Response of testate amoebae to a late Holocene ecosystem shift in an Amazonian peatland

Graeme T. Swindles[a,*], Thomas J. Kelly[a], Katherine H. Roucoux[b], Ian T. Lawson[b]

[a]*School of Geography, University of Leeds, UK*
[b]*School of Geography and Sustainable Development, University of St Andrews, UK*

Abstract

To date there have only been two studies using testate amoebae as palaeoecological indicators in tropical peatlands. Here we present a new ∼500-year testate amoeba record from San Jorge, a domed peatland in Peruvian Amazonia, which has a well-constrained vegetation history based on pollen analysis. We observe a major shift from *Hyalosphenia subflava* to *Cryptodifflugia oviformis*-dominated communities at ∼50 cm depth (*c.* AD 1760), which suggests a change to drier conditions in the peatland. The application of a statistical transfer function also suggests a deepening of the water table at this time. The transition in the microbial assemblage occurs at a time when pollen and geochemical data indicate drier conditions (reduced influence of river flooding), leading to an ecosystem switch to more ombrotrophic-like conditions in the peatland. Our work illustrates the potential of testate amoebae as important tools in tropical peatland palaeoecology, and the power of multiproxy approaches for understanding the long-term development of tropical peatlands.

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Keywords: Amazonia; Amazon rainforest; Palaeohydrology; Testate amoebae; Tropical peatlands

Introduction

Tropical peatlands represent a carbon store of global importance and can be found in Asia, Africa, and Central and South America (Dargie et al., 2017; Page et al., 2011). In South America, the Pastaza-Marañon foreland basin (PMFB) in NW Peru represents the most carbon dense landscape in Amazonia owing to an abundance of peatlands (e.g. Draper et al., 2014), including nutrient-poor ombrotrophic peat domes and river-influenced minerotrophic peat swamps (Lähteenoja and Page, 2011). It has been estimated that peatlands of the PMFB account for 3.5% of the global tropical peatland carbon stock, cover $35{,}600 \pm 2133\,\mathrm{km}^2$ and contain 3.14 (0.44–8.15) Pg C (Draper et al., 2014). One type of ecosystem in the Pastaza-Marañon foreland basin – peatland pole forest – has been identified to be the most carbon-dense ecosystem type in the Amazon Basin $(1391 \pm 710\,\mathrm{Mg\,C\,ha}^{-1})$ once below ground carbon stocks are taken into account (Draper et al., 2014). Despite the importance of this ecosystem type, to date there have only been two studies examining the long-term development of pole-forest peatlands in Amazonia (Kelly et al., 2017; Swindles et al., 2018).

Peatlands in Amazonia have so far escaped the widespread damage seen in Southeast Asia, but are nevertheless threatened by human activities including drainage, deforestation, mining, agricultural expansion and infrastructure projects

(Householder et al., 2012; Roucoux et al., 2017). Although tropical peatlands are behaviourally similar to northern peatlands in many ways (University of Leeds Peat Club, 2017), studies of their hydrology have shown that tropical peatlands can have high hydraulic conductivities (Baird et al., 2017; Kelly et al., 2014), potentially making them vulnerable to rapid carbon loss when drained or if hydrological boundary conditions are altered by natural processes.

Testate amoebae (TA) can be sensitive wetness indicators and have become a standard tool for hydrological reconstruction in northern peatlands (e.g. Amesbury et al., 2016; Charman and Warner 1992; Swindles et al., 2009). However, TA have only been used as hydrological indicators in one Amazonian peatland to date — Aucayacu, a nutrient-poor peat dome in Peruvian Amazonia (Reczuga et al., 2015; Swindles et al., 2014, 2016, Swindles et al., 2018). A statistical transfer function has been developed from this site that can be used for long-term reconstruction of water-table depth down-core (Swindles et al., 2014). Despite problems of poor preservation and low concentration of TA in some tropical peats, it has been demonstrated that the approach can be used to infer major palaeohydrological shifts through time (Swindles et al., 2016). However, this method needs to be tested further in other tropical peatlands in Amazonia and beyond (e.g. Biagioni et al., 2015). In this study we test the response of TA to an ecosystem shift reconstructed using pollen and geochemical analyses at San Jorge, an ombrotrophic domed peatland bordering the Amazon River in Peruvian Amazonia (Fig. 1).

Material and Methods

San Jorge peatland is located in one of the wettest parts of Amazonia with a total annual rainfall exceeding 3000 mm, and remaining above 100 mm per month even in the dry season (Marengo 1998). Mean annual temperature is c. 25 °C, with high relative humidity of 80–90% throughout the year (Marengo 1998). The vegetation of the core site is characterised by 'pole' forest (Draper et al. 2018), dominated by three species: *Pachira* aff. *brevipes* (A. Robyns) W.S Alverson (Malvaceae), *Remijia* aff. *ulei* K. Krause (Rubiaceae), and *Calophyllum brasiliense* Cambess (Clusiaceae) (Kelly et al., 2014); *Mauritia flexuosa*-dominated palm swamp occurs towards the margins of the peatland.

The peatland was sampled in 2010 using a Russian peat corer (e.g. De Vleeschouwer et al., 2010) at location 4°03′48″ S, 73°11′42″ W. Detailed pollen analysis has previously been undertaken on the core and supplemented with loss-on-ignition, C/N and geochemical analyses (Kelly et al., 2017). Chronological control was achieved using a combination of ^{14}C and ^{210}Pb dating (Tables 1 and 2; Kelly et al., 2017). A Bayesian age-depth model incorporating the ^{210}Pb and ^{14}C dates was produced using the BACON package (Blaauw and Christen, 2011). For the purpose of this study TA were extracted from the peat samples in the top 1-m of the peat core (which spans the ecological transition of interest). Prior to analysis testate amoebae were stored in refrigeration at 4 °C and analysed in 2012 (2 years after the field campaign). This was achieved by sieving at 300 μm and back-sieving at 15 μm following Booth et al. (2010). TA were counted under transmitted light at 200–400× magnification and were identified using morphology, composition, size and colour to distinguish taxa. At least 100 specimens were counted ($n = 101–186$) in each sample to ensure statistical reliability (e.g. Patterson and Fishbein 1989). TA were identified using several sources (Charman et al., 2000; Mazei and Tsyganov, 2006; Meisterfeld, 2000a,b; Ogden and Hedley, 1980; Siemensma, 2018). The taxonomy used a morphospecies approach in certain circumstances, where a designation that includes other species or several morphotypes is referred to as a "type" (e.g. Mitchell et al., 2014). The weighted averaging partial least-squares (WA-PLS) transfer function (component 3) of Swindles et al. (2014) was applied to the TA data and sample-specific errors of prediction were calculated from 999 bootstrap cycles. Weak silicic idiosomic tests that do not preserve well in peatlands were removed before running the reconstruction (Euglypha, Trinema and Tracheleuglypha spp.) (e.g. Swindles and Roe, 2007). Detrended Correspondence Analysis (DCA) was carried out and axis one scores were used as a one-dimensional summary of the major changes in the assemblages. The Shannon Diversity Index (SDI) was also calculated for each sample to examine diversity down-core.

Results

A total of 33 TA taxa from 16 genera were identified in the San Jorge peat core (Table 3; Fig. 2). The most abundant taxa in the core include *Hyalosphenia subflava* "minor" (<60 μm length) and *Hyalosphenia subflava* "major" (>60 μm length), *Cryptodifflugia oviformis*, *Phryganella acropodia* and *Trigonopyxis arcula* "polygon aperture". Shannon diversity and richness decrease down-core suggesting poorer preservation of some taxa in the deeper levels. In particular, taxa with idiosomic siliceous tests (*Euglypha*, *Tracheleuglypha* and *Trinema* spp.) disappear down-core, which is likely related to poor preservation (e.g. Swindles and Roe 2007).

A major shift from an assemblage dominated by *Hyalosphenia subflava* to one dominated by *Cryptodifflugia oviformis* occurs around 50 cm (c. AD 1760), suggesting a change to drier conditions. This is also demonstrated by the DCA axis 1 score and water table reconstruction (Fig. 2). The pollen zones of Kelly et al. (2017) are indicated on the diagram (Fig. 2). When the average reconstructed water table is calculated for each zone, a clear shift to drier conditions is observed between zones SJ-4 and SJ-5. A shift to slightly wetter conditions in the most recent period may be suggested by the appearance of the unambiguous wet indicator *Centropyxis aculeata* at the very top of the core (Fig. 2).