Using palaeobotanical techniques to guide peatland restoration. A case study from Byron Bay, Australia

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Using Palaeobotany to resolve ecological disasters in East Australian peatlands

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Introduction

Low lying coastal peat-lands were once common in the inter-dune areas of Byron Bay, New South Wales. While small areas remain, the majority have been cleared and drained for agricultural and urban use during the past century. One of these areas of peat-land is currently undergoing review for restoration. This provided an opportunity to investigate the vegetation history of the site to set remediation targets for the restoration project.

Peat-lands are valuable ecosystems, highly vulnerable to degradation by a range of activities (Gorham and Rochefort 2003; O'Connell 2003; Rochefort *et al*. 2003; Vasander *et al.* 2003). In Australia peat-lands are an unusual and infrequent component of the landscape (Whinman *et al*. 2003). Mostly distributed in the south east, in the alpine areas of New South Wales, Victoria and Tasmania, they usually occur between 600 and 1000 metres in altitude (Clarke and Martin 1999). However, areas of peat also occur in the coastal lowlands, often in dune swales, both on the east coast of Australia and the south west coast of Western Australia (Whinman *et al*. 2003). The vegetation on these sedgeland deposits is usually dominated by Restionaceae and Cyperaceae species rather than Sphagnum and are sometimes forested (Whinman *et al.* 2003).

In recent years, public awareness of peat-lands has increased and much effort has been aimed at the restoration of peat-land structure and function (Vasander *et al*. 2003, Price *et al.* 2003). Forested peat-lands are some of the most urgent sites to be restored as these were the first to be cleared for their agricultural value, and few areas remain (Vasander *et al*. 2003). The major impediment to expedite restoration of peat-lands in Australia is a lack of knowledge of restoration techniques appropriate to the environmental conditions (Whinman *et al*. 2003). Historical conditions need to be examined to understand how a wetland once functioned naturally and thus how it might best be restored (Steedman *et al*. 1996). Although some degraded sites can be restored naturally if given enough time, severely degraded sites need human design and intervention to restore their condition and functionality.

Palaeoecological records can provide valuable baseline data regarding the physical and biological characteristics of a peat-land prior to human impact, and can also serve to provide information on the natural variability of these characteristics over long periods of time (Kowalski and Wilcox 1999). Palaeoecology has been used overseas to set remediation targets for peat land restoration (Lavoie *et al.* 2001, Girard *et al*. 2002) but it is an under-utilised tool (Gorham and Rochefort 2003), particularly in Australia (Martin 1999). Palaeoecology can supply a detailed reconstruction for a site, and is a valuable tool for clearly establishing the goals of a restoration program (Lavoie *et al*. 2001).

This project investigated the vegetation composition that contributed to a peat layer in Byron Bay, using palaeobotanical techniques and makes suggestions to assist formulation of the restoration plan for the Byron Bay site. The major aims of this study were to: establish a chronology for the wetland sediments; detect any major temporal changes in vegetation types; and identify species that have played a key role in the accumulation of peat at this site.

Site description

The Byron Bay peat-lands now have an extensive drainage network to keep water tables artificially low, resulting in pyrite oxidation and the episodic discharge of damaging acid products into the local waterway, the Belongil estuary. The estuary frequently runs red with iron floccules from acid sulphate discharge and causes fish kills. In response to these pressing problems, Byron Shire Council and the Centre for Acid Sulfate Soil Research at Southern Cross University, are developing a remediation strategy (Bolton 2001). The strategy incorporates effluent reuse with acid sulfate soil management, peat restoration and carbon credits.

The regeneration of the 24 ha peat wetlands area will involve planting suitable vegetation types as bioremediators that will be irrigated with tertiary treated effluent receiving up to 7 ML of effluent per day. The effluent is used to manage acid sulfate soils in two ways: (i) the alkaline effluent (pH ≈ 8.0) buffers existing acid products, increasing the pH of the groundwater and; (ii) the effluent maintains water levels above the pyrite layer, preventing oxidation, and the subsequent production of acid products. Furthermore, effluent will provide water and nutrients for the regenerating wetland vegetation ensuring optimal conditions for their growth. This study was conducted to examine the vegetation history of the site, to set restoration goals and examine the feasibility of the existing plans for remediation. It is necessary to understand the vegetation history of the site to select suitable species to plant for the successful regeneration of the wetlands.

Methods

Two sediment cores were extracted from the Byron Bay peat-lands using a Vibracorer. The first core (B1) was 1.75m and was extracted from the peat sediments in the north eastern area of the site. The second core (B2) was retrieved from the southern plot area and was 1.65 m. Using scalpels, sediments from both cores were divided into 5cm samples for the entire length of the cores. The sampling strategy was to process samples from the upper and lower sections of each sediment horizon to investigate dominant changes in the peat environment over time. Pollen was extracted from one cubic centimetre of sediment using the method described in Cotter and Boyd (1998), excluding the Hydrofluoric Acid treatment that was considered unnecessary due to the low silica content of the sediment. Pollen extracted from each sample was mounted onto microscope slides and scanned at 600x and 1000x magnification on an Olympus BH2 microscope. A total pollen sum of 500 grains was counted per sample. Phytoliths were extracted from sediment using the method of Parr (2002). Phytoliths extracted from each sample were weighed, mounted onto microscope slides and scanned at 400x magnification on an Olympus BH2 microscope. A total of 150 phytoliths was counted for each slide. Absolute numbers of phytolith types were recorded. The presence of specific taxa were also recorded from the phytolith slides to assist in determining temporal changes in habitat and salinity. Charcoal particles were counted according to the method of Clarke (1982). Bulk fossil phytoliths samples from B1 (Laboratory No.s OZH476-81) were processed and carbon dated at the ANSTO AMS dating facility, Sydney.

Results

The two sediment cores correlated closely in stratigraphy and microfossil results, hence only results from core B1 are presented here. The stratigraphy of the B1 sediment core is shown in Figure 1. At the base of the core, marine sands are present. Above this section, dating from around 8710 ± 50 years BP to 6590 ± 50 years BP, there is a layer of fine peat and clay development. A coarser peat layer begins at around 6590 ± 50 years BP and persists until 6050 ± 60 years BP. The next layer is composed of sulphidic clay and spans from 5430 ± 50 years BP to 5110 ± 50 years BP. From about 4540 ± 40 years BP to the uppermost layer, it is composed entirely of a coarse peat. The peat accumulation rates are very low. Peat within zone 4 has accumulated 0.022 cm per year. Peat in zone 3 has accumulated at 0.048 cm per year and peat in zone 1 at 0.015 cm per year, much lower than at other periods in the development of this sediment profile.

The relative abundance of pollen for each taxa present and dominant vegetation types from core B1 are presented in Figure 1. The dominant peat forming vegetation has been Sphagnum and Cyperaceae. Sphagnum was the dominant peat forming vegetation prior to 4540 ± 40 years BP and Cyperaceae most recently. Dominant tree species have been Casuarinaceae and Myrtaceae. The pollen data indicates that herbaceous taxa have been the dominant vegetation component of this peat environment for the past 8000 years. The shrub and tree component are minor but show significant fluctuations through time. At around 4540 ± 40 years BP tree pollen made a significant recovery, however, this trend does not persist and tree pollen gradually decreased to present levels when herbaceous plants once again become the dominant vegetation type represented.

Phytolith percentages for each taxa present and summaries of vegetation types for sites are also shown in Figure 1. The phytolith record shows a dominance of Myrtaceae in the tree component and Restionaceae and Cyperaceae as the dominant peat forming herbs. At around 4540 ± 40 years BP tree phytolith types made a significant recovery and continue to be strongly represented through to the present. Shrubs are poorly represented during this period, however, herbaceous plants remain the dominant types represented throughout the sediment core profile.

The proportion of fine charcoal particles (Figure 1) shows that around 8710 ± 50 years BP there are low charcoal counts, however, counts significantly increase around 6590 ± 50 years BP. Between 6050 ± 60 years BP and 5110 ± 50 years BP charcoal particle counts are very low. A large increase in charcoal occurs at around 4540 ± 40 years BP and these particle deposits remain relatively high to the top of the core samples. The pH of the site decreases towards the present with zone 1 showing highly acidic conditions.

Implications

The Byron Bay peat-lands are low lying coastal peats that have formed in the interdune swale. Marine sands found in the basal layers of this site indicate that the ocean was in close proximity to it 8710 ± 50 years BP. The peats at this site have thus formed during the past 8000 years. The vegetation history shows that the peats formed below a forested canopy were dominated by Myrtaceae and Casuarinaceae. As indicated by Whinman *et al.* (2003), this type of peat-land is very rare within Australia after its destruction for agricultural and urban land-use, and hence in dire need of restoration for their ecological value.

The pollen and phytolith records show that the peat forming vegetation has been composed of Sphagnum, Cyperaceae and Restionaceae species throughout its history. Prior to 5000 years BP the peat was dominated by Sphagnum and Restionaceae but this changed to Cyperaceae and Restionaceae species in the last 5000 years. Charcoal counts indicate that the area has experienced an increase in fire activities over the past 5000 years, a threat to the peat environment that might account for the disappearance of Sphagnum from this site, and the absence of Restionaceae pollen.

Conclusions

For the restoration of this site, the naturalness of the area was assessed using palaeobotanical techniques. Pollen and phytolith records indicated that this area, under natural conditions, was a forested peat-land. In most recent times it was dominated by Myrtaceae tree species with Cyperaceae and Restionaceae as the dominant peat forming vegetation. To return this area to a state representing pre human impact this vegetation will need to be restored.

The proposed remediation strategy involving irrigation with treated effluent will raise water tables reinstating a more natural hydrology that is more conducive to peat formation and maintenance. The treated effluent will also increase the pH of the site to neutral conditions, also more conducive to return of vegetation. However, the ability of Myrtaceae, Restionaceae and Cyperaceae to grow under high nutrient loads from the treated effluent is currently unknown and warrants further investigation.

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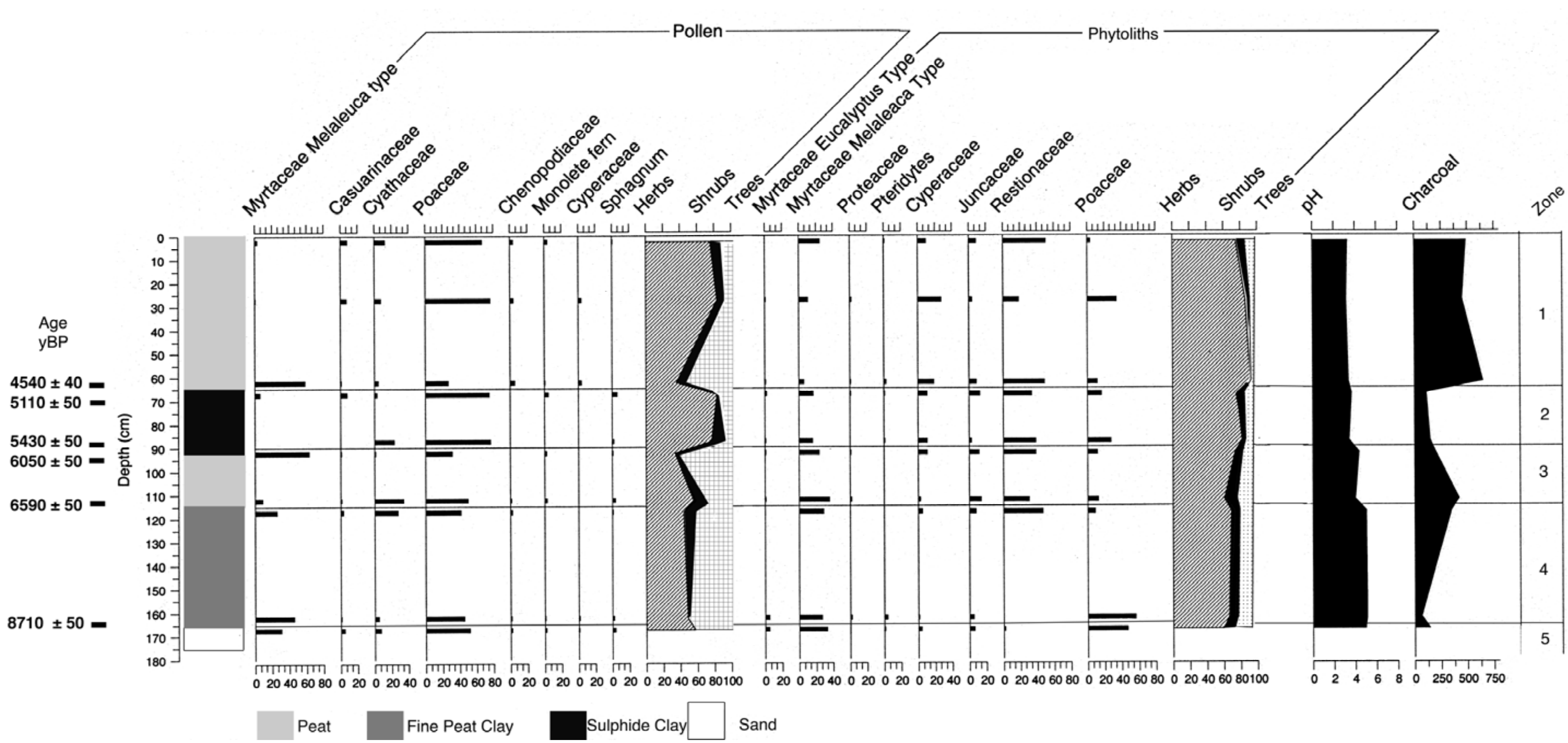

Figure 1: Palaeobotany Results of Byron Bay Peat Core