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Variations in diatom communities at genus and species levels in peatlands (central China) linked to microhabitats and environmental factors

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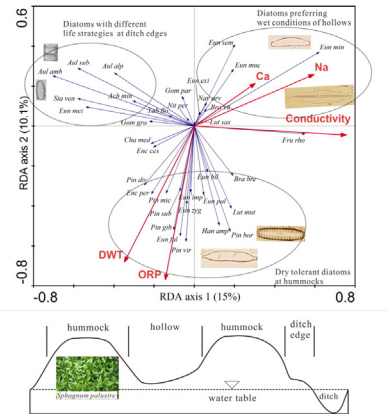
HIGHLIGHTS

- Diatom communities and physiochemical factors in three peatlands were examined.
- Hummocks, hollows and ditch edges were indicated by different diatoms.
- Water level, redox potential, conductivity and calcium were important factors.
- Genus-level taxonomic analysis can be a potential tool for environmental assessment.

GRAPHICAL ABSTRACT



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ABSTRACT

Peatlands are a specialized type of organic wetlands, fulfilling essential roles as global carbon sinks, headwaters of rivers and biodiversity hotspots. Despite their importance, peatlands are being lost at an alarming rate due to human disturbance and climatic variability. Both the scientific and regulatory communities have focused considerable attention on developing tools for assessing environmental changes in peatlands. Diatoms are widely used in biomonitoring studies of lakes, rivers and streams as they have high abundance, specific ecological preferences and can respond rapidly to environmental change. However, diatom-based assessment studies in peatlands remain limited. The aims of this study were to identify indicator species and genus for three types of habitats (hummocks, hollows and ditch edges) in peatlands (central China), to examine the effects of physiochemical factors on diatom composition at genus and species levels, and to compare the efficiency of species- and genus-level identification in environmental assessment. Our results revealed that hummocks were characterized by drought-tolerant diatoms, while hollows were dominated by species and genus preferring wet conditions. Ditch edges were characterized by diatoms with different life strategies. Depth to water table, redox potential, conductivity and calcium were significant predictors of both genus- and species-level composition. According to ordination

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analyses, pH was not correlated with species composition while it was a significant factor associated with genus-level composition. Genus-level composition outperformed species composition in describing the response of diatoms to environmental variables. Our results indicate that diatoms can be useful environmental indicators of peatlands, and show that genus-level taxonomic analysis can be a potential tool for assessing environmental change in peatlands.

1. Introduction

Under the scenario of reducing greenhouse gas emissions globally, peatlands as net carbon sinks have received considerable attention (Rydin and Jeglum, 2013; Hargan et al., 2015). In the waterlogged and deoxygenated conditions of peatlands, the remains of plants accumulate owing to incomplete decomposition. As a consequence of their rich plant diversity, peatlands harbour a multitude of characteristic microorganisms, insects, birds and other animals, and therefore they are unique and complex ecosystems of global importance for biodiversity conservation at the genetic, species and ecosystem levels (Rydin and Jeglum, 2013). In addition, peatlands fulfil an essential role as headwaters of rivers, thus being referred to as natural "water towers" (Joosten and Clarke, 2002). Hence, effective conservation of peatlands is critical for the maintenance of global biodiversity, and storage of water and carbon. To ensure conservation goals are met, it is essential to be able to effectively assess present status and past environmental changes of peatlands (Charman, 2002; Parish et al., 2008; Gaiser and Rühland, 2010).

Microorganisms inhabiting peatlands, such as algae, bacteria, fungi and invertebrates, respond quickly to environmental changes because of their wide distribution, high species richness and rapid reaction to variations in habitat (Hájek et al., 2011; Poulíčková et al., 2013). In particular, peatlands can display high environmental heterogeneity in surface microtopography (e.g., hummocks and hollows) and chemical composition (e.g., pH and conductivity) at a small spatial scale (Charman, 2002; Bu et al., 2013; Rydin and Jeglum, 2013). Hence, the identification of biological communities specific to different habitats is essential for the development of sound biological indicators and criteria. Previous studies have demonstrated that diatoms have high abundance, specific ecological preferences and a short life span which enable them to respond rapidly to environmental changes at genus and species levels (Heino and Soininen, 2007; Teittinen et al., 2015; Juggins et al., 2016). Thus we hypothesized that different habitats within peatlands could be predicted by their corresponding indicative diatom genera and species.

The mountainous region in western Hubei Province (central China) has been identified as one of the Earth's distinctive ecoregions due to the preservation of its rich broadleaved and mixed forest which has a high degree of endemism (Olson and Dinerstein, 1998). There are also some patches of natural peatlands which developed in topographic lowlands in this forested region (Qin et al., 2013). To maintain representation of biodiversity, most of these rare peatlands have been enclosed within national nature reserves. Among these peatlands, Dajiuhu peatland is a rare representative of a typical subalpine *Sphagnum* bog wetland, and it has been designated as a wetland of international importance under the Ramsar Convention. Surface microtopography of peatlands is characterized by the complex of hummocks, hollows and ditches. External disturbances, such as climate warming, agricultural drainage and atmospheric deposition, are directly or indirectly altering the microtopographical pattern (e.g., an increase in hummock height) of these peatlands, probably resulting in the acceleration of environmental degradation and peat decomposition in the future (Moore, 2002). Hence, it is crucial to conduct water-quality and biological assessments for the maintenance and restoration of these peatlands.

The aims of this study were therefore to: (1) identify indicator species and genus for hummocks, hollows and ditch edges using the method of Indicator Species Analysis; (2) examine the effects of physiochemical parameters on diatom distribution at genus and species levels using multivariate analyses; and (3) compare the efficiency of species- and genus-level composition as an indicator for effective environmental assessment.

2. Material and methods

2.1. Study area

Our study area is located the transitional region between the Eastern Plain and the Tibetan Plateau in China's mainland, characterized by limestone and dolomite bedrock and a mountainous terrain with a mean elevation between 1000 and 2000 m a.s.l. (Fig. 1). This region is famous for its high biodiversity and is reported to be "the only well-preserved subtropical forest ecosystem in the world's mid-latitudes" (Olson and Dinerstein, 1998). A number of conservation areas have been established in this region. In particular, the Shennongjia National Nature Reserve is listed in the UNESCO's World Network of Biosphere Reserves. The climate of this region is influenced by a subtropical monsoonal climate with a mean annual rainfall of ~1500–1800 mm, and a mean annual temperature of ~7–14 °C (Chen et al., 2014b). Surface *Sphagnum* samples were collected from Dajiuhu peatland (31°28′56″ N, 109°59′07″E; ~1760 m a.s.l.), Qizimeishan peatland (29°57′50″N, 109°45′11″E; ~1800 m a.s.l.) and Erxianyan peatland (29°43′31″N, 108°48′12″E; ~1550 m a.s.l.). Dajiuhu peatland is located within a closed basin, and other two peatlands are situated in valleys. In the three peatlands, the field layer is formed by *Carex* sp. and the moss layer by *Sphagnum palustre*. In some associations, co-dominants include *Juncus* sp., *Phyllostachys heteroclada*, *Veratrum* sp. and *Sanguisorba officinalis* (Table A.1).

2.2. Sampling method and laboratory analyses

A total of 21 samples from Dajiuhu peatland, 14 samples from Erxianyan peatland and 20 samples from Qizimeishan peatland were collected in July 2014 (Table A.1). The sampling points span three types of habitats including hummocks, hollows and ditch edges. Hummocks are raised more than 10 cm above the lowest surface level, while hollows are wet pits between the hummocks (cf. Rydin and Jeglum, 2013). Ditches are narrow channels on the peatland surface resulting from agricultural drainage or flood erosion. At each sampling point, geographic coordinates were determined using a Garmin Etrex GPS, and depth to water table (DWT) was measured in a ~ 5 cm diameter hole using a graduated ruler. Conductivity, pH and oxidation-reduction potential (ORP) were measured in situ using portable electrodes (Sanxin PD-501 for conductivity and pH, Thermo ORION 3-STAR for ORP). All electrodes were calibrated before use.

Water samples were collected and filtered through a 0.45-μm-membrane filter before the analysis of nutrients and elements. Samples were refrigerated under dark conditions until laboratory analysis. Concentrations of NO_3^-, NH_4^+, NO_2^- and PO_4^{3-} were measured using a continuous-flow autoanalyser (Skalar San Plus). Concentrations of major cations (Ca^{2+}, K^+, Mg^{2+} and Na^+) and silicon (Si) were determined by an inductively coupled plasma-atomic emission spectrometer (PRODIGY SPEC). Total organic carbon (TOC) was measured using a total organic carbon analyser (TORCH). The reproducibility of the duplicated water samples was >90% for all parameters.