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A multimetric macroinvertebrate index for assessing the water quality of the Cau river basin in Vietnam

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ABSTRACT

In this study we developed and applied a multimetric index to assess the biological water quality of rivers in Vietnam as a complementary tool to the traditional physical–chemical analysis. Macroinvertebrate samples were collected at 15 monitoring sites in the Cau river basin, Northern of Vietnam. Eighteen candidate metrics were tested for their range, stability, sensitivity and responsiveness to anthropogenic impacts. The MMI was calculated as the arithmetic mean of five metrics that were retained being the Biological Monitoring Working Party (BMWP) – Viet, total number of taxa, Margalef index, number of ephemeroptera, plecoptera and trichoptera (EPT) and percent of insects. The MMI is split up in five water quality classes, ranging from class one (high biological status) to class five (bad biological status). The study demonstrated that the multimetric approach is suitable for application in the Vietnamese national monitoring and assessment program.

Introduction

The practice of using organisms in water quality assessment has been implemented for many years (Metcalfe 1989; Davis 1995; Boonsoong et al. 2009). Biological assessment factors are direct measures of conditions of biota and integrate different environmental drivers impacted by human and natural activities over a long period of time (De Pauw and Hawkes 1993; Karr et al. 2000; Wolterbeek 2002). The number and types of organisms present in a water body reflects the quality of the site from which they were collected (Metcalfe 1989; Boonsoong et al. 2009). Benthic invertebrates are among the most frequently applied groups in freshwater monitoring and assessment (Knoben et al. 1995; Barbour et al. 1995, 1999) as they offer a spectrum of responses to different degrees of environmental stress over time (Hawkes 1997; De Pauw et al. 2006).

The use of macroinvertebrates as bio-indicators for freshwater quality has a long history and multiple biological indices have been proposed (Armitage et al. 1983; Barbour et al. 1995; De Pauw et al. 2006). However, using a single index for water quality assessment encountered several constraints (Hilsenhoff 1977; Gabriels et al. 2010). Evaluations based on species occurrences allow a detection of pollution, however, these indices are in many cases quite subjective as they require knowledge in ecological life strategies as well as intensive sampling (Dauer 1984; Chutter 1972). As such, a single index is often unable to reflect the overall picture of the aquatic ecosystem under a myriad of anthropogenic pressures. Therefore, a more integrated approach, such as the development of a multimetric index, has received increased attention in recent years for its ability to include complementary information from a broad spectrum of stressors (Vlek et al. 2004; Gabriels 2007). A multimetric index is defined as an index that combines different metrics or indicators, each being tested, rescaled and transformed into a unitless score before combining them into a single value (Haase et al. 2004; Verdonschot and Moog 2006; Lock et al. 2011).

While biomonitoring and assessment have been adopted in many countries in the Asian region as a regular monitoring tool for managing the ecological quality status of river basins (Thorne and Williams 1997; Watanabe et al. 2000; Morse et al. 2007), in the case of Vietnam, the activities in this field is still at the preliminary stage (Nguyen et al. 2004; Truong and Ngo 2006; Hoang et al. 2013). Vietnam has in total 392 rivers with an average density of 0.60 km/km^2. For the three main river basins, being Nhue – Day, Cau and Dong Nai, 21 basic physical–chemical variables are monitored within the national monitoring program with frequency of four to six times

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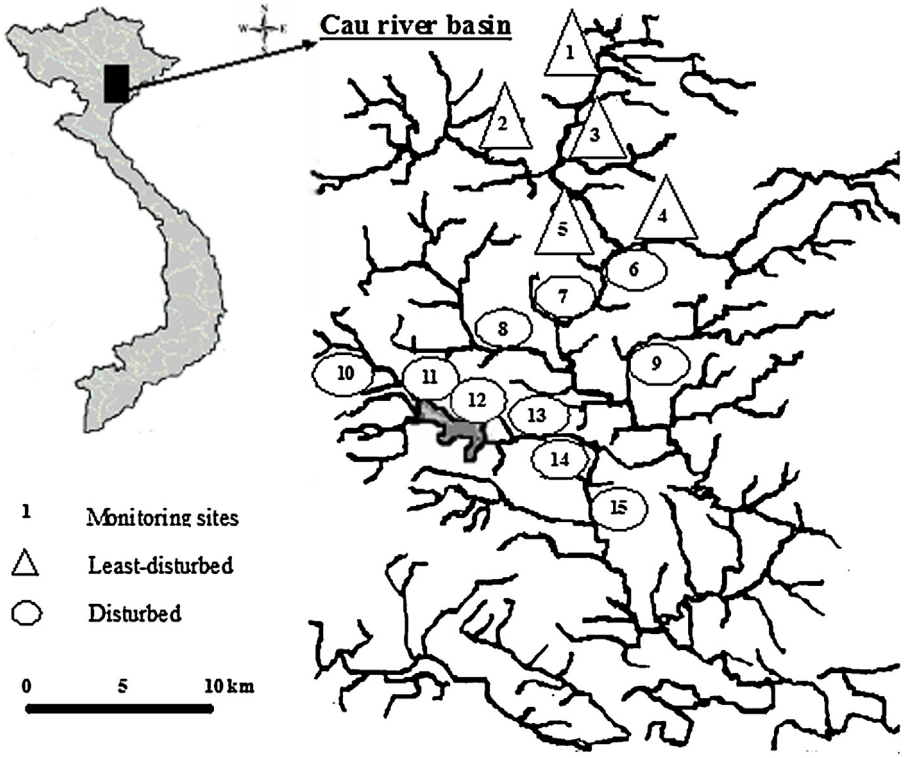

Fig. 1. Map of the study area and sampling sites with indication of the ecological quality status at the Cau river basin, Northern of Vietnam.

per year (Table S1). In contrast, the frequency for biomonitoring remains very low, i.e. once or twice per year and concentrated only in few river basins. Several metrics, such as Biological Monitoring Working Party (BMWP) – Viet, Average Score Per Taxon (ASPT) and Shannon–Wiener index (H′), have been introduced and tested in the national monitoring program for main river basins but were never integrated in one multimetric score. Therefore, this study aimed to develop an easy to apply and cost-effective MMI for ecological quality assessment of rivers applicable at the national monitoring system of Vietnam.

Materials and methods

Study area

Data were collected throughout the Cau river basin (Fig. 1), which is one of the three major river basins in Vietnam and is situated in the Northern economic zone with the tropical monsoon climate. The Cau river originates from the Phia Biooc mountain (1578 m), has an average altitude of 190 m and an average slope of 16.1% (SOE 2006). The total catchment area of the river basin is 6030 km^2; the total length of rivers is 1600 km of which 288 km belongs to the main river Cau (SOE 2006). The river network is diverse and is subdivided in different tributaries in which a high number reflects the smaller branches. Hence, the network includes 26 level I tributaries (total length of 671 km), 41 level II tributaries (total length of 643 km) and hundreds of km of rivers less than 10 km in length (SOE 2006). The Cau river basin is characterized by a high population density (with 648 inhabitants per square km, 2.5 times higher than the national population average density) and intensive industrial and mining activities, particularly in the sand and gravel exploitation sectors (SOE 2006).

Fifteen sites were monitored, i.e. along the Cau river (six sites), the Cong river (five sites), and four sampling sites in streams that directly connected with the main tributary of the Cau river (namely Du (SDU), Phuong Hoang (SPH), Ngu Huyen Khe (NHK) and Cho Chu (SCC)). The sites were divided into two groups, including five *least-disturbed* and 10 *disturbed* ones, on the basis of the anthropogenic impact records. *Least-disturbed* sites were identified as those with low population density (<200 inhabitants per square km), no observation of riparian vegetation destruction or intensive agricultural activities and wastewater treatment facilities within 5 km up- and downstream. All other sites were considered as *disturbed*. Samples were taken in two periods of the year, i.e. June and October to represent the typical months of wet and dry seasons of the year during time from 2009 to 2010. Data collected in 2009 were used to develop the multimetric index, and those collected in 2010 were used for validation purposes.

Collection of physical–chemical data

Physical–chemical data were obtained from the national monitoring and management program of Vietnam (Table 1). The sampling procedure and analysis followed the ISO 17025 standard. For each sampling site, data on pH, temperature, electrical conductivity (EC), dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), ammonium nitrogen (NH_4-N), nitrite nitrogen (NO_2-N), nitrate nitrogen (NO_3-N), Kjeldahl nitrogen (KjN) and total phosphorus (TP) were obtained.

Macroinvertebrate assemblage sampling and identification

Macroinvertebrates were sampled using a standard hand net (mesh size 350 μm). With the hand net, all accessible aquatic habitats within a stretch of 10–20 m were sampled. This included the bed substrate (stones, sand or mud), macrophytes (floating, submerged, emerged), immersed roots of overhanging trees and all other natural or artificial substrates, floating or submerged in the water (De Pauw and Vanhoren 1983; Barbour et al. 1999). Each aquatic habitat was explored in order to collect the highest