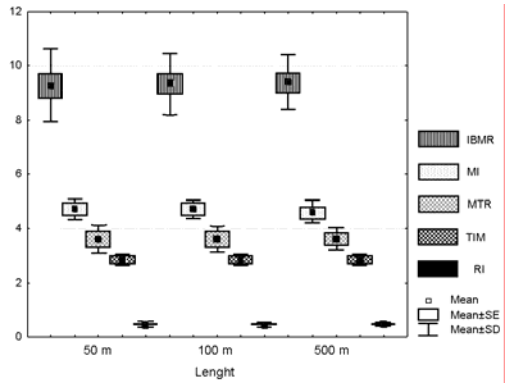



**Fig. 7.** Impact of length of the survey section on macrophyte metrics (IBMR, MI, MTR, TIM and RI).

## DISCUSSION

Analysis undertaken by Staniszewski at al. (2006) showed that metrics indicating the largest level of uncertainty can not be utilized for estimating the ecological status of rivers according to the WFD (Directive, 2000). A high level of variance generates great uncertainty as regards site status class assessment,

and the probability of misgrading a site is too high to use such an index in monitoring (Clarke at al. 1996). Indices reflecting species diversity (the number of species and the Shannon-Weaver index), as well as plant abundance (total cover), were shown to be among the metrics offering limited confidence in assessments.

Four of the tested metrics, MTR, IBMR, TIM and MI, proved sufficiently robust in relation to potential sources of variation, caused by shading and hydromorphological modification, to be useful in river assessment. Three of them (MTR and IBMR, TIM) appeared also to be resistant to inter-surveyor variation on the medium lowland rivers (Staniszewski et al. 2006) and some other river types (Szoszkiewicz et al. 2007). Two of them (MTR and IBMR) appeared to be most strongly correlated with nutrients (Szoszkiewicz et al. 2006a). Therefore, these metrics can be recommended as trophic indicators for monitoring, and in the assessment of the ecological status of rivers.

Analysis showed that macrophyte-based metrics such as MTR, IBMR, MI, RI and TIM are not disturbed by the length of the survey section. Therefore the length of the survey section might be adapted to the local conditions encountered during a field survey, although a distance close to 100 m is recommended as delivering a sufficient pool of macrophytes for accurate indication.

## CONCLUSIONS

- Metrics reflecting species diversity (number of species and the Shannon-Weaver index) as well as plant abundance (total cover) are strongly influenced by shading, hydromorphology, and length of the survey section. Therefore they can not be used in the assessment of the ecological status of river sites.
- Four of the tested metrics, MTR, IBMR, TIM and MI, proved sufficiently robust in relation to potential sources of variation caused by shading and hydromorphological modification. Therefore these metrics are recommended as trophic indicators for monitoring, and in the assessment of the ecological status of rivers.
- Macrophyte-based metrics such as MTR, IBMR, MI, RI and TIM are not disturbed by the length of the survey section. Therefore the length of the survey section might be adapted to the local conditions met with during a field survey.

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