The 'cultured rainforests' of Borneo

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ABSTRACT

Borneo has a 50,000-year record of *Homo sapiens*' interactions with rainforest on the coastal lowlands assembled especially by the interdisciplinary investigation of the archaeology and palaeoecology of the Niah Caves on the coastal plain of Sarawak (Barker, 2013; Barker et al., 2007). More recent work by many of the same team in the interior of Borneo, in the Kelabit Highlands of Sarawak, has combined those approaches with ethnography and anthropology to investigate recent and present-day, as well as past, human-rainforest interactions. In combination, the two projects indicate that the present-day rainforests of Borneo are the product of a deep ecological history related to both natural factors such as climate change and cultural factors such as how different groups of people chose to extract their livelihoods from the forest, including in ways that do not have simple analogies with the subsistence activities of present-day rainforest foragers and farmers in Borneo.

1.Introduction

As late as the 1980s it was commonly held that Quaternary climates in the tropics were virtually stable and that the great tropical forests of the world had been little affected by climate change. Botanical and archaeological opinion also held that these tropical forests were effectively primeval, largely unaffected by human activity until recent times (e.g. Gamble 1993; Meggers, 1971; Balee, 1989), even though the 1950s and 1960s excavations by Tom and Barbara Harrisson in the Niah Caves in Sarawak, Borneo (Harrisson, 1970) and the 1960s and 1970s work of Jack Golson at Kuk in the New Guinea Highlands (Golson and Hughes 1980; Golson, 1985; Golson, 1989) had demonstrated that archaeological sites existed in the Pleistocene and Early Holocene where the available evidence suggested that there had been rainforest environments contemporary with the human activity. It was also debated amongst archaeologists and anthropologists whether past foraging (hunting and gathering) peoples would have been able to live in rainforest, because trading forest products with neighbouring agriculturalists was a critical part of the survival strategies of most present-day tropical foragers (e.g. Headland, 1987; Hutterer, 1988; Bailey et al., 1989; Townsend 1990; Bailey and Headland 1991; Dentan, 1991).

By the 1990s it was apparent that tropical forests had waned in area and changed markedly in composition during the Pleistocene glaciations (e.g. Flenley, 1996; van der Kaars and Dam, 1997; Morley, 2000) and in Southeast Asia and New Guinea palynologists were reporting biomass burning and forest disturbance across the region (e.g. Maloney, 1980; Maloney, 1985; Hope, 1998; Kealhofer and Piperno, 1998; Maloney, 1999; Flenley and Butler, 2001). The limited amount of multi-proxy work meant that the causes of these disturbances had not been firmly identified though the forest-clearance activities of people, especially early farmers, were suspected (e.g. Flenley, 1985; Maloney, 1985; Flenley, 1988; Hope and Golson, 1995; Hope, 1998). In Island Southeast Asia it was thought that agriculture was introduced to the region around 4000 years ago by Austronesian-speaking people who spread southwards from mainland China via Taiwan bringing with them Neolithic material culture (pottery, polished stone tools etc), and domestic rice and pigs, replacing or absorbing the existing populations of hunter-gatherers living in the rainforest without agricultural resources (Bellwood, 1984; Bellwood, 1985).

This was the background against which a new programme of investigation in the Niah Caves was proposed to the Sarawak archaeological authorities in the late 1990s (Fig. 1). The largest excavations of the Harrissons were in the West Mouth (Kuala Besar) of Niah Great

Cave, their results here in particular making the Niah Caves one of the iconic archaeological sites in the world. in particular their discovery in 1958 of a skull (the "Deep Skull") and other bones of an anatomically modern human (Brothwell, 1960). The antiquity of these remains was indicated by charcoal found the previous year near the find location, and at the same depth, which was dated by the then revolutionary method of ^{14}C dating to about 40 ka (Harrisson, 1959a; Harrisson, 1959b), making the 'Deep Skull' at that time the earliest modern human in the world. A suite of other finds indicated that the West Mouth was used for human occupation and burial from the time of the 'Deep Skull' more or less to the present day (e.g. T. Harrisson, 1966; B. Harrisson, 1967; T. Harrisson, 1972). The Harrissons' excavations in the other entrances of the Great Cave and other caves elsewhere in the Gunong Subis massif in which the Niah caves are located yielded further evidence for human activity in different periods of the past.

[Fig. 1 about here]

The new fieldwork (the 'Niah Caves Project') was undertaken between 2000 and 2003, and analytical work on the wealth of data collected continued for the rest of the decade, the project involving in all some 75 researchers in archaeology (e.g. material culture studies, archaeobotany, zooarchaeology), geomorphology, palynology and paleobiology. The results have been summarized in an integrated account of the history of rainforest foraging and farming at Niah (Barker, 2013) and a companion volume with detailed supporting data is in press (Barker and Farr, 2016). In the light of the project's findings about the longevity and scale of human impacts on the rainforests of the coastal lowlands of northern Borneo, further fieldwork was then undertaken in the Kelabit Highlands in the interior of Sarawak near the border with Kalimantan, termed the Cultured Rainforest Project. This work has involved a combination of archaeology, palynology, and anthropology/ethnography, because the focus of the project has been not only on the history of human activities in the landscape but also on how the past – archaeological, historical, mythical - intersects with the lives of the present-day inhabitants of the region: Penan foragers and Kelabit rice farmers (Barker et al., 2008; Barker et al., 2009; Lloyd-Smith et al., 2010).

In the following sections of the paper we summarize the evidence from the Niah Caves for climate, environment and hominin activity on the northern lowlands of Borneo in the Late Pleistocene and Early and Mid Holocene, and the evidence from the Kelabit Highlands for human-rainforest interactions through the Holocene to the present day. The deep ecological

histories that are emerging from the two projects indicate that modern humans have been 'culturing' or impacting on Borneo's rainforests for at least 50,000 years, but also that this history has been complex and non-linear (e.g. Barton, 2012; Hunt and Rabett, 2014). These spatially and temporally variable ecological histories were related to people's different ways of living together as well as how they extracted their livelihoods from the forest, including in ways that do not have simple analogies with the subsistence activities of present-day rainforest foragers and farmers in Borneo.

2. The coastal lowlands: Late Pleistocene foraging and its ecological impacts

The Deep Skull has now been dated directly by the uranium-series method to 37-36 ka (Reynolds et al., 2013) and our interpretation of the stratigraphic record of occupation episodes in the West Mouth is that this *Homo sapiens*, recently identified as an adult female (Curnoe et al., 2016), was probably deliberately buried with associated ritual including the placing of large shiny quartz grains brought from a considerable distance (Hunt and Barker, 2014). The ^{14}C record indicates that hominins, almost certainly anatomically modern humans also, were regularly visiting the caves during the Late Pleistocene from at least 50 ka (Higham et al., 2008).

The palynology (pollen, phytoliths, diatoms) of the Late Pleistocene sediments in the Great Cave indicates that interstadial phases were characterized by wet tropical forest similar to today's rainforests and stadial phases by open ground, regeneration and upland taxa (the latter depressed by as much as 1400 m relative to their positions today), but even at the LGM rainforest never entirely disappeared from around the cave (Hunt et al., 2012; Hunt et al., 2016; Fig. 2). The faunal remains from the old and new excavations demonstrate that the modern humans using the caves in the Late Pleistocene employed hunting strategies well adapted to inhabiting tropical rainforest environments (Piper and Rabett, 2016). In the earliest phases of occupation there was a strong focus on terrestrial game and in particular the bearded pig, which would have been attracted to the forest-edge habitats, and a range of terrestrial, arboreal terrestrial and aquatic prey was also captured (Table 1). Hunting technologies probably included snares and traps. Pigs remained the primary prey in the Terminal Pleistocene but there was more emphasis on hunting arboreal and arboreal/terrestrial animals, coinciding with a rise in the use of bone technology and in particular the appearance for the first time of range weaponry, which would have increased the effectiveness of hunting monkeys and other small arboreal prey (Barton et al., 2009). The

range of mollusc species brought back to the cave also implies planned and targeted gathering by hand from rivers and streams in contrast to the more casual gathering of brackish-water species practised in the Holocene (Szabó, 2016).

[Fig. 2 and Table 1 about here]

Late Pleistocene foraging at Niah also involved the exploitation of a wide range of tuberous and leafy plants including starchy plants of the families of Aracaceae (palms), Araceae (aroids) and Dioscoreaceae (yams), the edible nuts and fruits of *Canarium* trees, the edible flesh of *Elaeocarpus* fruits, and Moraceae, a Family which includes a number of important species with edible fruits and seeds (Barton et al., 2016; Table 2). Many of these plant foods have toxic chemicals and cellular crystals that can range from being discomforting to deadly, and present-day tropical foragers have developed a range of practices, usually involving boiling or roasting, to destroy or alleviate the toxins and render the plants edible (Barton and Paz, 2007). The presence of such plants at Niah from ~ 50 ka clearly implies a high level of knowledge and expertise. The Niah evidence chimes with emerging data elsewhere in Island Southeast Asia and Melanesia for the high level of knowledge and expertise in rainforest plant exploitation developed by Late Pleistocene foragers (Loy et al., 1992; Barton and White, 1993; Paz, 2005; Summerhayes et al., 2010; Barker et al., 2011; Oliveira, 2012).

[Table 2 about here]

Furthermore, virtually every phase of afforestation identified in the Late Pleistocene palynological record from the West Mouth is accompanied by numerous pollen grains of *Justicia* (Acanthaceae) that in wet forest and mangroves today invariably follows fire. The pollen and phytolith assemblages of these phases are also characterized by regeneration taxa such as bamboos, *Macaranga* and at times grasses and other herbaceous plants. The implication is that the people camping in the Niah Caves knew how to burn back the forest to create the forest-edge and regenerating habitats that would have been naturally available during the phases with relatively open environments (Hunt et al., 2007; Hunt et al., 2016). Secondary forest of this kind was maintained by many tribes in early 20th century Borneo (Gibbs, 1914) and is still significant in the economy of people such as the Kelabit (Janowski, 2003). Indicators of Late Pleistocene anthropogenic biomass burning have also been found at

Lake Sentarum in southern Borneo (Anshari et al., 2001), Sumatra (Maloney, 1980, 1985; Flenley and Barber, 2001), and widely across Australasia (Haberle, 1998; Hope, 1998; Wang et al., 1999; van der Kaars et al., 2000; Haberle et al., 2001; Kershaw et al., 2001, Kershaw et al., 2002; Haberle, 2005; Hope, 2009; Summerhayes et al., 2010; Summerhayes et al., 2016), suggesting that modification of forest has been a very ancient practice amongst modern humans in Southeast Asia and Australasia.

3. The coastal lowlands: Early and Mid Holocene foraging, vegeculture – and rice farming?

Palynological evidence for the development of the Holocene landscapes of the lowlands of northern Borneo is available from the West Mouth sediments, two ~5 m cores taken from the forest floor in the vicinity, and a ~40 m core from Loagan Bunut, a lake in the floodplain of the Tinjar River some 60 km inland from Niah (Hunt and Rushworth, 2005a; Hunt and Rushworth, 2005b; Hunt et al., 2006; Hunt and Premithalake, 2012; Hunt et al., 2016). The earliest Holocene assemblages in the West Mouth are marked by very high percentages of lowland forest and swamp forest species, suggesting temperatures and rainfall comparable with modern levels, with global sea level rise then bringing coastal mangrove forest up to the caves and even to Loagan Bunut (Fig. 3). There is consistent evidence from the beginning of the Loagan Bunut record at the Pleistocene/Holocene transition for small-scale burning and the local presence of sago species including not only *Eugeissona*, *Caryota*, *Arenga* and but also, from 10.5 ka, *Metroxylon*, a sago palm that is native to New Guinea (Hunt and Premathilake, 2012; Hunt and Rabett, 2014, 26). Its apparent translocation to Borneo at this remarkably early date over some 3000 km of ocean is part of the growing evidence for the extensive maritime connections that linked the coastal communities of Island Southeast Asia from the very beginning of the Holocene following the flooding of the Sunda shelf (Blench, 2012; Blench, 2013; Bulbeck, 2008; Denham, 2010; Rabett and Piper, 2012; Rabett et al., 2013), thousands of years before the supposed Austronesian diaspora of Austronesian rice farmers.

Present-day Penan foragers heavily rely on sago as their plant staple, practising a kind of stewardship that they call *molong* (‘caring for’) that involves clearing areas to encourage young plants to thrive (Brosius, 1991; Koizumi, 2005). The Loagan Bunut evidence is highly suggestive that from the Early Holocene on the lowlands of northern Borneo a form of ‘arboriculture’ or ‘vegeculture’ was being practised of the kind postulated elsewhere for

Island Southeast Asia during the Holocene (Barton and Denham, 2011; Barton, 2012; Hunt and Rabett, 2014). Whether this was of the 'plant and leave' type of the Penan (Kedit, 1982) or part of a more intensive system of management is impossible to determine at present.

[Fig. 3 about here]

The West Mouth was primarily used as a place of burial in the Early Holocene, then abandoned during the Mid Holocene high sea stand c. 6–4.5 ka when mangrove swamps surrounded the caves. As the sea retreated rainforests were re-established and people returned. The West Mouth once again was mainly used for burying people, of the same physical type as before (Manser, 2016) but now accompanied by, or with burial rites associated with, Neolithic pottery and other items of Neolithic material culture (Cole, 2012; Lloyd-Smith et al., 2013). An early attempt to date the more than 250 human burials in the West Mouth using samples of human bone indicated that the Neolithic burials had a date range of c. 6.0–1.3 ka (Brooks et al., 1977), but these dates were undertaken before the effects of wet tropical environments on bone diagenesis were realised, and a new dating programme using wood, bamboo and cremated bone from about 40 secure burials indicates that the Neolithic burial phase spanned from c. 3.5 ka to c. 2.2 ka (Lloyd-Smith et al., 2013, 263). On the evidence of stable isotopes from human tooth enamel the diet at this time derived from a larger proportion of food from open environments than that of the Early Holocene people buried in the West Mouth (Krigbaum, 2005).

Did these 'Neolithic people' cultivate rice? Rice pollen, some of it comparable morphologically with that of domestic rice (*Oryza*) but not attributable to species (either wild or domestic), is present in the two Niah cores from the time of the Neolithic cemetery and there are numerous rice phytoliths in the Loagan Bunut core, many of them burnt (Hunt and Premathilake, 2012). The latter point to some form of rice cultivation or management possibly being practised at Logan Bunut by the Mid Holocene, though whether this involved morphologically-cultivated or wild species is at present unclear, as is the nature of the human intervention practices. Impressions of morphologically domestic rice grains have been found within the fabrics of 14 sherds of the ~1500 sherds recovered by the Harrisson excavations at Niah (Doherty et al., 2000). Whilst they could be trade items from rice-users elsewhere, it is certainly possible that rice was being cultivated around the caves as it was at Gua Sireh cave in western Sarawak c. 4.3 ka (Bellwood et al., 1992). Nevertheless, rice appears to have made a very small contribution to the diet, which remained dominated by tubers, nuts, fruits, wild

animals and molluscs (Lloyd-Smith et al., 2013, 294-95). There is no evidence for domestic pigs or dogs at Niah before the Metal Age (Szabo et al., 2013).

4. The interior highlands: Late Holocene 'sago and mound people'

The pollen record for the Kelabit Highlands obtained by the Cultured Rainforest Project goes back as early as the Niah record, but the first hints at human presence, in the BPG core from Pa' Buda south of Pa' Dalih (Fig. 4), are indications of repeated burning with associated forest canopy openings and soil erosion, and a distinct rise in the pollen of the palm *Caryota* and of fruit trees such as *Callicarpa* (beautyberry), c. 7–6.2 ka (Jones et al., 2013b; Jones et al., 2014; Jones et al., 2015; Table 3). Increasing frequencies of grass phytoliths are another indicator of the repeated nature of forest disturbance here and a spike in burnt phytoliths suggests the kind of hot fires associated today with farmers clearing and cleaning their garden plots. These events are a thousand years earlier than the onset of the El Niño/Southern Oscillation (Moy et al. 2002) so are unlikely to relate to climate; human disturbance of the vegetation seems much more likely.

[Fig. 4 and Table 3 about here]

There is more definite evidence for human presence c. 4 ka: there are similar disturbance indicators and a high frequency of *Colocasia* (taro) pollen in Core BIO7 at Bario. At Ruma Ma'on Dakah on a terrace of the Kelapang 5 km south of Pa' Dalih we found a post-hole associated with abraded sherds of earthenware pottery, a fragment of a polished stone implement and burnt stones, with charcoal in its fill dating to around 3.7 ka, though a sherd of Qing Dynasty porcelain in the same post-hole indicates that the charcoal is likely to be residual. By c. 3 ka human disturbance of the rainforest is clearly evidenced at Pa' Dalih (Core PDH212) by a marked decline in forest taxa and a parallel increase in open-ground and scrub taxa with, a century later, the appearance of echinate (palm) phytoliths and a notable band of charcoal (Jones et al., 2013b). *Eugeissona* sago pollen first appears in a section of peat dated to around 3 ka preserved underneath a now-bulldozed stone mound called Perupun Payeh Telipa on a high terrace of the Kelapang. The natural habitat of *Eugeissona* in the Highlands today appears to be ridge tops and steep scarps, so its appearance in the pollen records of the Kelapang Valley, and a little later in those of the Bario basin, is strongly suggestive of its deliberate translocation from the ridges to gardens or fields near river

terrace. At c. 2.5 ka the PHD212 and PDH223 cores at Pa' Dalih record significant and repeated forest disturbances accompanied by extremely high frequencies of *Eugeissona* pollen, as does the Ba core at Bario around 2 ka (Jones et al., 2013b). There is evidence for ephemeral human presence at this time in a small rock shelter in the Kelapang valley called Lepo Batuh, the kind of location that would be used for overnight camps by mobile foragers, but by 2 ka there were also two dramatic changes in the direct archaeological record of human activity.

The first was the construction of stone mounds (*perupun*), the largest being around 30 m in diameter and 2 m in height. The tradition of mound-building has lasted to ethnohistorical times: according to written records and oral traditions, *perupun* were believed by the Kelabit to have been constructed by their ancestors for notable individuals, involving the deposition of valuable possessions and feasting (*irau*). Their purpose in prehistory is not certain, but excavations, both authorized investigations and illegal quarrying, have found a range of pottery, stone and metal artefacts in their rubble fills. An excavation by the Sarawak Museum in 1962 of Perupun Rayeh Pa'Lungan in the northern Highlands reportedly found cremated human bone as well as artefacts, suggesting that their construction in prehistory may have been associated with funerary rites, but reinvestigation of the site by LLS in 2013 found no cremated bone. The artefacts found in the original excavation can probably be associated with the re-use of the monument 300-500 years ago when a large dolmen megalith was constructed on it.

The second class of monument consisted of substantial open settlements, the best understood of which is Ruma Ma'on Taa Payo, a kind of site entirely unsuspected in Borneo hitherto (Lloyd-Smith et al., 2010; Fig. 5). It consists of a flat-topped spur surrounded on three sides by a meander of the Kelapang river. Geophysical survey and test excavations found traces of ditches and well-made structures of river-rolled stones. There were hundreds of earthenware sherds mixed in with the wall material perhaps used as a 'clay-mortar' to bind the stones and stabilize the structure. Charcoal from underneath the base of one of the walls gave a ^{14}C date of 1620±40 BP or 1605-1409 cal. BP (cal. AD 345–540) and an almost identical date was obtained from charcoal in the fill of a stone-packed posthole, from the top of which came a heavily corroded iron knife. The name Taa Payo means 'deer enclosure' and our informants said that the name was given because, it was said, deer were once trapped there. They told us how people used to trap and keep sambar deer in bamboo enclosures to provide a ready-made meat supply for *irau* feasts. Food and other charred residues stuck to the inner surfaces of many of the sherds indicate that they were cooking pots, but whether

they were used for domestic cooking, or *irau*-type feasts, or both, we cannot tell. Other artefacts included fragments of cylindrical polished stone pounders known locally as *batu pra'it* ('thunder stones') (Fig. 6). Nearly 70 of these artefacts are in the Sarawak Museum collections, 50 from the Kelabit Highlands (Janowski and Barton, 2012). They have long been interpreted as sago pounders used for shredding the pith of the sago palm trunk to release the starch flour (e.g. Collings, 1949; Haddon, 1900) and that theory has now been given strong credence by the discovery by HB of palm starches in the organic residues attached to two of them. Two open settlement sites probably similar to Rumah Ma'on Taa Payo have been found, one in the southern Highlands at Long Diit and one in the northern Highlands at Ra'an Ubud Pa'it, both dating to around 2 ka and like Rumah Ma'on Taa Payo both located close to a *perupun*.

[Figs 5 and 6 about here]

The repeated nature of the disturbances in the pollen records, along with the transformations in monument-building, suggest that these 'sago and mound people' practised a much more systematic and proactive strategy of sago management than 'plant and leave'. On the evidence of the iron knife at Rumah Ma'on Taa Payo this was presumably facilitated by metal tools. The first metal artefacts on the coast date to around 2.5 ka (Lloyd-Smith et al., 2013, 289–290), so it may be that metal artefacts penetrated into the Highlands as trade items, though on the evidence of fragments of clay vitrified at high temperature at Menatoh Long Diit the interior forest peoples by this time could well have had control of the high-temperature fire technologies necessary to make such implements.

5. The interior highlands: Late Holocene rice farming and longhouse living

None of the archaeological sites investigated by the CRF team produced dates in the first centuries of the second millennium AD, and there is also a gap in the pollen record for the southern Highlands, though sago pollen is frequent in the Bario records at this time. By the middle centuries of the second millennium AD, however, we can discern a transformed cultural landscape. Megalithic cemeteries (*menatoh*) of stone jars were constructed such as Menatoh Long Diit, that consisted of 14 massive stone jars, some erect and some fallen, averaging over 1.5 m in height and at least 0.5 m in width, each made from a single stones block with the inside of the jar carved out to a depth of at least 0.8 m (Fig. 7). At a later stage

a series of boxes or cists of stone slabs was added. Cremated human bone found in the sediment between the jars was dated to 310±40 BP or 480-296 cal. BP (cal. AD 1470–1655). In the sediments at the base of the jars were sherds and complete vessels of earthenware (over 20 vessels in all), finer stoneware and Chinese porcelain, clay plugs (*aol*) for holding ear pendants in place, hundreds of glass beads, whetstones, iron knives, an iron ring probably part of the belt mechanism for a *parang* or bushknife, and bronze ear-rings and bells, presumably associated with the burial rituals (Lloyd-Smith et al., 2010, 72). The porcelain was mostly of the late Ming dynasties, a large blue and white bowl with a stamp showing that it was made in southern China dating to dynasties spanning the period AD 1450-1644. There were also *tuning*: small tubular vessels locally made of handmade pottery fired at low temperatures and coated with tree resin to make them waterproof, a type still made by the Kelabit in the 1970s (Janowski, 1991). Our excavations of Perupun Long Kelit produced a similar range of material including sherds of a Chinese brittleware that dates to the 13th/14th centuries. Charcoal from a soil horizon underneath the mound provides a *terminus post quem* ^{14}C date for its construction of 501±22 BP or 542-508 cal. BP (cal AD 1408–1442).

[Fig. 7 about here]

Dragon Jar cemeteries, so called because they consist of groups of large globular ceramic vessels over 1 m high decorated by images of dragons in relief, were another class of funerary monument constructed in recent centuries. Dragon Jars (*belanai*), also known as Martavan, were imported from the coast, many of them ultimately from China, from the 15th to the 19th centuries, and many Kelabit today have Dragon Jars that have been passed down the generations as heirlooms (B. Harrisson, 1986). At Menatoh Pa'Diit near the Menatoh Long Diit stone jar cemetery we found 13 jars with their bases buried in the ground, though the cemetery was probably far larger. An elderly informant who had officiated at pre-Christian rites at the site said that the dead were placed directly in a jar in a crouching position, the jar being cut in two to make access possible, though it is clear that in other cases they were used for secondary burials of bones of bodies that had been first exposed or buried elsewhere in the forest. Another form of monument, constructed until the years before WWII, are ditches (*nabang*) cut in prominent locations such as through sharp-sided ridges. We recorded ten of these in the forests around Pa'Dalih, all around 2–2.5 m wide and 1–2 m deep. The Kelabit say that in the past such *nabang* ditches were cut to memorialize events such as the deaths of prominent individuals, like the building of *perupun*, the ditches in this

case perhaps providing a path for the soul to reach the afterlife (T. Harrisson, 1959a, 307). People had to come together to dig such monuments to the dead, the *irau* feast being part of the 'rewards' for their efforts.

Alongside constructing formal cemeteries, people may have started to live in substantial domestic structures such as longhouses. Logging tracks exposed a ridge-top habitation site called Rumah Ma'on Ra'an Berangan with burnt and fire-cracked stones and a post-hole for a timber the size of the load-bearing ones in present-day longhouses. A carbonized branch of a short-lived tree yielded a ^{14}C date virtually identical to that of the cremated human bone at the Menatoh Long Diit stone jar cemetery, of 400±40 BP or 519-317 cal. BP (cal. AD 1430–1640). At Rumah Ma'on Dakah by the Kelapang River we used geophysical survey techniques and test pits to investigate a more recent longhouse site and were able to recognise one main longhouse and a smaller building to its south (Fig. 8) defined by drainage gullies and timber posts of varying sizes and, in the case of the main building, traces of regularly-spaced hearths like those of traditional Kelabit longhouses. The geophysical results, trench stratigraphies and finds all indicate multiple phases of occupation in the 18th, 19th and early 20th centuries.

[Fig. 8 about here]

Coinciding with the likely development of longhouse life around 500 years ago, the Pa'Daleh pollen cores indicate the development of systematically managed landscapes maintained by regular burning. A sharp increase in the magnetic susceptibility of the sediments indicates intense burning and erosion. Numerous *Oryza sativa* bulliform types of phytoliths suggest that rice was now the dominant crop (Jones et al., 2013a; Jones et al., 2013b) and there are macroscopic remains of rice in the foundation trench of an isolated stone jar at Long Kelit from which charcoal gave a date of 240±40 BP or 431–0 cal. BP (cal. AD 1520–1950). At Bario, by contrast, on the evidence of the Ba core, intensive sago management looks to have continued until the past 100 years until it too gave way to rice as the dominant plant staple (Jones et al., 2013a).

6. The diverse trajectories of foraging-farming transitions in Borneo

The Niah Caves Project has shown that, from their arrival at Niah around 53 ka, modern humans used a wide range of cognitive and technical skills to exploit rainforest as

well as a wide variety of other habitats. Their activities impacted the landscape in the process, most obviously in biomass burning, though the scale of such impacts cannot be measured. It is tempting to argue from the long-term record of biomass burning at Niah, Loagan Bunut and the Kelabit Highlands that the rainforests of Borneo have been shaped and managed by people for at least 50,000 years in ways reminiscent of the system of caring for the landscape (*molong*) practised today and in the recent past by Penan foragers.

However, we should be cautious about reading back the world views and behaviours of these present-day foragers in a simplistic way. For example, the zooarchaeological study of the Late Pleistocene faunas from the West Mouth and Lobang Hangus found intriguing hints at variability in the butchery methods used, with different *chaïnes opératoires* for different species of primate and viverrid, whereas a similar butchery and skinning sequence was applied to three carnivores adapted to different habitats: *Aonyx cinerea* (Oriental small-clawed otter), *Arctictis binturong* (bearcat) and *Prionailurus bengalensis* (leopard cat) (Piper and Rabett, 2016). Some of the differences can be understood in terms of the hunting systems at the different sites, like the targeted trapping of nocturnal species from the Lobang Hangus entrance. Others, however, are less easy to explain in terms of present-day rationality and zoological divisions, including those of the Penan. The Niah foragers seem to have perceived ethno-taxonomic differences within what is currently defined as the Linnaean Family Viverridae, and potentially at least two ethno-taxonomic categories of monkey (Piper and Rabett, 2016). Similarly, if we are right in our interpretation of the appearance c. 3 ka of *Eugeissona* pollen in Core PDH212 at Pa' Daleh as representing the deliberate translocation of sago plants from ridges to valley bottoms and their deliberate manipulation in systems of Penan-style *molong*, we should also note that this kind of plant transport is not practised by the Penan today in the southern Highlands. They often exploit sago clumps on ridges and when asked by our team why they didn't move sago saplings to more convenient locations by streams lower down (as processing the sago involves repeated washing), they said that this would show disrespect: "people should move to plants, not plants to people". Because, like the Kelabit, they imbue their landscape with real and mythical ancestors, moving trees could mean moving people, perhaps against their wishes.

There are hints in the phytolith record that rice cultivation may have started in the Kelabit Highlands around 3 ka, some 1000 years or so after the earliest secure occurrences of rice grains in the Neolithic ceramics at Niah. However, the isotope record of the 'Neolithic' skeletons buried in the West Mouth indicates the return of more closed environments by c. 2.0 ka (Lloyd-Smith et al., 2013, 293), implying the abandonment of rice cultivation

(Krigbaum, 2005; Lloyd-Smith et al., 2013, 293–294). In both parts of Borneo rice appears to have been actively resisted as a plant food staple in favour of sago until recent centuries (Barton, 2012). The post-holes of timber scaffolding and imported tradewares and beads that we found in the West Mouth indicate that the peoples of the north Bornean littoral have probably engaged in birds-nesting for the Chinese market for at least 1000 years (Barker et al., 2013, 329), like the Penan have done in recorded times (Brosius, 1991). Again, however, we cannot 'read the Penan back' simplistically into the pre-recorded past. The archaeology of the Highlands indicates forms of sociality in the rainforest two millennia ago that have no analogies in the present or historically-recorded past. The construction of *perupun* mounds needed communal labour and cooperation, and their regular spacing down the Kelapang valley suggests that they may have served as some kind of territorial markers for the communities that built them, a form of landscape division quite unlike the natural physical and ancestral story-based boundaries of the forest landscapes of Penan and Kelabit cosmologies (Janowski, 2003; Janowski and Langub, 2011). The enclosed habitation site Ruma Ma'on Taa Payo represents an extraordinary form of investment and landscape intervention by foragers/sago vegeculturalists 2000 years ago quite unlike the ephemeral Penan camps of the present and recent past, or the longhouses of Kelabit rice farmers.

We do not know when longhouse living developed on the lowlands of Borneo, but the broad contemporaneity of the development of rice farming (both hill swidden and paddy field) and longhouse living in the Highlands some 500 years ago is very striking. Today rice is at the centre of the Kelabits' cosmology and worldview (Janowski, 2003): unlike all other plants in the forest, they say, "rice needs people to grow it". They use their term for the forest, *polong*, to differentiate it from the areas created by humans such as rice fields, buffalo pastures, gardens and longhouses, taking pride in these and the other marks that they make, such as (before Christianity) mounds (*perupun*), megalithic cemeteries (*menatoh*) and ceremonial ditches (*nabang*), to show their separation from the forest (Janowski and Langub, 2011, 125). By contrast the Penan term for the forest*, tana',* refers to the entire forest world in which they live and of which they are a part: a spirit-animated forest that needs nurturing (and in some cases appeasing) through *molong* stewardship. For this reason they take care to leave only footprints in the forest, a form of 'being' and 'being part of' the forest that is necessarily at odds with the separation from the forest, and the marks imposed on it, necessitated by the cassava and rice cultivation that government policy is encouraging them to undertake. It is possible that the development of Kelabit and Penan lifestyles around 500 years ago - the contrasting subsistence modes and cosmologies of rice-based communal

longhouse living, on the one hand, and family-based mobile foraging and sago dependence, on the other hand - had its origins in internal social processes, but we know too little about Kelabit Highland rainforest lives in the preceding centuries (e.g. c. AD 1000–1500) to speculate on this. It is equally possible that the development of Kelabit and Penan lifestyles and cosmologies was at least partly a product of the interior people's varying responses of engagement with or resistance to developing contacts with the Borneo lowlands and the maritime world systems – Indian, Chinese, European - in which the latter increasingly participated (Szabó et al., 2013).

7. Conclusion

Island Southeast Asia is one of the most organically diverse regions on the planet (Gower et al., 2012). It houses three of Myers et al.'s (2000) 25 biodiversity hotspots (Sundaland, Wallacea and the Philippines), whilst also supporting some of the densest human populations in the world with rapidly expanding economies. Destruction of forest cover through unsustainable logging of dipterocarp forests (Ashton, 2014) and conversion of vast tracts of lowland forest habitat to industrial monocultures of exotics such as the West African oil palm and the Brazilian rubber tree has led to a veritable 'biodiversity crisis' (Sodhi and Brook, 2006), whilst the pace of forest conversion is causing displacement of indigenous groups of people (Alcorn, 1993; Brosius, 2004) and the degradation of rural livelihoods (Sodhi et al., 2006). The recognition of the impact of these factors, combined with global environmental change, has generated substantial conservation concerns at scales ranging from the local to the global (Gower et al., 2012). Within many such initiatives, the long-term monitoring of trends in ecological change is increasingly prioritized to improve future predictive capacities, yet even with these goals most ecologists study organisms on a time scale of less than 100 years, only a fraction of a single generation of many rainforest canopy trees (Ashton, 2014). Clearly a deeper temporal perspective is needed to understand many long-term patterns and processes affecting rainforests, including human impacts (Willis et al., 2004; Willis and Baghwat, 2010; Willis et al., 2013). The role of palaeoecology, especially palynology, is clearly paramount in such investigations, but in this paper we have argued that the combination of palaeoecological and archaeological approaches, informed by anthropological studies of recent and present-day rainforest societies, provides powerful complementary insights into human-rainforest history.

The ‘culturing’ of the rainforest evident both on the lowlands and in the interior highlands of Borneo fits into a developing regional picture of landscape intervention in Mainland and Island Southeast Asia and New Guinea through the Holocene and, in places, the Late Pleistocene. There is widespread evidence for forest disturbance, for the exchange of technology, animals, plants, and genes, and for forms of food production based on the manipulation and management of plants, thousands of years before the supposed migration of Austronesian rice farmers ~4000 years ago (Hunt and Rabett, 2014; Summerhayes et al., 2016). The latter hypothesis, long regarded as securely grounded in a combination of archaeological, genetic, and linguistic evidence, is increasingly criticised under all three headings as an explanatory model for the spread of domestic rice across Island Southeast Asia and of the practices associated with its cultivation (Blench, 2010; Donahue and Denham, 2010; Barker et al., 2011; Barker and Richards, 2012; Blench, 2012; Blench, 2013). Instead of a dichotomy between pre-Austronesian foraging and Austronesian farming, a complex variety of resource management economies can increasingly be discerned across this vast region throughout the course of the Early and Mid Holocene that combined different mixes of hunting, fishing, gathering, arboriculture and vegeculture, associated with different degrees of rainforest intervention. The evidence is often ephemeral, and the research agenda is only at an early stage of development, but there are already enough data to indicate that we should not replace the two-stage model of pre-Austronesian foraging and Austronesian farming with a ‘staircase’ model of ever increasing complexity in landscape intervention: “patterns of activity…were far too complex, nuanced and locally-contingent to be attributed neatly to simple economic categories or narratives” (Hunt and Rabett, 2014, 31).

In the case of Borneo, it is apparent that modern humans have been shaping the forest since they first encountered it over 50,000 years ago, but also that these ‘cultured rainforests’ have developed in spatially and culturally diverse ways rather than in a simple linear trajectory of ever increasing scales of human impact. Also, past ways of living in the forest sometimes appear to have resonated strongly with recent and present-day rainforest lives and *mentalités*, but at other times have represented remarkably different solutions to its challenges and opportunities. Such findings underline the necessity for developing both more sophisticated theoretical models of potential human-rainforest interactions and archaeological and palaeoecological methodologies sensitive enough to distinguish between them.

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Table 1. Species representation in the Hell Trench of the West Mouth of Niah Great Cave, combining the vertebrate remains from the Harrisson Excavation Archive and NCP excavations; excluding fish, hominins, and vertebrates smaller than squirrel-size. Identified by P. Piper and R. Rabett except birds, which were identified by C. Stimpson.

Table 2. Starch and macroscopic plant remains recovered from Late Pleistocene sediments in the West Mouth of Niah Great Cave. The Hell Trench, so called by the Harrissons because of the difficulties working in it in the full afternoon sun, was their deepest trench, excavated a few metres into the cave entrance. Area was the term given by our own project to the area underneath and around a rock shelter that forms the northern side of the West Mouth ~10 m to the north of the Hell Trench and which was probably the main focus of habitation. Blocks A and B in Area A were two blocks of sediment under the rock shelter unexcavated by the Harrissons. *Indicates contexts sampled but without starch. ** Indicates contexts without starch but with ^{14}C dates (the latter shown as calibrated to 2 sigma). X = fragment; R = rare (fewer than five fragments); F = few (fewer than twenty fragments); C = common (fewer than 100 fragments).

Table 3. Radiocarbon dates from the Kelabit Highlands: a. archaeological sites; b. palaeoecological sites. Site codes: LKT: Rumah Ma'on Dakah, Long Kelit; LOB: Lepo Batu; PAY: Rumah Ma'on Taa Payo; BDT: Menatoh Long Diit; BAR: Rumah Ma'on Raan Berangan; BLK: Benatuh Long Kelit; POK: Perupun Long Kelit; LAM: Laman Pa' Ramain. Palynological site codes: Ba, BOI5, BIO7, BIO16, BIO50, BIO51, BIO53: Bario; BPG: Pa' Buda; PDH: Pa' Daleh; PPP: Perupun Payeh Telipa.

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Fig. 1. Borneo, showing the locations of the Niah Caves, Loagan Bunut, and the Kelabit Highlands: 1. Niah Caves; 2. Loagan Bunut; 3. Bario, northern Kelabit Highlands; 4. Upper Kelapang Valley, southern Kelabit Highlands.

Fig. 2. Summary pollen diagram for Niah Great Cave. (After Hunt et al., 2012)

Fig. 3. Reconstruction of the changing Holocene geography of the north Bornean coast near the Great Cave of Niah from the Baram delta and the alluvial lowlands of the Baram and Tinjar Rivers to the modern freshwater lagoon of Loagan Bunut. (After Gilbertson et al., 2016, 138)

Fig. 4. Map of the Kelabit Highlands showing the location of the principal archaeological and palynological sites mentioned in the text. Modern sites: 1. Bario; 2. Pa' Dalih; 3. Kelapang River. Archaeological sites: 4. Lepo Batu; 5. Rumah Ma'on Dakah, Rumah Ma'on Taa Payo, Perupun Long Kelit; 6. Menatoh Long Diit; 7. Perupun Rayeh, Pa' Lungan, Ra'an Ma'on Ubud; 8. Perupun Payeh Telipa; 9. Rumah Ma'on Raan Berangan. Palynological sites: 10. PDH212; 11. PDH223; 12. BPG, Pa' Buda; 13. Ba (Bario) and Core 7 (Bario). (Illustration: L. Farr)

Fig. 5. Plan of Ruma Ma'on Taa Payo, showing plan of surface remains and excavated features and artefacts. (Illustration: L. Lloyd-Smith)

Fig. 6. Stone pounder (*batu pra'it*) used for processing sago, from Ruma Ma'on Taa Payo. Scale: 5 cm. (Photograph: L.Lloyd-Smith)

Fig. 7. Plan (left) and photograph (right) of Menatoh Long Diit stone jar cemetery; scales in photograph measure 1 m. (Plan: L. Lloyd-Smith; photograph: G. Barker)

Fig. 8. The 'old longhouse' site Rumah Ma'on Dakah showing the interpretation of the geophysical survey data and the excavated trenches. (Illustration: L. Lloyd-Smith, L. Farr, R.

Ferraby)