Assessing acid stress in Swedish boreal and alpine streams using benthic macroinvertebrates

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Abstract

Sixty streams in northern Sweden were sampled for benthic macroinvertebrates in spring and autumn of 2000 as part of the European Union project AQEM (the Development and Testing of an Integrated Assessment System for the Ecological Quality of Streams and Rivers throughout Europe using Benthic Macroinvertebrates). Samples were taken using a harmonised multi-habitat sampling procedure and a large number of parameters describing the streams and their catchments were recorded for all sampling sites. From the stream water chemistry characteristics unbiased measures of acid stress were derived, based on the Swedish Ecological Quality Criteria (EQC) for acidity status. These criteria do not, however, assess the degree of human influence to a stream. Therefore, in the following analysis of classification, the Swedish EQC status criteria are applied as if they were a measure of human influence. Three new multimetric acid indices using benthic macroinvertebrates were developed for the AQEM project. These, together with a large number of other benthic macroinvertebrate indices including a number of indices aimed at detecting acid stress, were evaluated for their ability to detect acid stress, using both spring/early summer and autumn sampling. Surprisingly, the acid index that is in general use in northern Sweden worked well in spring/early summer, but because of a (probable) re-colonisation of more acid sensitive taxa, the index values changed from classifying streams as affected in spring/early summer to classify streams as non-affected by acid stress in autumn. Another Swedish acid index (included in the Swedish Environmental Quality Criteria developed by the Swedish EPA) and developed for southern Sweden was strongly correlated between spring/early summer and autumn and could thus be sampled in the autumn and indicate acid stress from spring flood declines in pH. This is of great importance since the local County boards of northern Sweden generally argue that sampling has to be done in the spring to see the effects of acid stress, when sampling is difficult for logistic reasons. Whether or not the three indices developed for the AQEM project (and extensively based on the south Swedish acid index) were truly better than the south-Swedish acid index to assess acid stress in northern Sweden could not be clearly determined in the present study.

Introduction

Running waters are among the most important natural resources, but also among the most threatened on earth, at the same time the pressure on running water ecosystems will probably increase in the future (e.g., Malmqvist & Rundle, 2002). It is therefore of great importance to have adequate tools to assess and monitor the water quality and biota of streams and rivers. With the EC Water Framework Directive (WFD; Directive 2000/60/EC – Establishing a Framework for Community Action in the Field of Water Policy) a new legal structure for the assessment of all types of water bodies in Europe is defined. The focus of the WFD is the use of biotic indicators (benthic invertebrates, fish and aquatic flora) in stream assessment. Furthermore, the ecological status of a water body has to be defined by comparing the biological community composition present with near-natural reference conditions using
stream types defined according to selected attributes such as size, geology, and altitude. The somewhat innovative approaches outlined in the European WFD have generated a strong demand for the development of new or adaptation of existing assessment systems.

The first indications of acidification in northern Sweden were documented in the beginning of the 1990s (e.g., Ahlström & Isaksson, 1990). The susceptibility of aquatic ecosystems in northern Sweden to acid deposition is largely due to the slow weathering of the bedrock, resulting in much of this area having a low buffering capacity (Schindler, 1998). Episodic acidification events during spring flood are caused by elusion of $\text{SO}_4^{2-}$ and $\text{NO}_3^-$ from the snow pack at melting, and the short residence time of the water in the soil (Bishop et al., 2000). Such episodic acidification can be caused both by natural (dilution of acid neutralising capacity, organic acidity, or $\text{SO}_4^{2-}$ derived from the bedrock or sediment) and anthropogenic (deposition from the atmosphere) processes (Laudon et al., 2000). Both natural (e.g., Jansson & Ivarsson, 1994; Laudon et al., 2001b; Laudon & Hemond, 2002) and anthropogenic causes (Jacks et al., 1986) have also been shown to be the main causes of pH decline during spring flood episodes. To mitigate the effects of acidification, a liming strategy was developed by the Swedish Environmental Protection Agency (1988). The policy states that all surface waters with a pH $< 6.0$ or an alkalinity $<0.05$ meq l$^{-1}$ at any time of the year are eligible for subsidized liming. Thus over 100 million Euros have been spent on liming activities in northern Sweden in the last decade (Bishop, 1997).

Lowered pH and/or increased metal concentrations of stream water are two of the most important factor associated with changes in benthic macroinvertebrate community structure of running waters (e.g., Townsend et al., 1983; Raddum & Fjellheim, 1984; Herrmann et al., 1993 Larsen et al., 1996). Hildrew et al. (1984) found that the pool of occurring species was limited at more acidic sites compared to neutral ones, and that the available food resources was lower in acid streams. The rather straightforward relationship between acid conditions and the presence/absence of certain benthic macroinvertebrate species have therefore been used to assess the effects of acid stress on stream ecosystems (e.g., Henrikson & Medin, 1986; Raddum et al., 1988; Bækken & Aanes, 1990; Degerman et al., 1994).

Several of the Swedish local County boards, responsible for liming activities, argue that assessment of spring flood pH declines using benthic macroinvertebrates has to be done in conjunction with these episodes (i.e., in the spring). However, as often stated, one of the main advantages of using benthic macroinvertebrates to assess stress on freshwater ecosystems is that they integrate perturbation over a longer time period (e.g., Johnson et al., 1993). The aims of this study were therefore: (i) to evaluate the ability of selected indices to detect the effects of acid stress on stream ecosystems in northern Sweden, (ii) to compare benthic macroinvertebrate assemblage composition and index values between spring and autumn, respectively, and (iii) to test the typology (system A) suggested by the EC Water Framework Directive for partitioning macroinvertebrate variance among stream types.

### Material and methods

#### Site selection and sampling

Benthic macroinvertebrate samples were taken in four stream types (named S01–S04) in northern Sweden. The criteria defined by the EC Water Framework Directive (system A) were used to classify the stream sites. Accordingly, types were classified by ecoregions (according to Illies, 1978), size classes (based on catchment area), geology of the catchment, and altitude classes (Table 1). Eight sites had catchment areas $> 100$ km$^2$, but were still included in the analysis, none of these streams had, however, a stream order higher than four. For each stream type we selected sites covering the whole range from 'reference sites' to degraded sites. Reference sites were selected using the criteria specified in Hering et al. (2003); see also Nijboer et al. (2004). For the degraded sites a pre-classification procedure was used. This was done using existing chemical and biological data and expert opinion from the local Swedish County boards, including a classification of the sites according to the Swedish Ecological Quality Criteria (Swedish Environmental Protection Agency, 2000). Within the AQEM project, 15 sites in southern Sweden, along an eutrophication gradient was also sampled (Dahl et al., 2004).

According to the WFD, the assessment of stream quality must be based on a ratio between observed and expected values, where the expected condition is defined as near-natural reference conditions. For applied purposes, it is most important to clearly distinguish between the degradation classes ‘good’ and