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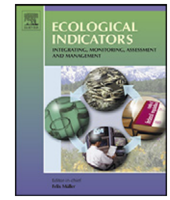

Development and testing of a phytoplankton index of biotic integrity (P-IBI) for a German lowland river

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ABSTRACT

We developed a phytoplankton index of biotic integrity (P-IBI) for a German lowland river to assess effects of human disturbances on the biotic condition of riverine phytoplankton community. Six metrics (out of 36 original metrics) were selected from a training data set, based on Cumulative_R^2 and correlation index (CoI) between biotic metrics and environmental variables. The final P-IBI scores were calculated by averaging metrics for a site after transforming them to a discrete 1 (bad), 2 (low), 3 (moderate), 4 (good), 5 (high) scale according to the requirements of the European Water Framework Directive (WFD). We then tested the robustness of P-IBI. The P-IBI and its six metrics were indicative of ecological integrity and water quality as indicated by canonical correspondence analysis and comparisons with other single metrics, although Cumulative_R^2 and CoI values declined in the testing data set. By implementing the developed P-IBI in the study area, we found that the ecological status varied seasonally. The general ecological status of the study region was 'Moderate' regardless of seasonal variations, which was lower than the requirement ('Good' status) of WFD by 2015. The relative lower ecological status was probably caused by point sources, diffuse sources emissions and artificial drainage systems of the study area. Our study was an important trial for the development of IBI in a catchment without reference sites and the constructed P-IBI could be a useful tool to measure the long-term status of streams and the effectiveness of various watershed managements. Besides, further river basin managements are suggested to address point sources, diffuse sources as well as artificial drainage systems in order to gain a better water quality in the study region.

1. Introduction

Multi-metric indices are increasingly used in the assessment of the river ecological status as well as in resource and ecosystem management because (1) they are often more robust than their component metrics (Lacouture et al., 2006), (2) they integrate chemical and physical properties of streams over time that could otherwise be missed by one-time water chemistry sampling (Winter and Duthie, 2000), and (3) furthermore they represent different taxonomic and functional groups within the assemblage, which respond differently to various stressors and can reflect the ecological status in a comprehensive manner (Tang et al., 2006; Blanco et al., 2007; Zalack et al., 2010). The majority of these indices have focused on stream macroinvertebrates, fish, macrophytes and epilithic algae (e.g., Karr, 1981; Prygiel and Coste, 1993; Kerans and Karr, 1994; Hill et al., 2003; Wang et al., 2005; Mattsson and Cooper, 2006; Rothrock et al., 2008; Bae et al., 2010; Hermoso et al., 2010), which have been used as tools for monitoring stream health for a long time in the USA and European countries (Zalack et al., 2010).

Phytoplankton (mainly planktonic algae) constitutes the autochthonous primary producers in aquatic ecosystems and form part of the basis of the food web for other organisms in terms of energy and material input (Hötzel and Croome, 1999). Thus, any changes that affect the biotic integrity of the algal community may impact higher trophic levels as well. In addition, compared to other biotic assemblage indicators of water quality, planktonic algae have shorter regeneration time and life cycle, allowing the community to respond quicker to anthropogenic influences (Domingues and Galvão, 2007; Cabecinha et al., 2009). Moreover, unlike fish and macroinvertebrates, algal communities are usually present before disturbance and generally persist in some form after disturbances. Therefore, applications of algal indicators to rivers are increasing (Borics et al., 2007; Blanco et al., 2007; Plenković-Moraj et al., 2007;

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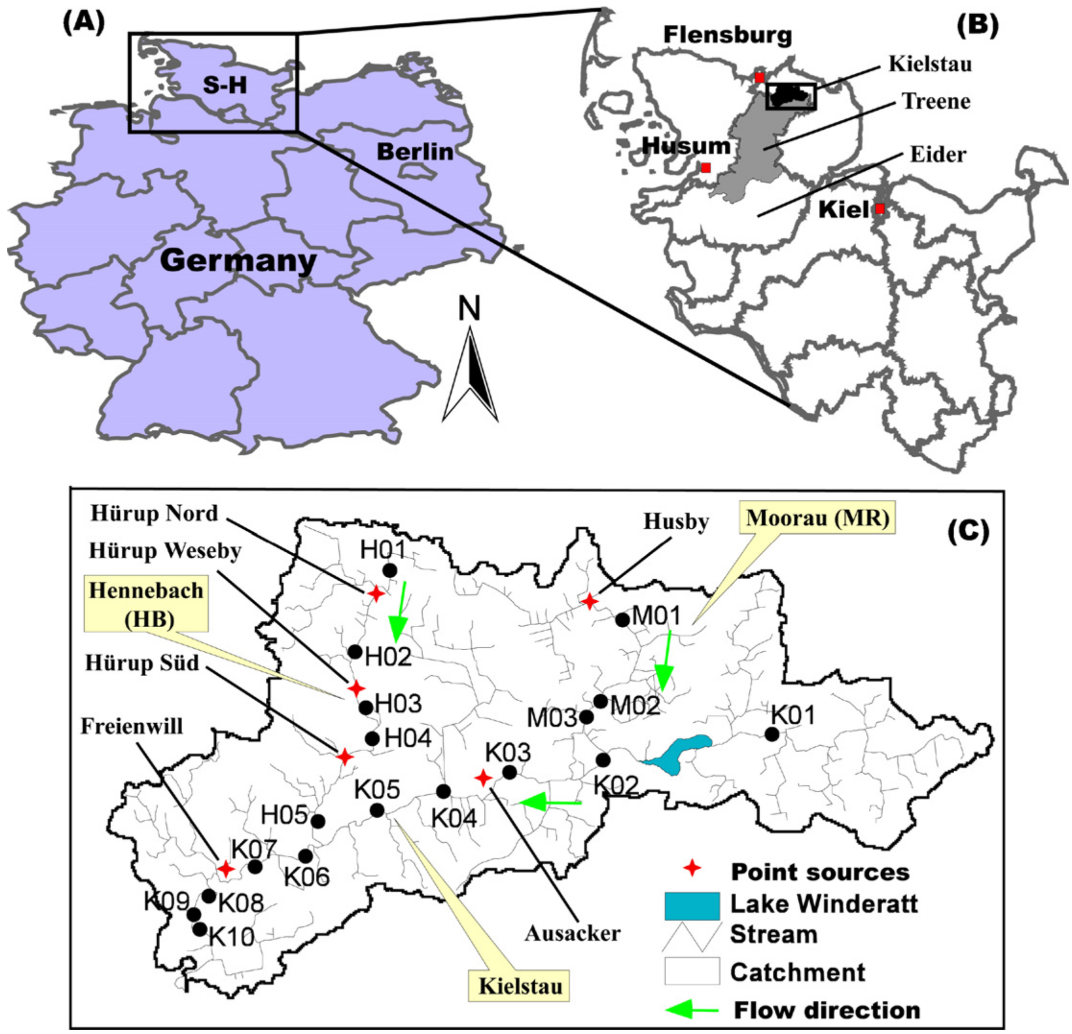

Fig. 1. The location of the Kielstau catchment in Schleswig-Holstein state (B), Northern Germany (A; map source: CDC, 2010) and the sampling sites (C). S-H = Schleswig-Holstein state; M01–M03 = sampling sites collected from Moorau (MR) tributary; H01–H05 = sampling sites from Hennebach (HB) tributary; K01–K10 = sampling sites from main stream Kielstau.

Reavie et al., 2010). However, comparing to the huge investigations in lentic water bodies (e.g., oceans, gulfs, lakes and reservoirs), little attention has been paid to the applications of the phytoplankton in ecological evaluation of rivers so far (Borics et al., 2007). And to our knowledge, a multi-metric based phytoplankton index of biotic integrity (P-IBI) has been rarely considered for river 'health' assessment.

In this paper, we developed and tested a P-IBI using a training data set and a testing data set, respectively, from a German lowland river – the Kielstau catchment. Our specific objectives were to: (1) develop a phytoplankton index of biotic integrity (P-IBI), which can assess effects of human disturbances on the ecological status of the lowland river; (2) test the robustness of the P-IBI by canonical correspondence analysis (CCA) and comparing the performances with other single metrics; (3) deduce the ecological status of the study area by implementing the developed P-IBI.

2. Materials and methods

2.1. Description of the study area

The Kielstau catchment is a lowland watershed with a drainage area of 50 km^2, and located in the Northern part of Germany. It has its origin in the upper part of Lake Winderatt and is a tributary of the Treene River, which is the most important tributary of the Eider River (Fig. 1). Moorau (MR) and Hennebach (HB) are two main tributaries within the Kielstau catchment. Sandy, loamy and peat soils are characteristic for the catchment. Land use is dominated by arable land and pasture (Schmalz et al., 2008b; Schmalz and Fohrer, 2010). The drained fraction of agricultural area in the Kielstau catchment is estimated 38% (Fohrer et al., 2007). The precipitation is 841 mm/a (station Satrup, 1961–1990, DWD, 2010) and the mean annual temperature is 8.2 °C (station Flensburg, 1961–1990, DWD, 2010).

In order to take into account possible inter-seasonal variations, the study was performed seven times at 18 sites (Fig. 1C) along the main stream Kielstau and its tributaries from November 2008 to May 2010. Ten sites (K01–K10) were located along the main stream, three (M01–M03) at the Moorau tributary and five (H01–H05) at the Hennebach tributary. A total of 122 samples were collected.

2.2. Sampling methods and primary procedures

At each site and on every sampling date, three replicate samples of a known volume subsurface (5–40 cm) water were taken with a 10 L bucket and then filtered through a plankton net. The retained