Available online at www.sciencedirect.com
ScienceDirect
Palaeogeography, Palaeoclimatology, Palaeoecology 251 (2007) 150–173
PALAEO
www.elsevier.com/locate/palaeo

The archaeology of Australia's tropical rainforests

Richard Cosgrove[a,*], Judith Field[b], Åsa Ferrier[a]

[a] *Archaeology Program, Latrobe University, Melbourne, 3052 Victoria, Australia*
[b] *Australian Key Centre for Microscopy and Microanalysis F09 and the School of Philosophical and Historical Inquiry, The University of Sydney, NSW 2006, Australia*

Accepted 27 February 2007

Abstract

Archaeological research in the Australia's northeast Queensland rainforest and margins has revealed a human antiquity of at least 8000 cal year BP within the rainforest and at least 30,000 years on the western edge. Rainforest occupation before 2000 cal year BP was at generally very low levels, after which time settlement of this environment became intensive and probably permanent. Exploitation of toxic varieties of nuts began about 2500 cal year BP, peaking after 1500 cal year BP. This economic development appears crucial to successful human adaptation to rainforests in the area and was pivotal in facilitating the long-term permanent human settlement of the wet tropics. The role of fire, El Niño Southern Oscillation (ENSO) activity and shifting vegetation regimes were important catalysts in providing opportunities for permanent Australian rainforest Aboriginal occupation. The results have implications for global understandings of rainforest occupation by modern people. It demonstrates the wide temporal and spatial variability of human rainforest colonization processes worldwide.

Keywords: Australian tropical rainforest; Hunter–gatherer; El Niño Southern Oscillation; Toxic plant exploitation; Fire

---

1. Introduction

Over the last 4 decades, research on the Atherton Tablelands in northeast Queensland has built an impressive set of palaeoecological, geomorphological, and ethnohistorical evidence that indicates the presence of a historically complex rainforest Aboriginal culture and highly dynamic palaeoecological regimes through time and space. (Kershaw, 1970, 1976; Harris, 1978; Kershaw, 1986; Harris, 1987; Ash, 1988; Hopkins et al., 1993; Kershaw, 1994; Hopkins et al., 1996; Trott, 1997; Moss and Kershaw, 2000; Nott et al., 2001; Thomas and Nott, 2001; Turney et al., 2001a,b; Haberle, 2005). However, the quantity and intensity of archaeological research in the same region have not matched that of the physical sciences due to the apparent poor preservation of cultural remains, inaccessibility of the terrain and the dense vegetation. Nevertheless preliminary archaeological research has suggested increases in human occupation intensity, subsistence specialisation and increased site occupation through time (Cosgrove, 1980; Horsfall, 1987; Cosgrove, 1996; Horsfall, 1996; Cosgrove and Raymont, 2002).

The rainforest archaeological research undertaken here has laid the foundations for investigating whether people could permanently occupy rainforests without access to agriculture, open woodland resources or marine foods (Bailey et al., 1989; Bailey and Headland, 1991), and to further examine questions concerning

---

* Corresponding author. Tel.: +61 3 94792385.
E-mail address: r.cosgrove@latrobe.edu.au (R. Cosgrove).

0031-0182/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.palaeo.2007.02.023

the antiquity of rainforest colonisation on a world scale (Gamble, 1993, p. 197). The former problem has received considerable attention (see Harris, 1987; Brosius, 1991; Dwyer and Minnegal, 1991; Cosgrove, 1996; Mercader, 2002; Barton, 2005; Cosgrove, 2005), with arguments that the definition of 'rainforest' deemed too narrow. Furthermore, the assumption that these environments were somehow stable and immutable was viewed as flawed. In a global sense the Australian wet tropics data are crucial to understanding the timing, intensity and potential catalysts for permanent human occupation of rainforests, since these people remained hunter–gatherers and no agriculture was evident. Thus these rainforest people and their prehistory are central to notions about the spatial and temporal adaptations of humans to rainforest ecosystems worldwide.

Here we explore these issues with new evidence gained over the past 4 years from the northeast Queensland Wet

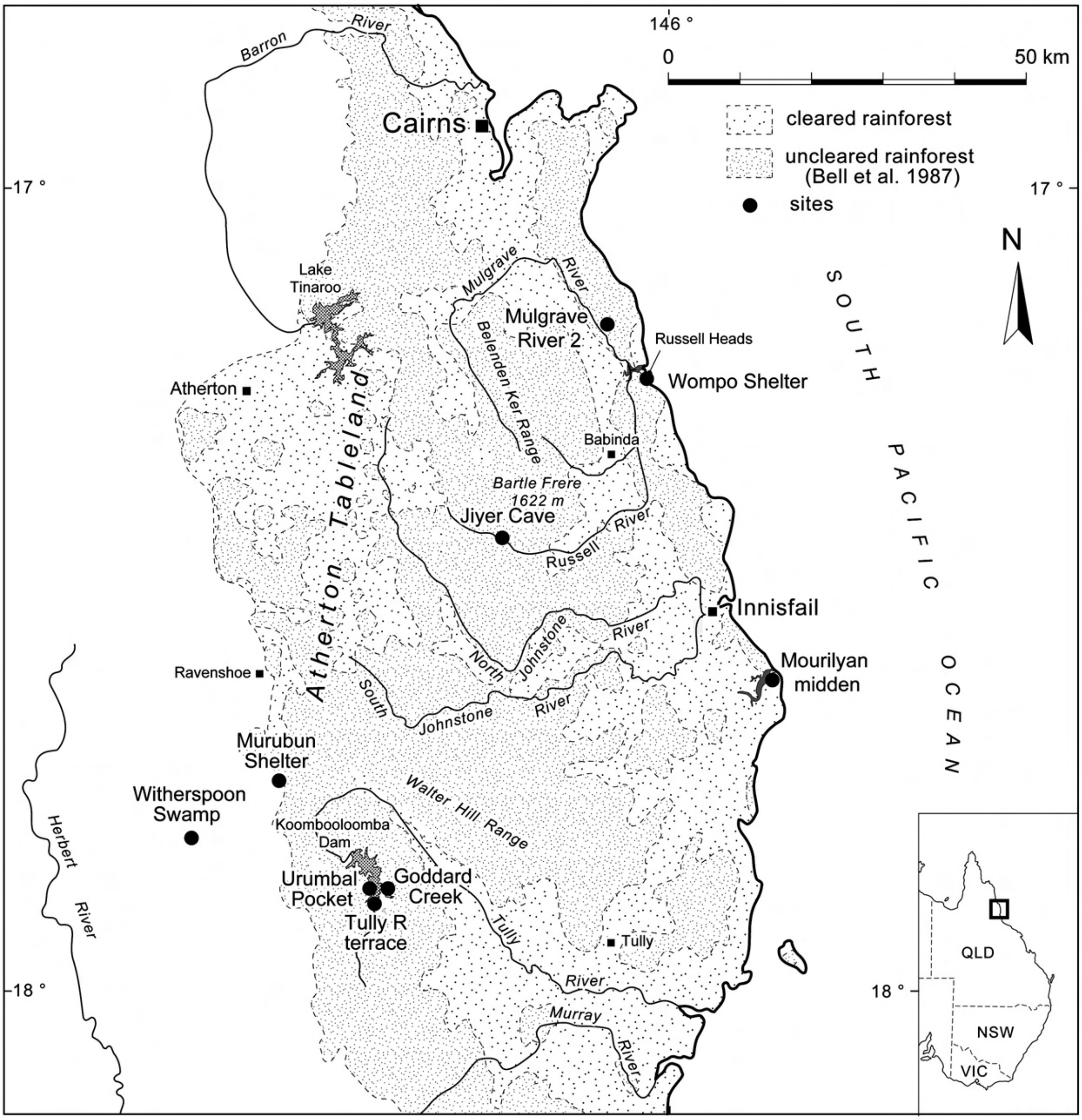


Fig. 1. Location of rainforest region and archaeological sites.

Tropics zone (Fig. 1). The aim of this paper is to address three key questions:

(1) what is the antiquity of human occupation of Australian rainforests;
(2) is increasing regional intensity of human occupation and changing resource exploitation patterns a feature of these environments and, if so
(3) what catalysts can be identified that may explain changes in the tempo of settlement?

2. Archaeological background

Initial archaeological research in the northeast Queensland rainforests indicated human occupation by at least 5000 years ago (Horsfall, 1987). Plant food exploitation was dominated by the processing of toxic nuts from endemic tree species, beginning at least 1000 years ago with high levels of stone artefact discard commencing about 2600 BP (Horsfall, 1996, p. 187). A key question raised by this research was why were not these environments occupied earlier, perhaps within the first 1000 years of Holocene rainforest expansion (Cosgrove, 1996). Indeed if people had been able to settle Melanesian rainforests in the late Pleistocene and Early Holocene without access to agriculture (Allen et al., 1989; Pavlides and Gosden, 1994; Allen and Gosden, 1996), why had it taken another 4000 years for people to colonise the Queensland wet tropics given the behavioural flexibility and adaptability shown by the earliest Sahul colonists over 40,000 years ago.

David and Chant (1995) and Campbell (1982, 1984) have reported evidence of earlier human occupation outside the N.E. Queensland rainforest zone by 35,000 BP at Walkunder Arch, Fern Cave and Ngarrabullgan. Pollen records from Lake Euramoo show the area was dominated by sclerophyll woodland taxa, especially *Casuarina, Eucalyptus* and *Callitris* during the late Pleistocene (Haberle, 2005). Evidence for early human occupation of the Atherton Tablelands has been implied from biomass burning beginning around 45,000 BP (Kershaw, 1994; Turney et al., 2001b). However, archaeological excavation undertaken at Jiyer cave, in the Russell River failed to find evidence of Pleistocene human occupation (Cosgrove and Raymont, 2002) and our more recent research has only strengthened this case.

Nevertheless, indications of the presence of people in rainforests in antiquity are clear from the subsurface discoveries of many thousands of undated stone axes, incised slate grinding stones, flaked stone artefacts and the conspicuous but enigmatic Ooyurka implements (Cosgrove, 1980, 1981, 1984; Horsfall, 1987). Indented nut stones and top and bottom grinding stones are commonly ploughed up during sugar cane cultivation on the coast and demonstrate intensive plant food exploitation. Long distance transfer of raw material for slate axes into stone poor regions of up to 60 km has also been found, as well as the use and exploitation of marine environments along the coast dated from at least 3800 BP (Patterson, 2004; Stevens, 2004). Archaeologically the region is rich, but gaining a systematic understanding of the behaviours that lead to these temporal and spatial patterns is challenging.

One of the most significant aspects of the wet tropics is the rainforest vegetation itself. The understorey is replete with vines, shrubs and impenetrable lawyer cane (*Calamus* sp.) making travelling through the rainforest almost impossible at times. The fact that Indigenous people lived permanently in this environment is testimony to their inventiveness and adaptability. To appreciate past human–environment relationships, it is important to understand the tropical rainforest distribution and form in both time and space.

3. Palaeoenvironmental background

The evidence for significant landscape change and evolution in the Wet Tropics shows dramatic swings in vegetation structure and distribution across the region over the last ca. 200,000 years (Kershaw, 1970, 1994; Kershaw et al., 2002, 2003, 2007-this volume). Recent work has also produced high-resolution records from Lake Euramoo, particularly for the Holocene—a period that is poorly preserved at Lynch's Crater (Haberle, 2005). The period between 23,000 BP and 16,000 BP is characterised by dry woodland dominated by *Eucalyptus* sp., and from 16,000 BP until 8500 BP the area is covered by wet sclerophyll forest with some rainforest patches. Between 8500 BP and 5000 BP there was a dramatic expansion of rainforest during a warmer phase of climate. After this period until about 70 years ago, dry subtropical rainforest had an expanded range due to higher seasonality and less predictable precipitation patterns. Evidence for fire in the form of charcoal is variable in the Lake Euramoo core with increases between 16,000 BP and 8500 BP, a dramatic decrease in charcoal between 8500 and 5000 and then an increase after 5000 BP. Haberle (2005) suggests that the presence of species producing more open canopies indicates that this later period was a time of rainforest disturbance. The source of this disturbance and ignition has been identified as principally climatic in origin, with an increase in ENSO activity beginning about 5000 BP with drier conditions prevailing (Gagan et al., 2004). Human activity has been implicated in the burning, but identifying the magnitude of this influence is a complex issue. Separating the anthropogenic from the natural sources of ignition is difficult but may be possible with high-resolution archaeological chronology discussed in the sections below. The other challenge is establishing the sources of charcoal around the catchment and the relative location of any archaeological sites. If increases in firing during the wettest periods can be identified then an anthropogenic source is more likely. At present no archaeological sites have been identified in the vicinity of Lake Euramoo but this may be due to a lack of systematic survey and discovery.

Rainforest does not appear to have spread evenly across the region at the end of the late Pleistocene (Walker and Chen, 1987), and its range has been quite variable through time (Hiscock and Kershaw, 1992). At several nearby upland pollen sites the return of rainforest to the Atherton Tablelands is estimated to be separated in time by up to 2000 years. The Lake Barrine data suggest a reduction in sclerophyll vegetation about 6100 BP with a concomitant increase in rainforest and a much lower influx of charcoal particles. Rainforest is established at ca. 8000 BP at Blomfield Swamp, similar in time to Lake Euramoo. On the coast, our sampling of two buried tree stumps identified as river red gum (*Eucalyptus tereticornis* or *E. camaldulensis*) (J. Ilic, personal communication CSIRO) near the township of Babinda, shows that sclerophyll vegetation was established here until at least 9393±56 BP (10,740–10,390 cal year BP; Wk-15893) and 9385±69 BP (10,750–10,250 cal year BP; Wk-10083), respectively. Additional buried tree stumps 4.5 km to the north were identified as two mangrove apples (*Sonneratia alba* or *S. caseolaris*) and red oak (*Carnarvonia araliifolia*) (J. Ilic personal communication CSIRO) and have been dated to 6178±47 BP (7170–6850 cal year BP; Wk-17307), 6236±46 BP (7250–6940 cal year BP; Wk-17308) and 6205±47 BP (7180–6890 cal year BP; Wk-17309), respectively. The findings parallel the patterns identified in the nearby Deeral Landing pollen site, ca. 1 km south of the Mulgrave River 2 site (Crowley et al., 1990) i.e., the establishment of lowland coastal rainforest and mean tide levels. It is also the time when rainforests reach their maximum extend on the Atherton Tablelands.

In some areas rainforest did not become established until recently, with evidence for the persistence of *Eucalyptus* sp. in the Daintree area, to the north of the study area, until 1500 BP (Hopkins et al., 1996). Several factors appear to be at work, with fire being the likely culprit, either through natural lightning strikes or anthropogenic burning. It is notable that Christie Palmerston regularly described Aboriginal burning during his explorations in the region in the 1880s (Savage, 1992).

Landscape instability also characterises the last glacial cycle with pulses of erosion and deposition. Nott et al. (2001) has identified periods of sediment liberation during times of aridity and heightened river discharge in the early Holocene (Thomas and Nott, 2001). Evidence for these processes is also manifest in the upper reaches of the Tully River which feeds Koombaloomba Dam. Six profiles were excavated along a 40 m exposed section of a large terrace of sandy alluvium rising ca. 4.5 m above the river channel. The deposit has five distinct stratigraphic units [SU] (Fig. 2). The upper and most recent unit is a grey (10YR 6/3) sandy deposit ca. 25 cm thick. Stone artefacts of slate and quartz were recorded on the surface and eroding out of the section 5 cm below the surface. Unit 2 is 40 cm thick, comprised of coarser sediments than Unit 1, and contains unconsolidated gravel (10YR 7/1). Unit 3 is 180 cm thick, is a yellowish-orange colour (10 YR 5/8) and consists of granular granitic sand. The quartz grains are highly angular and are derived primarily from granite bedrock. Unit 4 is a brown (10 YR 4/4) fine silty deposit 170 cm thick with occasional rounded quartz grains. It contains abundant, large lumps of charcoal with a minor clay component. Unit 5 is a yellowish brown (10 YR 5/8) granular deposit of ca. 60 cm depth with slightly rounded quartz grains and some small fragments of charcoal. Unit 6 is a bright yellow orange (10 YR 8/3) granular material of unknown depth grading into a finer sand sized material.

Two charcoal samples were assayed from the upper and lower part of Unit 4. The lower sample returned a date of 10,056±156 BP (10,400–9200 cal year BP; Wk-11346), while the upper sample was assayed at 9829±75 BP (9600–9100 cal year BP; Wk-11345). No charcoal was found in the other units which were dated by thermoluminescence (TL) between 10,700±1600 (W3579) and 12,500 (W3578). The chronology suggests that the terrace was deposited between ca. 9000 and 12,000 cal year BP. The deposit below Unit 1 in all 6 profiles is culturally sterile and suggests that there was no human occupation of the terrace during the terminal Pleistocene.

The build up of sediments on the Tully River terrace at the terminal Pleistocene signifies episodes of high and low water flows and landscape instability represented by units 2 to 3 (coarser sediments) and 4 to 5 (finer sediments). The instability was probably due to reduced vegetation cover and fluctuating precipitation. Nott et al. (2001) has also identified similar landscape change on the coast between Cairns and Babinda dating between 27,000 and 14,000 cal year BP when drier conditions

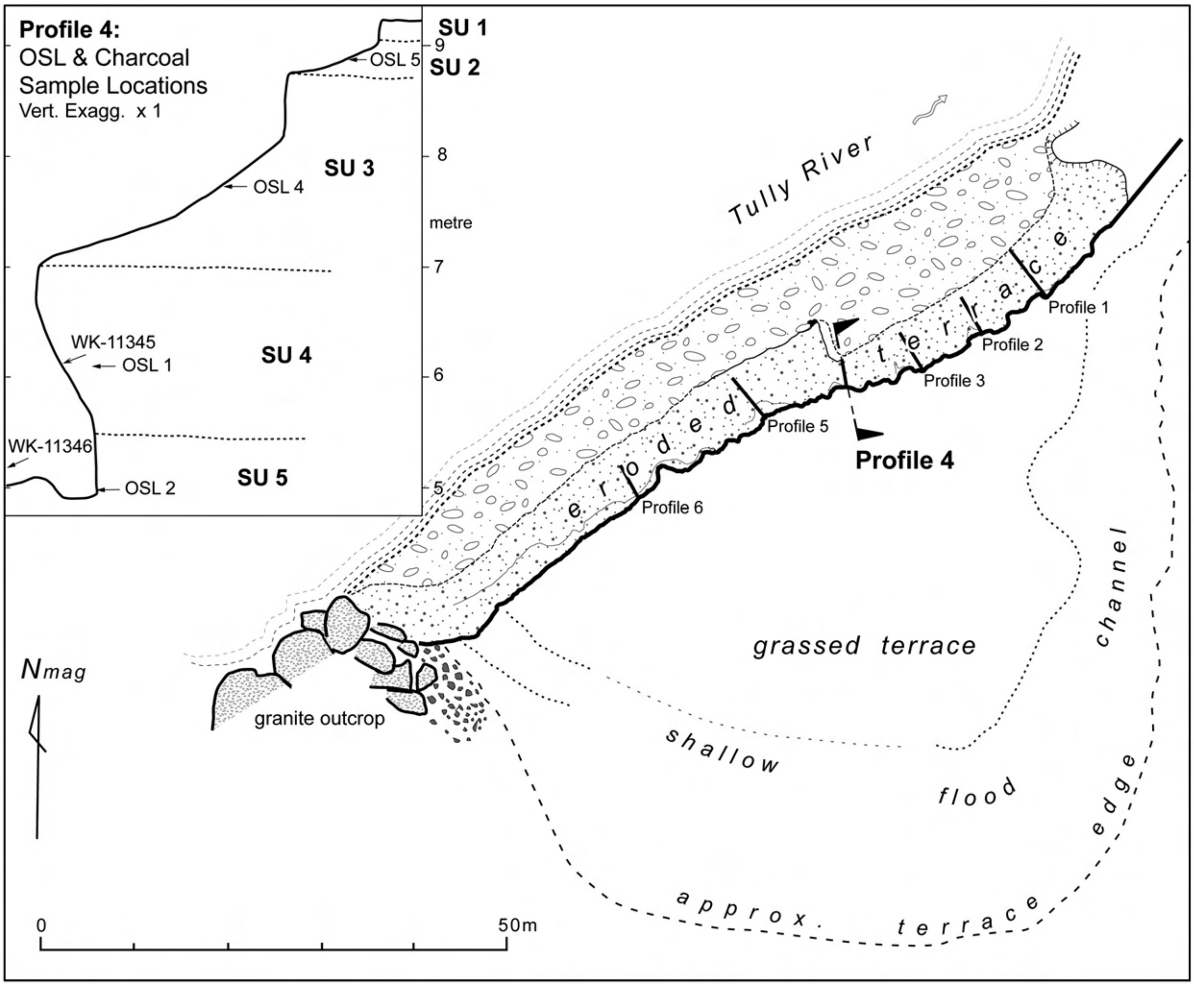


Fig. 2. Plan and cross section of the Tully River terrace site.

prevailed. The deposition of the Tully River sediments occurred slightly later than those identified in the coastal areas. The associated evidence for fire in Unit 4 points to much drier conditions in this part of the Atherton Tablelands about 10,000 BP and supports findings by Haberle (2005) for higher fire frequencies at this time. Furthermore, the major period of river incision must have occurred after 10,000 years ago, slightly later than that identified by Nott et al. (2001) for the lowland areas around Cairns, suggesting reactivation of water flows within the upper Tully River catchment perhaps after 8500 cal year BP.

Two charcoal lumps recovered from Unit 4 dated to 9829±75 BP (10,400–9200 cal year BP; Wk-11346) and 10,056±156 (9600–9100 cal year BP; Wk-11345) were identified to *Casuarina cunninghamiana* (J. Ilic personal communication, CSIRO), a riparian tree species that is commonly found on well drained cobble substrates (Woolfrey and Ladd, 2001). The identification of this charcoal as *Casuarina* supports the pollen evidence which indicates a reduction in rainfall and temperature between 24,000 and 12,000 BP (Moss and Kershaw, 2000), and increased fire regimes between 13,000 and 8000 BP (Hopkins et al., 1993). In 1922 surveys, Campbell (1923) described this part of the riverbank as covered in dense tropical rainforest indicating changed environmental conditions from 10,000 years ago. It is apparent that there was reduced rainfall and vegetation cover in the area during the terminal Pleistocene.

The palaeoenvironmental evidence suggests that rainforest was unevenly distributed until 8300 BP, prior to which, much of the Atherton Tablelands was covered in sclerophyll woodland with patches of riparian rainforest in the deeper gullies. Apparently the timing of rainforest establishment varied between sites, and fires played a role in its heterogenous makeup. The Mid to Late

Holocene experienced drier and more unpredictable conditions, possibly as a result of increased ENSO activity beginning about 5000 cal year BP.

4. Regional archaeology

A representative sample of open and rock shelter sites from the coast, the tropical tablelands and the transition zone between sclerophyll and rainforest were selected to investigate the antiquity of human occupation. Horsfall (1996) and Cosgrove and Raymont (Cosgrove and Raymont, 2002; Patterson, 2004) had previously surveyed and excavated Jiyer Cave, Mulgrave River 2, Mourilyan Harbour midden and Babinda coastal lowland open sites. Suffice to say that none of these sites exceeds an antiquity of 5000 BP and most intensive cultural activity was identified from 2500 BP, especially in the last 1000 years.

The most informative of the new sites are located on the Atherton Tablelands, southeast of Ravenshoe (Fig. 1). These lie within the traditional lands of the Jirrbal people located around Koombooloomba Dam where 131 new artefact locations were discovered during survey. Three archaeological sites were excavated and a further six palaeoecological sites from the region were investigated to ascertain regional environmental changes. Here we discuss three archaeological sites, Urumbal Pocket, Goddard Creek and Murubun rockshelter. Taphonomically these sites have different formation processes and come from a wide range of geographic locations. Despite this, all have similar temporal patterns of occupation, distribution of cultural remains, chronology and levels of preservation. It suggests that irrespective of the differing contexts they reflect a similar Aboriginal settlement history.

Koombooloomba Dam is approximately 40 km south of Ravenshoe and was built in the late 1950s for hydroelectric generation. Water demand is such that the lake can fall to below 25% capacity in late spring, exposing a band of bare soil on which many Aboriginal artefacts were recorded. Thirty-one artefact scatters, 66 axes (hatchets) and 34 broken axes were recorded from a survey of approximately two-thirds of the lake margin (Stevens, 2004). Many artefact scatters are composed of quartz, crystal quartz, rhyolite and minor quantities of chert. Ground-edge tools are also common, particularly axes (or hatchets) made on basalt and hornfels slate. Broken, incised grey slate grinding stones (Morah) and top stones (Moogi) were also present at various locations around the lake indicative of plant food processing.

Seven square metres was excavated at Urumbal Pocket with a total sediment weight of 3560 kg. Two square metres totaling 1695.60 kg was excavated from Goddard Creek deposit. All soil was wet sieved through 1 mm, 3 mm and 7 mm mesh. The average depth of the cultural sediment was 80 cm to 100 cm and both excavations reached sterile layers. Significant quantities of cultural charcoal, carbonized nutshell endocarps, seeds and stone artefacts were recovered.

At Urumbal Pocket a total of 33,718 artefacts were analysed with quartz artefacts <1 cm comprising 66% ($n=22{,}334$) and crystal quartz 4% ($n=1385$) of the assemblage. Quartz >1 cm makes up 25% ($n=8643$) of all stone raw material and reflects the use of local quartz for artefact manufacture. Other stone types contribute only a minor proportion. The presence of rhyolite, silcrete, jasper and hornfels suggests contact with areas to the west where acid volcanics dominate the regional geology (Henderson and Stephenson, 1980; Bultitude et al., 1997, p. 236).

At Goddard Creek a total of 13,009 stone artefacts were recovered, with quartz <1 cm comprising $\sim70\%$ ($n=9061$) of the total artefact number suggesting intensive stone knapping activities. Quartz artefacts >1 cm comprise 24% ($n=3152$) of the assemblage while crystal quartz <1 cm and >1 cm form 2% ($n=261$) and 1% ($n=150$), respectively. The other minor raw materials identified are quartzite, rhyolite, silcrete and volcanics. The metamorphic group of plain slate and phyllite is associated with grinding technology such as axe bevels and incised grinding stones. Quartz dominates every excavation level, and parallels the findings at Urumbal Pocket as well as Jiyer Cave and the Mulgrave River 2 site (Horsfall, 1987).

To the northwest of Koombooloomba Dam, a large granite overhang first identified by Horsfall (1988) was also excavated. It lies at a strategic location on the sclerophyll/rainforest boundary. The boundary forms an abrupt transition from the fire dominated eucalypt vegetation in the west and the fire sensitive rainforest in the east.

Two and a half square metres was excavated with the 956.8 kg of deposit wet sieved through 1 mm, 3 mm and 7 mm mesh. A total of 1539 stone artefacts were recovered from the three squares. Quartz was the predominant raw material in all squares making up 53% of the total, although finer grained isotropic materials such as chert (9%, $n=81$), rhyolite (8%, $n=72$), crystal quartz 6% ($n=52$), volcanic material (3%, $n=27$) and chalcedony (2%, $n=20$) were more prevalent in this site compared to Goddard Creek and Urumbal Pocket. This site lies within an area of acid volcanics and is probably the reason for the higher use of these raw materials.

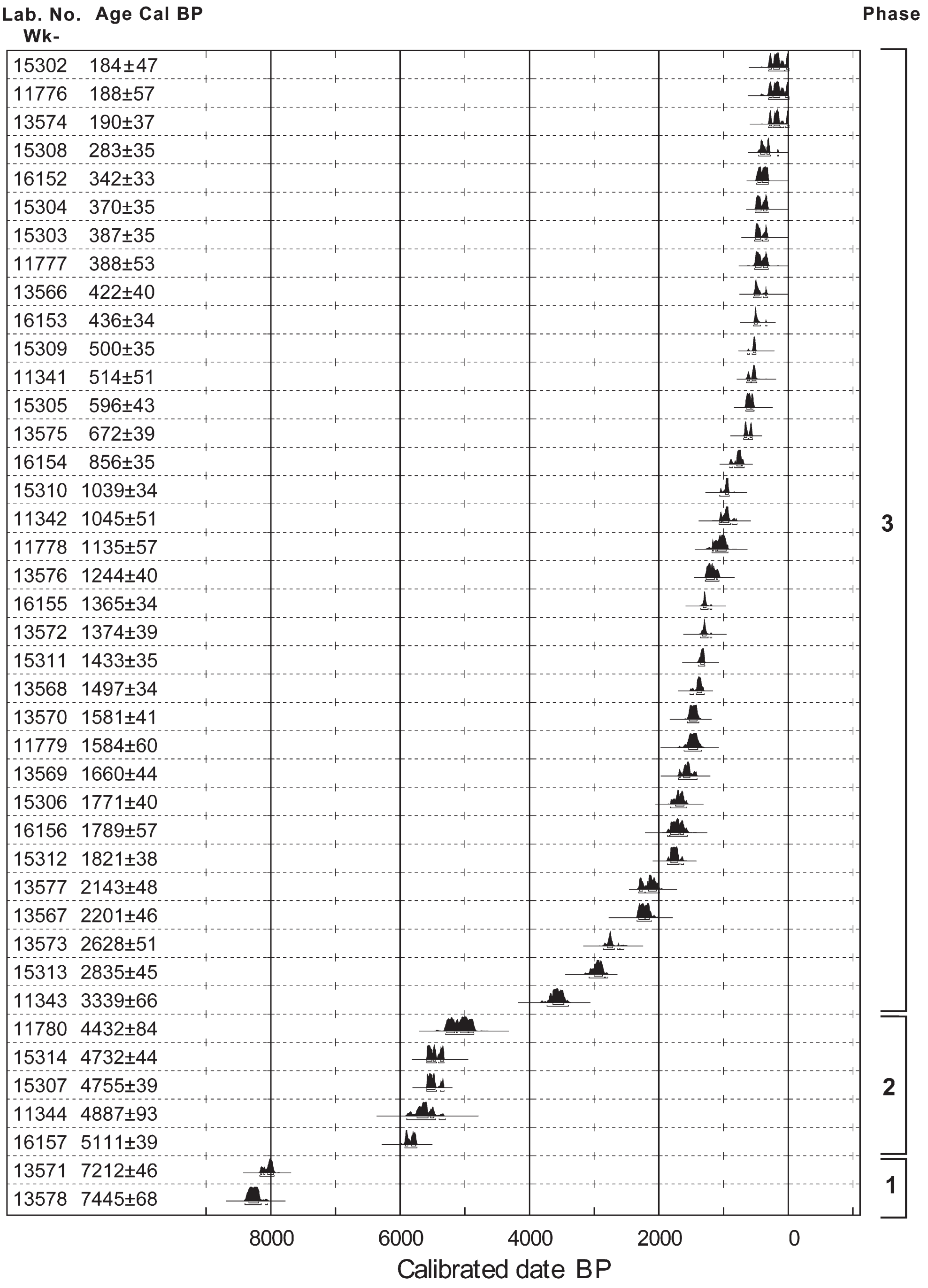
5. Chronology

Forty-six radiocarbon and three OSL dates were obtained from the four sites including the Mourilyan Midden (Table 1). The earliest ages come from Murubun rock shelter where late Pleistocene human occupation is dated to at least 30,200±1600 BP (GLO5030) and 16,000±800 (GLO5029), respectively. Very low-level occupation is suggested by the presence of 19 stone artefacts associated with OSL sample GLO5029 while 7

Table 1
Radiocarbon and OSL dates from the sites discussed in the text

Site	Square	Field code	Wk	dC13	Material	% modern	Result
Urumbal	A2	UP/A2/3	11341	−26.8±0.2	Charcoal	93.8±0.6	514±51 BP
	A2	UP/A2/5/01	11342	−25.2±0.2	Charcoal	87.8±0.6	1045±51 BP
	A2	UP/A2/8	11343	−27.2±0.2	Charcoal	66.0±0.5	3339±66 BP
	A2	UP/A2/10	11344	−28.1±0.2	Charcoal	54.4±0.6	4887±93 BP
	O2	UP/O2/7	13566	−26.9±0.2	Charcoal	94.9±0.5	422±40 BP
	O2	UP/O2/10	13567	−27.3±0.2	Charcoal	76.0±0.4	2201±46 BP
	S2	UP/S2/13	13568	−26.8±0.2	Charcoal	83.0±0.3	1497±34 BP
	S2	UP/S2/15	13569	−27.7±0.2	Charcoal	81.3±0.5	1660±44 BP
	V5	UP/V5/7	13570	−26.7±0.2	Charcoal	82.1±0.4	1581±41 BP
	V5	UP/V5/9	13571	−27.5±0.2	Charcoal	40.7±0.2	7212±46 BP
	V8	UP/V8/6	13572	−26.3±0.2	Charcoal	84.3±0.2	1374±39 BP
	V8	UP/V8/8	13573	−27.7±0.2	Charcoal	72.1±0.5	2628±51 BP
	Z3	UP/Z3/2	13574	−27.7±0.2	Charcoal	97.7±0.4	190±37 BP
	Z3	UP/Z3/8	13575	−25.8±0.2	Charcoal	92.0±0.4	672±39 BP
	Z3	UP/Z3/11	13576	−26.6±0.2	Charcoal	85.6±0.4	1244±40 BP
	Z3	UP/Z3/14	13577	−26.4±0.2	Charcoal	76.6±0.5	2143±48 BP
	Z3	UP/Z3/16	13578	−28.0±0.2	Charcoal	39.6±0.3	7445±68 BP
Goddard	A1	GC/A/2	11776	−29.2±0.2	Charcoal	97.7±0.7	188±57 BP
	A1	GC/A/4	11777	−27.3±0.2	Charcoal	95.3±0.6	388±53 BP
	A1	GC/A/6	11778	−28.2±0.2	Charcoal	86.8±0.6	1135±57 BP
	A1	GC/A/9	11779	−28.1±0.2	Charcoal	82.1±0.6	1584±60 BP
	A1	GC/A/13	11780	−26.5±0.2	Charcoal	57.6±0.6	4432±84 BP
	A1	GC/A1/26	16150	−27.8±0.2	Charcoal	63.8±0.7	3615±88 BP
	A1	GC/A1/29	16151	−27.7±0.2	Charcoal	85.8±0.4	1233±±39 BP
	A5	GC/A5/2	16152	−28.0±0.2	Charcoal	95.8±0.4	342±33 BP
	A5	GC/A5/4	16153	−28.3±0.2	Charcoal	94.7±0.4	436±34 BP
	A5	GC/A5/9	16154	−28.2±0.2	Charcoal	89.9±0.4	856±35 BP
	A5	GC/A5/14	16155	−28.3±0.2	Charcoal	84.4±0.4	1365±34 BP
	A5	GC/A5/19	16156	−28.4±0.2	Charcoal	80.0±0.6	1789±57 BP
	A5	GC/A5/24	16157	−25.5±0.2	Charcoal	52.9±0.3	5111±39 BP
Murubun	A1	MUR A1/2	Wk-15303	−26.1±0.2	Charcoal	95.3±0.4	387±35 BP
	A1	MUR A1/4	Wk-15304	−26.9±0.2	Charcoal	95.5±0.4	370±35 BP
	A1	MUR A1/6	Wk-15305	−26.5±0.2	Charcoal	92.8±0.5	596±43 BP
	A1	MUR A1/9	Wk-15306	−26.7±0.2	Charcoal	80.2±0.4	1771±40 BP
	A1	MUR A1/16	Wk-15307	−24.8±0.2	Charcoal	55.3±0.3	4755±39 BP
	A1	MUR OSL 1	GLO5029		Sediment		16,000±800 BP
	A1	MUR OSL 2	GLO5030		Sediment		30,200±1600 BP
	A1	MUR OSL 3	GLO5031		Sediment		39,400±2100 BP
	B2	MUR B2/2	15308	−26.6±0.2	Charcoal	96.5±0.4	283±35 BP
	B2	MUR B2/4	15309	−26.2±0.2	Charcoal	94.0±0.4	500±35 BP
	B2	MUR B2/8	15310	−26.4±0.2	Charcoal	87.9±0.4	1039±34 BP
	B2	MUR B2/12	15311	−25.8±0.2	Charcoal	83.7±0.4	1433±35 BP
	B2	MUR B2/16	15312	−25.7±0.2	Charcoal	79.7±0.4	1821±39 BP
	B2	MUR B2/21	15313	−26.9±0.2	Charcoal	70.3±0.4	2835±45 BP
	B2	MUR B2/26	15314	−24.6±0.2	Charcoal	55.5±0.3	4732±44 BP
Mourilyan	XX	2	Wk-15315		Shell	85.5±0.4	1256±34
	XX	10	Wk-15316		Shell	83.0±0.4	1492±36
	XX	19	Wk-15317		Shell	84.4±0.4	1361±38
	XX	25	Wk-11350		Shell	62.1±1.3	3827±172

Shell dates based on oyster shell.



Atmospheric data from Reimer et al (2004);OxCal v3.10

Fig. 3. Ordered radiocarbon dates from Urumbal Pocket, Goddard Creek and Murubun rock shelter. Dates appear to group into three phases. Two early ones representing ephemeral occupation of the sites with very low levels of archaeological material. The third phase represents initial occupation between 3000 calBP and 2000 calBP with very low levels of activity. High levels of discarded artefacts and burnt nutshells begin about 1800 calBP and drop off after about 250 years, probably in response to European incursions and settlement in Aboriginal tribal territories.

were found in lower levels from the GLO5030 OSL sample. A date of 39,400±2100 years (GLO5031) was assayed from the light yellow silty deposit at a depth of 60 cm from the surface. No cultural material was found in this layer but it clearly indicates that the site has been available as a human shelter from at least this time. There is a hiatus of 11,245 years until reoccupation of the shelter begins again between 4732±44 BP (5590–5440 cal year BP; Wk-15314) and 4755±39 BP (5800 cal year BP; Wk-15307). This is marked by the presence of a sticky dark brown organic rich soil overlying the light yellow sandy deposit and contains increasing densities of stone artefacts, cracked nutshell and charcoal. Discard rates of cultural material rise rapidly after 1771±40 BP (1820–1560 cal year BP; Wk-15306) in all parts of the excavation.

This pattern is repeated at Urumbal Pocket and Goddard Creek where the former site pre dates the Holocene occupation of Murubun by at least 2500 years. The earliest dates at Urumbal Pocket of 7445±68 BP (8420–8150 cal year BP; Wk-13578) occur in the central area of the excavation and use of the site ceases around 190±37 BP (cal year AD 1650–1890; Wk-13574). At Goddard Creek occupation begins by 5111±39 BP (5900 cal year BP; Wk-16157) while abandonment of the site occurs at 188±57 BP (230–130 cal year BP; Wk-11776). Pieces of flaked European glass on the surface of both sites suggest continued Aboriginal use into the twentieth century.

The coastal midden site at Mourilyan Harbour also reflects the chronological pattern found in the Tableland sites. Early occupation occurs in the lower levels associated with a clay soil devoid of marine shell but with some quartz stone artefacts dating to 3827±172 BP (4700–3700 cal year BP; Wk-11350). The midden material is dated between 1256±34 BP and 1492±36 BP. A chronological reversal occurs between the lower and middle midden layers (1361±38 BP) through disturbance to the midden. The top of the site has been destroyed by mechanical damage so a minimum date for occupation was not obtained although a significant Aboriginal presence in Mourilyan Harbour was noted by Captain Moresby in the 1870s (McRobbie, 1985).

Similar chronologies were obtained by Horsfall (1987) for her excavations at Jiyer Cave in the Russell River and Mulgrave River sites on the coastal lowlands. Occupation began around 5100 BP at Jiyer Cave and 2500 BP at Mulgrave River.

Overall the important point to note about this chronology is that the dated samples come from a range of site types with very different sedimentation histories and surface exposure with variable soil types. Irrespective of the context of the dated materials, there appears to be a consistent, Early to Mid Holocene Aboriginal settlement of the Atherton Tablelands and lowland coastal zone. This has significant implications for understanding population distribution in the late Pleistocene and Early Holocene period.

When the 49 dates are ordered and calibrated, at least three phases of rainforest occupation can be identified beginning about 8200 to 8000 cal year BP (Fig. 3), coinciding with initial rainforest expansion (Haberle, 2005) and with significant increases in microscopic charcoal in the pollen record. There appears to be an occupational hiatus until about 6000 cal year BP to 5000 cal year BP. These two early phases have extremely low discard rates and reflect occasional use of the area when rainforests were beginning to re-establish themselves. The third phase between 3300 and 2100 cal year BP represents initial settlement but again at very low levels. After 2000 cal year BP extremely high levels of activity are recorded at each site, particularly after 1700 cal BP to 1500 cal BP. Significant rises in nutshell and stone artefact numbers occur, with 69% of all radiocarbon dates being younger than 2000 BP. It is a period of major increases in cultural remains, including the appearance of incised grinding stones and axes. When considered together the evidence points to significant changes in the way Aboriginal people were exploiting the rainforest.

6. Density of cultural remains

Discard rates of stone and nutshell have been used widely in Australian archaeology to track occupation intensities through time. Although problems can arise through the imprudent application of these methods (Hiscock, 1985) it is generally felt that the inclusion of multiple data sets spread amongst a variety of sites dating to the same time periods can give useful insights into the intensity, if not population levels, of humans occupying a region.

Discard rates were calculated on the basis of two 1200-year occupation periods while the third on the basis of the first 5100 years of occupation at each site (Figs. 4, 5, and 6). The values were derived from squares with detailed radiocarbon chronologies, where the most intense phase of occupation at all sites occurs after 2000 cal year BP. For example at Urumbal Pocket increased discard rates for stone artefacts in square Z3 start about 2143±48 BP (Wk-13577) while nutshell begins to increase a little later, around 1244±40 BP (Wk-13576). In square A2 at the same site, the trend is slightly later but both reflect quite late depositional increases in nutshell. Fig. 4A and B show the combined frequency of stone artefact and nutshell discard in three occupation periods that increase dramatically after ca. 1200 years ago. In the preceding 1200-year period discard rates are relatively low and even lower in the first 5100 years of occupation. Evidence from Goddard Creek reveals a

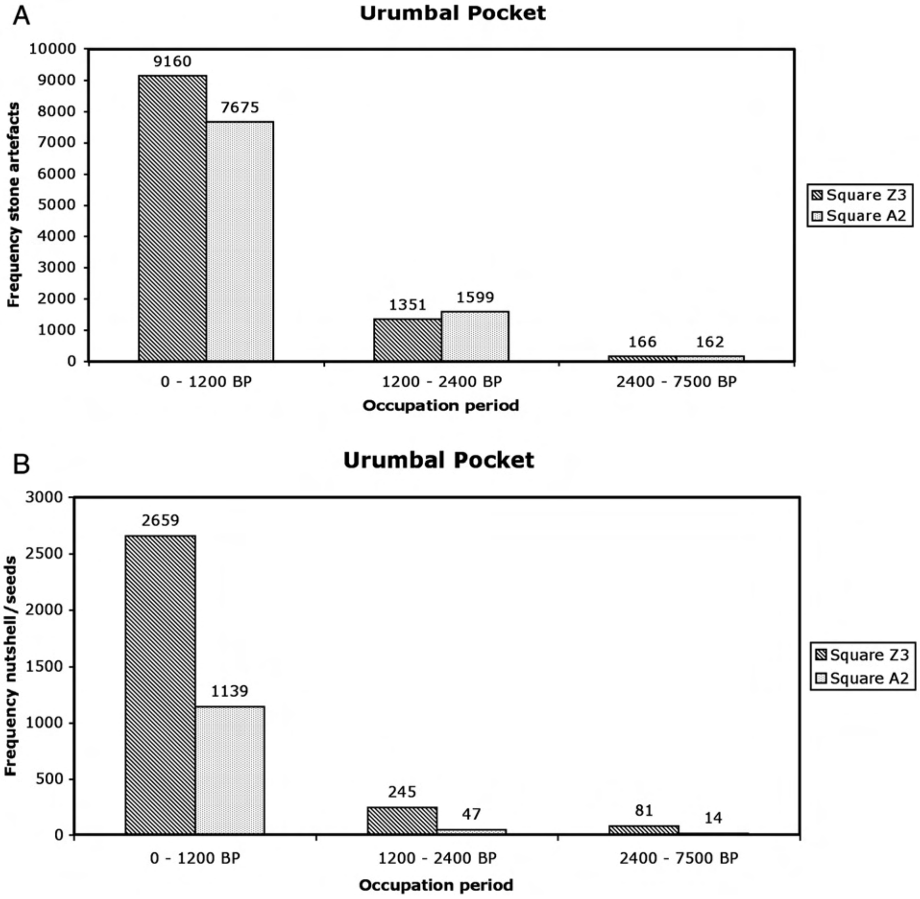


Fig. 4. Discard rates of stone artefacts (A) and nutshell/seeds (B) at Urumbal Pocket in two 1200 and one 5100-year occupation period.

similar trend with nut exploitation starting after 1365±34 BP (Wk-16155) in square A5 and after 1135±57 BP (Wk-11778) in square A1. Fig. 5A and B demonstrates a similar trend to Urumbal Pocket based on occupation periods. The pattern is repeated at Murubun with stone artefact (Fig. 6A) and nutshell discard (Fig. 6B) rates again rising after 1200 BP. All the excavated squares from all the sites have concomitant trends in cultural discard rates through time, particularly evident after 1200 BP.

The increase in the archaeological material appears to be a regional phenomenon as increases in site usage are also documented elsewhere in the wet tropics zone at this time. The patterns of initial occupation and increasing discard compare very favourably with results obtained from Jiyer Cave and the Mulgrave River sites investigated by Horsfall (1996) 70 km to the north. Occupation at Jiyer Cave begins about 5000 BP but at very low levels. Increases in stone artefact frequencies at Jiyer Cave occurred slightly later than increases in nutshell deposition, and Horsfall (1987) suggested that this might have been linked to increased occupancy of the cave. Toxic nuts identified to species date to less than 1000 BP although unidentified nutshell was found in older layers dated to 3000 BP (Horsfall, 1987, p. 263). The Mulgrave River site was occupied for the first time about 2690±100 BP (SUA-2284), with toxic nuts dating to about 2000 BP. Horsfall (1987, p. 268) also noted a temporal lag between stone artefacts and nutshell discard rates at the Mulgrave River site and reported that both sites show increases in nutshell and artefacts after 1000 BP. The earliest carbonized nut fragment identified as walnut (family: Lauraceae) is from Urumbal Pocket in an horizon (square V8 spit 9) dated to 2628±51 BP (Wk-13573).

The findings parallel changes in the archaeological record identified within the last 3000 years from wide areas of mainland Australia and Tasmania. It is important to note that in the rainforest there is an apparent lag of about 1000–

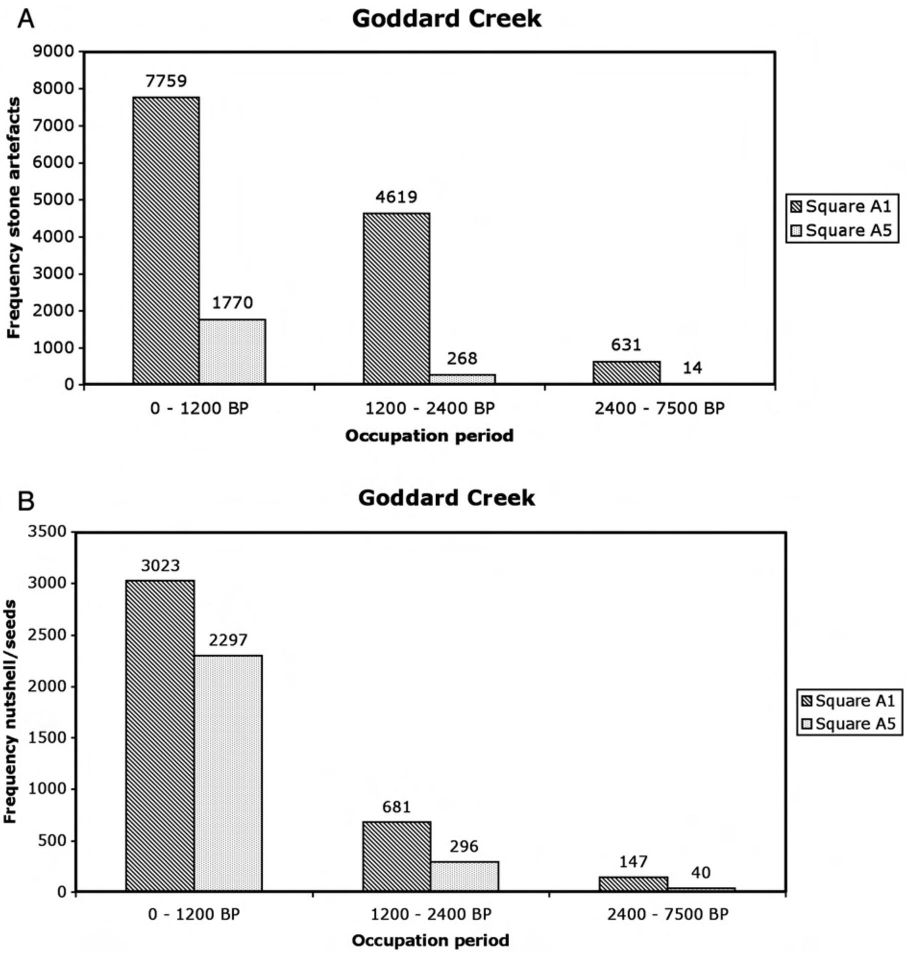


Fig. 5. Discard rates of stone artefacts (A) and nutshell/seeds (B) at Goddard Creek in two 1200 and one 5100-year occupation period.

800 years between the increasing amounts of stone artefacts from around 2000 BP and the nutshell, and, the very late intensive occupation of this environmental zone.

7. Organic remains

7.1. Nutshell analysis

Over 20,000 pieces of plant remains (847 g) were recovered from archaeological excavations at Urumbal Pocket, Goddard Creek and Murubun shelter (Table 2). Of these, over 90% are unidentified carbonised endocarp fragments less than 10 mm in size. The remainder consists for the most part of diagnostic endocarp fragments greater than 10 mm, in addition to a number of complete and partially complete seeds. All burnt fragments and seeds were found through the deposits associated with stone artefacts. No pits or hearths were identified but considerable amounts of charcoal were found throughout the deposits.

Two hundred and eighteen pieces of endocarp were identified as *Endiandra palmerstonii* (Black Walnut) or *Beilschmiedia bancrofti* (Yellow Walnut) (Family: Lauraceae), and another 181 fragments were smooth, curved pieces of endocarp from a large unidentified seed. The curved shape, the thickness of the endocarp wall and the estimated size of these partial remains are consistent with modern walnuts (Figs. 7, 8, and 9). A number of complete and partially complete walnut seeds were identified, some still partly encapsulated in the stony endocarp (Fig. 10). If we include these fragments ($n=399$) in the NISP calculations for walnuts, 35.9% of diagnostic fragments recovered from the archaeological sites may be attributed to Lauraceae. Furthermore modern and archaeological samples showed no significant difference in size of

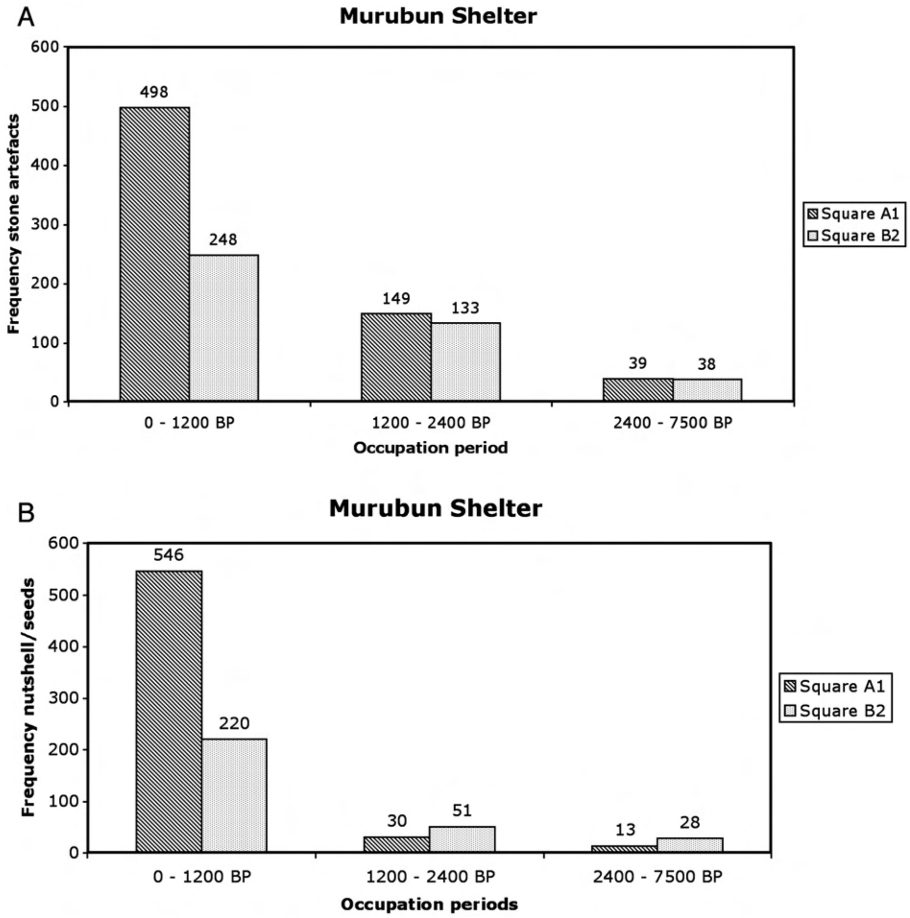


Fig. 6. Discard rates of stone artefacts (A) and nutshell/seeds (B) at Murubun Shelter in two 1200 and one 5100-year occupation period.

the nuts or endocarp wall thickness, and it is concluded that no major shrinkage occurred to the fragments at the time they were burnt.

The remaining 323 identified specimens (complete and partially complete seeds) have been identified to the Sapotaceae family and, more specifically to varieties of *Pouteria* spp. (Boxwood) (B. Grey, personal communication CSIRO). *Pouteria* spp. seeds have some key distinguishing features; they are ovate in shape with one or two pointed ends and a smooth surface with a groove running down the centre of the body (Figs. 11 and 12). A survey of the ethnohistoric literature and interviews with Aboriginal elders, however, failed to find any historical evidence relating to the use of *Pouteria* spp.

The presence of *Pouteria* spp. at all three sites, and their association with walnut endocarp fragments, stone artefacts and other cultural material, suggests that they were discarded by humans, rather than as a result of animal activity or from plants growing on the site. Rodents, which leave distinct gnaw marks, often prey upon *Pouteria* seeds in modern contexts. Toxic varieties like Black Walnut have been reported by Pedley (1993, p. 193) to be eaten by rodents if left on the ground uncollected, and we encountered numerous endocarp fragments with gnaw marks during our surveys. The archaeological remains show no gnaw marks, are burnt and are directly associated with stone artefacts, suggesting that their presence in the deposits is the result of human activity.

To test this further a series of ten soil pits were dug over a 150 m transect away from the Urumbal site to

Table 2
Charred archaeobotanical remains from sites discussed in the text

Site	Total number of fragments	Diagnostic fragments	Non-diagnostic fragments	Total weight (g)
Urumbal pocket	9463	496	8967	369.9
Goddard creek	9177	559	8618	436.7
Murubun rockshelter	1453	54	1399	40.7
Grand total	20,093	1109	18,984	847.3

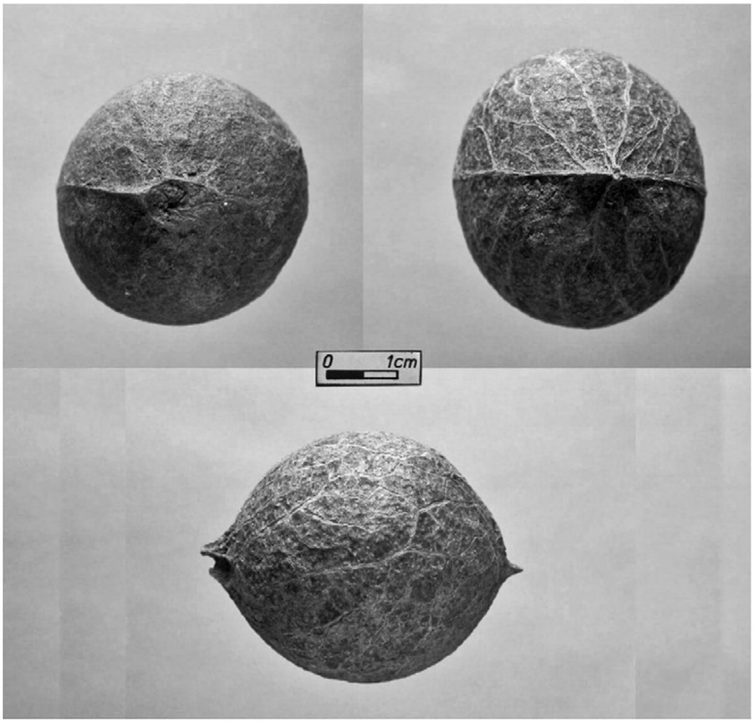


Fig. 7. Modern yellow walnuts (*Beilschmiedia bancroftii*) showing characteristic surface features.

determine the presence of nutshell and charcoal in the natural soil. All the soil was sieved with a 3 mm mesh and, although some wood charcoal was noted and collected, no nutshell was identified in the these pits.

Another relatively common type of complete and partly complete seed found within the cultural deposits is a round or slightly oval seed, between 10 and 14 mm in diameter, with distinctive surface ornamentation. The seed is enclosed within a wrinkled woody endocarp and has been tentatively identified as Elaeocarpaceae, is represented in all three sites ($n = 36$), and is probably one of the quandong species (B. Hyland, personal communication CSIRO). Unlike the *Pouteria* sp. seeds, there are references in the ethno-historical literature to the use of non-toxic varieties of Elaeocarpaceae by rainforest people, specifically the larger sized (10–12 mm)

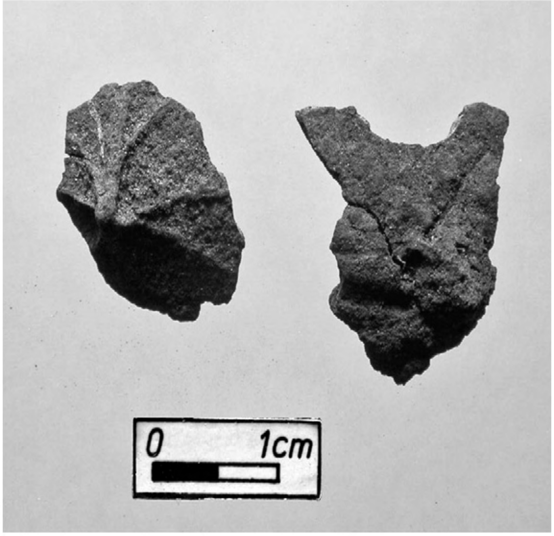


Fig. 8. Walnut endocarp fragments showing characteristic pointed ends.

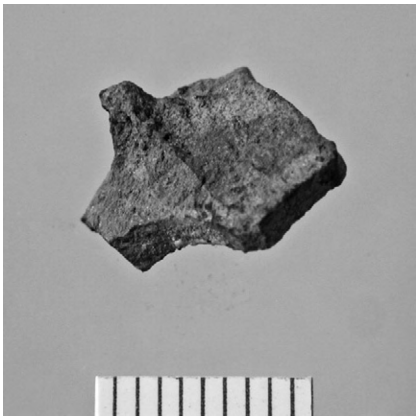


Fig. 9. Walnut endocarp fragment showing thickness of endocarp wall.

Fig. 10. Excavated black walnut seed (*Endiandra palmerstonii*).

Fig. 12. Modern *Pouteria* sp. seeds. CSIRO, Atherton.

Elaeocarpus bancroftii, the Johnstone River almond or Kuranda quandong. This was recorded as being eaten (Harris, 1975, p. 39–43) but no nut remains have been found at any of the sites.

The analysis of archaeologically derived plant assemblages from three sites located in the rainforest region of far north Queensland has shown:

1. Large endocarp fragments with distinguishing diagnostic features are identified to either *E. palmerstonii* or *B. bancrofti*.
2. While the use of black pine (*Sundacarpus amara*) by Aboriginal rainforest groups was widely recorded in the ethnographic literature and is still collected by Jirrbal elders, none was identified. Discrimination may be achieved by studying the cell structure of the remaining endocarps. At this stage we cannot confirm the exploitation of black pine at any of the sites under investigation.
3. Two types of seeds were recovered from the archaeological sites that have not been previously identified as economically important. Modern Elaeocarpaceae fruits are recorded as food for cassowaries, other birds and native rats. Like Sapotaceae, the archaeological remains show no evidence of animal activity to suggest introduction by non-human agents.

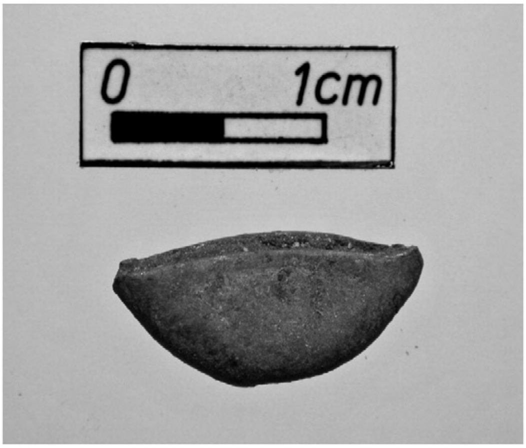


Fig. 11. Excavated *Pouteria* spp. seed.

7.2. Starch analysis

Although nutshell is abundant at the sites, linking food processing directly to tools can only be done through starch residue analysis. On the basis of our knowledge of preparation techniques for toxic nuts (Pedley, 1993; M. Barlow, personal communication 2002), the material culture most likely to be associated with processing is grinding stones. Two types of grinding stones have been identified in the area, slate incised grinding stones and slabs manufactured from granite. The latter do not typically feature surface modifications and incised lines are associated with slate raw material. Incised grinding stones are confined geographically to the rainforests of far north east Queensland (Woolston and Colliver, n/d). They have been found on the coastal plain from Tully to Babinda and further west in the rainforests of the Atherton Tablelands. Their specific function has not been recorded ethnographically though they are a ubiquitous feature of the region (Horsfall, 1987).

During our surveys of the Koombaloomba Dam foreshores, incised grinding stones, both fragmented and whole were commonly found. At the Urumbal Pocket excavations, a small fragment of an incised grinding stone was recovered during excavation. At Goddard

Creek a number of incised grinding stones were found on the surface in close proximity to the excavations, though none were recovered subsurface. The sharply defined incisions on the grinding stone surfaces have great potential as 'residue traps', preserving microfossils such as starch and phytoliths, thereby potentially providing direct evidence of the plants being processed.

7.3. Comparative reference collections of starch

A comparative reference collection was first prepared to establish the range of variation in morphology and size of starch granules from different species, and to determine the potential of these microfossils as markers of particular species or genera. Inter- and intra-specific variability was also important as environmental variation may influence the development and rate of formation of starch (Field and Gott, 2006; Field, 2007; Lance et al., in press). Fresh specimens were collected during fieldwork and voucher specimens were sampled from the CSIRO Rainforest Herbarium at Atherton.

Specimens were prepared as smears and mounted in Karo™ (corn syrup). Starch was viewed using a Zeiss Axiomat bright field microscope equipped with Differential Interference Contrast optics and polarizing filters. Images were collected with an Axiocam HrC digital camera and archived using Zeiss Axiovision v4.2 software. The economic toxic plant species used in this study (see Table 3) showed considerable variation with respect to size and morphology of starch as indicated in the box plot graph shown in Fig. 13.

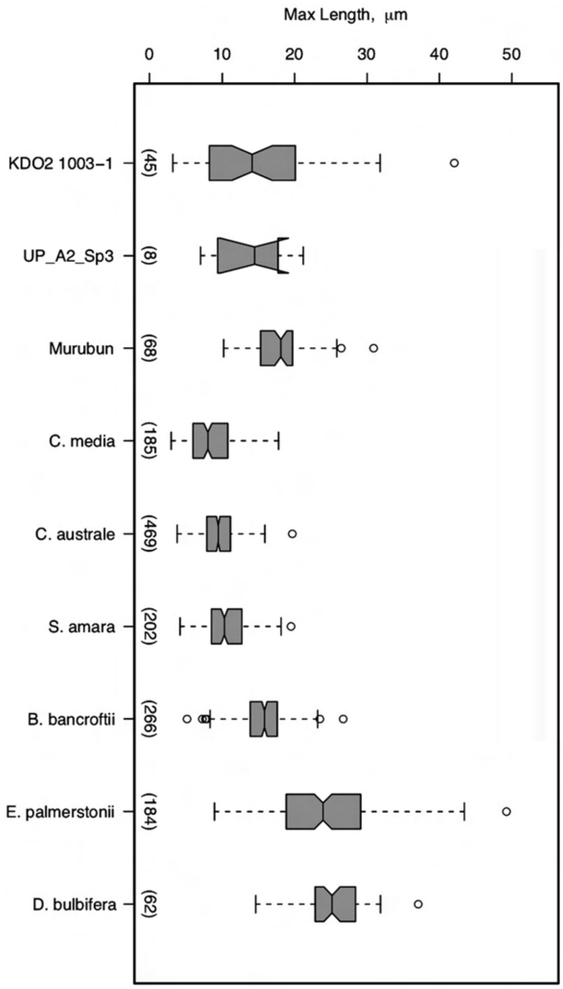


Fig. 13. Size range of starch sampled from three incised grindstones from the Koombaloomba Dam area on the Atherton Tableland in north-eastern Queensland, shown alongside samples from economically important species within the study area, and plotted by maximum length as measured through the hilum. In this box plot, box edges represent the interquartile range, meaning half of all observations within each group are contained within the box; whiskers extend to the lesser of the most extreme observations above and below the median, and 1.5 times the interquartile range, with outliers marked by circles; notches mark an approximate 95% confidence interval for differences between two medians. Sample size (number of starch grains) is shown in brackets below each box. Sample size (number of starch grains) is shown in brackets below each box.

Table 3
Detoxified plants as identified by Savage (1992), Roth (1901–1910), Harris (1978) and Pedley (1993:5)

Scientific name	Common name
Castospermum australe	Black bean
Beilschmedia bancroftii	Yellow walnut
Endiandra insigns	Hairy walnut
Sundacarpus amara	Black pine
Prunus turnerana	Almond bark
Endiandra palmerstonii	Black walnut
Lepidozamia hopei	Zamia
Cycas media	Cycad
Bowenia spectababilis	Zamia fern, ricketty bush
Dioscorea bulbifera	Round yam
Tacca leontopetaloides	Polynesian arrowroot
Bruguiera gymnorhiza	Red mangrove
Calophyllum inophyllum	Beach calophyllum
Entada phaseoloides	Matchbox bean
Macadamia whelanii	Silky oak (Dambon nuts)

In Fig. 13 a box plot shows the range of comparative starch grain size from various comparative reference material and from two starch deposits from two archaeological grindstones. The grinding stones in Fig. 13 are slate incised morahs and were collected from three different contexts: grinding stone KDO2 1003 is a surface find which was found lying face down and adjacent to a creek bank near Urumbal Pocket; UP_A2_Sp3 is an incised grinding stone fragment excavated from Urumbal Pocket and dates to ca. 560 BP (uncalibrated); and

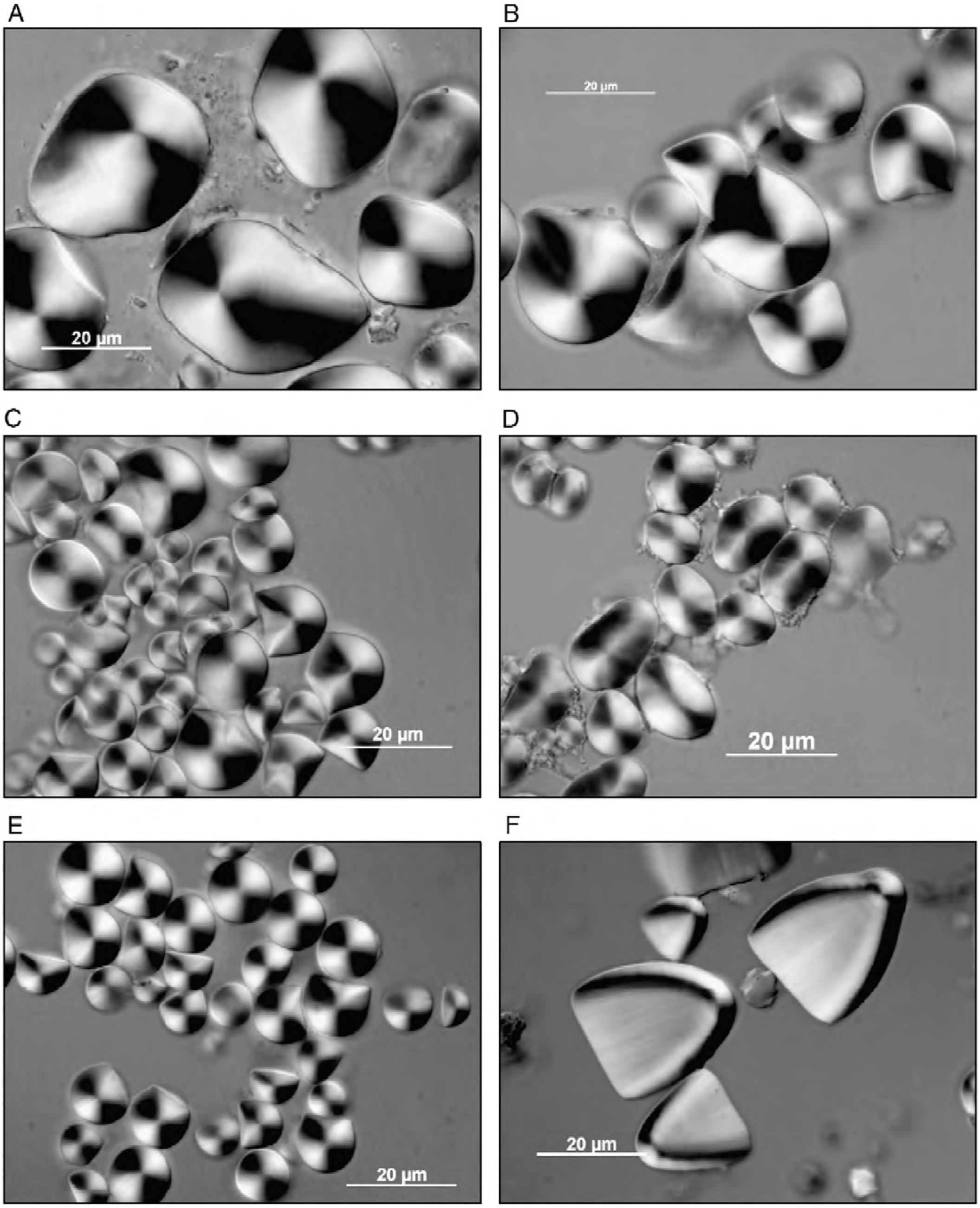


Fig. 14. Starch granules from comparative reference specimens of economically important plant from the rainforest of north east Queensland. (A) *Endiandra palmerstonii* (Black Walnut), which has very large irregular grains with an eccentric hilum; faceting is uncommon to rare, dependent on the packing densities in the plant cell. (B) *Beilschmiedia bancroftii* (Yellow Walnut), grains have a high incidence of faceting, though spherical grains are found; twinning is common. Fissures at hilum are also common and are accentuated by mounting in water. (C) *Cycas media* (Cycad). Granules are similar in shape to those of *B. bancroftii* though are generally smaller. Faceting is high and smaller grains are generally spherical. (D) *Sundacarpus amara* (Black Pine), granules are irregular in shape, similar to *E. palmerstonii* but much smaller overall. Hilum is eccentric, but faceting is uncommon. (E) *Castanospermum australe* (BlackBean) Grains rounded and faceted, twinning common, granules very similar to *B. bancroftii* and *C. media*. (F) *Dioscorea bulbifera* (Hairy Yam) granules typical of the *Dioscorea* family, roughly triangular in shape, very eccentric hilum, not spherical and has very large granules.

the Murubun grinding stone was collected from the ground surface of the rockshelter. The median grain size of these samples does not appear to be different from *B. bancroftii*, although the samples from the Urumbal Pocket have a greater spread, which is most prominent in KDO2 1003. The broad range of granule sizes seen in

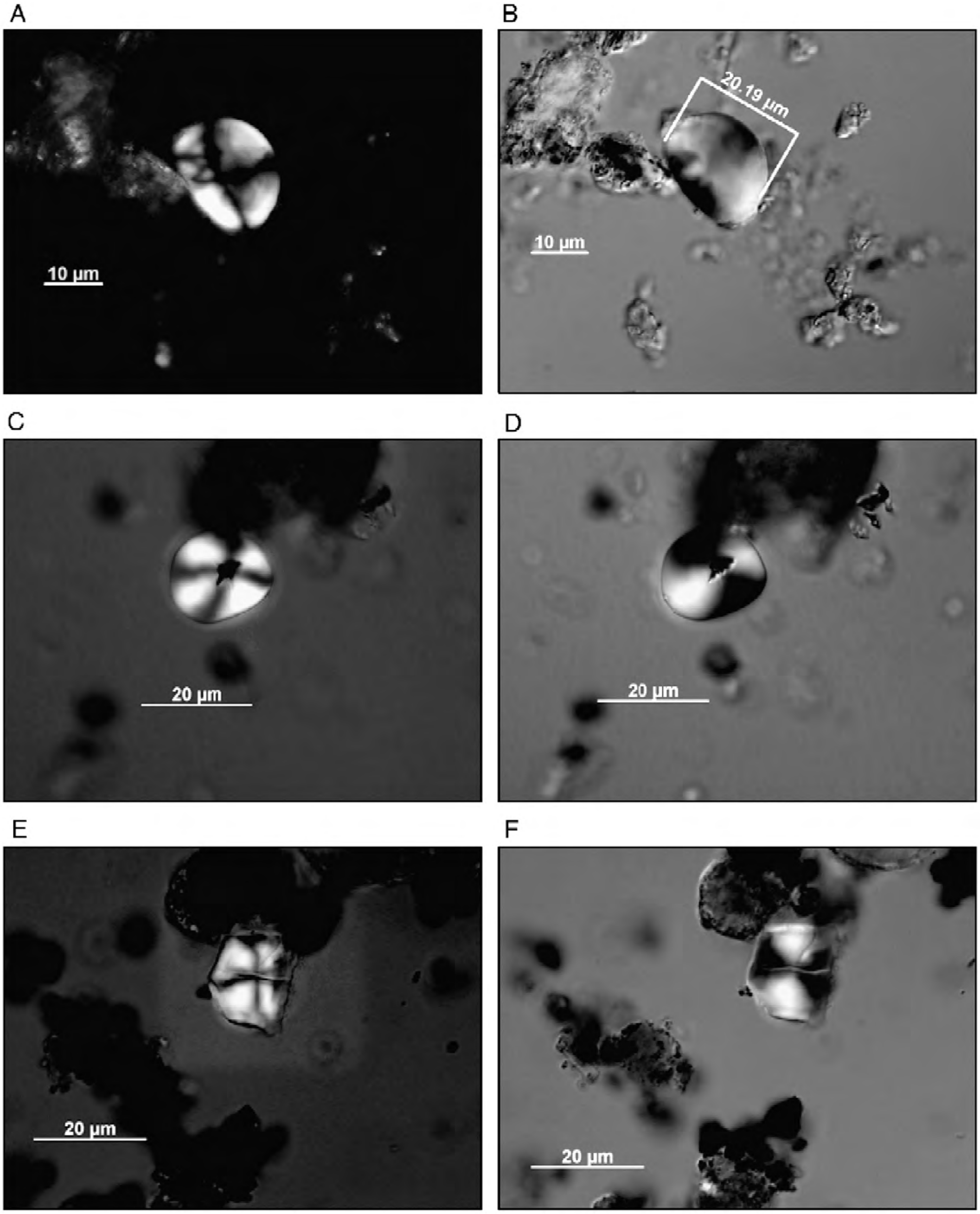


Fig. 15. Examples of starches recovered from the surface of grinding stones. Images collected using both Differential Interference Contrast (DIC) microscopy and under polarized light showing extinction crosses. (A) Starch from grindstone KDO2 1003(polarizing filters); (B) Same as A with DIC, note similarity to the morphology of *Sundacarpus amara*; (C) starch from grind stone UP A2 Sp3 (polarizing filters); (D) Same as C with DIC, note damage to the hilum often seen in starch grains recovered from grind stones surfaces; (E) starch from Murubun Shelter grindstone (polarizing filters); (F) same as E with DIC. Note fissure at hilum.

the starch samples may indicate that more than one species was processed on the KDO2 1003 grinding stone, such as *E. palmerstonii*, which fruits in the same period as *B. bancroftii*. In our observations of fruiting and quantity of seeds on the forest floor, *E. palmerstonii* is generally less abundant than *B. bancroftii*.

While the sample of starch granules extracted from the excavated grinding stone UP_A2_Sp3 is very low, it is consistent with the small size of the fragment recovered. Nonetheless, the size range of starch recovered is supportive of the identifications made for the carbonized nutshell as *B. bancroftii* as the primary economic species being processed at Urumbal Pocket.

Murubun Shelter is located in the dry country on the edge of the rainforest, and so the incised grinding stone from the surface of the shelter was expected to have a different starch assemblage compared with the two rainforest finds. Interestingly, it does not appear to fall within the range of locally prevalent *Cycas media* (Fig. 14F), but is more similar to *B. bancroftii* and *E. palmerstonii*.

Furthermore, there appeared to be similarities between some species, which, on the basis of morphology could not be separated (Fig. 14A–E). The maximum dimension of ≥100 starch granules was measured from at least one specimen of each species to determine the variation in size of grains. In some cases starch grains exhibit faceting of their surfaces, the result of either high packing densities in cells or as a distinct morphological feature of the grain.

Identifying starch in archaeological studies requires a good understanding of the range of plant species that may be present in the area under study. A suite of plant species that are starch producers (both economic and non-economic) need to be assayed to provide the basis of a comprehensive reference collection. Importantly, the features used to identify starch granules in arid zone studies (Fullagar et al., in press) may not be suitable for studies in other environmental zones where a different suite of economic plants is found. The research questions in this case were:

1. Were starch granules preserved on the surfaces of the grinding stones?
2. Could the assemblages of starch granules recovered from the grinding stone surface be attributed to one or more species of known economic plants? Furthermore, the sediments associated with the excavations were assayed for the presence and concentration of starch. The preliminary results of the analysis are presented here.

7.4. Starch on grinding stones

Starch was recovered from the surfaces of all incised grinding stones examined in this study. The concentrations of starch varied, but overall these were much higher than those in sediments at any location within the study area. The size and morphology of starch granules varied. Most starch granules were within the range of 10–30 μm and the numbers of granules recovered from a residue sample varied from a low of <10 up to ca. 100.

The difference in recovery of starch between soils samples (Field and Cosgrove, unpublished results) and grinding stones appears to be an order of magnitude, the original residue sample size for artefacts being ≤0.1 g while the soil extractions start with a sample size of 1–3 g. However, in the case of this study, only one grinding stone fragment was recovered from enclosing sediments and the remaining two from different surface contexts. Examples of starch grains recovered from the surface of grinding stones are shown in Fig. 15A–F. Some of these grains show faceting and are in the same size range as Yellow Walnut (*B. bancroftii*) and Black Bean (*Castanospermum australe*). Fig. 14 presents some of the comparative reference material, and Fig. 15 the starch assemblages recovered from the three grinding stones mentioned above (Fig. 16A–B).

The three artefacts have morphological features consistent with grinding stones found elsewhere on the Australian continent (e.g. Smith, 1988). While made of

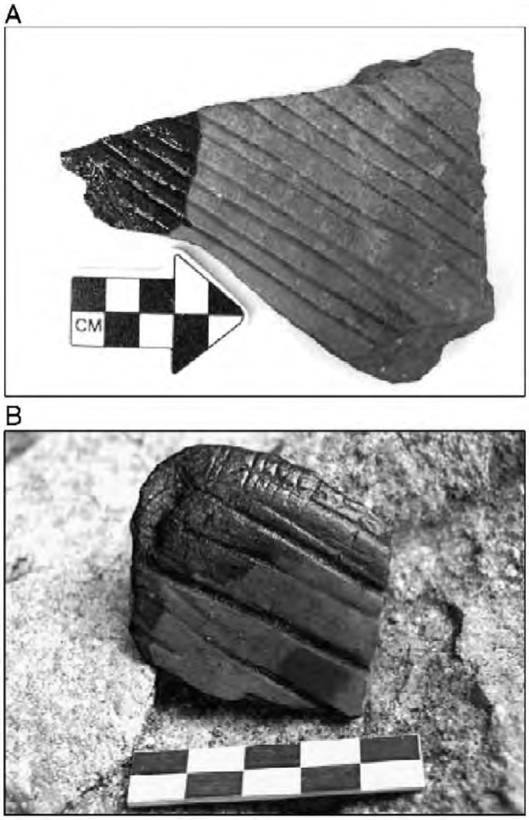


Fig. 16. Koombaloomba Dam grindstones from which residue extractions have been made for starch analysis. (A) KDO2 1003 1. Note the wetted area where it was placed in an ultrasonic bath to facilitate removal of sample. Note also the sediment on the artefact surface. (B) Murubun Shelter grindstone that was recovered from the surface of the shelter floor and sampled in the field.

slate, they are flattened dorso-ventrally, are generally concave from use and have at least one smoothed (used) surface. The incisions on the used surfaces are unique to this region and may have been made with either a bone point or a piece of quartz (Horsfall, 1987).

In summary, the residue analysis of incised grinding stones from the Koombaloomba Dam sites has extracted and identified a range of starch granules from the used surfaces. The assemblages presented here support an interpretation of the processing of toxic starchy seeds, and is consistent with the identification of carbonized nutshells to *B. bancroftii*. Yellow Walnut (*B. bancroftii*) was the likely plant being targeted for processing at Urumbal Pocket and around Sylvania Creek. It is equally likely that other economic plant species contributed to some extent to the overall starch suite, e.g. *E. palmerstonii* and although *Pouteria* sp. seeds are present at the sites no evidence of this species starch was recognized on the grinding stones. It also provides compelling evidence that the carbonized nutshell recovered from the excavations represents processing and detoxification of Yellow Walnut for human consumption. At Murubun Shelter, a similar trend is identified with an apparent higher input from *E. palmerstonii*. *Dioscorea* sp. is excluded on the basis of morphology for this size range (see Fig. 14E and F). Further study of the starch and phytolith assemblages from the soils will further assist in plotting site patterning and chronological change in the use of toxic starchy nuts.

8. Discussion

Aborigines began to use the rainforest environment soon after it re-established ca. 8000 cal year BP although these initial forays appear to reflect occasional visits to the area. Between 5000 BP and 2000 BP discard rates of cultural material remained very low with some nutshell exploitation and stone artefact production. It is at this time we see the initial use of toxic nut varieties at about 2600 BP. After 2000 BP there is a rapid increase in the amount of cultural material at the sites, particularly quartz stone flakes and carbonized nutshell. It is at this point that we can identify the increased exploitation of toxic varieties of nuts, like the Yellow and Black Walnut species, *B. bancrofti* and *E. palmerstonii.* The use of ground-edge technology and incised grinding stones appears at least 1500 BP and 600 BP, respectively. These patterns have also been identified in both rock shelter and open sites presented here. The results also parallel findings at Jiyer Cave and the Mulgrave River sites where increases appear about 800 BP and 1000 to 1800 BP, respectively (Horsfall, 1996, p. 188).

There has been much debate about the pattern, tempo and causes of increasing Aboriginal site occupation during the mid to late Holocene in Australia. Various explanations have been put forward for the general observations of increasing site use and deposition of cultural remains within the last 5000 years compared to the preceding 40,000 years or so. These changes have been explained in a variety of ways; social intensification and broad spectrum resource use (David and Lourandos, 1997; Haberle and David, 2004), population increase (Beaton, 1983, 1985, 1990), large scale climatic change (Morwood and Hobbs, 1995) smaller, high intensity El Niño Southern Oscillation (ENSO) activity (Rowland, 1999; Cosgrove, 2005; Turney and Hobbs, 2006) and other explanations (Ulm, 2004). Identifying prime movers in this debate has been as problematic as those for the appearance of food production and domestication in other parts of the world (Smith, 1994). We believe that many of these explanations do not sufficiently explain the abrupt and rapid changes in the rainforest record seen in our more detailed radiocarbon and OSL dating analyses, principally the rise in discarded cultural material in the sites.

Our dating coupled with associated artefact and nutshell discard rates described above shows clear evidence for a punctuated change in cultural tempo in the very Late Holocene. The ordered sequence of dates and allied material remains demonstrate three phases of occupation beginning about 8200 to 8000 cal BP, then another occupation phase from 6000 to 5000 cal BP. These two early phases have extremely low discard rates and reflect occasional use of the area when rainforests were beginning to re-establish themselves. The third phase between 3300 and 2100 cal BP represents initial settlement but again at very low levels. After 2000 cal BP extremely high levels of activity are recorded at each site with decreases beginning about 250–200 cal BP and probably represents the period of European incursion, who displaced rainforest Aboriginal people from their tribal lands.

The long term timing and intensity of these changes are significant in light of evidence for Early Holocene sea level advance. Seas began to rise rapidly after 9000 BP, drowning all of the continental shelf in a matter of centuries or even decades in this region (Hull, 2005). It is estimated to have risen between 10 m and 30 m per year or at least 700 m per decade (Hopkins et al., 1996; Trott, 1997). Hopkins has asserted that this would have pushed Aboriginal populations up against the coastal mountain ranges, significantly reducing their territories and stimulating burning activities that retarded early rainforest expansion.

However, we find no support for this scenario in our data. If populations had been squeezed between the rising seawaters and the rugged coastal mountain ranges archaeological sites dating to this period should be numerous with consequent increased evidence of activity early in the sequences around 9000 BP onwards. This is not the case. Our data suggest that Aboriginal populations at this time were extremely low across the whole region only increasing about 2000 years ago. Increased burning between 13,000 and 8000 may have been due to climatic factors rather than anthropogenic ones. The Tully River terrace data, as well as pollen (Moss and Kershaw, 2000) and sediment data (Nott et al., 2001; Thomas and Nott, 2001) support a reduction in rainfall and drier conditions about this time. After 8000 BP conditions become wetter and warmer although there is no evidence to suggest that rainforests were colonized by humans in any intensive way at, or immediately after this time.

Horsfall (199, p. 187) records activity at the lowland coastal Mulgrave River site beginning about 2600 BP and then a reduction about 1000 years BP although no such decrease was identified at Jiyer Cave. Jiyer Cave is first occupied about 5000 BP but again, human occupation of any intensity only begins between 1000 and 2000 years ago.

We believe that the phase post 2000 years ago sees the north east Queensland rainforest occupied on a permanent basis with the increased use of both toxic and non-toxic plant varieties. Prior to this period, human occupation of rainforest was intermittent with people using the zone in much the same way as the Anbarra and Yolngu people used different ecosystems for subsistence in the recent past (White and Meehan, 1993). The focus was perhaps on readily available foods that required little in the way of extensive processing, providing insurance against food scarcity and preserving high quality. This is a common behavioural pattern in semi-arid tropical areas of northern Australia to reduce economic risk in lean times. Where access to such resources is reduced there are serious consequences for population survival (White, 2001).

Some years ago Rowland (1999) asked whether the potential of Holocene environmental variability had been underestimated in Australian pre-history. He was particularly interested in the effect that El Nino/Southern Oscillation had on Aboriginal economies and investigated a number of prior explanations in terms of ENSO variability. This theme was expanded upon by Hiscock (2002) who argued that these short-term but highly influential events had a significant influence on the organization of stone tool technology that began around the mid-Holocene. ENSO has even been implicated in the colonisation of Pacific Ocean islands (Anderson et al., 2006).

More recent detailed climatic research has dated these events more precisely and has confirmed the unpredictability of ENSO at various scales in the Australasian region (Gagan et al., 2004; Mayewski et al., 2004). The research has also identified changing vegetation and burning patterns over the past 9000 years from the Atherton Tablelands (Haberle, 2005) and southeastern Australia (Cupper et al., 2000). In the Americas these ENSO events have been implicated in the reconfiguration of local vegetation and regional human occupation strategies (Dillehay and Kolata, 2004; Donders et al., 2005; Sylvestre et al., 2005) as well as the collapse of agricultural societies (Abbott et al., 1997).

What emerges from the Australian studies is that the rainforest expanded after 8000 years ago in conditions much wetter than the preceding period, yet it seems humans only began to permanently settle here ca. 2000 years ago. An explanation for this pattern perhaps lies in the highly variable climate driven by El Nino-Southern Oscillation (ENSO) events, which cause damaging droughts across Australia (Cosgrove, 2005). Recent studies of corals from the Great Barrier Reef (Gagan et al., 2004) show that the severity and frequency of ENSO events have changed through time. The last strong increases in ENSO events started 5000 years ago and increased further after 3000 years ago. The most intense period of ENSO activity occurred from 2500 to 1700 years ago, coincident with increased levels of Aboriginal activity in the region. Rainfall appears to have not only been 20–40% lower but highly seasonal. These fluctuations may have had a profound effect on the surrounding semi-arid regions, forcing people to permanently occupy rainforest only used occasionally, perhaps on a seasonal basis before 2000 years ago. Making a living may have become increasingly risky and unpredictable, encouraging people to find alternative sources of subsistence such as the abundant but bitter-tasting toxic nuts and fruits of the rainforest, previously avoided as too time-consuming to process.

Turney and Hobbs (2006) recently argued for millennial-scale peaks of human occupation, centred on 5000, 3800, 2500 and 1000 years ago apparently coincidental with increased ENSO activity. While the radiocarbon chronology for Aboriginal settlement in Queensland and ENSO appears coincident at this scale it is only when the cultural remains are examined that a much clearer picture emerges. Despite the fact people had been on the Atherton Tablelands for at least 8000 cal year BP, our data suggest permanent rainforest occupation only beginning about 2400 cal year BP with a rapid rise after 1200 cal year BP. Although our dates appear to match the 2500 and 1000 cal year BP peaks, the analysis of archaeological data does not support Turney's observation of the 5000 and 3800 cal year BP peaks in human activity.

With ENSO came resource unpredictability, which heightened risk and uncertainty. The hunter–gatherer response was a move towards a previously less favoured high cost/high return resource such as the higher producing toxic but nutritious arboreal nuts. Harris (1987) and Pedley (1993, pp. 179–180) note that nuts like the Yellow Walnut (*B. bancroftii*) contained very high quantities of carbohydrates (71.82%), some protein (7.96%) but were low in fats (0.59%). These nuts could provide up to 1396 kJ of energy or 322.41 calories per 100 g of their edible portion. Other varieties like the non-toxic Johnstone River almond (*E. bancroftii*) contained lower amounts of carbohydrates (19.85%), about the same amount of protein (7.23%) but much higher quantities of fat (45.11%) that provided 516.6 calories per 100 g. In addition large quantities could be gathered relatively quickly. Pedley (1993, pp. 88–90) notes that 8.5 kg of black pine (*S. amara*) nuts was gathered from under a single tree in 20 min, taking a further hour to shell them. During her experiments, 12.75 kg of black bean (*C. australe*) was collected from a single tree in 30 min (Pedley, 1993, p. 66).

A factor in the ability of Australian Aborigines to successfully settle the rainforest in the face of climatic perturbations was the exploitation of the wide array of highly toxic nuts and fruits by cooking and complex processing. We do not believe that terrestrial animal food was as important as the increased access to plant foods seen in the archaeological record, to permanent rainforest settlement. Toxic plant processing appears to be based upon the recent development of a very specialised and elaborate material culture like the Ooyurka and incised grinding stones, a material culture found nowhere else. The toxic nuts were also attractive because of their abundant production, their durability and high food value. The elaboration of leaching technology probably increased the amounts of starch and protein that could be processed, a development which could have been a catalyst for the increase in the intensity of occupation and population growth 2000 years ago.

9. Conclusion

Our work on the Atherton Tableland has shown that toxic plants were incorporated quite late into the rainforest economy probably as a result of climatic instability with the onset of ENSO events 5000 years ago. Since it is costly and time-consuming to process such resources, the pay-off must have been significant in terms of predictable resources, higher food quality and subsequent population increases. Thus we have identified a potential causal link between the environmental perturbations as a catalyst for rainforest occupation.

Although speculative at present, the rise of the large and regular ceremonial gatherings at the beginning of the wet season in north-east Queensland rainforests, as witnessed by European settlers, may have been a consequence of this development. The widespread processing of toxic species appears significant in Aboriginal people's adaptation to rainforest settlement and may be central to notions about how humans adapt to rainforest ecosystems worldwide. It appears that far from being a series of catastrophic events that effected settled agricultural communities on the eastern Pacific Rim, Aboriginal communities prospered under the ENSO regimes, these being a catalyst for permanent occupation of rainforest environments. Once established, the unique rainforest culture developed on its own terms.

Acknowledgements

This project was funded by an Australian Research Council Discovery Project grant (DP0210363). We would like to thank the Jirrbal, Njatjon and Mamu Aboriginal communities for their support on this project. In particular we would like to thank Maisie Barlow, Fred Barlow, Lena Mitchell, Ernie Raymont, Victor Maund and Corinne Barlow. We thank all the volunteers who participated in the project, who helped with logistics and assisted with excavation and survey. We thank Ron and Deanna Stager, chef Eric Stadler, Laurance May of QPWS, Bernie Hyland for field support and discussions and Rebel Elick and Bruce Gray of CSIRO Atherton herbarium who identified the charred plant remains and provided comparative reference material. We thank referees Peter Kershaw, Jane Balme and Wendy Beck for constructive criticisms on a previous draft of this paper. As ever we are deeply indebted to Mr. Rudy Frank for his on-going technical and field support and, for preparing the illustrations and maps.

References

Abbott, M.B., Binford, M.W., Brenner, M., Kelts, K.R., 1997. A 3500 14C yr high-resolution record of water-level Changes in Lake Titicaca, Bolivia/Peru. Quat. Res. 47 (2), 169–180.

Allen, J., Gosden, C., 1996. Spheres of interaction and integration: modeling the culture history of the Bismarck Archipelago. In: Davidson, J.M., Irwin, G., Leach, B.F., Pawley, A., Brown, D. (Eds.), Oceanic Culture History: Essays in Honour of Roger Green. N. Z. J. Arch. Spec. Pub, pp. 183–197.

Allen, J., Gosden, C., White, J.P., 1989. Human Pleistocene adaptations in the tropical island Pacific: recent evidence from New Island, a Greater Australian outlier. Antiquity 63, 548–561.

Anderson, A., Chappell, J., Gagan, M., Grove, R., 2006. Prehistoric maritime migration in the Pacific islands: an hypothesis of ENSO forcing. The Holocene 16, 1–6.

Ash, J., 1988. The location and stability of rainforest boundaries in north-eastern Queensland, Australia. J. Biogeogr. 15, 619–630.

Bailey, R.C., Headland, T.N., 1991. The tropical rainforest: is it a productive environment for human foragers? Hum. Ecol. 19 (2), 261–285.

Bailey, R.C., Head, G., Jenike, M., Owen, B., Rechtman, R., Zechenter, E., 1989. Hunting and gathering in tropical rain forest: is it possible? Am. Anthropol. 91 (1), 59–82.

Barton, H., 2005. The case for rainforest foragers: the starch record at Niah Cave, Sarawak. Asian Perspect. 44 (1), 56–72.

Beaton, J., 1983. 'Fire and water': aspects of Australian Aboriginal management of cycads. Arch. Oceania 17 (1), 51–58.

Beaton, J., 1985. Evidence for a coastal occupation time-lag at Princess Charlotte Bay (North Queensland) and implications for coastal colonisation and population growth theories for Aboriginal Australia. Arch. Oceania 20, 1–20.

Beaton, J., 1990. The importance of past population for prehistory. In: Meehan, B., White, N. (Eds.), Hunter–Gatherer Demography: Past and Present. University of Sydney Press, Sydney, N.S.W, pp. 23–40.

Brosius, J.P., 1991. Foraging in tropical rain forest: the case of the Penan of Sarawak, East Malaysia. Hum. Ecol. 19, 123–150.

Bultitude, R.J., Garrad, P.D., Donchak, P.T.J., Domagala, J., Champion, D.C., Rees, I.D., Mackinzie, D.E., Wellman, P., Knutson, J., Fanning, C.M., et al., 1997B. Cairns region. In: Bain, J.H.C., Draper, J.J. (Eds.), North Queensland Geology. Commonwealth Department of Primary Industries and Energy, Canberra, ACT.

Campbell, J.B., 1982. New radiocarbon results for North Queensland Prehistory. Aust. Archaeol. 14, 62–66.

Campbell, J.B., 1984. Extending the archaeological frontier. Q. A. R. 1, 173–184.

Campbell, W.W., 1923. Theodolite Traverse of the Tully River. Field notes, Cwl. 555 and 6. Department of Natural Resources and Mines, Queensland Government.

Cosgrove, R., 1980. Ground-edge artefacts from the rainforest area, northeast Queensland: a preliminary review. Townsville: Material Culture Unit, James Cook University. Unpublished report to Australian Institute of Aboriginal Studies, Canberra. 81 p.

Cosgrove, R., 1981. Rainforest aboriginal lithic technology. C.O.M.A. 11–13.

Cosgrove, R., 1984. A stylistic and use-wear study of the Ooyurka. M.A. thesis. James Cook University, Townsville, Australia.

Cosgrove, R., 1996. Past human use of rainforests: an Australasian perspective. Antiquity 70, 900–912.

Cosgrove, R., 2005. Coping with noxious nuts. Nat. Aust. 28 (6), 46–53.

Cosgrove, R., Raymont, E., 2002. Jiyer Cave revisited: preliminary results from northeast Queensland rainforest. Aust. Archaeol. 54, 29–36.

Crowley, G.M., Anderson, P., Kershaw, A.P., Grindrod, J., 1990. Palynology of a Holocene marine transgressive sequence, lower Mulgrave River valley, north-east Queensland. Aust. J. Ecol. 15, 231–240.

Cupper, M., Drinnan, A.N., Thomas, I., 2000. Holocene palaeoenvironments of salt lakes in the Darling Anabranch region, south-western New South Wales, Australia. J. Biogeogr. 27, 1079–1094.

David, B., Chant, D., 1995. Rock art and regionalisation in North Queensland prehistory. Mem. Qeensl. Mus. 37 (2).

David, B., Lourandos, H., 1997. 37,000 years and more in tropical Australia: investigating long-term archaeological trends in Cape York Peninsula. Proc. Prehist. Soc. 63, 1–23.

Dillehay, T.D., Kolata, AL., 2004. Long-term human response to uncertain environmental conditions in the Andes. PNAS 101 (12), 4325–4330.

Donders, T.H., Wagner, F., Dilcher, D.L., Visscher, H., 2005. Mid- to late-Holocene El Niño-Southern Oscillation dynamics reflected in the subtropical terrestrial realm. PNAS 102 (31), 10904–10908.

Dwyer, P., Minnegal, M., 1991. Hunting in lowland, tropical rain forest: towards a model of non-agricultural subsistence. Hum. Ecol. 19, 187–212.

Field, J., 2007. Analysis of botanical remains: starch grain analysis. In: Pearsall, D. (Ed.), Encyclopedia of Archaeology. Elsevier, Oxford.

Field, J., Gott, B., 2006. Case study: compiling a reference collection for identification of starch from Pleistocene grinding stones. In: Torrence, R., Barton, H. (Eds.), Ancient Starch Analysis. Left Coast Press, California, USA.

Fullagar, R., Field, J., Kealhofer, L., in press. Grinding stones and seeds of change: starch and phytoliths as evidence of plant food processing. In: Rowan, Y.M., Ebeling, J.R. (Eds.), New Approaches to Old Stones: Recent Studies of Ground Stone Artifacts: Equinox Publishing P/L.

Gagan, M.K., Hendy, E.J., Haberle, S., Hantoro, W.S., 2004. Post-glacial evolution of the Indo-Pacific Warm Pool and El Nino-Southern oscillation. Quat. Int. 118–119, 127–143.

Gamble, C., 1993. Timewalkers: The Prehistory of Global Colonisation. Alan Sutton, Great Britain.

Haberle, S., 2005. A 22Ka pollen record from Lake Euramoo, Wet Tropics of NE Queensland, Australia. Quat. Res. 64 (3), 343–356.

Haberle, S., David, B., 2004. Climates of change: human dimensions of Holocene environmental change in low latitudes of the PEPII transect. Quat. Int. 118–119, 165–179.

Harris, D., 1975. Traditional Patterns of Plant-Food Procurement in the Cape York Peninsula and Torres Strait Islands: Report on Fieldwork Carried Out August–November 1974. Australian Institute of Aboriginal and Torres Strait Islander Studies, Canberra, pp. 32–61.

Harris, D., 1978. Adaptation to a tropical rain-forest environment: aboriginal subsistence in northeast Queensland. In: Blurton-Jones, N.G., Reynolds, V. (Eds.), Human Behaviour and Adaptation. Taylor and Francis, London, pp. 113–134.

Harris, D., 1987. Aboriginal subsistence in a tropical rain forest environment: food procurement, cannibalism, and population regulation in Northeastern Australia. In: Harris, M., Ross, E.B. (Eds.), Food and Evolution: Toward a Theory of Human Food Habits. Temple University Press, Philadelphia, pp. 357–385.

Henderson, R.A., Stephenson, P.J., 1980. The Geology and Geophysics of Northeastern Australia. Geological Society of Australia, Queensland Division.

Hiscock, P., 1985. The need for a taphonomic perspective in stone artefact analysis. QAR 2, 82–97.

Hiscock, P., 2002. Pattern and context in the Holocene proliferation of backed artifacts in Australia. In: Elston, R.G., Kuhn, S.L. (Eds.), Thinking Small: Global Perspectives on Microlithization. Archaeol. Papers Am. Anthr. Assoc. (AP3A), pp. 163–177.

Hiscock, P., Kershaw, A.P., 1992. Palaeoenvironments and prehistory of Australia's tropical Top End. In: Dodson, J. (Ed.), The Naive Lands: Prehistory and Environmental Change in Australia and the Southwest Pacific. Longman Cheshire, Melbourne, pp. 43–75.

Hopkins, M.S., Ash, J., Graham, A.W., Head, J., Hewett, R.K., 1993. Charcoal evidence of the spatial extent of the Eucalyptus woodland expansions and rainforest contractions in North Queensland during the late Pleistocene. J. Biogeogr. 20, 357–372.

Hopkins, M.S., Head, J., Ash, J.E., Hewett, R.K., Graham, A.W., 1996. Evidence of a Holocene and continuing recent expansion of lowland rain forest in humid, tropical north Queensland. J. Biogeogr. 23, 737–745.

Horsfall, N., 1988. Tully-Millstream Hydro-Electric Scheme Feasibility Study: Environmental Issues and Planning Responses. Queensland Electricity Commission, Brisbane.

Horsfall, N., 1987. Living in the rainforest: the prehistoric occupation of North Queensland's humid tropics. Ph.D thesis. James Cook University, Townsville.

Horsfall, N., 1996. Holocene occupation of the tropical rainforests of North Queensland. In: Veth, P., Hiscock, P. (Eds.), Archaeology of Northern Australia. Anthropology Museum. The University of Queensland, Brisbane, pp. 175–190.

Hull, K., 2005. Acient mangroves reveal rapid sea rise. Aust. Sci. 26 (4), 31–33.

Kershaw, P., 1970. A pollen diagram from Lake Euramoo, north-east Queensland, Australia. New Phytol. 69, 785–805.

Kershaw, A.P., 1976. A late Pleistocene and Holocene pollen diagram from Lynch's Crater, northeastern Queensland, Australia. New Phytol. 77, 469–498.

Kershaw, A.P., 1986. The last two glacial–interglacial cycles from northeastern Australia: implications for climate change and Aboriginal burning. Nature 322, 47–49.

Kershaw, P., 1994. Pleistocene vegetation of the humid tropics of northeastern Queensland, Australia. Palaeogeogr. Palaeoclimatol. Palaeoecol. 109, 399–412.

Kershaw, A.P., Bretherton, S.C., van der Kaars, S., 2007. A complete pollen record of the last 230 ka from Lynch's Crater, northeastern Australia. Palaeogeography, Palaeoclimatology, Palaeoecology 251, 23–45 (this volume). doi:10.1016/j.palaeo.2007.02.015.

Kershaw, P., van der Kaars, S., Moss, P., 2003. Late Quaternary Milankovich-scale climatic change and variability and its impact on monsoonal Australasia. Mar. Geol. 201, 81–95.

Kershaw, A.P., van der Kaars, S., Moss, P., Wang, S., 2002. Quaternary records of vegetation, biomass burning, climate and possible human impact in the Indonesian–Northern Australian Region. In: Kershaw, P., David, B., Tapper, N., Penny, D., Brown, J. (Eds.), Bridging Wallace's Line: The Environmental and Cultural History and Dynamics of the SE-Asian-Australian Region. Reiskirchen. CATENA VERLAG GMBH, Germany.

Lance, B., Field, J., Cosgrove, R., in press. Intra-taxonomic variability in starch reference collections and the implications for ancient starch studies. In: Fairbairn, A., O'Connor, S. (Eds.), Proceedings of the Archaeometry Conference 2005.

Mayewski, P.A., Rohling, E.E., Stager, J.C., Karlén, W., Maasch, K. A., Meeker, L.D., Meyerson, E.A., Grasse, F., Kreveld, Sv., Holmgren, K., et al., 2004. Holocene climatic variability. Quat. Res. 62, 243–255.

McRobbie, W.J., 1985. Local history—aborigines. In: Hutcheon, K. (Ed.), Innisfail and District Historical Society, Innisfail, pp. 13–37.

Mercader, J. (Ed.), 2002. Under the Canopy: The Archaeology of Tropical Rainforests. Rutgers University Press, New Brunswick.

Morwood, M.J., Hobbs, D.R. (Eds.), 1995. Quinkan Prehistory: The Archaeology of Aboriginal Art in SE Cape York Peninsula, Australia. Anthropology Museum, University of Queensland, St Lucia, Brisbane, Queensland.

Moss, P., Kershaw, A.P., 2000. The last glacial cycle from the humid tropics of northeastern Australia: comparison of a terrestrial and a marine record. Palaeogeogr. Palaeoclimatol. Palaeoecol. 155, 155–176.

Nott, J., Thomas, M.F., Price, D.M., 2001. Alluvial fans, landslides and Late Quaternary climatic change in the wet tropics of northeast Queensland. Aust. J. Earth Sci. 48 (6), 875–882.

Patterson, S., 2004. Foraging for clues: an investigation of temporal variability in the northeast Queensland rainforest. B.A. Honours thesis. Archaeology Program, La Trobe University, Melbourne.

Pavlides, C., Gosden, C., 1994. 35,000 year old site in the rainforests of West New Britain, Papua New Guinea. Antiquity 68, 604–610.

Pedley, H., 1993. Plant detoxification in the rainforest: the processing of poisonous plant foods by the Jirrbal-Girramay people. M.A. thesis. Material Culture Unit, James Cook University, Townsville, pp. 279.

Roth, W.E., 1901–1910. North Queensland Ethnography. Department of Home Secretary, Brisbane. Bulletins 1−8.

Rowland, M., 1999. Holocene environmental variability: have its impacts been underestimated in Australian pre-History. The Artefact 22, 11–48.

Savage, P., 1992. Christie Palmerston, Explorer. Department of History and Politics, James Cook University, Townsville.

Smith, M.A., 1988. Central Australian seed grinding implements and Pleistocene grindstones. In: Meehan, B., Jones, R. (Eds.), Archaeology With Ethnography: An Australian Perspective. Department of Prehistory, Research School of Pacific Studies, ANU, Canberra, pp. 94–108.

Smith, B.D., 1994. The emergence of agriculture. Freeman, New York.

Stevens, J., 2004. Instruments of a thousand uses: a comparative study of edge-ground axe assemblages from tropical rainforest environments in far north Queensland. B.A. Honours thesis. Archaeology Program, La Trobe University, Melbourne.

Sylvestre, F., Sifeddine, A., Turcq, B., Gil, I.M., Albuquerque, A.L.S., Lallier-Vergés, E., Abrao, J., 2005. Hydrological changes related to the variability of tropical South American climate from Cabo Frio lagoonal system (Brazil) during the last 5000 years. The Holocene 15 (4), 625–630.

Thomas, M.F., Nott, J.F., 2001. The Late Quaternary alluvial record in humid tropical environments. Geomorphology 39, 53–68.

Trott, P., 1997. When woodlands ruled the Daintree: rainforest reveal their not-so-shady past. Ecos 91, 6–10.

Turney, C.S.M., Bird, M.I., Fifield, L.K., Kershaw, A.P., Cresswell, R.G., Santos, G.M., di Tada, M.L., Hausladen, P.A., Zhou, Y., 2001a. Development of a robust 14C chronology for Lynch's Crater (North Queensland Australia) using different pretreatment strategies. Radiocarbon 43, 45–54.

Turney, C.S.M., Kershaw, A.P., Moss, P., Bird, M.I., Fifield, L.K., Cresswell, R.G., Santos, G.M., di Tada, M.L., Hausladen, P.A., Zhou, Y., 2001b. Redating the onset of burning at Lynch's Crater (North Queensland): implications for human settlement in Australia. J. Quat. Sci. 16 (8), 767–771.

Turney, C.S.M., Hobbs, D.R., 2006. ENSO influence on Holocene aboriginal populations in Queensland, Australia. J. Archaeol. Sci. 33, 1744–1748.

Ulm, S., 2004. Themes in the archaeology of Mid-to-Late Holocene Australia. In: Murray, T. (Ed.), Archaeology from Australia. Australian Scholarly Publishing, Melbourne, pp. 187–201.

Walker, D., Chen, Y., 1987. Palynological light on tropical rainforest dynamics. Quat. Sci. Rev. 6, 77–92.

White, N., 2001. In search of the traditional Australian aboriginal diet—then and now. In: Anderson, A., Lilley, I., O'Connor, S. (Eds.), Histories of Old Ages: Essays in Honour of Rhys Jones. Pandanus

Books, Research School of Pacific and Asian Studies. The Australian National University, Canberra, pp. 343–359.

White, N., Meehan, B., 1993. Traditional knowledge: a lens on time. In: Williams, N., Baines, G. (Eds.), Traditional Ecological Knowledge: Wisdom for Sustainable Development. Centre for resource and environmental studies, Canberra, pp. 31–40.

Woolfrey, A.R., Ladd, P.G., 2001. Habitat preference and reproductive traits of a major Australian riparian tree species (*Casuarina cunninghamiana*). Aust. J. Bot. 49, 705–715.

Woolston, F.P., Colliver, F.S., n/d. Some Stone Artifacts from North Queensland Rain Forests. Melbourne Museum.