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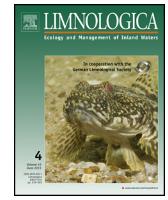


# Macroinvertebrate metrics and their integration for assessing the ecological status and biocontamination of Lithuanian lakes

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ABSTRACT

We present an assessment system for determining the ecological status (eutrophication and land use pressures) and non-indigenous macroinvertebrate species (NIMS) specific deviation from naturalness of Lithuanian lakes, using semi-quantitative sampling of littoral macroinvertebrates. This system includes two integrated indices, the multimetric Lithuanian Lake Macroinvertebrate Index (LLMI) and the Fauna Autochthony Index (FAI). The LLMI, developed for the assessment of ecological status, averages four metrics: the conventional Average Score Per Taxon (ASPT) and the first Hill's number ($H_1$), as well as the newly validated number of Coleoptera, Ephemeroptera and Plecoptera taxa (#CEP) and the proportion of Coleoptera, Odonata and Plecoptera individuals (COP). Furthermore, the metrics of biocontamination were transformed into the WFD-compliant FAI for the NIMS-specific naturalness evaluation.

The LLMI had significant correlations with total phosphorus, total nitrogen, chlorophyll *a*, biochemical oxygen demand, water transparency, the morphoindex and the combined trophomorphoindex. Relationships between the LLMI or its core metrics and biocontamination were not found; thus the LLMI and the FAI are not interdependent and have the advantage of separately accounting for pressures requiring different management techniques. Variation of the LLMI and the FAI did not differ between stony/pebbly and vegetated littoral mesohabitats suggesting that any of the mesohabitats or a multihabitat sampling technique can be suitable for a reliable evaluation of lake status.

Aquatic beetles revealed themselves as good indicators of the trophic status, while caddisflies and conventional macroinvertebrate metrics ETO and EPT proved unworkable. The ineffectiveness of the latter metrics may be due to the relatively low trophic level in most of the studied lakes which resulted in an increment of caddisfly metrics with an increase of nutrient loads, as well as due to the susceptibility of caddisflies to the invasive species, the zebra mussel *Dreissena polymorpha* and amphipod *Pontogammarus robustoides*.



## Introduction

The EU Water Framework Directive (WFD) requires member states to maintain high or attain at least good status for all types of natural surface waters by 2015 (EU, 2000). According to the WFD, the status of surface water is determined by the poorer of either its ecological or chemical status, each subject to a robust assessment. One of the biological elements required in the assessment of all surface waters is benthic macroinvertebrates. It is required that taxonomic composition, abundance, ratio of disturbance sensitive to insensitive taxa and community diversity are all taken into account. A derived quality index (a multimetric index, as proposed) must be expressed as an ecological quality ratio (EQR), reflecting the deviation of an observed community from one in type-specific reference conditions. The EQR is used to assign an assessment unit to one of the five ecological quality classes.

Nutrient enrichment, i.e. eutrophication, is the most widespread pressure affecting European lakes (Solimini et al., 2006), a situation also true in Lithuania. Lake littoral benthic invertebrates are generally assumed to be sensitive to acidification (Solimini et al., 2006; Johnson et al., 2007; McFarland et al., 2010) and hydromorphological disruptions (Hunt and Jones, 1972; Smith et al., 1987; Palomäki, 1994; Bänziger, 1995; Christensen et al., 1996; Solimini et al., 2006; Brauns et al., 2008), but restricted in their response to trophic state changes (Rasmussen and Kalff, 1987; Solimini et al., 2006; Brauns et al., 2007; Timm and Möls, 2012) that are particularly soundly reflected by profundal macroinvertebrate communities (Saether, 1979; Lang, 1985; Bazzanti and Seminara, 1987; Solimini et al., 2006). However, due to expedience in sample collection and hence the amenability to cost-efficient monitoring, using littoral assemblages, probably associated with a particular habitat, e.g. hard

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substrata (Donohue et al., 2009), is preferred. Ideally, macroinvertebrate metrics should be able to track nutrient concentrations while being indifferent to the habitat type.

Macroinvertebrate metrics developed to detect organic pollution resulting in oxygen depletion in the riffle zones of lotic systems may not be applicable to stagnant waters. Furthermore, different geographical or climatic conditions and national monitoring experience usually require local validation of metrics. All these circumstances often result in regional integrated indices. So far, only a few WFD-compliant macroinvertebrate assessment methods targeted at eutrophication have been established for lakes in the Central Baltic ecoregion (e.g. Anonymous, 2007; Gabriels et al., 2010; Ruse, 2010).

Another important issue when designing biological surface water assessment methods is non-indigenous macroinvertebrate species (NIMS). Although the WFD does not specifically mention invasive NIMS among other relevant pressures, such as eutrophication, acidification, hydromorphological modification or dangerous substances (EU, 2000), in the context of the directive's objectives, invasive species represent an important constraint since they can modify native biological structure and ecological functioning of aquatic systems (Cardoso and Free, 2008). Recognition of invasive species as ecological and economic threats has initiated a debate on their role in ecological status classifications. Almost all EU member states support a supplementary evaluation for NIMS impact to uncouple the assessments of NIMS-specific status and anthropogenic pressures (Vandekerkhove and Cardoso, 2010). For a separate assessment reflecting NIMS-specific deviation from naturalness, a biocontamination index which can be derived from the data of routine biological monitoring has been proposed (Arbačiauskas et al., 2008, 2011; MacNeil et al., 2010). In this way, the impairments of different origin may be less obscured by each other, and the effectiveness of pressure-specific management measures may be observed clearly (Cardoso and Free, 2008).

However, even after separating NIMS-specific status assessment, the possibility of misjudgment of ecological status when using metrics derived from invaded sites still persists. In addition to native species being replaced by differently tolerant NIMS from the same family that are treated as having the tolerance values as established for natives, invasive species can have impacts on the overall assemblage structure through biological interactions (e.g. competition or predation) and consequently, they may greatly influence the scores of biotic indices. It gets even more complicated due to the fact that some NIMS may exhibit negative (Kelly et al., 2003, 2006; Gumuliauskaitė and Arbačiauskas, 2008) and some positive (Karatayev et al., 2002; Zaiko et al., 2009) impacts on indigenous fauna. In rivers, conventional macroinvertebrate metrics, such as the BMWP (Biological Monitoring Working Party) score and EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa number, have been shown to be negatively correlated with biocontamination indices (Arbačiauskas et al., 2008, 2011). Furthermore, MacNeil et al. (2010) found that the BMWP score may even become unresponsive to changing chemical water quality in invaded sites. Macroinvertebrate metrics of ecological status should thereby be not only responsive to environmental stressors but preferably also unsusceptible to the presence of NIMS.

The goal of this study was to design a WFD-compliant macroinvertebrate assessment system for the evaluation of Lithuanian lake status. The pressure-specific system was aimed to deal separately with response to eutrophication and land use pressures (ecological status) and NIMS-specific deviation from naturalness. Firstly, the core metrics meant for the compilation of the multimetric Lithuanian Lake Macroinvertebrate Index (LLMI) of ecological status were validated using original lake survey data, their reference values were derived, and the correlative relationships between the LLMI and environmental stressor parameters were evaluated. Secondly, the NIMS-specific deviation from naturalness of lake survey sites was estimated using biocontamination metrics (see Arbačiauskas et al., 2008) which were further rescaled to a WFD-compliant Fauna Autochthony Index (FAI), and the relationships of selected and conventional metrics of ecological status with metrics of biocontamination were investigated. Thirdly, the effect of mesohabitat on these metrics was tested. Finally, the association between the integrated indices, the LLMI and FAI in particular, and environmental and NIMS-specific stressor parameters was analysed to provide the overall visualisation of relationships between the status indicators and stressor parameters.

## Materials and methods

### *Sampling and sample processing*

For the development of the integrated indices of ecological status and NIMS-specific deviation from naturalness, a semi-quantitative survey of eulittoral macroinvertebrates was carried out in 23 lakes across Lithuania during the growing seasons of 2009–2010 (Fig. 1). Samples were collected following the procedure proposed by O'Hare et al. (2007). Using a standard dip net, two semi-quantitative three-minute samples were taken in the two core eulittoral mesohabitats of each lake, a stony/pebbly littoral bottom kick sample and a submerged vegetation sweep sample. Within each mesohabitat, a 15–20 m long stretch was sampled while moving along the shore in a trajectory of a zigzag curve, repeatedly wading from the very shoreline to a depth of 1 m. Each sample was supplemented by a three-minute qualitative search sample in the corresponding mesohabitat.

In the field, collected samples were fixed with 4% formaldehyde solution. In the laboratory, they were examined for the presence of macroinvertebrates that were sorted according to their taxonomic dependence and preserved in 70% ethanol. Using a stereomicroscope, macroinvertebrates were identified to the taxonomic levels outlined in Table 1, and specimens of each taxon were counted. On a few occasions, abundances of very numerous taxa were assessed by subsampling. Taxa found only in qualitative search samples were added to the taxa lists of kick or sweep samples respectively, at an abundance of one specimen per sample. The survey resulted in 66 macroinvertebrate samples with abundances varying between 163 and 3693 specimens per sample.

**Table 1**
Operational taxonomic identification levels of macroinvertebrate groups considered in the current study with numbers of recorded taxa (Taxa #).

| Group | Identification level | Taxa # |
|---|---|---|
| Turbellaria | Species | 3 |
| Oligochaeta | Class | 1 |
| Hirudinea | Species | 12 |
| Mollusca | Species[a] | 45 |
| Crustacea | Species[a] | 12 |
| Plecoptera | Species | 1 |
| Ephemeroptera | Species | 19 |
| Odonata | Species | 26 |
| Heteroptera | Species[a] | 10 |
| Megaloptera | Species | 1 |
| Plannipenia | Species | 1 |
| Coleoptera | Genus[a] | 39 |
| Trichoptera | Species | 63 |
| Lepidoptera | Species | 4 |
| Diptera | Family | 17 |

[a] Some snails (Gastropoda: Succineidae, Zonitidae), fish lices (Crustacea: Argulidae), gerromorphs (Hemiptera: Mesoveliidae, Gerridae), leaf beetles *Donacia sp.* (Coleoptera: Chrysomelidae) and all watermites (Hydrachnidia) were excluded from the operational taxa list as their attribution to aquatic, benthic or macroinvertebrates is ambiguous.