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Kuku–Yalanji Rainforest Aboriginal People and Carbohydrate Resource Management in the Wet Tropics of Queensland, Australia

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Carbohydrate food sources have emerged as a critical factor limiting occupation of rainforests by hunter–gatherer peoples globally. In the wet tropics bioregion of northeastern Australia, Kuku–Yalanji aboriginal people occupied the rainforests through a hunter–gatherer subsistence economy prior to European occupation. Collaborative environmental research between a researcher at the James Cook University and Kuku–Yalanji people has established that their fire management protected carbohydrate resources in the fire-sensitive rainforests and their margins, and ensured ongoing access to the critical dry season carbohydrate resource, Cycas media*, growing in patches of fire-prone open forest on each clan estate. Carbohydrate resources in the wet season were obtained predominantly from seeds of rainforest tree nuts, a high proportion of which are wet tropics endemic species. Several of the genera utilized by aboriginal people in the wet tropics bioregion also occur in the rainforests of eastern Cape York Peninsula, where they were not utilized as foods. It is hypothesized that use of rainforest seeds for carbohydrate is a cultural adaptation that occurred in the wet tropics bioregion, stimulated by the unique availability of the substantial number of large-seeded rainforest trees that are wet tropics endemics. The implications of these data for concepts about the impact of aboriginal fires on Australian rainforests are considered. Aboriginal fires imposed a fine patterning on the vegetation at the local scale, with little effect on the vegetation at the regional scale, which is determined by environmental factors.*

KEY WORDS: Australian aborigines; fire; carbohydrate management; rainforest.

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INTRODUCTION

Hunter–gatherer (foraging) peoples who inhabit rainforest have often been depicted as remnants of Palaeolithic populations who have been subsisting in their forest habitats for millennia (Bahuchet, 1993; Headland and Bailey, 1991). An alternative view, that foragers could never have lived in tropical rainforest without direct or indirect access to cultivated foods, was proposed separately by Headland (1987) and Bailey *et al.* (1989). Headland (1987) hypothesized that rainforest ecosystems had insufficient carbohydrate plant foods to support human foragers (although he noted the Australian continent may provide a notable exception), and Bailey *et al.* (1989) hypothesized that energy resources in general, including fat and other nutrient sources, were limited, both agreeing with Piperno (1989) that these were more important limiting factors than protein. Piperno (1989) also argued that secondary forests were more productive of human foods. In a special edition of *Human Ecology* in 1991 a number of scientists claimed that foragers can live off wild resources alone in rainforest (Bahuchet *et al.*, 1991; Brosius, 1991; Dwyer and Minnegal, 1991; Endicott and Bellwood, 1991). The evidence comes from both contemporary and recent foraging societies and the archaeological record. However, management of carbohydrate resources appears a critical aspect in the occupation of rainforests by hunter–gatherer peoples (Sponsel *et al.*, 1996).

Several authors who have considered the question of carbohydrate as a limiting factor for humans in rainforest have discussed the difficulty in clearly maintaining a separation between "foraging" and "agriculture" (Brosius, 1991; Harris, 1989; Yen, 1989). Sago, yams, and taro are examples of important carbohydrate sources both gathered from the wild and cultivated by contemporary rainforest foraging societies (Cook, 1996; Hladik and Dounias, 1993; Ohtsuka, 1983). Australia has been portrayed as having been an entire continent of hunter–gatherer peoples prior to European occupation after 1788 (Lourandos, 1997). Nevertheless, various cultivation techniques such as planting of seeds and vegetative material, and protection of young plants have been widely documented (Chase and Sutton, 1981; Harris, 1975; Hynes and Chase, 1982). Jones (1969, pp. 227–228) proposed that Australian aborigines used "fire-stick farming" to greatly extend their natural habitat, by pushing back the forest, and that there was a symbiosis between "man, grassland, and kangaroos," implying a central dependence on meat. Jones' subsequent collaboration with Meehan (Jones and Meehan, 1989) reported that in pre-European times aborigines in Arnhem Land got approximately half their foods and some 57% of their energy requirements from plants (see also Russell-Smith *et al.*, 1997).

Although the use of fire by Australian aborigines has received considerable attention, most studies have been in very fire-prone regions, and generally little attention has been paid to elucidating the precise products being "farmed" (Gould, 1971; Hallam, 1975; Haynes, 1985; Kimber, 1983; Stevenson, 1985; Yibarbuk, 1998). Lewis' studies in Kakadu (Lewis, 1985, 1989) demonstrated uses of fire in managing a range of plant and animal resources, including deliberate suppression of fire on rainforest margins, and Russell-Smith *et al.* (1997) have highlighted the importance of fire to protect the yams found in monsoon rainforest patches in Arnhem Land. The use of fire by hunter–gatherers to manage various aspects of plants is well documented outside Australia. Examples include the Gitskan and Wet'suwet'en peoples of British Columbia, Canada, using fire to stimulate the fruiting of two species of berry bushes (Gottesfeld, 1994), and the management by fire of plants for basketry by Californian Indian tribes (Anderson, 1999). This study focuses attention on carbohydrate resource management through fire by Kuku–Yalanji aboriginal people, who inhabit the wet tropics of northeast Australia, an environment dominated by rainforest.

COLLABORATIVE RESEARCH

The People and the Place

The Kuku–Yalanji are a group of some 3000 Australian aboriginal people, whose traditional lands lie in the wet tropics bioregion of northeast Australia and who are now concentrated in two small towns, Wujal Wujal and Mossman (Fig. 1). This region is recognized as containing a distinctive Australian aboriginal rainforest culture (Dixon, 1976; Horsfall, 1987a; Horsfall and Fuary, 1988; Tindale and Birdsell, 1941). The region has a population of more than 300,000 people, concentrated in two urban centres, Cairns and Townsville.

In 1988, an area of some 900,000 ha in the region was placed on the World Heritage List for its exceptional natural values, and is managed by the Wet Tropics Management Authority (WTMA). Many of the distinctive features of the region arise from its high rainfall (1200–8000 mm pa). Rainforest is the major vegetation habitat type, with other types distributed throughout, including tall open forest, drier eucalypt and acacia forests, mangrove forests, and paperbark swamps (WTMA, 1992). The terrestrial common law native title rights[4] of the Kuku–Yalanji extend over several hundred thousand

[4]Native title is the term used by Australia's High Court to describe the rights and interests, recognized by common law, of aboriginal and Torres Strait Islander people in land and waters, according to their traditional law and customs.

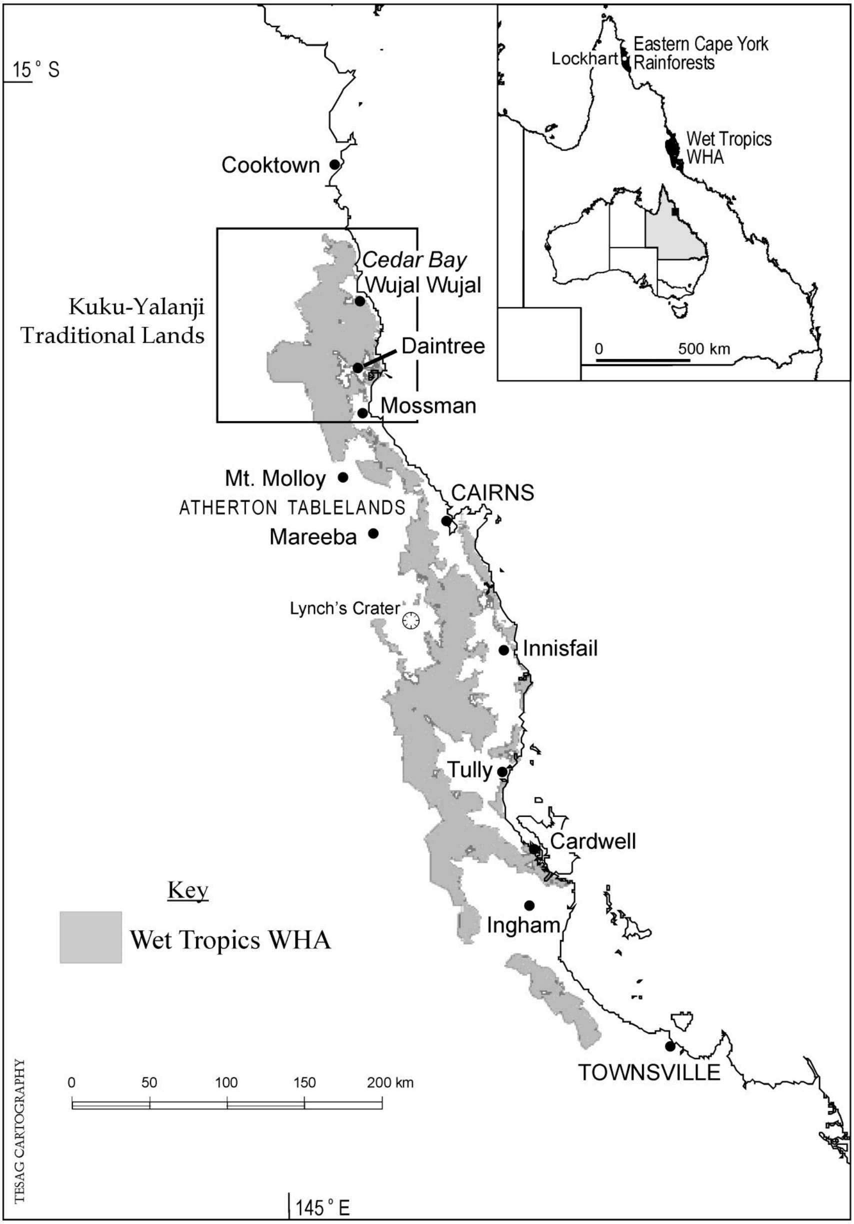

Fig. 1. The study area: Kuku Yalanji Traditional lands.

hectares, much of which has not been affected by urban or agricultural development, and is included within the Wet Tropics of Queensland World Heritage Area (WTWHA, Fig. 1). In May 1995, the Kuku–Yalanji people registered a Native Title Claim over parts of their traditional land under the *Native Title Act 1993 (Federal).*

Settlement of the Kuku–Yalanji traditional lands by non–indigenous people began after the area was opened to selection in 1877 (Bolton, 1963). Despite the loss of access to areas cleared for urban development and agriculture, and despite government policies aimed at removal of aboriginal peoples to missions and reserves, Kuku–Yalanji people have continued to occupy their traditional lands throughout, and maintain their language and customary law. A Lutheran Church mission established for Kuku–Yalanji people on the Bloomfield River in 1886 failed by 1902; Kuku–Yalanji people made little use of the mission, rather forming economic relationships with farmers, miners, and fishers to survive outside the institutional setting (Anderson, 1982, 1983). These economic relationships allowed Kuku–Yalanji people to develop a mixed economy, in which rice, flour, and other store goods replaced the traditional carbohydrate foods, and hunting and gathering targeted easily obtained resources. Access to land, and the economic importance of hunting and gathering, gradually diminished through the twentieth century. In the 1930s some Kuku–Yalanji people were forcibly moved into church missions established at Daintree and Mossman, and in 1957 others were relocated into a mission established in Bloomfield. The old mission sites at Mossman and Bloomfield are now the major centers for Kuku–Yalanji people, who are gradually reasserting their native title rights over their traditional lands (Fig. 1).

The Methodology

The research described in this paper is part of a larger collaborative research project undertaken between a Principal Researcher based at James Cook University, and Kuku–Yalanji people, focused on the management of fire within the WTWHA. There are four major methods in the collaborative process that developed: (1) ensuring outcomes of relevance to Kuku–Yalanji people, (2) protecting intellectual, cultural, and spiritual property rights, (3) ensuring their participation in the research process, and (4) establishing a process to reach agreement about publication of the research data (Hill, 2001; Hill and Smyth, 1999). The research is meaningful to Kuku–Yalanji people primarily in relation to their goal of regaining full control of fire and related management practices in their traditional lands. Data relevant to Kuku–Yalanji management practices were collected from unstructured, bounded interviews undertaken during 1996 and 1997, field collections, and documentary sources. Interviewees were selected through stratified purposive sampling using the "snowball" method (Sarantakos, 1993). A total of 41 Kuku–Yalanji people were interviewed; generally two formal interviews were conducted, with the third, fourth, and subsequent interviews associated with the process of feedback.

The emergence of plant food resources as an important factor in fire management led to further focus on data relevant to the significance of rainforest and open forest environments in the traditional subsistence economy. As many of these foods are rarely or no longer used, this was in effect a reconstruction based on oral history and plant collection, supported by some earlier documentation (Horsfall, 1987a; Roth, 1901; Webb, 1960). A full survey of food plants was not completed as some occur only in inaccessible locations, and a few could not be identified because of the difficulties in obtaining identifiable samples from large rainforest trees. Despite the limitations of the data, the Kuku–Yalanji interviewees agreed that the plant collections included all the taxa relied on for the bulk of subsistence, and most of the plants used in small amounts.

Mapping through aerial photographic interpretation and field survey of a number of localities within Kuku–Yalanji traditional lands was undertaken as part of the larger research project, and the work is described elsewhere (Hill, 1998; Hill *et al.*, 2000). Descriptive data relevant to each vegetation habitat type were collected from surveys of the structural and floristic characteristics at 94 sites each 400 m^2. Variables assessed included aspect, slope, rock cover, structure of the vegetation layers, height and projective foliage cover (PFC)[5] of the ground and shrub layers, composition of the ground layer, height and sclerophyll species composition of the canopy layer, grouped into seven size classes, and numbers of *Cycas media* plants. Further data on percentage of *Cycas media* plants producing seed were collected from 12 sites in the open forest, each 400 m^2, during 2002, and the total mass and number of seeds was measured from three fruiting individuals.

CARBOHYDRATE RESOURCES, FIRE MANAGEMENT, AND ENDEMICITY IN THE KUKU–YALANJI TRADITIONAL SUBSISTENCE ECONOMY

Vegetation Habitat Types

The primary land management unit in Kuku–Yalanji society is the clan estate, a tract of country associated with a particular extended family group.

[5]Defined as the percentage of ground that would be covered by a vertical projection of the foliage onto the ground.

The land areas of coastal estates, which also include offshore reefs, is about 2000 ha; inland estates are about 5000 ha. The density of occupation was between 1 and 2 persons per km^2 prior to European occupation, with a group of some 20–50 people hunting and gathering on an estate for most of the year (Harris, 1978; Hill, 1998; Horsfall and Hall, 1990). Rainforest forms the dominant vegetation on the estates in this study. The rainforest vegetation has a closed, continuous, uneven canopy layer to 30 m, sometimes with emergents, and discontinuous shrub and ground layers, which generally show $<5\%$ PFC because of the low light conditions. Within the rainforest, differences in climate, altitude, geology, soils, and topography are associated with differences in rainforest structural features such as leaf size, tree buttresses, woody lianas, palm trees, and vascular epiphytes (Tracey, 1982; Webb and Tracey, 1981). However, for the purposes of this study, the rainforests are considered as one vegetation habitat type; Kuku–Yalanji people similarly refer to rainforest by one major term, *madja*. More information about variation in the rainforests of Kuku–Yalanji traditional lands is available from Tracey (1982), and Tracey and Webb (1975).

Each clan estate also includes at least one area of open forest, *ngalkal*, which is a fire-prone and highly flammable vegetation community (Christensen *et al.*, 1981). Figure 2 shows the vegetation mapped at one locality that includes a coastal clan estate centered on Cedar Bay. The open forest vegetation has an open canopy layer to 20 m, with an open discontinuous shrub layer to 3 m, and a sometimes continuous ground layer to 1.5 m dominated by grasses. The floristic composition of the canopy and understorey varies according to rainfall, soil type, and fire frequency; frequent low intensity fires are typical of this forest type (Tracey, 1982). Species most frequently encountered during the surveys include *Acacia aulacocarpa, A. crassicarpa, A. flavescens, Allocasuarina torulosa, Cycas media, Erythrophleum chlorostachys, Eucalyptus intermedia, E. tessellaris, E. tereticornis, E. pellita, E. nesophila, Lophostemon suaveolens, Planchonia careya, Syncarpia glomulifera*, and *Timonius timon*.

Other vegetation habitat types where plant foods are found include littoral and swamp communities, which occur as a coastal mosaic of beach ridge and swale formations with a mixture of patches of open forest, rainforest, and freshwater swamps, dominated by *Melaleuca* species. In this study, plants were assigned to a habitat type on the basis of where the plant was most likely to occur in the wet tropics, as well as where specimens were actually found (Brooker and Kleinig, 1994; Cribb and Cribb, 1975; Hyland and Whiffin, 1993; Jackes, 1987; Jessup, 1985; Jones, 1984; Morley and Toelken, 1983; Stanley and Ross, 1983; Tracey, 1982).

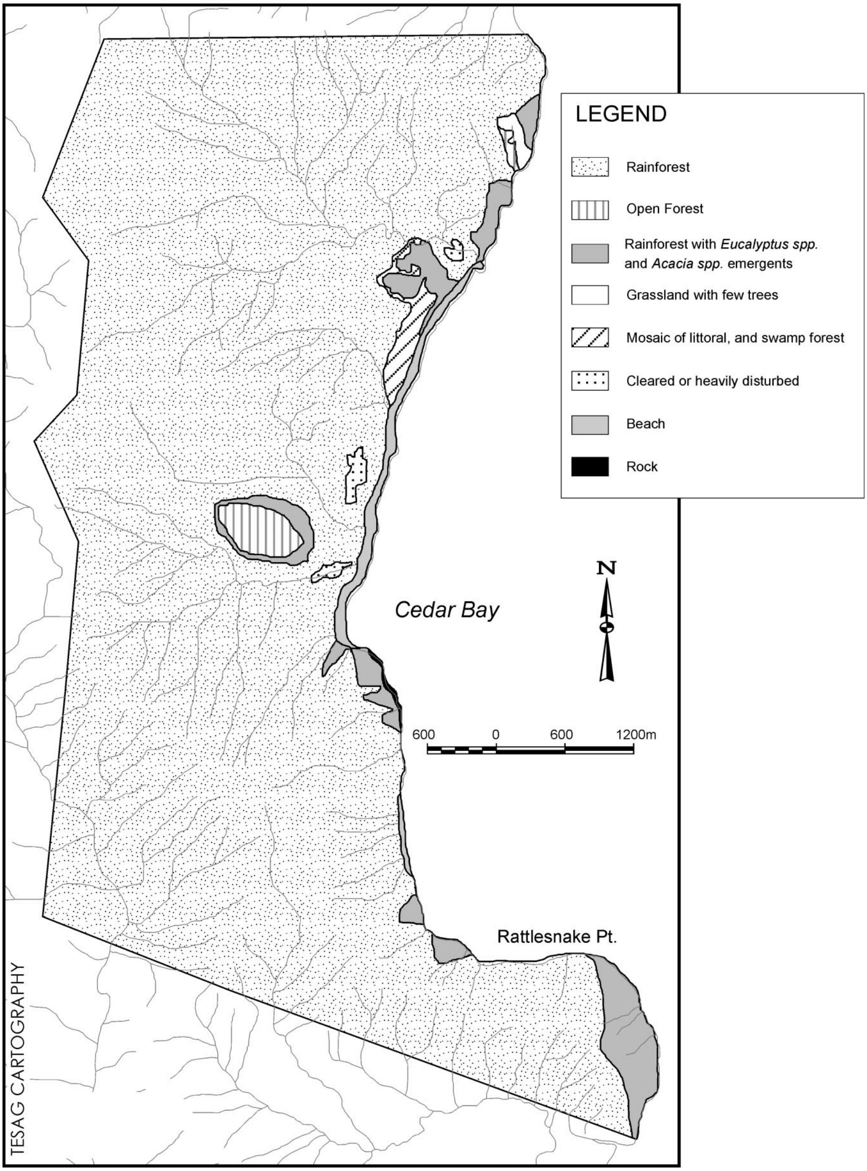

Fig. 2. Vegetation patterns at Cedar bay.

Table I. Plants Eaten by Kuku–Yalanji People According to Plant Part Eaten and Habitat

Plant part used	Rainforest species	Open forest species	Littoral forest species	Swamp species	Total
Root	10	5	0	3	18
% Roots	56	28	0	17	
Fruit	39	5	3	0	47
% Fruits	83	11	6	0	
Seeds	11	1	3	0	15
% Seeds	73	7	20	0	
Greens	9	2	1	0	12
% Greens	75	17	8	0	
Subtotal	69	13	7	3	92
Double entries (more than one part used)	9	0	0	0	9
Total	60	13	7	3	83
% Total used	72	17	8	4	

Carbohydrate Resources and Fire Management

Cultural data on 161 species of plant used by Kuku–Yalanji people were collected in this study, including 83 species that were used as foods.[5] The largest proportion of food plant species came from the rainforest (Table 1). The significance of plant foods in the traditional subsistence economy was assessed through the interviews; resources are considered staples if they are consistently reported as being the most important source for a substantial period of time (cf Jones and Meehan, 1989). As these foods have now been almost completely replaced by rice and wheat flour, no quantitative assessment could be made. However, views amongst Yalanji people about the use of these foods in precolonial times are strongly consistent, and the assignment of staples is believed very reliable. Three sources of staple carbohydrate food were identified that occur in the rainforests and their margins, and in the littoral and open forests:

(i) *Cycas media* subs. *banksii*, found in the open forest;
(ii) Yams — primarily two species of *Dioscorea*, found in the rainforest margins and littoral rainforests, of which one, *Dioscorea bulbifera* subs. *bulbifera*, is greatly preferred; and
(iii) Rainforest seeds — primarily *Beilschmiedia bancroftii*, with *Aleurites moluccana* and *Elaeocarpus bancroftii* as secondary sources of carbohydrate, although they are both more important for their fat content.

[5]The Kuku–Yalanji community do not wish data identifying all these species to be made available in this paper.

Table II. Nutritional Analysis of Staple Carbohydrate Foods

Species	% Moisture	% Protein	% Carbohydrate	% Fat	% Fibre	% Ash	kJ per 100 g
Cycas media[a]	49.91	5.09	43.52	0.22	0.55	0.71	843
Cycas media (av.)	67.7	5.1	24.9	1.1	0.4	0.9	511
Dioscorea bulbifera	70.8	2.7	25.8	0.2	9.8	0.6	357
Dioscorea transversa	68.3	2.6	26.2	0.4	4.6	1.4	404
Beilschmedi[a] bancroftii	37.1	7.5	54.4	0.2	—	0.6	1005
Elaeocarpus bancroftii[a]	9.48	7.23	19.75	45.11	16.18	2.25	2162
Aleurites molucanna	1.4	20.6	10.7	61.9	Below detection limits	3.0	2836

[a]From Harris (1975); all other data from Brand Miller *et al.* (1993).

Table II presents results of analyses of the energy and nutrient content of these food staples, some undertaken by Australasian Food Research Laboratories at Cooranbong, New South Wales (Harris, 1975), and others at the University of Sydney Human Nutrition Unit, the Material Research Laboratory (Defence) in Tasmania (Brand Miller *et al.*, 1993).

Each of the three staple carbohydrate resources in the traditional Kuku–Yalanji diet is associated with a particular seasonal application of bushfire, *ngalku*. Kuku–Yalanji people recognize five main seasons, all of which have associated plant and animal seasonal markers (Anderson, 1984; Hill *et al.*, 1999). These fire management activities, habitat responses, and associated carbohydrate resource utilization strategies are depicted in Table III.

The most important wet season staple, *Beilschmiedia bancroftii*, was affected by fire management only through the practice of preventing in any season fires of sufficient energy to kill large trees in or near the rainforest. Logging and occasional hot fires burning from the rainforest margins late in the year have greatly reduced *Beilschmeida bancroftii* populations since European occupation. During the winter rain and cold times, productivity of yams in the rainforest margins was ensured by burning along these margins, thereby preventing hot fires that kill the yam crop before it is harvested; similar protective burning has been reported around small rainforest patches by aborigines in Australia's tropical savannas (Jones, 1980; Russell-Smith *et al.,* 1997).

In the hot dry time of year, fires are lit for ease of access to *Cycas media* growing in the open forest. Beaton's analysis (Beaton 1982) suggests that fire

Table III. Associations Between Kuku–Yalanji Fire Management Activities, Habitat Responses, and Staple Carbohydrate Resource Utilization in their Traditional Subsistence Economy

Season[a]	Important fire management activities	Habitat and other responses to the fires	Staple carbohydrate resource utilization
Kambar: Wet time (Late December to March)	No fires: too wet	Not applicable	Peak period for seeds from rainforest tree nuts; mangrove fruits
Kabakada: winter rain time (April to May)	Small, enclosed and other hunting fires	These fires ensure regions of low fuel as breaks for later fires	Beginning of season for yams; some seeds from rainforest tree nuts
Bulur: cold time (June to August/September)	Fires along rainforest margins for hunting wallabies	These fires protect the rainforest and particularly the yams in the rainforest margins from later fires	Peak period for some yams; beginning of the period for cycad seeds
Wungariji: hot time (September/October to early November)	Fires lit for ease of access to cycad stands	These fires enhance the productivity of cycads, and ensure maintenance of the open forest habitat	Peak period for cycad seeds
Jarramali: storm time (Late November to mid-December)	Fewer fires; fires are lit for hunting—green pick encouraged by storm rains attracts animals	The potential destructive effects of fires at this hot time is ameliorated by fire-break effect of earlier fires	Some cycad seeds available; beginning of period for seeds from rainforest tree nuts

[a]Months indicate approximate correspondence only as the timing varies each year.

enhances the seed productivity of a related cycad, *Macrozamia communis*, as seed production varied from 6% of individuals in the unburnt stands to 49% in burnt stands. Kuku–Yalanji people believe that fire greatly enhances the production of *marra*, *Cycas media*. *Cycas* spp. display mast seeding (huge natural variation from year to year in seed output in perennial plants) in addition to any impact of fire. In one study over five years, seed production ranged from 0% of adult individuals to 71%, with an average of 25% (David Liddle, personal communication, 2002). In this study, seed production from adult individuals was measured in one year only from 12 plots of 400 m^2, with an average of 10% found to be producing seed. Diversity in open forests is maintained by a diversity of fires, and in the absence of fire, open forests in the wet tropics frequently revert to rainforest (Bowman, 2000; Christensen *et al.,* 1981; Harrington and Sanderson, 1994; Hill *et al.*, 2001; Tracey, 1982). *Cycas media* is a frequent understorey plant of the open forest communities (Cronin, 1989; Tracey, 1982) and was recorded at an average density of 23 stems per 400 m^2, ranging from a minimum of eight to a maximum of 30. *Cycas media* did not occur in any of the rainforest plots. Although it was found in plots in rainforest with *Eucalyptus* spp. and *Acacia* spp. emergents (Fig. 2), this was always where the vegetation history showed that the site had formerly been open forest (Hill *et al.,* 2000, 2001).

Of all the staple carbohydrate foods, *marra* is rated most highly by Kuku–Yalanji people. Most of the early explorers and visitors to Kuku–Yalanji traditional lands commented on the large volume of cycad nuts at the camp sites (Hann, 1873; Le Souef, 1897; Roth, 1898; 1901; Rowan, 1898). Roth (1906) reported that patches of *Cycas media* on the Bloomfield were apportioned amongst the women, each one bequeathing her lot to her daughters or other female relatives. The central role of women in *Cycas media* management, particularly its processing, is also reflected in Kuku–Yalanji mythology (McConnel, 1931) and in the views of contemporary Kuku–Yalanji women. Processing *Cycas media* required water, and some of the places where this water is obtained were special places for women, some of whom were believed to have the power to control the flow of waters. Two varieties of *Cycas media* are recognized by Kuku–Yalanji people, a coastal and an inland form; both are recognized by botanists as *Cycas media* subs. *banksii* K.D. Hill.

At least one stand of *Cycas media* plants existed in all the traditional clan estates, although most stands have now been affected by clearing associated with cattle grazing, and by invasion of rainforest into areas of formerly open forest. The productivity of *Cycas media* found in these open forest patches is potentially comparable with resource production techniques more commonly considered to be "farming." Beaton (1982) calculated the production from a stand of *Cycas media* on the Atherton Tableland, of which 20% were producing seed, at 550 kJ/m^2/year, which compares well with the

Table IV. Productivity in *Cycas media* Stands in Open Forest Within the Kuku–Yalanji Traditional Lands

Sample area	400 m^2
Av. no of mature *Cycas media* per plot[a]	23
Av. percentage producing seed	10%
Average number of seeds per plant	253
Average weight of seeds (g)	14
Mass of seeds per m^2	20.4
kJ/m	104

[a] 1996/1997 data; densities from 2002 data were slightly higher, 27; all other data are 2002 as described in methods section.

MacKinnon *et al.* (1996) estimate of 200–500 kJ/m^2/year from slash-and-burn shifting cultivation. Table IV presents data on *Cycas media* production collected in this study. From these data, and the average nutritional values presented in Table II (Brand Miller *et al.*, 1993), the potential productivity of the *Cycas media* within the Kuku–Yalanji traditional lands is somewhat less (104 kJ/m^2/year). However, the open forest patch shown in Fig. 2 is about 30 ha in area and forms the primary area of open forest available within a traditional clan estate about 2000 ha in size, which supported a group of about 30 people in the traditional subsistence economy. Total annual energy production from the *Cycas media* in this patch would be expected to be 31.2 million kilojoules, a substantial proportion (28%) of an estimated total annual energy requirement of the whole group of 30 people of 109.5 million kilojoules, based on the United Nations recommendation of a daily intake of 10,000 kilojoules per person (de Blij and Murphy, 1999).

Without the stands of open forest on each clan estate, access to carbohydrate would have been very limited in the middle of the dry season. However, mapping of the area of vegetation communities has shown that as little as 7% of the area of the terrestrial estate was open forest prior to European occupation (Fig. 2; Hill, 1998). Fire management is essential therefore for ensuring some area of open forest is available to supply seasonally critical resources, but not for generally expanding the area of fire-prone forest at the expense of rainforest.

In summary, Kuku–Yalanji fire management protected carbohydrate resources in the fire-sensitive rainforests and their margins, and ensured ongoing access to carbohydrate resources in small patches of fire-prone open forest on each clan estate. Specialist carbohydrate resources that enabled hunter–gatherer societies in other parts of the world to occupy rainforests without access to other ecosystems do not appear to be available in the wet tropics. For example, Brosius (1991) suggested that in Borneo, only reproducing sago genera such as *Metroxylon* and *Eugeissona*, absent from the Australian wet tropics, provide exceptions to the rule that rainforests generally have insufficient carbohydrate resources to support independent forager populations. In the western Congo rainforest, Bahuchet *et al.* (1991) suggest yams provide sufficient resource to support Aka pygmies — however yams occur throughout these rainforests, whereas they are found only in rainforest margins in the wet tropics. In the Malay Penisula, Endicott and Bellwood (1991) have argued that independent foraging in rainforest was made possible by a diversity of resources, particularly *Dioscorea* spp. yams, which are available all year round. However, in the rainforests occupied by Kuku–Yalanji people, yams are a seasonal resource only, and the hot dry time of year was a relatively poor season for carbohydrates.

In the Australian tropical savannas, dominated by open forest with plentiful supplies of *Cycas* spp. in the dry season, aboriginal people used fires to protect the small patches of rainforest that provided a highly significant source of yams in the relatively lean wet season (Russell-Smith *et al.*, 1997). The Kuku–Yalanji strategy is an interesting complementary mirror image: in an environment dominated by rainforest, with plentiful supplies of rainforest seeds and some yams in the wet season, aboriginal people used fires to maintain open forests that provided a highly significant source of *Cycas* seeds in the otherwise relatively lean dry season. In both cases, the human fire management enhanced ease of occupation by imposing a fine patterning on the vegetation at the local scale, with little effect on the vegetation at the regional scale, which is determined by environmental factors.

Carbohydrate Resources and Australian Wet Tropics Rainforest Endemics

In contrast to the Kuku–Yalanji, the Aboriginal people of the Lockhart region on eastern Cape York Peninsula (Fig. 1), a large block of tropical rainforest to the north of the wet tropics, viewed the wet season as quite a hard one when relying on traditional foods; they depended on two mangrove fruits *Bruguiera gymnorhiza* and *Avicennia marina* together with *Dioscorea* spp., *Tacca leontopetaloides* and *Entada phaseoloides* (Chase and Sutton, 1981; Harris, 1975; Hynes and Chase, 1982). The relative wet season carbohydrate plentitude in the Kuku–Yalanji traditional subsistence economy compared to the situation further north on Cape York has arisen primarily from the availability of rainforest seeds at this time. Several of these seed-producing plants do not occur outside the Australian wet tropics bioregion.

Table V presents data about the distribution and usage elsewhere of the most important rainforest seeds eaten by Kuku–Yalanji people. Five of the 11 species, or 45%, are restricted to the wet tropics region; two of the eight genera, or 25%, are Australian endemic genera. The level of endemicity

Table V. Rainforest Seeds Used as Food by Kuku–Yalanji People[a]

Species	Distribution and Usage[b,c]
Aleurites moluccana L. Willd.	Species also eaten in Malesia, Lockhart
Aleurites rockinghamensis (Baill.) P.I. Forst.	Species occurs only in the wet tropics in Australia and may also occur in New Guinea[d]
Beilschmiedia bancroftii (F.M. Bailey) C.T. White	Australian endemic species restricted to the wet tropics; genus occurs Malesia and Lockhart[d]
Bowenia spectabilis Hook. ex Hook. f.	Australian endemic species restricted to the wet tropics; genus Australian endemic[e]
Castanospermum australe A. Cunn. & Fraser ex Hook.	Species occurs in Cape York, Vanuatu, and New Caledonia,[d] but is not eaten in the Lockhart region; genus does not occur in Malesia
Elaeocarpus bancroftii F. Muell. & F.M. Baill	Australian endemic species restricted to the wet tropics,[d] genus occurs but the seed is not used in Malesia or the Lockhart region
Elaeocarpus stellaris L.S. Sm.	Australian endemic species restricted to the wet tropics[d]
Entada phaseoloides (L.) Merr.	Species eaten in Malesia and Lockhart region
Lepidozamia hopei Regel	Australian endemic species restricted to the wet tropics region; Australian endemic genus, does not occur in Lockhart region[e]
Prunus turnerana (F.M. Bail.) Kalkman	Species occurs in wet tropics and New Guinea, genus in Malesia where it is eaten. Genus does not occur in Lockhart region[d]
Sterculia quadrifida R. Br.	Species occurs in New Guinea and northern Australia and is eaten at Lockhart; genus is eaten in Malesia[d]

[a]Notes on their Distribution and Usage Elsewhere.
[b]Data on usage at Lockhart from Harris, 1975.
[c]Data on Malesian usage from Burkill, 1935.
[d]Hyland & Whiffin, 1993.
[e]Clifford & Constantine, 1980.

within the wet tropics as a whole is not this high. For example, of the known 1161 wet tropics higher rainforest plant species, 37% are found only in the wet tropics (RCSQ, 1986); of 406 genera of tropical rainforest trees, 54 or 13% are endemic; of 1040 species, 374 or 36% are endemic (Hyland and Whiffin, 1993; RCSQ, 1986). Within the Kuku–Yalanji food plants as a whole, five of the 65 genera, or 8%, are endemic; 32 of the 82, or 39%, of the species are endemic.

Although wet tropic endemic species were clearly important to enabling seed utilization by aboriginal people, some of these rainforest seeds occur in other parts of Australia where they were not utilized. The species *Castanospermum australe*, for example, occurs but is not utilized in the Lockhart region, although it is used both in the wet tropics and in rainforests further south, and yields some 43% carbohydrate (Brand Miller *et al.*, 1993; Petrie, 1904). Genera not utilized locally but known to be present in the rainforests of the Lockhart area, such as *Beilschmedia*, *Macadamia*, and *Endiandra* were a major resource for aborigines throughout the wet tropics bioregion (Harris, 1975; Horsfall and Hall, 1990). Groube (1989) advanced the idea that the lack of familiar Malesian plant foods in the Gondwanan-dominated flora of the upland forests of New Guinea caused human foraging societies as early as 40,000 B.P. to undertake rainforest clearing to enhance the productivity of species such as yams, local bananas and sago. Golson (1971) argued from an analysis of plant food use by Australian aborigines that exploitation of many edible Australian genera only occurs where forced by the absence of a whole series of food-providing genera from Malesia.

An analysis was undertaken in this study of the influence of Malesian plant foods on the traditional subsistence strategy of Kuku–Yalanji people in the northern wet tropics, compared with that of aborigines at Lockhart in the eastern Cape York rainforests (Harris, 1975). Data on distribution were taken from RCSQ (1986), Henderson (1997), Hyland and Whiffin (1993), Golson (1971), Morley and Toelken (1983), Webb (1960); and on Malesian ethnobotany from Barrau (1965) and Burkill (1935), the latter being a prodigious work. Table VI shows that the aborigines in the rainforest-dominated environments of both the Lockhart area and the northern wet tropics utilized a high proportion of food genera that are also used in Malesia (71% and 78% respectively) despite the known significance of a Gondwanan element in the rainforests of both regions (Abrahams *et al.*, 1995; RCSQ, 1986; WTMA, 1992).

However, when habitat is considered (Table VII), it is clear that the shared food genera occur primarily in the rainforests, swamp forests, and littoral forests. In the open forest only 60% of the genera used at Lockhart River are used in Malesia, and only 46% of the genera used in the northern wet tropics are used in Malesia. The further analysis presented

Table VI. Malesian Affinities of Plant Genera Used as Foods by Aborigines in the Rainforest Regions of the Northern Wet Tropics and Lockhart Area of Eastern Cape York Peninsula

Place	No. of genera used here as foods that also occur in Malesia Malesia	No. of genera used here as foods and also used in as foods	Genera also used Malesia as foods as % of genera that occur in Malesia	Total no. of genera used here as foods	Genera also used in Malesia as foods as % of no. of genera used here as foods
Northern wet tropics	53	47	89	66	71
Lockhart River[a]	40	36	90	46	78

[a] Data taken from Harris (1975).

Table VII. Malesian Affinities of Plant Genera Used as Foods by Aborigines in the Rainforest Regions of the Northern wet Tropics and Lockhart Area of Eastern Cape York Peninsula According to Habitat

Habitat	No. of genera used here as foods	No. of those genera used here as food that also occur in Malesia[a]	No. of genera used here as foods and also used in Malesia as foods, and as % of no. of genera used here as foods[a]
NWT rainforest	46	36 (78)	34 (74)
Lock. rainforest	26	23 (88)	21 (81)
NWT open forest	13	11 (85)	6 (46)
Lock. open forest	10	7 (70)	6 (60)
NWT littoral forest	7	6 (86)	6 (86)
Lock. littoral forest	8	8 (100)	7 (88)
NWT swamp forest	3	3 (100)	3 (100)
Lock. swamp forest	3	3 (100)	3 (100)

[a]Values in parentheses are percentages.
Note. NWT= Northern Wet Tropics (Kuku–Yalanji lists), Lock. = Lockhart (Harris, 1975 lists).

in Table VIII of rainforest plant usage according to plant part (roots, fruits, seeds, or greens) shows that 100% of the rainforest seeds used in Lockhart River are also used in Malesia, while only 33% of the rainforest seeds used in the wet tropics are also used in Malesia.

Table VIII. Malesian affinities of rainforest plant genera used as foods by Aborigines in the rainforest regions of the northern wet tropics and the Lockhart area of eastern Cape York Peninsula according to plant part used

Plant part (all from rainforest)	No. of genera used here as foods	No. of those genera used here also occur in Malesia[a]	No. of genera as food that used here as foods and also used in Malesia as foods, and as % of no. of genera used here as foods[a]
NWT rainforest roots	8	6 (75)	6 (75)
Lock. rainforest roots	6	6 (100)	5 (83)
NWT rainforest fruits	29	26 (90)	26 (90)
Lock. rainforest fruits	13	13 (100)	12 (92)
NWT rainforest seeds	9	5 (56)	3 (33)
Lock. rainforest seeds	3	3 (100)	3 (100)
NWT rainforest greens	6	3 (50)	2 (33)
Lock. rainforest greens	4	1 (25)	1 (25)

[a]Values in parentheses are percentages.
Note. NWT = Northern Wet Tropics (Kuku–Yalanji lists), Lock. = Lockhart (Harris, 1975 lists).

These data are consistent with the view advanced by Golson (1971) that the rainforests in general may have been a familiar and relatively easily exploitable habitat for the first occupants of Australia. However, the data also suggest that the seasonally-critical use of rainforest seeds for carbohydrate is a unique adaptation that occurred in the wet tropics bioregion, perhaps stimulated by the availability of the substantial number of large-seeded rainforest trees that are only found in the wet tropics. This unique adaptation, based primarily on unique elements in the wet tropics flora, would have greatly enhanced successful occupation of the rainforest region. As the majority of the seeds used are highly toxic and require extensive processing (Horsfall, 1987b), this adaptation may have occurred through gradual stages in refining the processing techniques for a wider variety of seeds.

IMPLICATIONS FOR THE IMPACT OF ABORIGINAL VEGETATION FIRES ON THE RAINFORESTS

The likelihood that aborigines altered vegetation communities in the wet tropics bioregion of Australia during the late Pleistocene by their use of fire was first proposed by Kershaw (1975, 1985, 1986) to explain the extreme response of vegetation at Lynch's Crater on the Atherton Tableland during the last glacial maximum climate change (Fig. 1). An increase in charcoal in the fossil record from about 38,000 B.P. at Lynch's Crater is associated with a much more gradual increase in the sclerophyll fossil taxa than that evident in the previous equivalent period in the climatic cycle, from 179,000 to 165,000 B.P. (Kershaw, 1993). Recent redating of samples from Lynch's Crater with more rigorous radiocarbon techniques suggests the increase in fire occurred at 45,000 ^{14}C yr B.P., although the earliest direct evidence for human occupation in northeast Australia is 37,000 B.P. (David *et al.*, 1997; Turney *et al.*, 2001). The period between 26,000 and 10,000 B.P. dominated almost entirely by sclerophyll taxa has no equivalent event anywhere else in the glacial cycle, as sclerophyll vegetation did not totally replace rainforest vegetation during the penultimate dry glacial (Kershaw, 1986). The extinction of *Dacrydium* from the site during this period was also attributed to the impact of aboriginal fires (Singh *et al.,* 1981), as was the sharp decline in *Callitris* vegetation around 40,000 B.P. at the same site (Kershaw, 1984).

The idea that aboriginal fires caused substantial attrition of rainforests in Australia has gained widespread acceptance with the publication of syntheses of these and other data (Flannery, 1994; Kirkpatrick, 1994). However, subsequent analysis of pollen cores from Bandung, Lombok Ridge, and the Banda Sea in southeast Asia show an increase in charcoal and sclerophyll vegetation at different times over the last 100,000 years that are difficult to relate to human impact (Kershaw *et al.*, 1998). A detailed pollen record from the Ocean Drilling Program (ODP) Site 820 off northeast Queensland, which reflects regional wet tropics vegetation, did not detect a sustained reduction in rainforest angiosperm pollen. However, a sustained reduction in rainforest gymnosperm pollen occurred in stepwise manner dating from 140,000 years and beyond. More extreme climatic variability associated with the formation of the warm pool in the Coral Sea may be the cause of these vegetation changes, although people may be involved in some of the more recent changes (Isern *et al.*, 1996; Moss and Kershaw, 2000).

Charcoal fragments collected from under soil in rainforest communities in the wet tropics region were identified by Hopkins *et al.* (1993) as *Eucalyptus* species. Although Hopkins *et al.* (1993) suggest lightning ignition may provide sufficient sources of fire to produce the charcoal, they also recognize that aboriginal use of fire may have affected the rate of recolonization of rainforest from the early Holocene to the present. The majority of charcoal samples were dated in the period 13,000 to 8000 B.P. and provide evidence that *Eucalyptus* forests reached their maximum extent in the region in that period. This is 5000–12,000 years after the glacial maximum peak. Hopkins *et al.* (1993) related this time lag first to the occurrence of the most arid period approximately between 15,000 and 11,500 B.P. (Kershaw and Nanson, 1993) and second to the occurrence of very short-lived cold, dry glacial conditions around 11,000–10,000 B.P. However, Hopkins *et al.* (1996) subsequently produced strong evidence for aboriginal ignition when they found that many coastal charcoal dates were as late as 3500 B.P., a very warm, wet period when lightning ignition of the coastal rainforests seems quite unlikely. They suggested aboriginal burning practices may have retarded the recolonization by rainforest on the coastal lowlands (their study site is within Kuku–Yalanji lands) during the late Holocene, and that increased burning activity was associated with the displacement of aborigines when the coastal plain was inundated with seawater. The flat terrain of the Pleistocene coastal plain meant the rate of submersion was very rapid, with the shoreline moving about 26 km between 12,000 and 9000 B.P. The area of Australia was 30% greater and the aboriginal population may also have been greater at the height of the last glacial maximum (Dodson, 1989).

The carbohydrate resource management strategy of the Kuku–Yalanji people described here depends on the maintenance of small areas of open forest within the rainforest. These data suggest a reason for aborigines to use fire to oppose the climatic trend towards complete rainforest cover in the coastal estates during the Holocene (Hopkins *et al.*, 1996); in the inland areas there was no such need to oppose the climatic trend as open forest was available. These cultural data support an effect of aboriginal burning practices on the rate of the vegetation change, to ensure ongoing maintenance of small pockets of fire-prone forest within large areas vegetated by rainforest, with little effect on the overall extent of change that occurred (Bowman, 1998, 2000; Clark, 1983; Horton, 2000). While the effect of the aboriginal burning practices in producing a fine patterning on the vegetation community distribution is critically important at the local clan estate scale, some 2000–5000 ha, it appears insignificant at the regional scale, where environmental factors determine vegetation.

CONCLUSION

The significance of carbohydrate resources as key limiting factors in rainforest occupation is highlighted by Kuku–Yalanji people's dual strategy of fire management and use of rainforest seeds. Fires lit in the dry season maintained small patches of open forest that provided access to *Cycas media*, a critical carbohydrate resource in the dry season. However, the total amount of fire-maintained open forest that would otherwise be rainforest across Kuku–Yalanji traditional lands in the rainforest (some 350,000 ha in total) may only amount to a few hundred hectares in the wettest areas, much less than 1% of the whole. Mapping of open forest undertaken in this study showed although one clan estate of some 2000 ha had only 30 ha of open forests, the *Cycas media* present could have provided around one quarter of the total annual energy requirements of the occupants in the traditional subsistence economy.

Fire management also protected the carbohydrate resources in the fire-sensitive rainforest and its margins. In the wet season when *Cycas media* fruits were not available, Kuku–Yalanji used rainforest seeds, predominantly from large trees, as the main carbohydrate resource. Although a high proportion of seeds used are from plant genera endemic to the wet tropics bioregion, several also occur in the rainforests of eastern Cape York Peninsula, where they were not utilized by the aboriginal peoples as foods. These data are consistent with the view that use of rainforest seeds for carbohdyrate is a unique adaptation that occurred in the wet tropics bioregion, stimulated by and based on unique elements in the wet tropics flora.

The idea that aboriginal fires have caused a substantial diminution of the rainforest areas, which has gained widespread acceptance (Flannery, 1994; Kirkpatrick, 1994), is not supported by these data. As well as supplying carbohydrate in the wet season, the rainforests supplied the greatest number of plant food species. Fires were used to maintain relatively small patches of open forest within the larger rainforest matrix. The attrition of rainforest commencing at 38,000 B.P. (or as more recently dated, 45,000 B.P.) in the wet tropics bioregion that is suggested by the fossil pollen record at Lynch's

Crater, may reflect a fine-scale change associated with human impact, rather than a regional trend. Changes in vegetation detected from fossil pollen and charcoal data from the ODP-820 core, which measures vegetation across the wet tropics bioregion, do not show the same pattern of rainforest attrition. Moss and Kershaw (2000) suggest that a regional sea-surface temperature increase may have some influence on these regional vegetation changes, although people may be involved in more recent changes.

Aboriginal fires to produce the fine-scale patterning on the vegetation are also consistent with the fossil data that show fires occurred as recently as 3500 B.P. in some of the wettest coastal regions in Kuku–Yalanji traditional lands. Preventing the rainforest completely covering coastal estates during the Holocene rainforest expansion would have enabled the ongoing use of *Cycas media* carbohydrate resources from the open forests, which seems to have been critically important in the Kuku–Yalanji traditional subsistence strategy.

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REFERENCES

Abrahams, H., Mulvaney, M., Glasco, D., and Bugg, A. (1995). *Areas of Conservation Significance on Cape York Peninsula*, Australian Heritage Commission, Canberra.

Anderson, J. C. (1982). The Bloomfield community, North Queensland. In Young, E. A., and Fisk, E. K. (eds.), *Small Rural Communities*, Canberra: Development Studies Centre, Australian National University, pp. 89–156.

Anderson, J. C. (1983). Aborigines and tin mining in North Queensland: A case study in the anthropology of contact history. *Mankind* 13: 473–498.

Anderson, J. C. (1984). *The Political and Economic Basis of Kuku-Yalanji Social History*, PhD Thesis, Department of Anthropology and Sociology, University of Queensland, St Lucia.

Anderson, M. C. (1999). The fire, pruning and coppice management of temperate ecosystems for basketry material by Californian Indian tribes. *Human Ecology* 27: 79–113.
Bahuchet, S. (1993). History of the inhabitants of the central African rain forests: perspectives from comparative linguistics. In Hladik, C. M., Hladik, A., Linares, O. F., Pagezy, H., Semple, A., and Hadley, M. (eds.), *Tropical Forests, People and Food*, United Nations Educational, Scientific and Cultural Organisation, Paris, pp. 37–54.
Bahuchet, S., McKay, D., and de Garine, I. (1991). Wild yams revisited: Is independence from agriculture possible for rain forest hunter–gatherers? *Human Ecology* 19: 213–244.
Bailey, R. C., Head, G., Jenike, M., Owen, B., Rechtman, R., and Zechenter, E. (1989). Hunting and gathering in tropical rain forest: Is it possible? *American Anthropologist* 91: 59–82.
Barrau, J. (1965). Witnesses of the past: Notes on some food plants of oceania. *Ethnology* 4: 282–294.
Beaton, J. M. (1982). Fire and water: Aspects of Australian aboriginal management of cycads. *Archaeology in Oceania* 17: 51–58.
Bolton, G. C. (1963). *A Thousand Miles Away*, Jacaranda Press in Association with Australian National University, Brisbane.
Bowman, D. M. J. S. (1998). Tansley Review No. 101 The impact of aboriginal landscape burning on the Australian biota. *New Phytologist* 140: 385–410.
Bowman, D. M. J. S. (2000). *Australian Rainforests: Islands of Green in a Land of Fire*, Cambridge University Press, Cambridge.
Brand Miller, J., James, K. W., and Maggiore, P. M. A. (1993). *Table of Composition of Australian Aboriginal Foods*, Aboriginal Studies Press, Canberra.
Brooker, M. I. H., and Kleinig, D. A. (1994). *Field Guide to Eucalypts, Vol. 3*, Inkata Press, Sydney.
Brosius, J. P. (1991). Foraging in tropical rain forests: The case of the Penan of Sarawak, East Malaysia (Borneo). *Human Ecology* 19: 123–150.
Burkill, I. H. (1935). *A Dictionary of the Economic Products of the Malay Peninsula, 2 Vols*, Crown Agents for the Colonies on Behalf of the Governments of the Straits Settlements and Federated Malay States, London.
Chase, A., and Sutton, P. (1981). Hunter—gatherers in a rich environment: Aboriginal coastal exploitation in Cape York Peninsula. In Keast, A. (ed.), *Ecological Biogeography of Australia*, Dr. W. Junk, The Hague, pp. 1819–1849.
Christensen, P., Recher, H., and Hoare, J. (1981). Responses of open forests (dry sclerophyll forests) to fire regimes. In Gill, A. M., Groves, R. H., and Noble, I. R. (eds.), *Fire and the Australian Biota*, Australian Academy of Science, Canberra, pp. 367–394.
Clark, R. L. (1983). Pollen and charcoal evidence for the effects of aboriginal burning on the vegetation of australia. *Archaeology in Oceania* 18: 32–37.
Clifford, H. T., and Constantine, J. (1980). *Ferns, Fern Allies and Conifers of Australia*, University of Queensland Press, Brisbane.
Cook, C. D. (1996). The divided island of New Guinea: People, development and deforestation. In Sponsel, L. E., Headland, T. N., and Bailey, R. C. (eds.), *Tropical Deforestation The Human Dimension*, Columbia University Press, New York, pp. 272–295.
Cribb, A. B., and Cribb, J. W. (1975). *Wild Food in Australia*, Fontana Books.
Cronin, L. (1989). *Australian Palms, Ferns, Cycads and Pandans*, Envirobook, Sydney.
David, B., Roberts, R., Tuniz, C., Jones, R., and Head, J. (1997). New optical and radiocarbon dates from Ngarrabullgan Cave, a Pleistocene archaeological site in Australia: Implications for the comparability of time clocks and for the human colonization of Australia. *Antiquity* 71: 183–189.
de Blij, H. J., and Murphy, A. B. (1999) *Human Geography Culture, Society and Space*, Wiley, New York.
Dixon, R. M. W. (1976). Tribes, languages and other boundaries in northeast Queensland. In Peterson, N. (ed.), *Tribes and Boundaries in Australia*, Australian Institute of Aboriginal Studies, Canberra, pp. 207–238.
Dodson, J. R. (1989). Late Pleistocene vegetation and environmental shifts in Australia and their bearing on faunal extinction. *Journal of Archaeological Science* 16: 207–217.

Dwyer, P. D., and Minnegal, M. (1991) Hunting in lowland, tropical rain forest: Towards a model of nonagricultural subsistence. *Human Ecology* 19: 187–212.
Endicott, K., and Bellwood, P. (1991). The possibility of independent foraging in the rain forests of peninsular Malaysia. *Human Ecology*: 151–186.
Flannery, T. F. (1994) *The Future Eaters*, Reed Books, Chatswood.
Golson, J. (1971). Australian aboriginal food plants: Some ecological and culture-historical implications. In Mulvaney, D. J., and Golson, J. (eds.), *Aboriginal Man and Environment in Australia*, Australian National University Press, Canberra, pp. 197–238.
Gottesfeld, L. M. J. (1994). Aboriginal burning for vegetation management in northwest British Columbia. *Human Ecology* 22: 171–188.
Gould, R. A. (1971). Use and effects of fire among the Western Desert aborigines of Australia. *Mankind* 8: 14–24.
Groube, L. (1989). The taming of the rain forests: A model for Late Pleistocene forest exploitation in New Guinea. In Harris, D. R., and Hillman, G. C. (eds.), *Foraging and Farming The Evolution of Plant Exploitation*, Unwin Hyman, London, pp. 292–304.
Hallam, S. J. (1975). *Fire and Hearth*, Australian Institute of Aboriginal Studies, Canberra.
Hann, W. (1873). Report from Mr W. Hann, leader of the Northern Expedition Party. *Queensland Legislative Council Journal* XXI: 724–762.
Harrington, G. N., and Sanderson, K. D. (1994) Recent contraction of wet sclerophyll forest in the wet tropics of Queensland due to invasion by rainforest. *Pacific Conservation Biology* 1: 319–327.
Harris, D. R. (1975). Traditional patterns of plant-food procurement in the Cape York Peninsula and Torres Strait Islands. Report on field work carried out August–November 1974, Unpublished manuscript, Department of Geography, University College London, London.
Harris, D. R. (1978). Adaptation to a tropical rain forest environment: Aboriginal subsistence in north-eastern Queensland. In Jones, N. B., and Reynolds, V. (eds.), *Human Behaviour and Adaptation*, Taylor & Francis, London, pp. 113–134.
Harris, D. R. (1989). An evolutionary continuum of people–plant interaction. In Harris, D. R., and Hillman, G. C. (eds.), *Foraging and Farming The Evolution of Plant Exploitation*, Unwin Hyman, London, pp. 11–25.
Haynes, C. D. (1985). The pattern and ecology of *munwag*: Traditional aboriginal fire regimes in north-central Arnhemland. *Proceedings of the Ecological Society of Australia* 13: 203–214.
Headland, T. N. (1987). The wild yam question: How well could independent hunter–gatherers live in a tropical rain forest ecosystem. *Human Ecology* 15: 463–491.
Headland, T. N., and Bailey, R. C. (1991). Introduction: Have hunter–gatherers ever lived in tropical rain forest independently of agriculture? *Human Ecology* 19: 115–122.
Henderson, R. J. F. (ed.). (1997). *Queensland Plants Names and Distribution*, Queensland Herbarium, Department of Environment, Brisbane.
Hill, R. (1998). *Vegetation Change and Fire in Kuku–Yalanji Country: Implications for Management of the Wet Tropics of Queensland World Heritage Area*, PhD Thesis, Department of Tropical Environment Studies and Geography, James Cook University, Townsville.
Hill, R. (2001). Collaborative environmental research with Kuku–Yalanji people. In Baker, R., Davies, J., and Young, E. (eds.), *Working on Country Contemporary Indigenous Management of Australia's Lands and Coastal Regions*, Oxford University Press, Oxford, p. 143.
Hill, R., Buchanan, D., and Baird, A. (1999) Aborigines & fires in the wet tropics of Queensland, Australia: Ecosystem management across cultures. *Society and Natural Resources* 12: 205–223.
Hill, R., and Smyth, D. (1999). Collaborative environmental research with Kuku–Yalanji people in the wet tropics of Queensland World Heritage Area, Australia. In Posey, D. (ed.), *The Cultural and Spiritual Values of Biodiversity*, United Nations Environment Program with Intermediate Technology Publications, London, pp. 227–232.
Hill, R., Griggs, P., and Bamanga Bubu Ngadimunku Inc. (2000) Rainforests, agriculture and aboriginal fire-regimes in wet tropical Queensland, Australia. *Australian Geographical Studies* 38: 138–157.

Hill, R., Smyth, D., Shipton, H., and Fischer, P. (2001) Cattle, mining or fire? The historical cause of recent contractions of open forest in the wet tropics of Queensland through invasion by rainforest. *Pacific Conservation Biology* 7: 187–194.

Hladik, A., and Dounias, E. (1993). Wild yams of the African rain forest as potential food resources. In Hladik, C.M., Hladik, A., Linares, O.F., Pagezy, H., Semple, A., and Hadley, M. (eds.), *Tropical Forests, People and Food*, United Nations Educational, Scientific and Cultural Organisation, Paris, pp. 163–176.

Hopkins, M. S., Ash, J., Graham, A. W., Head, J., and 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. *Journal of Biogeography* 20: 357–372.

Hopkins, M. S., Head, J., Ash, J. E., Hewett, R. K.,and Graham, A. W. (1996). Evidence of a Holocene and continuing recent expansion of lowland rain forest in humid, tropical North Queensland. *Journal of Biogeography* 23: 737–745.

Horsfall, N. (1987a). *Living in Rainforest: The Prehistoric Occupation of North Queensland's Humid Tropics*, PhD Thesis, James Cook University of North Queensland, Townsville.

Horsfall, N. (1987b). Aborigines and toxic north-eastern Queensland rainforest plants. In Covacevich, J., Davie, P., and Pearn, J. (eds.), *Toxic Plants & Animals: A Guide for Australia*, Queensland Museum, Brisbane, pp. 57–63.

Horsfall, N., and Fuary, M. (1988). The cultural heritage values of aboriginal archaeological sites and associated themes in and adjacent to the area nominated for World Heritage listing in the wet tropics rainforest region of north east queensland, Unpublished report to the State of Queensland, 12th December 1988, Permit No. 31, EIS. 88., Brisbane.

Horsfall, N., and Hall, J. (1990). People and the rainforest: An archaeological perspective. In Webb, L. J., and Kikkawa, J. (eds.), *Australian Tropical Rainforests*, CSIRO, Melbourne, pp. 33–39.

Horton, D. R. (2000) *The Pure State of Nature*, Allen and Unwin, Sydney.

Hyland, B. P. M., and Whiffin, T. (1993). *Australian Tropical Rainforest Trees*, CSIRO, Melbourne.

Hynes, 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.

Isern, I., McKenzie, J. A., and Feary, D. A. (1996). The role of sea-surface temperature as a control on carbonate platform development in the western Coral Sea. *Palaeogeography, Palaeoclimatology, Palaeocology* 124: 247–272.

Jackes, B. R. (1987). Revision of the Australian Vitaceae, 2. *Cayratia Juss*. *Austrobaileya* 2: 365–379.

Jessup, L. W. (1985). Anacardiaceae. *Flora of Australia* 25: 170–187.

Jones, D. (1984). *Palms in Australia*, Reed Books, Sydney.

Jones, R. (1969). Fire-stick farming. *Australian Natural History* 16: 224–228.

Jones, R. (1980). Hunters in the Australian coastal savanna. In Harris, D. R. (ed.), *Human Ecology in Savanna Environments.* Academic Press, London, pp. 107–146.

Jones, R., and Meehan, B. (1989). Plant foods of the Gidjingali: Ethnographic and archaeological perspectives from northern Australia on tuber and seed exploitation. In Harris, D. R., and Hillman, G. C. (eds.), *Foraging and Farming: The Evolution of Plant Exploitation*, Unwin Hyman, London, pp. 120–135.

Kershaw, A. P. (1975). Late Quaternary vegetation and climate in northeastern Australia 10,000 years. In Suggate, R. P., and Cresswell, M. M. (eds.), *Quaternary Studies*, The Royal Society of New Zealand, Wellington, pp. 181–188.

Kershaw, A. P. (1984). Late Cenozoic plant extinctions in Australia. In Martin, P. S., and Klein, R. G. (eds.), *Quaternary Extinctions: A Prehistoric Revolution*, University of Arizona Press, Tucson, Arizona, pp. 691–707.

Kershaw, A. P. (1985). An extended late Quaternary vegetation record from north-eastern Queensland and its implications for the seasonal tropics of Australia. *Proceedings of the Ecological Society of Australia* 13: 179–189.

Kershaw, A. P. (1986). Climatic change and Aboriginal burning in north-east Australia during the last two glacial/interglacial cycles. *Nature* 322: 47–49.

Kershaw, A. P. (1993). Pleistocene vegetation of the humid tropics of northeastern Queensland, Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 109: 399–412.
Kershaw, A. P., and Nanson, G. C. (1993). The last full glacial cycle in the Australian region. *Global and Planetary Change* 7: 1–9.
Kershaw, A. P., van der Kaars, S., Moss, P., and Wang, X. (1998). Palaeoecological records of climate change throughout the last 140,000 to 300,000 years in the Indonesian–northern Australian region, Paper presented to the *Cooperative Research Centre for Tropical Rainforest Ecology and Management Conference*, Cairns.
Kimber, R. (1983). Black lightning: Aborigines and fire in Central Australia and the Western Desert. *Archaeology in Oceania* 18: 38–45.
Kirkpatrick, J. (1994). *A Continent Transformed*, Oxford University Press, Melbourne.
Le Souef, W. H. D. (1897). Ascent of Mt Peter Botte, North Queensland. *The Victorian Naturalist* 14: 151–167.
Lewis, H. T. (1985). Burning the “Top End”: Kangaroos and Cattle. In Ford, J. R. (ed.), *Fire Ecology and Management of Western Australian Ecosystems*, Western Australian Institute of Technology, Perth, pp. 21–31.
Lewis, H. T. (1989). Ecological and technological knowledge of fire: Aborigines versus park rangers in northern Australia. *American Anthropologist* 91: 940–61.
Lourandos, H. (1997). *Continent of Hunter–Gatherers*, Cambridge University Press, Cambridge.
MacKinnon, K., Hatta, G., Halim, H., and Mangalik, A. (1996). *The Ecology of Kalimantan*, Periplus Editions, Jakarta.
McConnel, U. (1931). A moon legend from the Bloomfield River, north Queensland. *Oceania* 2: 9–25.
Morley, B. D., and Toelken, H. R. (1983). *Flowering Plants in Australia*, Rigby Publishers, Adelaide.
Moss, P. T., and Kershaw, A. P. (2000) The last glacial cycle from the humid tropics of northeastern Australia: Comparison of a terrestrial and a marine record. *Palaeogeography, Palaeoclimatology, Palaeoecology* 155: 155–176.
Ohtsuka, R. (1983). *Oriomo Papuans Ecology of Sago-Eaters in Lowland Papua*, University of Tokyo Press, Tokyo.
Petrie, C. C. (1904) *Tom Petrie’s Reminiscences of Early Queensland*. Watson, Ferguson & Co, Brisbane.
Piperno, D. R. (1989). Non-affluent foragers: Resource availability, seasonal shortages, and the emergence of agriculture in Panamanian tropical forests. In Harris, D. R., and Hillman, G. C. (eds.), *Foraging and Farming: The Evolution of Plant Exploitation*, Unwin Hyman, London, pp. 538–554.
RCSQ. (1986). *Tropical Rainforests of North Queensland: Their Conservation Significance*, Australian Government Publishing Service, Canberra.
Roth, W. E. (1898). Letter to Commissioner of Police, Brisbane, 13 May, In letter 97714/1898, Col/A139, QSA.
Roth, W. E. (1901). *Food: Its Search, Capture and Preparation. North Queensland Ethnography: Bulletin No. 3*, Queensland Government Printer, Brisbane.
Roth, W. E. (1906). *Notes on Government, Morals and Crime. North Queensland Ethnography: Bulletin No. 8*, Queensland Government Printer, Brisbane.
Rowan, E. (1898/1991). *A flower hunter in Queensland and New Zealand*, Collins/Angus & Robertson Re-publication, Sydney.
Russell-Smith, J., Lucas, D., Gapindi, M., Gunbunuka, B., Kapirigi, N., Namingum, G., Lucas, K., Giuliani, P., and Chaloupka, G. (1997). Aboriginal resource utilization and fire management practice in western Arnhem Land, monsoonal northern Australia: Notes for prehistory, lessons for Future. *Human Ecology* 25: 159–195.
Sarantakos, S. (1993). *Social Research*, MacMillan Education, South Melbourne.
Singh, G., Kershaw, A. P., and Clark, R. (1981). Quaternary vegetation and fire history in Australia. In Gill, A. M., Groves, R. H., and Noble, I. R. (eds.), *Fire and the Australian Biota*, Australian Academy of Science, Canberra, pp. 23–54.
Sponsel, L. E., Bailey, R. C., and Headland, T. N. (1996). Anthropological Perspectives on the Causes, Consequences, and Solutions of Deforestation. In Sponsel, L. E., Headland,

T. N., and Bailey, R. C. (eds.), *Tropical Deforestation: The Human Dimension*, Columbia University Press, New York, pp. 3–52.

Stanley, T. D., and Ross, E. M. (1983). *Flora of South-Eastern Queensland, Vol. 1*, Queensland Department of Primary Industry, Brisbane.

Stevenson, P. M. (1985). Traditional Aboriginal resource management in the wet–dry tropics: Tiwi case study. *Proceedings of the Ecological Society of Australia* 13: 309–315.

Tindale, N. B., and Birdsell, J. B. (1941). Results of the Harvard–Adelaide Universities Anthropological Expedition, 1938–39. *Records of the South Australian Museum* 7: 1–9.

Tracey, J. G. (1982). *The Vegetation of the Humid Tropical Region of North Queensland*, CSIRO, Melbourne.

Tracey, J. G., and Webb, L. J. (1975). *Vegetation of the Humid Tropical Region of North Queensland*, CSIRO Long Pocket Labs, Indooroopilly, 15 Maps at 1:100,000 scale + key.

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., and Zhou, Y. (2001). Redating the onset of burning at Lynch's Crater (north Queensland): Implications for human settlement in Australia. *Journal of Quaternary Science* 16: 767–771.

Webb, L. J. (1960). Some new records of medicinal plants used by the aborigines of tropical Queensland and New Guinea. *Proceedings of the Royal Society of Queensland* 71 (6).

Webb, L. J., and Tracey, J. G. (1981). Australian rainforests: Patterns and change. In Keast, E. (ed.), *Ecological Biogeography of Australia*, Dr W. Junk, The Hague, pp. 607–694.

Wet Tropics Management Authority [WTMA]. (1992). *Wet Tropics Plan: Strategic Directions*, WTMA, Cairns.

Yen, D. E. (1989). The domestication of environment. In Harris, D. R., and Hillman, G. C. (eds.), *Foraging and Farming: The Evolution of Plant Exploitation*, Unwin Hyman, London, pp. 55–75.

Yibarbuk, D. (1998). Introductory essay—notes on traditional use of fire on upper Cadell River. In Langton, M. (ed.), *Burning Questions: Emerging Environmental Issues for Indigenous Peoples in Northern Australia*, Centre for Indigenous Natural and Cultural Resource Management, Northern Territory University, pp. 1–6.