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Robust Local Vegetation Records from Dense Archaeological Shell Matrixes: A Palynological Analysis of the Thundiy Shell Deposit, Bentinck Island, Gulf of Carpentaria, Australia

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Abstract

This study investigates the palynological remains (both fossil pollen and charcoal) recovered from the Thundiy shell midden deposit, Bentinck Island, Gulf of Carpentaria, northern Australia, to provide a vegetation and fire record for this site, which sheds light on human occupation of the southern Wellesley Archipelago over the late Holocene. Results show that the development of a high density shell deposit by human activities was directly responsible for pollen preservation, possibly through the creation of a moist, anaerobic environment that reduces oxidation of pollen grains. The presence of recoverable pollen from a shell midden deposit from Bentinck Island provides a valuable new proxy to provide greater context for archaeological records, particularly in terms of local vegetation information and potential insight into human land management practices.

Keywords

Midden, Palynology, Fire, Vegetation Change, Coastal, Northern Australia, Indigenous

Introduction

Nearshore coastal shell deposits, including both human-produced and natural accumulations, provide a wealth of information to archaeologists about human occupation and local environmental conditions (e.g. Waselkov, 1987; O'Connor and Sullivan, 1994; Claassen, 1998; Alvarez et al., 2011; Weisler et al., 2012). Although conventional analyses focus on faunal assemblages and associated artefacts, shell deposits also provide an ideal medium for the preservation of some types of organic remains, including macrobotanics, which can provide a broader picture of the environmental setting for the deposit (Waselkov, 1987; Alvarez et al., 2011).

Owing to the fact that the principal materials deposited in shell middens are shellfish, as opposed to plant remains, there have been limited studies of plant microfossils (either pollen or phytoliths) recovered from these contexts. Nevertheless, where such studies have been undertaken, phytoliths (siliceous plant microfossil remains) have proven particularly promising in providing palaeoenvironmental information. In the Australian context the first such study to attempt this was that of Parr and Carter (2003), who examined phytoliths from two sites (Ormi and Sokoli) on Dauar Island in the Torres Strait. Between ~2,600 and 2,000 cal BP Ormi had an open broad leaf (mesophyll) vegetation community dominated by an unidentified palm (Arecaceae) and other arboreal types including Combretaceae, with a sparse grass (Poaceae) cover. After that time, there was a substantive increase in grass types and a decrease in the presence of palms indicating a relatively open area. At Sokoli sometime

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post ~1,870 cal BP there was a shift from phytolith types found in *Themeda australis*, generally associated with stable habitats, to those observed in *Imperata cylindrica* often associated with disturbed areas, and in particular fire. At both sites from 2,000 years ago there was a shift from unidentifiable palm species to the economically important *Cocos nucifera*, and the presence of *Musa* and *Ipomea*, suggesting human induced changes to the local vegetation. Lentfer et al.'s (2013) study of a midden deposit from Lizard Island, some 500 km southeast of the Torres Strait in the far north Great Barrier Reef, Australia found excellent preservation of phytoliths and recorded a change from dry rainforest to more open vegetation over the last 3,800 years. An increase in grasses was also observed, most likely associated with European settlement in the last 200 years, with all the vegetation changes thought to be associated with anthropogenic alterations in fire regimes.

Beyond Australia, studies of plant microfossils from shell midden deposits are likewise limited in number. Zurro et al. (2009) examined 10 sediment samples from a single hearth feature in a nineteenth century occupation layer of a midden in Tierra del Fuego (Argentina). The samples all showed well preserved phytoliths, though generally at low concentrations, and the temporally limited context of the study meant it was not possible to reconstruct shifts in vegetation through time. However, a key finding was the necessity of sampling horizontally, owing to the highly structured nature of human behaviours resulting in variability of phytolith deposits in midden contexts.

In terms of palynological analysis of midden deposits there has been very little research undertaken, although Mudie and Leliévre's (2013) palynological analysis of midden deposits in Nova Scotia, Canada, found reasonable recovery of palynomorphs (i.e. pollen, fungal remains and algal spores) and microcharcoal. They observed that the pollen record from the

shell midden at Maligomish (Indian Island) on the Northumberland Strait correlated to existing late Holocene pollen zones from lake and marine studies within the region and that shifts in algal spores, testate amoebae and aquatic plant pollen indicated changes in depositional environment during the time of midden use.

Whatever the proxy being examined it must be remembered that coastal shell deposits occur in highly dynamic environments, which are influenced by natural (e.g. storm events and sea-level change) and anthropogenic factors that can dramatically impact the formation and post-depositional environment of the accumulations that in turn may affect the archaeological and/or environmental reconstruction of the site (e.g. Hughes and Sullivan, 1974; Bailey, 1983; Attenbrow, 1992; Bird, 1992; O'Connor and Sullivan, 1994; Claassen, 1998; Carter et al., 1999; Rick et al., 2006; Ulm, 2006; Rosendahl et al., 2007; Rowland and Ulm, 2012; Szabó, 2012; Sherwood et al. 2016). Several studies have investigated the microfossil record (both marine and terrestrial) of coastal shell deposits and found variability (ranging from poor to good) in the preservation of fossil pollen and foraminifera (e,g. Cann et al., 2000; Sobolick, 2003; Hebda et al., 2005; Rosendahl et al., 2007; Mudie and Leliévre, 2013; Nagel et al., 2016).

Within Australia and particularly for the northeast tropical coast the majority of coastal middens were created after 2,000 years ago, with relatively few sites pre-dating this period (Rowland, 1983, 1989; Ulm et al., 1995; Ulm 2011) and with a major expansion in middens occurring over the last 1,000 years (Ulm, 2011). The distribution and age of these coastal deposits have been used to support a range of archaeological arguments for Aboriginal occupation of the Queensland coast for the late Holocene period, ranging from environmental alterations impacting resource availability (Bailey, 1983; Beaton, 1985);

environmental/preservation factors (Rowland, 1983, 1989); possible effects of population changes (Lampert and Hughes, 1974; Beaton, 1985; Rowland, 1989); intensification (Lourandos, 1987; Barker, 2004)); and marked changes in land-use patterns (Morrison, 2003, 2013; Ulm, 2006; Williams et al., 2015). However, this research has mainly focussed on broad changes in site attributes and shell assemblages, and the associated marine vertebrate record, with very little emphasis on other proxies (e.g. macrobotanical remains and plant microfossils) that may be preserved in the shell deposit sediments. This study investigates the palynological remains (both fossil pollen and charcoal) for the Thundiy coastal shell deposit, Bentinck Island, Gulf of Carpentaria, to provide a vegetation and fire record for this site, which sheds light on human occupation of the southern Wellesley Archipelago over the late Holocene period.

Study Site

The Thundiy shell deposit is located on the north coast of Bentinck Island, South Wellesley Archipelago, Gulf of Carpentaria, northern Australia (17° 01' 06" S, 139° 29' 38" E) (Figure 1). The site comprises dense shell deposits and occasional stone artefacts across the surface of a mid-Holocene beach ridge extending between the mouths of Rukathi Creek and Makarrki River. The beach ridge (elevation ~6.25 to 6.5 m; partially consolidated beachrock) runs in a Southwest to Northeast direction for about 4 km and is up to 150 m wide (Figure 1). There is a large low-lying salt-clay plan running parallel to the beach ridge on the seaward side, which extends for ~220 m where a dense mangrove forest (~100 m wide) fringes the shoreline. A dense concentration of named campsites was recorded by Tindale (1962:285) along the beach ridge, which he called a 'wooded plateau', as well as further describing the surrounding landscape as 'a quarter-mile belt of normally dry claypan [that] lies behind the mangrove fringe'.

At the surface the Thundiy deposit is a large, dense stratified midden covering an area of at least 600,000 m^2 and the main excavations (Squares A to C) were undertaken at the approximate centre of the site. High density concentrations of shell are found across much of the ground surface and are dominated by *Marcia hiantina*, *Tegillarca granosa*, *Saccostrea glomerata*, *Volegalea cochlidium* and *Telescopium telescopium*, with lesser quantities of *Gafrarium pectinatum*, *Semele sinensis* and *Placuna placentum*. A few species of small gastropods, including *Cerithidea* sp., *Clypeomorus* sp. and *Rhinoclavis* sp. are also commonly found at the site. Silcrete stone artefacts, along with the remains of marine fauna (i.e. fish and turtle bones) are also associated with the shell deposit.

The vegetation of the beach ridge consists of *Pandanus* sp., eucalypts, grevilleas, she-oaks (Casuarinaceae family), wattles (*Acacia* sp.) trees and spinifex grasses (*Triodia* spp.), forming a mixed savanna and coastal spinifex grassland community. The salt-clay pan has scattered salt-marsh plants (Chenopodiaceae) and the nearby mangrove consists primarily of the red mangrove (*Rhizophora stylosa*), yellow mangrove (*Ceriops tagal*), orange mangrove (*Bruguiera* sp.) and the grey mangrove (*Avicennia marina*), with telescope mud whelks (*T. telescopium*) common amongst the rearward mangroves. The intertidal sand-mud flats contain hiant venus clams (*M. hiantina*) and tumid venus clams (*G. pectinatum*). Low stone-walled intertidal fish-traps have been constructed on the seaward side of the dense mangrove forest and rocky outcrops in the nearby sea support clumps of oysters (*S. glomerata*) and *Calliotoma* sp.

The Wellesley Archipelago is marked by a tropical climate (mean annual temperature of 26.3°C), with a mean annual precipitation of ~1,200 mm and with 97% of the rainfall falling

during the summer wet season (from October to April) (Bureau of Meteorology, 2016). The movement of the Inter-Tropical Convergence Zone (ITCZ) governs this rainfall pattern, through its southward migration during the southern summer months bringing monsoonal rain and tropical cyclones. The El Niño Southern Oscillation phenomena has an important influence on intra-annual precipitation for the region, with a dramatic increase in rainfall and tropical cyclone activity during La Niña years associated with the more southerly movement of the ITCZ, and a marked reduction in precipitation and tropical lows during El Niño periods that are linked to a diminished southerly movement of the ITCZ (Nicholls, 1992). This climate generates a landscape that is dominated by savanna and open spinifex forest on high elevation areas (>5 m), with the lower elevation areas (<5 m) dominated by salt-clay pans and extensive mangrove forest.

Methods

Excavation

Thundiy was selected for analysis as one of the most extensive coastal archaeological sites investigated in tropical northern Australia, and as one of the few extensive sites on the north coastline of Bentinck Island protected from prevailing southeast wind and storm activity, as well as a place of high cultural significance to Indigenous Kaiadilt traditional owners. Based on these reasons and to determine patterns of variation in subsurface patterns, three 50 x 50 cm squares (labelled A to C) were excavated at 50 m intervals along a transect in the approximate centre of the deposit at the highest part of the beach ridge (Figure 1). Two other test pits were undertaken, one on the lower part of the beach ridge (D) and the other is located in the surrounding savanna (E) but are not part of this study. The excavations proceeded in shallow, arbitrary excavation units (XUs) averaging around 2.5 cm in depth and ~11 kg in weight within stratigraphic units, with excavation in the three squares ceasing at

approximately 60 cm below the ground surface. The sedimentological characteristics of the excavated units were logged and the excavated material was dry sieved through a 2.3 mm mesh on site. The material that passed through the sieve was sampled for palynological and sedimentological analyses. Results are reported for Square B (Figure 2).

Sedimentology and Age Control

The excavation of Square B revealed a high density and extensive cultural sequence with numerous shell materials, as well as rarer occurrences of bone, stone artefacts and charcoal extending to ~35–40 cm, which overlies ~20 cm of shelly beach ridge material that in turn covers partially consolidated beach rock. Four stratigraphic units have been identified and described (Figure 3). Stratigraphic Unit I (SUI) extends to ~35 cm and comprises a dense shell matrix in dark brown humic, sandy sediment; SUIIa is a transitional unit extending from ~35–43 cm that consists of dark brown humic sands with lower quantities of shells; SUIIb comprises brown to light-brown coarse sands with small pisolith gravels and numerous small gastropods (<10 mm), extending from ~43–55 cm; and SUIII extends to at least 60 cm and consists of light-brown consolidated sediments with abundant shell grit, small gastropods, water-worn pebbles and large pieces of coral. All units have highly alkaline pH values (9.5–10) and both SUIIb and SUIII are culturally sterile.

A total of 12 AMS radiocarbon dates were obtained from marine shells across the three squares, with five of these ages from Square B shown in Table 1. These dates suggest that cultural occupation at the site occurred from around 800 years ago, some 3,000 years after the formation of the beach ridge (Nagel et al., 2016). The ages directly related to the pollen analysis are shown on the pollen diagram (Figure 4).

Palynological Analysis

Pollen grains are microscopic, unicellular (generally ~15–100 μm) reproductive cells of seed-producing plants and spores are similar cells of non-flowering pteridophytes (e.g. ferns and mosses) (Moss, 2013). Different plant species can vary in terms of pollen and spore production rates, as well as the dominant transport mechanism (i.e. wind, water and animal), which in turn can impact their representation in the fossil record. Furthermore, the outer sporopollenin shell, that forms the basis of palynological identification, is best preserved in anaerobic environments and can be destroyed if oxidation occurs, which could also affect pollen and spore representation (Moss, 2013). Therefore it is important to have an understanding of pollen/spore production rates and sedimentological processes at a site to ensure that the palynological record reflects environmental, rather than taphonomic, factors. This does appear to be the case for the Thundiy site based on studies undertaken on Bentinck Island itself (Mackenzie, 2016) and more broadly across northern Australia (Kershaw and Strickland, 1990; Kershaw and Bulman, 1994; Crowley et al., 1994; Moss et al., 2005; Rowe, 2012; Proske et al., 2014). In addition, micro-charcoal or carbonized particles, commonly associated with pollen/spore samples, reflect past fire events and can also be counted to provide a record of regional fire regimes for a site (Moss, 2013).

Palynological samples from Square B, Thundiy, comprising 1 g samples of the <2.3 mm fraction, were prepared for analysis using the method developed by van der Kaars (1991) and discussed in detail in Moss (2013). Sodium pyrophosphate was used to disaggregate the samples (~10 cm), which were then sieved using an 180 μm screen to remove the sands/gravels and an 8 μm mesh was used to separate the clays from the silt-sized (including pollen/spores and micro-charcoal) component. The silt fraction then underwent heavy liquid treatment (using sodium polytungstate; specific gravity ~2.0) to separate the organic

component (including the pollen/spores and micro-charcoal or pollen concentrate) from the inorganic (mineral) fraction. Acetolysis (using a 9:1 acetic anhydride and concentrated sulphuric acid solution) was then undertaken on the pollen concentrate to remove excess organic material and stain the pollen grains/spores. The samples were then mounted in glycerol and were counted for pollen/spores and charcoal at 400x using a Leica compound light microscope.

Pollen/spore and charcoal concentrations were determined from counts of exotic *Lycopodium* marker spores, which were added as a tablet (i.e. at the start of the palynological analysis) with a known concentration of *L. clavatum* (Stockmarr, 1971; Wang et al., 1999). The pollen sum consisted of a minimum of 200 pollen grains/spores or two completely counted slides, while the charcoal analysis involved counting all black angular fragments >5 μm across three evenly spaced transects across all excavation units. The pollen diagram (Figure 4) illustrates the key pollen/spore taxa, charcoal and pollen concentrations, as well as the five radiocarbon dates taken from Square B. The pollen diagram was produced using TG View (Grimm, 2004), with the pollen sum based on arboreal taxa, herbs and grasses, pteridophytes, aquatic taxa (e.g. sedges and saltmarsh) and mangroves. A stratigraphically constrained classification analysis was undertaken on the raw pollen counts using CONISS (Constrained Incremental Sum of Squares cluster analysis; Grimm 1987, 2004) to produce pollen zones, which are discussed below.

Results

Pollen was retrieved from the top 13 XUs, with none present in the lower XUs 14–20, although charcoal was obtained for the entire record (Figure 4). Also, shown are the five ^{14}C dates obtained from marine shells for this zone, which provide age control for the record. There are 23 taxa in total, which have been divided into arboreal taxa, herbs and vines, and

other taxa [pteridophytes (monolete fern spores and *Anthroceros*), aquatic taxa (Cyperaceae) and mangroves (*Avicennia marina, Ceriops/Bruguiera* and *Rhizophora stylosa*)]. Grass dominates the record, with around 20% arboreal taxa, suggesting that the site was mixed savanna/spinifex grassland for the last 800 years. The culturally sterile beach ridge section (XUs 14–20) had relatively low charcoal values and pollen was not preserved within it. The top 13 XUs, which preserved pollen, were divided into four zones based on the CONISS classification analysis and are described below:

Thun A (XU13 to XU10)

The age of this zone is from around 800–500 years ago. There is a peak in grass (Poaceae) at XU13 (~80%), which then declines to around 40–50% for the remainder of this zone. Daisies [Asteraceae (Tubuliflorae)], which peak at XU11, and then saltmarsh (Chenopodiaceae subfamily) and Convolvulaceae, which peaks in XU12 and most likely the coastal vine *Ipomoea,* are the next most important herbaceous taxa. The key arboreal taxa in this zone are *Pandanus* (which peaks at XU11), eucalypts and she oaks (Casuarinaceae), there is also a peak in *Terminalia* (wild plum) at XU10, and *Ficus opposita* (sand paper fig) appears at this level as well. In terms of the other taxa, there is a peak in Cyperaceae (sedges) at XU12 and the mangroves *Ceriops* (yellow mangrove)/*Bruguiera* (orange mangrove) at XU10. Pollen concentrations are the lowest in the entire record, while charcoal concentrations are similar to the beach ridge sediments, except for a peak at XU11.

Thun B (XU9 to XU8)

The age of this zone is around 500 years and likely reflects a period of rapid sediment accumulation. This zone consists of two excavation units and is again dominated by grass, with an increase in salt marsh (Chenopodaceae subfamily) at the expense of Asteraceae

(Tubuliflorae). There is also a small peak in Brassicaceae (cruciferous herbs) (XU8) and the Convolvulaceae maintain similar variable values as in the previous zone. Casuarinaceae becomes the dominant arboreal taxa at the expense of *Pandanus* and *Eucalyptus*, while *Ficus opposita* maintain similar values to the previous zone (and for the remainder of the record). There are three small peaks in *Pipturis* (native mulberry), *Melaleuca* (paperbark) and the mangrove *Avicennia marina* (grey mangrove) in XU9. Pollen concentrations have slightly higher abundances, while charcoal concentrations are similar to the values in the previous zones (except for the peak in XU11).

Thun C (XU7 to XU4)

This zone correlates to the 250–500 year period and is again dominated by grass, along with a marked increase in Asteraceae (Tubuliflorae). Both saltmarsh and Convolvulaceae decline in this zone, while pigweed (Amaranthaceae subfamily) makes its first appearance in the record. Casuarinaceae is still the dominant arboreal taxa, although *Pandanus* and *Melaleuca* do recover in this zone and there is a slight peak in eucalypts at XU4. There are small peaks in Monolete fern spores (XU6), *Anthroceros* (hornworts) (XU7) and *Avicennia marina* (XU5), while *Rhizophora stylosa* (red mangrove) appears with very low but consistent values for the remainder of the record. There is a marked increase in both pollen and charcoal concentrations, with the highest values of carbonized particles in the record at XU6.

Thun D (XU3 to XU1)

This zone, which covers the most recent 250 years, exhibits an increase in grass values (to around 60%), while Asteraceae (Tubuliflorae) declines and saltmarsh, Amaranthaceae, Brassicaceae, as well as Rutaceae (citrus family) all peak in this zone. Casuarinaceae is still the dominant arboreal taxa, although *Ficus opposita* values increase at its expense in the top

two samples. In addition, there are slight peaks in Gyrostemonaceae (e.g. emu bush or native poplar) (XU1), Beyeria (turpentine bush) (XU3) and *Avicennia marina* (XU1). Charcoal concentrations are lower in this zone, while XU1 has the highest pollen concentrations in the record.

Discussion

Previous research of the Thundiy archaeological site has revealed a relatively deep high-density shell midden deposit located on an exposed beach ridge that provides an 800 year record of human occupation (Peck, 2016). The site content and structure is consistent with being a key campsite for the Kaiadilt people, which was utilized intensively particularly in the last 250 years. In addition, investigations of foraminifera preserved in this site suggest that AMS radiocarbon dating of these microfossils can contribute to an understanding of coastal archaeological deposit site integrity and chronostratigraphic analysis (Nagel et al., 2016). This study has also revealed the Thundiy shell deposit provides an environment that is conducive for the preservation of plant microfossils (i.e. pollen) and micro-charcoal, which can provide important context for the archaeological interpretation of the site. In particular, it is apparent that the development of a high density shell deposit by human activities was directly related to pollen preservation, possibly through the creation of a moist, anaerobic environment that reduces oxidation of pollen grains. A similar result has also been observed in other human created shell deposits (e.g. Mudie and Leliévre, 2013) in the northern hemisphere. This finding, along with the good potential of phytolith preservation seen at other sites within Australia (Parr and Carter, 2003; Lentfer et al., 2013) and internationally (Zurro et al., 2009), suggests that analysis of plant microfossils can provide important environmental contextual information that can be directly compared to archaeological data.

The pollen record from Thundiy indicates that the site was dominated by savanna vegetation (suggested by the high grass values) over the last 800 years but there are some dramatic changes in vegetation dynamics. An early coastal phase (from <800–500 years ago) is seen from XU 12 to 7 (Zones Thun A to C), which is suggested by higher values of saltmarsh and the coastal vine Convolvulaceae, suggesting that these species may have colonised the beach ridge. The higher occurrence of mangroves in these zones (the main component of the other taxa group) could also suggest higher than present sea-levels during this period. Similar results have been recorded on the southeast coast (Moss et al., 2015; Mackenzie et al., 2016; Mackenzie et al., in preparation), as well as the north and west coasts (Mackenzie et al., 2016; Mackenzie et al., in preparation) of Bentinck Island for this time period. There is an initial peak in arboreal taxa, particularly *Pandanus*, as well as daisies in XU 10, which may represent greater freshwater availability across the island and linked to the stabilization of sea-levels at this time (Moss et al., 2015; Mackenzie et al., 2016; Mackenzie et al., in preparation). Both *Pandanus* and daisies decline and are replaced by she-oaks and the sandpaper fig in Thun Zone B, which could also be a response to lower fire regimes during this zone, as both taxa are known to be fire sensitive taxa (Kershaw, 1988; Woinarski et al., 2004). There is a large charcoal peak at 510 years ago (XU 6 in the Thun C zone), which may be linked to permanent occupation of the South Wellesley Archipelago (Memmott et al., 2016), with increased burning associated with local occupation of this site. The final pollen zone (Thun D) observes a decline in arboreal taxa and daisies, with an increase in grass, suggesting a more open landscape. This finding could reflect an increase in occupation over the last 250 years through increased burning, which is also recorded in the archaeological record from Thundiy (Peck, 2016) that may have been facilitated by increased moisture availability recorded at the nearby Well Swamp record (Mackenzie et al., in preparation).

One of the key findings of this study is the development of a palynological record directly related to archaeologically derived sediments. These results provide a highly localized picture of vegetation change compared to other records taken from the more typical wetland environments, which generally reflect broader regional environments (Moss et al., 2015; Mackenzie et al., in preparation). In particular, the palynological findings from the archaeological derived sediments appear to be more reflective of the local Thundiy midden landscape, with a greater representation of some taxa, particularly *Ficus opposita* and Amaranthaceae and the underrepresentation of regionally derived pollen from the surrounding clay pan and mangrove forest. There are also some alterations in taxa that may represent land management by the Kaiadilt people around the Thundiy campsite. In particular, the increase in *Ficus opposita* from XU11 may represent the planting of shade trees around the campsite, as a similar situation has been documented on Cape York (Haynes and Chase, 1982) and the use of fire to 'clean up country' to create a more open landscape in zone Thun A, which has been ethnographically documented on the island (Tindale, 1962).

In XU11 both *Pandanus* and charcoal particles increase. *Pandanus* is a wetland indicator in northern Australia, however it also grows in coastal woodlands and can reflect localised disturbance as it is fire tolerant (Prebble et al., 2005; Rowe, 2015). Additionally, the Kaiadilt used the edible *Pandanus* nuts (Tindale, 1963 p. 117). The increased representation of Amaranthaceae over the last 250 years could also reflect land management practices that promoted the growth of this taxon. There is extensive evidence of the use of Amaranthaceae, as well as the closely related family Chenopodiaceae, as an important food source across Australia and there are records of Amaranthaceae seeds associated with the cultural deposits at Carpenters Gap shelter 1 in the Kimberley region of Western Australia, which demonstrates the prehistoric use of this taxon by Aborigines (McConnell, 1998).

Alternatively the expansions of Amaranthaceae in zone Thun D could represent an exotic plant invasion, as a species (alligator weed; *Alternanthera philoxeroides*) from this family is a known weed species from Africa that has spread across Australia since European settlement (Julien et al., 1992) and has been found in the Wellesley Islands (Evans et al., 1992).

Conclusions

The preservation of a wide range of pollen in an open shell deposit situated in a highly monsoonal environment suggests high potential for pollen recovery in midden matrices in a variety of contexts. In combination with phytolith, charcoal and macrobotanical analyses, palynological analysis of shell deposits could be applied more broadly across Australia and beyond to provide greater insight into local landscapes, as well as providing the opportunity to link with broader regional environmental records that are derived from traditional palynological analysis of lakes and wetlands, which will greatly enhance our understanding of human occupation patterns and human interactions with the environment. In particular, the analytical approaches to microfossil analysis in shell deposits used at Thundiy could be applied, for example, to directly test competing hypotheses about the formation and use of shell mound deposits across northern Australia. Debates here have focussed on whether shell mounds reflect intensive or focussed exploitation of specific ecosystems and associated resources (see Veitch, 1999; Bourke 2003; Morrison 2003, 2013; Clune and Harrison, 2009 Faulkner 2013) and/or longer-term curation of economically important species around mound sites (Cribb 1996). Palynological data could be used to shed light into these debates through directly testing shell mound sediments for the presence of economically important species, as well as providing new data on local environmental context, changing land management practices and the history of site use.

Acknowledgements

References

Álvarez, M., Godino, I.B., Balbo, A. and Madella, M. (2011) Shell middens as archives of

   past environments, human dispersal and specialized resource management.

   Quaternary International 239, 1–7.

Attenbrow, V. (1992) Shell bed or shell midden. *Australian Archaeology* 34, 3–21.

Bailey, G.N. (1983) Problems of site formation and the interpretation of spatial and temporal

   discontinuities in the distribution of coastal middens. In Masters, P.M., Flemming,

   N.C. (Eds.), *Quaternary Coastlines and Marine Archaeology.* Academic Press,

   London, 559–582.

Barker, B. (2004) *The Sea People: Late Holocene Maritime Specialisation in the Whitsunday*

   Islands, Central Queensland. Terra Australis 20. Pandanus Books, Canberra.

Beaton, J.M. (1985) Evidence for a coastal occupation time-lag at Princess Charlotte Bay

   (North Queensland) and implications for coastal colonization and population growth

   theories for Aboriginal Australia. *Archaeology in Oceania* 20, 1–20.

Bird, M.K. (1992) The impact of tropical cyclones on the archaeological record: an

   Australian example. *Archaeology in Oceania* 27, 75–86.

Bronk Ramsey, C.B. (2009) *OxCal Radiocarbon Calibration Program v4.2*.

Bourke, P. M. (2003) Advent of *Anadara* mounds and theories on mid- to late Holocene

   changes in forager economic strategies—A comment. *Australian Archaeology* 56, 42-

   43.

Bureau of Meteorology (2016) Monthly Climatic Statistics for Mornington Island,

   Queensland. http://www.bom.gov.au/climate/averages/tables/cw_029039.shtml

   (accessed 14.06.16).

Cann, J.H., Bourman, R.P. and Barnett, E.J. (2000) Holocene foraminifera as indicators of relative estuarine-lagoonal and oceanic influences in estuarine sediments of the River Murray, South Australia. *Quaternary Research* 53, 378–391.

Carter, M., Lilley, I., Ulm, S. and Brian, D. (1999) Mort Creek site complex, Curtis Coast: site report. *Queensland Archaeological Research* 11, 85–104.

Claassen, C. (1998) *Shells.* Cambridge University Press, Cambridge.

Clune, G. and Harrison, R. (2009) Coastal shell middens of the Abydos coastal plain, Western Australia. *Archaeology in Oceania* 44, 70-80.

Cribb, R. (1996) Shell mounds, domiculture and ecosystem manipulation on western Cape York Peninsula. In Veth, P. and Hiscock, P. (Eds.), Archaeology of Northern Australia: Regional Perspectives, *Tempus* 4. St Lucia: Anthropology Museum, University of Queensland, 150 - 174.

Crowley, G.M., Grindrod, J. and Kershaw, A.P. (1994) Modern pollen deposition in the tropical lowlands of northeast Queensland, Australia. *Review of Palaeobotany and Palynology* 83, 299–327.

Evans, N., Johnson, P. and Kohler, M. (1992) *Kayardild dictionary and thesaurus: a vocabulary of the language of the Bentinck Islanders, North-west Queensland*: University of Melbourne, Department of Linguistics and Language Studies.

Faulkner, P. (2013) Life on the Margins: An Archaeological Investigation of Late Holocene Economic Variability, Blue Mud Bay, Northern Australia. *Terra Australis* 38. Canberra, ANU E Press.

Grimm, E.C. (1987) CONISS: a FORTRAN 77 program for stratigraphically constrained cluster analysis by the method of incremental sum of squares. *Computers and Geoscience* 13, 13–35.

Grimm, E.C. (2004). *TGView Version 2.0.2.* Illinois State Museum, Springfield.

Haynes, R.A. and Chase, A.K. (1982) Plants, sites and domiculture: Aboriginal influence
upon plant communities in Cape York Peninsula. *Archaeology in Oceania* 17, 38–50.

Hebda, R.J., Pellatt, M.G., Mathewes, R.W., Fedje, D. and Acheson, S. (2005) Vegetation
history of Anthony Island, Haida Gwaii and its relationship to climate change and a
human settlement. In Fedje, D., Mathewes, R.W. (Eds.), *Haida Gwaii: Human
History and Environment from the Time of Loon to the Time of Iron People.*
University British Columbia Press, Vancouver, 59–76.

Hughes, P.J. and Sullivan, M.E. (1974) The re-deposition of midden material by storm
waves. *Journal and Proceedings of the Royal Society of New South Wales* 107, 6–10.

Julien, M.H., Bourne, A.S. and Low, V.H.K. (1992) Growth of the weed *Alternanthera
philoxeroides* (Martius) Grisebach (alligator weed) in aquatic and terrestrial habitats
in Australia. *Plant Protection Quarterly* 7, 102–108.

Kershaw, A.E (1988). Australasia. In: Huntley, B. and Webb III, T. (eds), *Vegetation History*,
Kluwer, Dordrecht, 237-306.

Kershaw, A.P. and Strickland, K.M. (1990) A 10 year pollen trapping record from rainforest
in northeastern Queensland, Australia. *Review of Palaeobotany and Palynology* 64,
281–288.

Kershaw, A.P. and Bulman, D. (1994) The relationship between modern pollen samples and
environment in the humid tropics region of northeastern Australia. *Review of
Palaeobotany and Palynology* 83, 83–96.

Lampert, R.J. and Hughes, P.J. (1974) Sea level change and Aboriginal coastal adaptations in
southern New South Wales. *Archaeology and Physical Anthropology in Oceania* 9,
226–235.

Lentfer, C.J., Felgate, M.W., Mills, R.A. and Specht, J. (2013) Human history and palaeoenvironmental change at Site 17, Freshwater Beach, Lizard Island, northeast Queensland, Australia. *Queensland Archaeological Research* 16, 141–164.

Lourandos, H. (1987) Pleistocene Australia: Peopling a continent. In Soffer, O. (Ed.) *The Pleistocene Old World: Regional Perspectives*. Plenum, New York, 147–165.

Mackenzie, L. (2016) Palaeoecology of the South Wellesley Archipelago: A history of human occupation and environmental change. Unpublished PhD thesis, The University of Queensland, St Lucia, Australia.

Mackenzie, L., Moss, P., Ulm, S. and Jacobsen, G. (in preparation) Coastal wetland development and fire regimes in the late Holocene, northern Australia.

McConnell, K. (1998) The prehistoric use of Chenopodiaceae in Australia: evidence from Carpenters Gap Shelter 1 in the Kimberley, Australia. *Vegetation History and Archaeobotany* 7, 179–188.

Morrison, M. (2003) Old boundaries and new horizons: the Weipa shell mounds reconsidered. *Archaeology in Oceania* 38, 1–8.

Morrison, M. (2013) Niche production strategies and shell matrix site variability at Albatross Bay, Cape York Peninsula. *Archaeology in Oceania* 48(2), 78–91.

Moss, P.T. (2013) Palynology and its application to geomorphology. In Schroder, J.F. (Ed.) *Treastise in Geomorphology*. Academic Press, San Diego, 315–325.

Moss, P.T., Kershaw, A.P. and Grindrod, J. (2005) Pollen transport and deposition in riverine and marine environments within the humid tropics of northeastern Australia. *Review of Palaeobotany and Palynology* 134, 55–69.

Mudie, P.J. and Lelièvre, M.A. (2013) Palynological study of a Mi'kmaw shell midden, northeast Nova Scotia, Canada. *Journal of Archaeological Science* 40, 2161–2175.

Nagel, T., Rosendahl, D., Hua, Q., Moss, P., Sloss, C., Petchey, F. and Ulm, S. (2016) Extended residence times for foraminifera in a marine-influenced terrestrial archaeological deposit and implications for palaeoenvironmental reconstruction. *Journal of Archaeological Science: Reports* 5, 25–34.

Nicholls, N. (1992) Historical El Niño/Southern Oscillation variability in the Australasian region. In Diaz, H.F., Markgraf, V. (Eds.), *El Niño: Historical and Paleoclimatic Aspects of the Southern Oscillation.* Cambridge University Press, Cambridge, 151–173.

O'Connor, S. and Sullivan, M. (1994) Distinguishing middens and cheniers: a case study from the southern Kimberley, WA. *Archaeology in Oceania* 29, 16–28.

Parr, J. and Carter, M. (2003) Phytolith and starch analysis of sediment samples from two archaeological sites on Dauar Island, Torres Strait, northeastern Australia. *Vegetation History and Archaeobotany* 12(2), 131–141.

Peck, H. (2016) The Application of Ecological Models and Trophic Analyses to Archaeological Marine Fauna Assemblages: Towards Improved Understandings of Prehistoric Marine Fisheries and Ecosystems in Tropical Australia. PhD thesis, James Cook University, Cairns.

Prebble, M, Sim, R, Finn, J and Fink, D. (2005) A Holocene pollen and diatom record from Vanderlin Island, Gulf of Carpentaria, lowland tropical Australia. *Quaternary Research* 64, 357–371.

Proske, U., Heslop, D. and Haberle, S. (2014) A Holocene record of coastal landscape dynamics in the eastern Kimberley region, Australia. *Journal of Quaternary Science* 29, 163–174.

Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Buck, C.E., Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P.,

Hafidason, H., Hajdas, I., Hatté, C., Heaton, T.J., Hoffman, D.L., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., Manning, S.W., Niu, M., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Staff, R.A., Turney, C.S.M. and van der Plicht, J. (2013) INTCAL13 and MARINE13 radiocarbon age calibration curves 0-50,000 years cal BP. *Radiocarbon* 55, 1869–1887.

Rick, T.C., Erlandson, J.M. and Vellanoweth, R.L. (2006) Taphonomy and site formation on California's Channel Islands. *Geoarchaeology* 21, 567–589.

Rosendahl, D., Ulm, S. and Weisler, M.I. (2007) Using foraminifera to distinguish between natural and cultural shell deposits in coastal eastern Australia. *Journal of Archaeological Science* 34, 1584–1593.

Rowe, C. (2012) Modern surface pollen from the Torres Strait Islands: exploring north Australian vegetation heterogeneity. In Haberle, S.G., David, B. (Eds.), *Peopled Landscapes: Archaeological and Biogeographic Approaches to Landscapes. Terra Australis* 34, 413–434. Pandanus Books, Canberra.

Rowe, C. (2015) Late Holocene swamp transition in the Torres Strait, northern tropical Australia. *Quaternary International* 385, 56–68.

Rowland, M.J. (1983) A note on corrections to radiocarbon dates from the Keppel Islands. *Australian Archaeology* 17, 134–135.

Rowland, M.J. (1989) Population increase, intensification or a result of preservation?: Explaining site distribution patterns on the coast of Queensland. *Australian Aboriginal Studies* 2, 32–42.

Rowland, M.J. and Ulm, S. (2012) Key issues in the conservation of the Australian coastal archaeological record: natural and human impacts. *Journal of Coastal Conservation* 16, 159–171.

Sherwood, J., McNiven, I.J., Laurenson, L., Richards, T. and Bowler, J. (2016) Prey selection, size, and breakage differences in *Turbo undulatus* opercula found within Pacific gull (*Larus pacificus*) middens compared to Aboriginal middens and natural beach deposits, southeast Australia. *Journal of Archaeological Science: Reports* 6, 14–23.

Stockmarr, J. (1971). Tablets with spores used in absolute pollen analysis. *Pollen et Spores* 13, 615–621.

Szabó, K. (2012) Terrestrial hermit crabs (Anomura: Coenobitidae) as taphonomic agents in circum-tropical coastal sites. *Journal of Archaeological Science* 39, 931–941.

Tindale, N.B. (1962) Geographic knowledge of the Kaiadilt people of Bentinck Island, Queensland. *Records of the South Australian Museum* 14, 259–296.

Tindale, N.B. (1963) *Journal of Visit to the Gulf of Carpentaria by Norman B Tindale.* Board for Anthropological Research Expedition AM, 702.

Ulm, S. (2006) *Coastal Themes: An Archaeology of the Southern Curtis Coast, Queensland. Terra Australis* 24. ANU E Press, Canberra.

Ulm, S. (2011) Coastal foragers on southern shores: marine resource use in northeast Australia since the late Pleistocene. In Bicho, N., Haws, J.A. and Davis, G. (Eds.), *Trekking the Shore*. New York, Springer, 441–461.

Ulm, S., Barker, B., Border, A., Hall, J., Lilley, I., McNiven, I., Neal, R. and Rowland, M. (1995) Pre-European coastal settlement and use of the sea: a view from Queensland. *Australian Archaeology* 41, 24–26.

Ulm, S., Petchey, F., Jacobsen, G., Rosendahl, D. in prep. Pre-bomb marine carbon reservoir variability in the eastern Gulf of Carpentaria, Queensland, Australia.

van der Kaars, W.A. (1991). Palynology of eastern Indonesian marine piston cores: A Late Quaternary vegetational and climatic record from Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 85, 239–302.

Veitch, B. (1999) Shell middens on the Mitchell Plateau: a reflection of a wider phenomenon? In Hall, J. and McNiven, I. (Eds.), *Australian Coastal Archaeology*. Canberra, ANU Publications, 105-112.

Wang, X., van der Kaars, S., Kershaw, P., Bird, M., and Jansen, F. (1999) A record of fire, vegetation and climate through the last three glacial cycles from Lombok Ridge core G6-4, eastern Indian Ocean, Indonesia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 147, 241–256.

Waselkov, G.A. (1987) Shellfish gathering and shell midden archaeology. *Advances in Archaeological Method and Theory* 10, 93–210.

Weisler, M.I., Yamano, H. and Hua, Q. (2012) A multidisciplinary approach for dating human colonization of Pacific atolls. *The Journal of Island and Coastal Archaeology* 7, 102–125.

Williams, A.N., Ulm, S., Turney, C.S.M., Rohde, D. and White, G. (2015) Holocene demographic changes and the emergence of complex societies in prehistoric Australia. *PLoS ONE* 10(6), e0128661.

Woinarski, J.C.Z., Risler, J. and Kean, L. (2004) Response of vegetation and vertebrate fauna to 23 years of fire exclusion in a tropical Eucalyptus open forest, Northern Territory, Australia. *Austral Ecology 29*, 156-176.

Zurro, D., Madella, M., Briz, I., and Vila, A. (2009) Variability of the phytolith record in fisher-hunter-gatherer sites: an example from the Yamana society (Beagle Channel, Tierra del Fuego, Argentina). *Quaternary International* 193(1–2), 184–191.

Tables

SQ	XU	Depth (cm)	Sample (species)	Lab Code	δ¹³C	CRA	Calibrated Age BP (95.4%)	Calibrated Age BP Median
B	1	0–2.5	*M. hiantina*	OZP-197	-3.3±0.1	370±30	0*–258	104
B	6	15.4–18.6	*M. hiantina*	Wk-34772	0±0.2	851±25	309–661	510
B	11	30.3–33.4	*T. granosa*	Wk-28560	-1.6±0.2	868±30	314–675	525
B	13	36.7–39.4	*M. hiantina*	Wk-37498	-2±0.2	1192±22	611–1007	793
B	20	57.5–60.4	*M. hiantina*	Wk-36175	1±0.2	4716±28	4795–5305	5039

Table 1: Radiocarbon ages on marine shells at Thundiy, Square (SQ) B, and XU is
Excavation Units. Samples with the laboratory code of OZP were dated at the Australian
Nuclear Science Technology Organisation (ANSTO) and those with the laboratory code of
Wk at the Radiocarbon Laboratory, University of Waikato, New Zealand. Calibrations
undertaken using OxCal v.4,2 (Bronk Ramsey, 2009) and Marine13 calibration dataset
(Reimer et al., 2013). For samples a **Δ** R of -49±102 as recommended by Ulm et al. (in prep.)
was employed.

Figure Captions

Figure 1: Location of Bentinck Island (A); the Thundiy midden/coastal beach ridge site (B); the three excavation squares (A, B and C) at the top of the Thundiy beach ridge site, a test pit located on the lower part of the beach ridge (D) and another in the surrounding savanna (E) (C); and a vertical cross-section of the Thundiy site (D).

Figure 2: Northern section of Thundiy, Square B. Scale bar = 10 cm.

Figure 3: Cross-section of the stratigraphy of Thundiy Square B. The Stratigraphic Units (SU) are: SUI – a dense shell matrix in dark brown humic, sandy sediment (0–~35 cm); SUIIa – a transitional unit of dark brown humic sands with lower quantities of shells (~35–43 cm); SUIIb – consists of brown to light brown coarse sands with small pisolith gravels and numerous small gastropods (<10 mm) (~43–55 cm); and SUIII – consists of light brown consolidated sediments with abundant shell grit, small gastropods, water-worn pebbles and large pieces of coral (~55–60 cm).

Figure 4: Thundiy Square B pollen diagram. The hashed line separates the cultural deposits from the natural beach ridge sediments and the solid lines represent the pollen zones derived from the cluster analysis. The + symbol reflects taxa with trace (less than 1%) amounts of pollen. The pollen taxa are grouped based on trees, herbs and vines and other taxa, which consists of pteridophytes (*Gleichenia*, Monolete Ferns Spores and *Anthroceros*), aquatics (Cyperaceae) and mangroves (*Avicennia mariana*, *Ceriops/Bruguiera* and *Rhizophora stylosa*).

NORTH   EAST   SOUTH   WEST

I

IIa

IIb

III

FS#98

FS#97

FS#99

root   shell   water rounded pebble   rock   spinifex