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Testing the relationship between testate amoeba community composition and environmental variables in a coastal tropical peatland

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ABSTRACT

We investigated the ecology of testate amoebae (TA) in a coastal tropical peatland to evaluate their potential as environmental indicators in these ecosystems. At 10 positions in five locations in a transect running into the peatland away from the coast, we measured pore-water pH, pore-water electrical conductivity, soil moisture content (MC), and water-table depth (WTD). The WTD data were collected using dipwells fitted with self-recording pressure transducers that logged at 10-min intervals over a 25-day period. Multivariate statistical analysis showed that hydrological metrics (WTD and MC) were the strongest environmental controls on TA ($p < 0.001$) in this site, corroborating the single previous study from western Amazonia. Changes in pH and electrical conductivity, reflecting marine influence, were also significant, but less so ($p < 0.05$; $p < 0.01$ respectively). Transfer functions for WTD and MC were developed using weighted averaging partial least-squares regression, and were found to perform well under 'leave-one-out' cross validation ($R^2 = 0.80$, RMSEP = 4.64 cm; $R^2 = 0.89$; RMSEP = 1.57 cm). Our results clarify the autecology of several taxa found in tropical peatlands. *Centropyxis aculeata* is an unambiguous indicator of surface water, *Hyalosphenia subflava* "minor" (< 60 µm length) is a dry indicator, whereas *Hyalosphenia subflava* "major" (> 60 µm length) lives in wetter conditions. The difference in habitat preference of the two forms of *Hyalosphenia subflava* suggests that this taxon is most probably a species complex. We use the new high-quality dataset to test an existing transfer function from western Amazonia: the results show that the previous model has good predictive power for reconstructing past WTDs in tropical peatlands ($r = 0.87$; $p < 0.005$). The reconstruction of sea-level change from tropical coastal wetlands may prove problematic because the key indicators of marine influence, reflected in pH and electrical conductivity, are taxa with weak idiosomic tests that do not preserve readily in the peat archive (e.g. *Tracheleuglypha dentata*, *Trinema lineare*). Our work shows the potential of using high-quality hydrological measurements for increasing the precision of transfer function models.

1. Introduction

Tropical peatlands represent a globally-important carbon store and can be found in Asia, Central and South America, and Africa (Page et al., 2011; Dargie et al., 2017). They have been severely damaged in Southeast Asia through drainage and subsequent conversion to palm oil and wood pulp production (Posa et al., 2011; Green and Page, 2017). This has led to extensive fires with significant implications for air quality and human health (Page and Baird, 2016). Coastal tropical peatlands have also been identified as particularly vulnerable to sea-level rise, with ~61,000 km^2 of them lying ≤5 m above sea-level (Whittle and Gallego-Sala, 2016). However, relatively little is known about how tropical peatlands have developed through time, and their ecohydrological responses to climate change and sea-level rise remain unclear (Swindles et al., 2018).

Multiproxy palaeoenvironmental studies of tropical peatlands are in their infancy (e.g. Hapsari et al., 2017; Swindles et al., 2018), and much uncertainty remains over the efficacy of proxy-based reconstruction methods in these systems. Testate amoebae (TA) are dominant microbial consumers in peatlands, representing up to 30% of the total microbial biomass, and may have a major influence on the ecological functioning of peatland ecosystems through nutrient and carbon cycling (Gilbert et al., 1998; Mitchell et al., 2003). TA are sensitive wetness indicators (e.g. Charman and Warner, 1992; Swindles et al., 2009; Turner et al., 2013; Amesbury et al., 2016), and have become a standard tool for palaeohydrological reconstruction in northern peatlands

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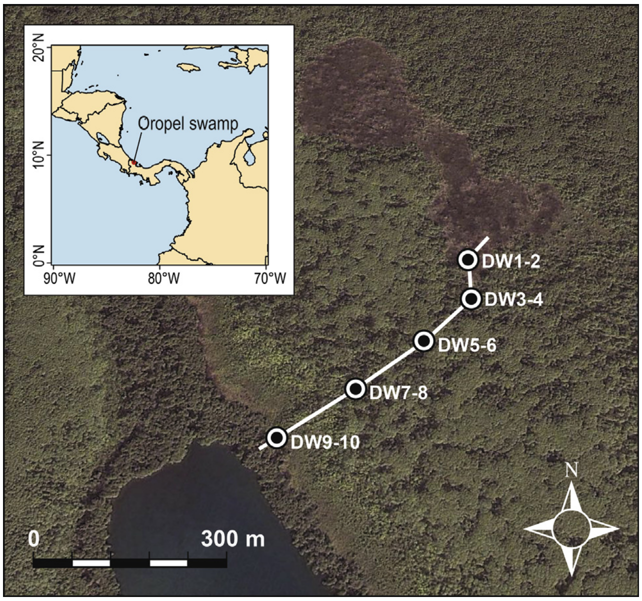

Fig. 1. The sampling locations (dipwells 1–10) and topographic survey line in Oropel Swamp (Google Earth, 2008).

using statistical 'transfer functions' (e.g. Woodland et al., 1998; Booth, 2008; Swindles et al., 2015a,b). To date, TA have only been used as hydrological indicators in one tropical peatland: Aucayacu, a raised peat dome in Peruvian Amazonia (Reczuga et al., 2015; Swindles et al., 2014, 2016, 2018). This work has shown that the distribution of TA is controlled primarily by hydrological variables, mirroring findings from northern ombrotrophic peatlands (Swindles et al., 2014). It has also been shown that a transfer function can be used to infer major hydrological changes down-core, although problems with low test concentration and preservation limit the sensitivity of the reconstruction (Swindles et al., 2016, 2018).

Here we present the first investigation of peatland testate amoebae communities from Central America. Specifically, we (i) investigate the ecology of TA in a Panamanian coastal peatland; (ii) use high-quality automatically-logged water-table depth (WTD) determinations to test the hypothesis that hydrological variables are the strongest environmental control on the distribution of TA; (iii) use the data to test the existing TA transfer function from Peruvian Amazonia; (iv) evaluate the potential of TA as sea-level indicators.

2. Study site

Oropel Swamp (Baird et al., 2017) (Fig. 1) is a coastal tropical peatland in Bocas del Toro province, northwest Panama, and represents part of the wider Changuinola peat swamp complex (Phillips et al., 1997). Coring has revealed peat up to 6.5 m thick across the site (Fig. 2). The climate of this region is humid-tropical with no distinct dry season; average annual temperature is c. 26 °C and average annual precipitation is around 3200 mm (Phillips et al., 1997; Baird et al., 2017).

3. Method

3.1. Fieldwork

We established a NE-SW transect encompassing all vegetation zones across the site from 9.383460°N, 82.366030°W to 9.379308°N, 82.367403°W (Figs. 1 and 3). The transect was surveyed to an arbitrary

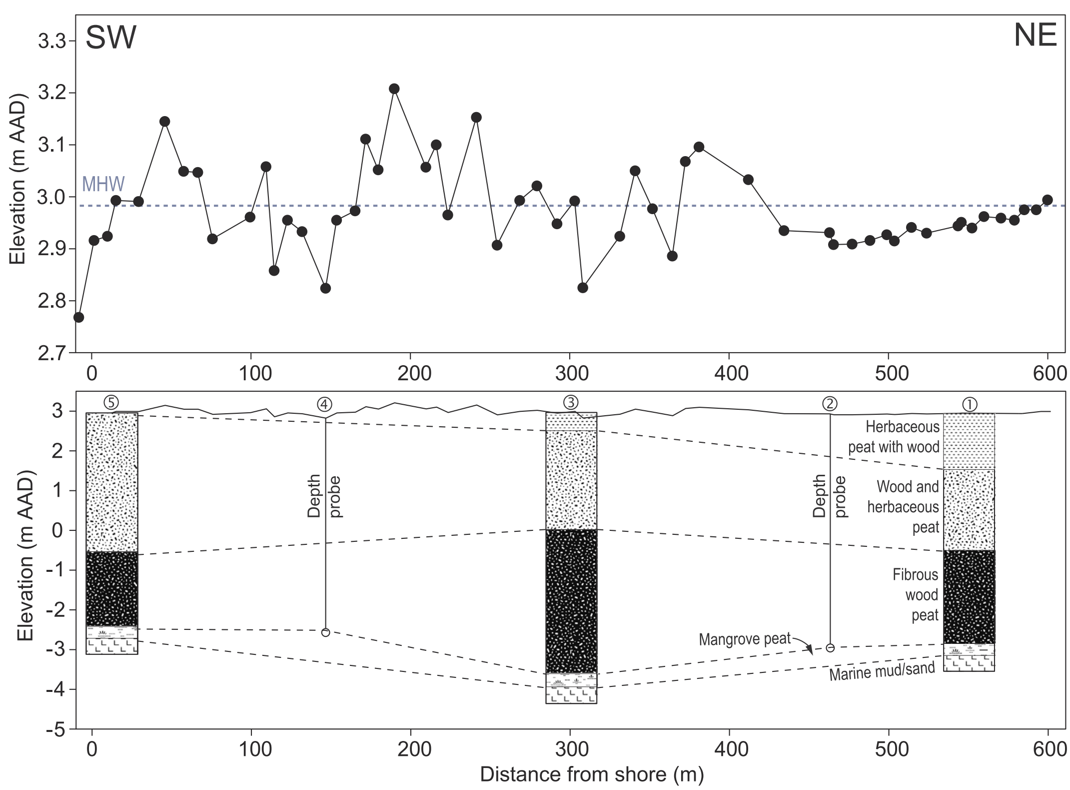

Fig. 2. Topographic and stratigraphic survey data from Oropel Swamp, showing the location of the points from which cores were extracted. Dipwells 1 and 2 were located at core point 1, Dipwells 3 and 4 were at core point 2, Dipwells 5 and 6 were at core point 3, Dipwells 7 and 8 were at core point 4, and Dipwells 9 and 10 at core point 5. The mean high sea water level (MHW) level during the monitoring period is also illustrated.