The Emergence of Bone Technologies at the End of the Pleistocene in Southeast Asia: Regional and Evolutionary Implications

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For many decades Palaeolithic research viewed the development of early modern human behaviour as largely one of progress down a path towards the 'modernity' of the present. The European Palaeolithic sequence — the most extensively studied — was for a long time the yard-stick against which records from other regions were judged. Recent work undertaken in Africa and increasingly Asia, however, now suggests that the European evidence may tell a story that is more parochial and less universal than previously thought. While tracking developments at the large scale (the grand narrative) remains important, there is growing appreciation that to achieve a comprehensive understanding of human behavioural evolution requires an archaeologically regional perspective to balance this.

One of the apparent markers of human modernity that has been sought in the global Palaeolithic record, prompted by finds in the European sequence, is innovation in bone-based technologies. As one step in the process of re-evaluating and contextualizing such innovations, in this article we explore the role of prehistoric bone technologies within the Southeast Asian sequence, where they have at least comparable antiquity to Europe and other parts of Asia. We observe a shift in the technological usage of bone — from a minor component to a medium of choice — during the second half of the Last Termination and into the Holocene. We suggest that this is consistent with it becoming a focus of the kinds of inventive behaviour demanded of foraging communities as they adapted to the far-reaching environmental and demographic changes that were reshaping this region at that time. This record represents one small element of a much wider, much longer-term adaptive process, which we would argue is not confined to the earliest instances of a particular technology or behaviour, but which forms part of an on-going story of our behavioural evolution.

One of the central focuses of Palaeolithic archaeology in the last forty years has been a global-scale study of the origins of cultural behaviours that we recognize as demonstratively those of human modernity. As the European Palaeolithic record has the oldest history of research and is the most extensively studied, the character of the Palaeolithic here has, for a long time, been the principal source of information upon which this grand narrative of human development has been written. The emergence of modernity was seen as a process bound up with the dispersal by *Homo sapiens* out of Africa during the Upper Pleistocene and their subsequent settlement of most landmasses around the world. It was informed, though, by this one dominant source of information, and whilst acknowledging the importance of the adaptive challenges involved in colonization (e.g. Mellars 2005), the model tended to be somewhat monochromatic in

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its perspective. All enclaves of anatomically modern humans were (and often still are) implicitly assumed to be as unified behaviourally as they are genetically: once key features of modernity were in place they were transposed to all settings and situations without further development. Any observed variability in the archaeological records of other regions away from this universal (but Europe-based) trajectory tended to be explained in terms of the pace at which different populations adopted distinguishing material practices, or through the loss of apparent complexity, for example, as a consequence of group isolation or a lack of suitable raw materials for tool manufacture.

In the last decade, as regional records in Africa and Asia have become known in more detail, the authority of this singular, pan-species model has come under increased scrutiny (e.g. Brantingham *et al*. 2004; Habgood & Franklin 2008; Haidle & Pawlik 2010; Henshilwood & Marean 2003; McBrearty & Brooks 2000; Rabett 2011; in press). In light of these discoveries, data from Europe are looking increasingly less like a canon of early humanity, and more like but one regional expression of it (e.g. Finlayson & Carrión 2007). *Homo sapiens* is unified as a biological species, and this will, inevitably, set certain parameters on how modern humanity has evolved. Within those parameters, however, trajectories of adaptation look increasingly to have been both more diverse and locally contingent than previously considered. To understand better the processes that have led to the global coalescence of behaviours we today embody as quintessentially those of modern humans, greater emphasis must now lie in charting the course of individual regional sequences through which early human societies emerged. The archaeology needs to be considered in the context of the immediate even as we remain mindful of the large scale and evolutionary.

The occurrence of 'bone technology' (the term is used generically herein for convenience to mean all osseous implements) in the Upper Palaeolithic and Middle Stone Age records of Europe and Africa, respectively, has been seen as one of the classic markers of emergent human modernity because of the technical and subsistence changes that it implies had come into being (e.g. d'Errico & Henshilwood 2007; Henshilwood & Sealy 1997; Mellars 2005). In this article we examine the Southeast Asian record, where bone technology has an antiquity at least equal to that of Europe, and of comparable age to that confirmed in north and south Asia (e.g. Derevianko 2010; Perera 2010). In accordance with the aforementioned shift in thinking, we are specifically concerned with its role in the context of those adaptive strategies that groups of early humans here devised with the resources and artifice at their disposal to meet local conditions. A detailed exposition on the history of research into bone technology in this part of the world has been covered elsewhere (Rabett in press) and it will, therefore, not be repeated here. Rather, this article will concentrate on exploring the distribution, antiquity and uses of this technology. In the concluding section we take tentative steps towards an explanatory model for its occurrence in relation to other commensurate changes known to have been impacting Southeast Asian communities during the late glacial and into the Holocene.

In order to make the cross-correlation of evidence between sites discussed as meaningful as possible we have standardized available radiocarbon dates, where it has been reasonable to do so, using a single calibration curve: Fairbanks_0107 (Fairbanks *et al*. 2005) — though dates calibrated using other standard curves are also referred to in some instances. All dates mentioned in the text are presented in Table 1, both in uncalibrated and calibrated forms. Herein, 'cal. BP' and 'cal. KBP' are used to refer to calibrated years and calibrated thousands of years before present (i.e. calendrical dates), 'uncal. bp' or 'uncal. kbp' refers to uncalibrated years and thousands of years before present. Also, for the purposes of this article the 'Late Pleistocene' is informally defined as covering the period from *c*. 40,000 years ago until the end of the last glacial period. Following the practice of using geomagnetic stratigraphy to mark Quaternary phases (e.g. Walker 2005) this sub-epoch is taken to commence with the Laschamp geomagnetic excursion (see Guillou *et al*. 2004). The Pleistocene–Holocene boundary is set at *c*. 11,700 calendar years ago, the Global Stratotype Section and Point (GSSP) for the base of the Holocene (Walker *et al*. 2009). The Last Glacial Maximum (LGM) is taken to span the period from 26,500–19,000 calendar years ago (after Clark *et al*. 2009). The period between isotopic minima and maxima in glacial-interglacial cycles are referred to as 'Terminations' (e.g. Anderson *et al*. 2007, 69). The 'Last Termination' is here considered to span the period from the height of the LGM to the Pleistocene–Holocene boundary: 22,000–11,700 calendar years ago, a definition aligned to Björck *et al*. (1998). Finally, the Holocene is divided into Early, Mid- and Late increments. The timing and duration of the sea-level high-stand towards the middle of this epoch is very variable (see e.g. Dickinson 2003); for our purposes the 'Mid-Holocene' is defined as *c*. 7500–4500 calendar years ago, based on dates obtained in the Strait of Malacca between Thai/Malay Peninsula and Sumatra (Geyh *et al*. 1979).

The prehistory of bone technology in Southeast Asia

*Pre-Last Termination (*c. *40,000–23,000 cal.* BP*)*

Bone technology appears in forager tool-kits from the beginning of known modern human occupation in Southeast Asia. The earliest confirmed examples of modified and utilized bone currently come from the Niah Caves (Reynolds *et al*. in press), and from Lang Rongrien, on the Thai/Malay peninsula (Anderson 1988; 1990; 1997). The Niah sample from this period (a total of eleven deliberately modified pieces taken from two areas of the West Mouth entrance) includes suid canines and a pigmented geoemydid plastron, as well as bone, and indicates that osseous media were employed in more than one use-context. Point forms are present at *c*. 45,000 cal. BP, but there is no evidence for use as armatures (Barker *et al.* forthcoming; Rabett *et al*. 2006). At Lang Rongrien, Anderson (1990) recovered three provisional pieces: one from Unit 9 and two from Unit 10, dating to 42,358±885 cal. BP (PITT-1248) and 42,108±1589 cal. BP (SI-6819), respectively. Only the piece from Unit 9, however, carries modification that strongly suggests anthropogenic working, in the form of groove-and-snap technique (Anderson 1990; 1997).

*The Last Termination (*c. *22,000–11,700 cal.* BP*)*

Assemblages containing early examples of bone technology continue to appear in both mainland and island regional settings during the first half of the Last Termination. These include, for example, material from Xom Trai, a cave site in northern Vietnam where all levels date to between 19,259±114 cal. BP (Bln-3042) and 22,012±211 cal. BP (Bln-3472) (Nguyen Viet 2000), and a probable early occurrence at Liang Lemdubu, from the Aru Islands in the Arafura Sea, dated to 19,720±530 cal. BP (OZD-460) (Pasveer 2006). Occurrences are few and far between, though preservation bias cannot be ruled out.

On current surviving evidence, bone technology appears to have attained a more central position in forager subsistence from the second half to the Last Termination and into the Holocene, and particularly so in Island Southeast Asia. Study of the artefacts from this period suggests that they continued to fill a range of technological niches, but that the new emphasis was tied to local innovation. Probable cutting and shaping tools were made on pig tusk (e.g. Rabett 2004); perforators and possible digging or fabrication implements, projectile armatures and axe-like edged pieces were made on primate and (probably) ungulate long bones (Rabett 2005). Bone-surface modifications, such as a single bevel and transverse binding-wear striations, on many of these pieces is consistent with the creation of hafting surfaces (Barton *et al*. 2009; Pasveer 2004; Piper & Rabett 2009a; Rabett 2005). In most cases, the principal focus of attention seems to have been in producing an effective working edge or point using coarse grinding or scraping techniques.

Most dated assemblages containing bone technology appear to fall within a period that opens during Greenland Interstadial 1 (GIS-1 — or the Bølling/Allerød of northwest Europe) *c*. 14,700–12,800 cal. BP, and finishes around the Mid-Holocene high-stand (7500–4500 cal. BP). At Niah, a high proportion of the bone tools Harrisson and Medway (1962) recovered from the West Mouth were from this time period *n* = 32/46. Radiocarbon dating by the Niah Caves Project (NCP) (Barker *et al*. 2007) indicates that at least 28 pieces, including possible projectile point forms, were deposited during the later millennia of the Pleistocene and into the Early Holocene (Barker *et al*. forthcoming). The NCP also found that the bulk of the bone tool assemblage from Lobang Hangus (*n* = 75/83) also dates to this period (Barker *et al*. forthcoming; Piper & Rabett 2009a). Most of the artefact forms described by Medway (1966) — including points that were probably used for piercing, probable projectile armatures and worked tusk — come from contexts there dated to between 14,484±131 cal. BP (OxA-13936) and 12,373±95 cal. BP (OxA-13939) (see Barton *et al.* in press). The appearance of this technology coincides with a shift towards a greater hunting emphasis on arboreal taxa at Lobang Hangus, with macaques and leaf monkeys becoming a dominant component of assemblages (Piper *et al*. 2008; Piper & Rabett 2009a). The Niah Caves evidence also provides one of the few locales in Southeast Asia where it has been possible to discuss the production process for bone tools in some detail (Rabett & Piper in press). Ten proximal and distal ends of monkey humeri, femora and tibia were found to exhibit evidence (as at Lang Rongrien) of the groove-and-snap technique (Fig. 1), a strategy that helps to control the morphology of the break and create a tool blank.

Bone implements found at Gua Braholo, east Java, have been dated to as early as 13,873±181 cal. BP (no lab code provided) and reportedly continue to appear in that site's archaeology until *c*. 4640±155 cal. BP (no lab code provided) (Morwood *et al*. 2008; Simanjuntak & Asikin 2004). Also from around the time of the Pleistocene–Holocene transition is the occupation at Con Moong cave in Cuc Phong Park, northern Vietnam (Pham Hui Thong 1980). This site has yielded an undisclosed number of bone implements, though apparently not a large number from

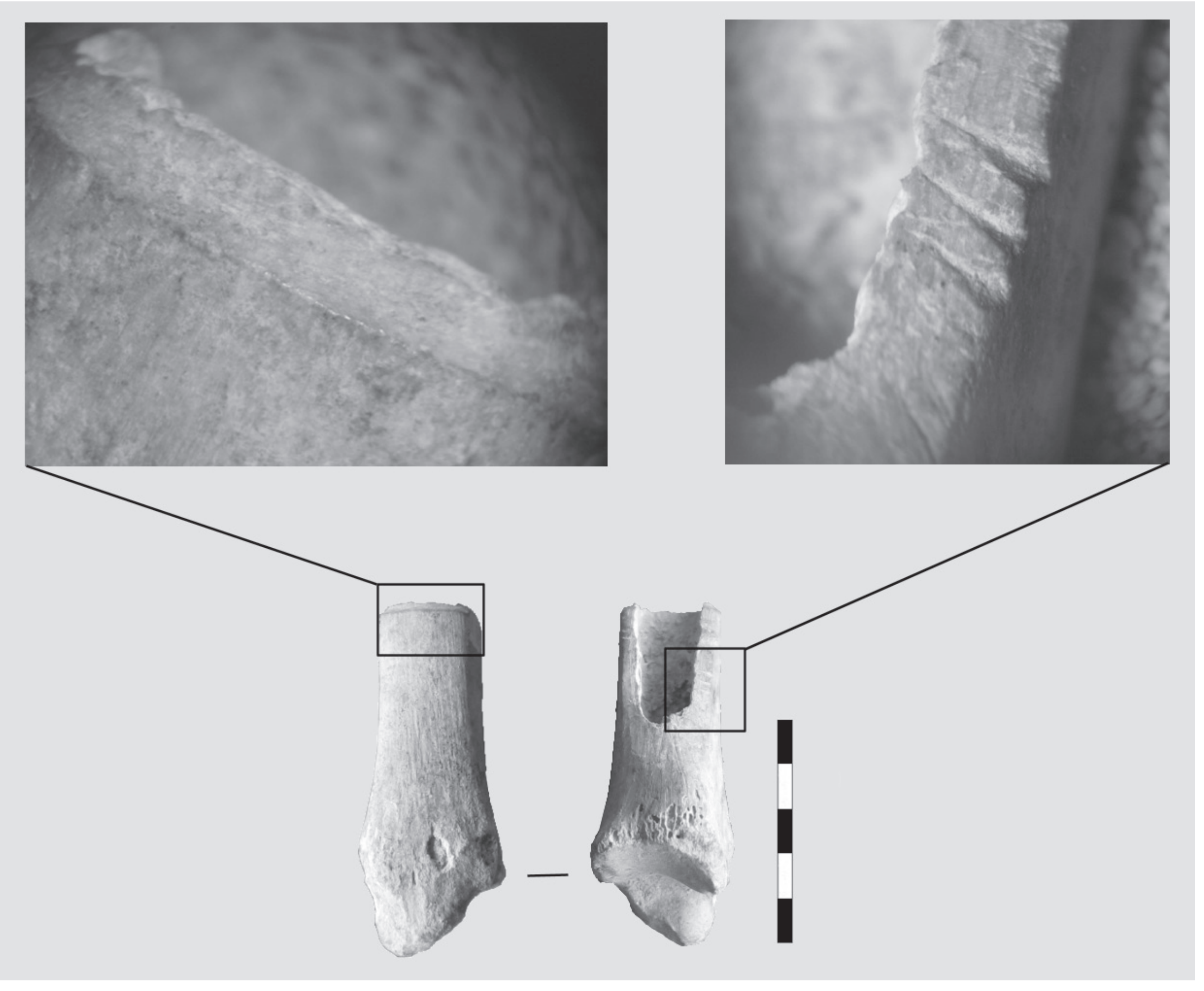

Figure 1. *A distal (L) Cercopithecidae tibia fragment displaying groove-and-snap technique (left images) and other associated surface working (right images). Fragment number: HLA-15407, trench US/26, 26–30", Lobang Hangus, Niah Caves, Borneo. Scale in 5 mm increments, microscope images: 10x. (Photographs: R. Rabett.)*

its Hoabinhian unit (Culture Layer II), dating to between 12,136±132 cal. BP (Bln-3485) and 11,351±229 cal. BP (ZK- 340) (Nguyen Viet 2000; Pham Hui Thong 1980, 19). Ha Van Tan (1999) reported that *c*. 250 bone artefacts have been recovered from some 150 Hoabinhian sites dating broadly to this period in northern Vietnam. With 105 reported from one undated site, Da Phuc, occurrences across that sample must generally be at a low frequency (see Matthews 1966). Current work by one of us (RR) at two cave sites in Ninh Bình province, northern Vietnam (see Rabett *et al*. 2011), dating from through Last Termination and into the Early Holocene also reflects this pattern. Two bone points have been thus far recovered: one from an undated, but likely Early Holocene context at Hang Trống. The second implement comes from the near-by Hang Boi, from a context (at most) a few hundred years younger than 13,601±43 cal. BP (UBA-14887) (Fig. 2).

Small numbers of bone implements similarly feature in the archaeology of Moh Khiew, a cave with complex stratigraphy in Krabi province, southern Thailand. The earliest date from a level with bone technology at this site is 12,893±128 cal. BP (OAEP-1284). The presence but low incidence of bone artefacts continues here, and at the neighbouring site of Sakai, into the Early Holocene. A total of twelve tools is published in Pookajorn *et al*. (1996) for these two sites, though re-analysis suggests that this might need to be revised downwards to perhaps six (Rabett 2002).

Figure 2. *(a) Bone point from Hang Trống, geological context of probable Early Holocene age; (b) bone point from Hang Boi, context 5219, slightly younger than 13,601±43 cal. BP (UBA-14887). Both cave sites are in Tràng An park, Ninh Bình, Vietnam. Scale in 5 mm increments. (Photograph: R. Rabett.)*

Early Holocene onwards (11,700 cal. BP and after)

Excavations undertaken in the West Mouth by the NCP (2001–02) brought to light a new suite of 31 osseous artefacts (Barton *et al*. 2009). All of these pieces are point-forms and half are made from sting-ray spines that have been explicitly modified for hafting — residual traces of the mastic and binding fibres have even been preserved in some instances (Fig. 3). The contexts that yielded these pieces date to between 10,886±148 cal. BP (OxA-12391) and 8793±109 cal. BP (OxA-18358) — four to five thousand years earlier than the next recorded instance of this kind of working, which comes from the Thai site, Khok Phanom Di, occupied between 3852±80 cal. BP (ANU-5493) and 3542±149 cal. BP (ANU-5482) (Higham & Thosarat 2004). While there is little doubt that the Niah artefacts were components in composite hunting or fishing tools — such as light pronged throwing spears (leisters) or arrows — precisely what they were used for is more difficult to ascertain. At the very least, a direct relationship can be assumed between the affordances that such range technology offered (killing at a distance) and the procurement contexts where it would have been required, such as hunting small arboreal game or fishing. A range of bone implements including 'spatulate' and 'adze' edged forms and points continue to be produced until the Metal Age at Niah and still on material from animals such as pig (*Sus* sp.) tusk and Asian soft-shell turtle (*Amyda cartilaginea*) plastron as well as bone.

Elsewhere in Borneo, isolated bone tools have come from the Madai Caves and Hagop Bilo, Sabah (Bellwood 1984; 1988). A comparatively large assemblage of 33 implements has been recovered at the coastal cave site of Gua Balambangan, on Balambangan Island off the northeast coast of Sabah dating to between 11,453±319 cal. BP (Beta-109141) and 10,007±227 cal. BP (Beta-109140); some eight thousand years after this coastal site was initially occupied (Zuraina Majid 1998; Zuraina Majid *et al*. 1998). In comparison to Niah, points of any form are a rarity at Gua Balambangan (*n* = 5/33), with the majority being ground-edge pieces made on dense bone elements and appearing in the site's sequence concurrently with the first examples of mangrove molluscan fauna.

In East Java, early excavations at the Gua Lawa rockshelter near the village of Sampung (Erdbrink 1954; van Es 1930) produced the region's first documented assemblage of bone tools and coined the term for what was perceived to have been a bone culture — the 'Sampung'. Edge-ground bone tools were predominately found higher in the sequence and spatulate pieces were found at lower levels (van Es 1930, 335). The fact that some of these implements were also described as having high polish to 'nearly the whole surface' makes it likely that a proportion of observed surface modifications may have been caused by non-anthropogenic processes such as water erosion. Over the following years, exploration of 19 other cave and rockshelter sites in East Java produced

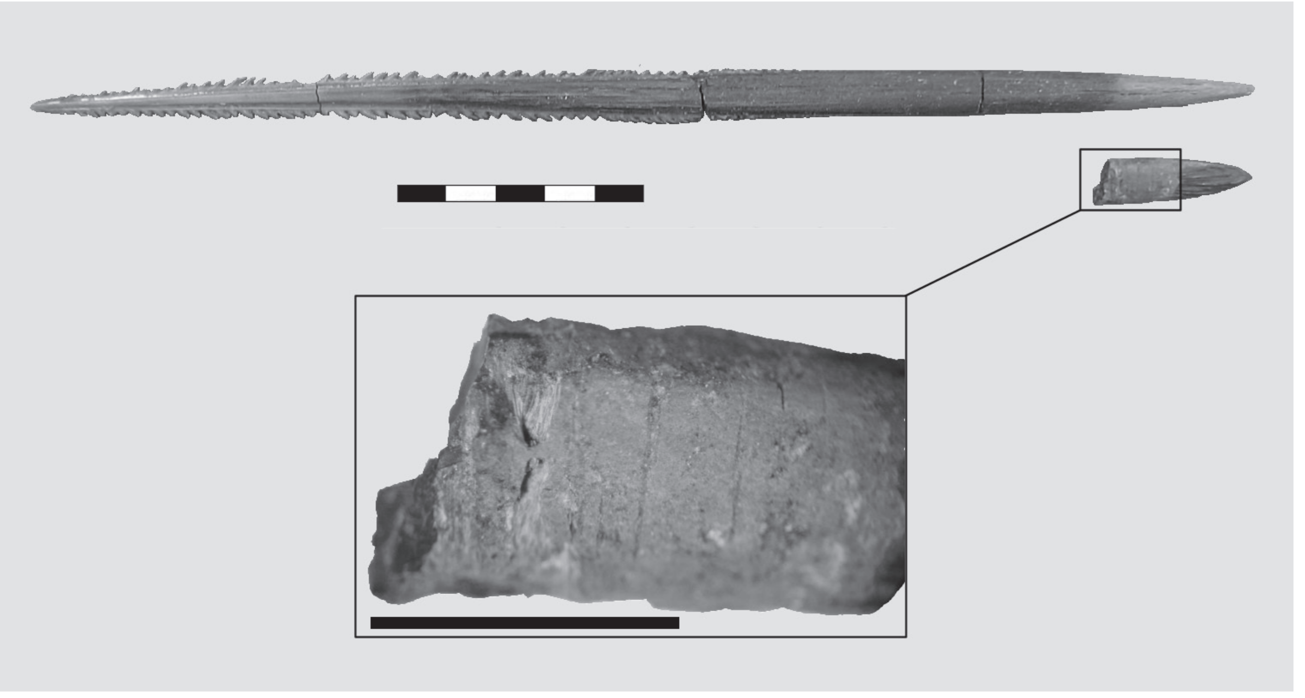

Figure 3. *Examples of worked sting-ray spines from Area D, West Mouth, Niah Caves. Mastic and binding materials are highlighted and shown magnified. Upper scale in 5 mm increments, lower scale is a 5 mm bar. (Photographs: R. Rabett and H. Barton.)*

comparable bone tools to those found at Gua Lawa. The tool-bearing horizons always appeared abruptly in the archaeological sequence, apparently never in association with ceramics, but generally underlying ceramic horizons. Details about the stratigraphy at Gua Lawa remain now as then problematic; however two radiocarbon dates have been obtained recently: 3242±123 cal. BP (no lab code provided) and an earlier one of 9141±232 cal. BP (no lab code provided) (Simanjuntak & Asikin 2004), placing occupation within the general period in question. Forestier (1999) reported bone implements associated with a date of 5174±160 cal. BP (no lab code provided) from excavation work at Song Keplek, Gunung Kidul. Dates subsequently obtained by Simanjuntak and Asikin (2004) may push bone tool use at this site back to as early as 9952±299 cal. BP, though detailed information about the association between tools and dates was not available at the time of writing. Recent excavations in the same part of Java at Song Gupuh (Morwood *et al*. 2008) have produced a large collection of bone tools (n = 91) from the upper deposits, including edge and point-form pieces that date as early as 11,400 cal. BP. This appearance coincides with a marked diversification in hunting strategy, and most notably a strong focus on the macaque (*Macaca* spp.). A similar increase in the production and use of bone technologies is observed at Song Terus Cave in the Punung Karst of East Java, where a suite of points, spatulae, pins and a small adze have been recovered dating to 8000–9000 cal. BP (Sémah *et al*. 2004). Again, this technology appears to coincide with an increase in the diversity of hunted terrestrial mammals such as rhinoceros (*Rhinoceros* sp.), elephant (*Elephas* sp.), macaque (*Macaca* spp.) and leaf monkeys (*Presbytis* spp.) and an increase in the exploitation of marine mollusca (Sémah *et al*. 2004).

Holocene bone tool industries have also been reported from several island sites in Wallacea and from the northern edge of the Sahul Shelf. For example, in southern Sulawesi, bone implements, considered typical of those from sites across this island attributed to the 'Toalean' culture, have been recovered from Ulu Leang 1 rockshelter, *c*. 20 km from the modern coast (Olsen & Glover 2004). Point forms are in the majority here (n = 80/134) and hafting mechanisms are inferred, as is the probability that many of these points were projectiles. The earliest charcoal date from the site is 8019±660 cal. BP (ANU-606), though its exact relationship to the bone tool inventory is not reported. Furthermore, at 7000–8000 cal. BP at other sites across the same peninsula, south of the Cenrana Valley, bone points (and shell scrapers) are added to the Toalean tool repertoire. Bone implements continue to be produced into the Neolithic and beyond on the island. For example, they occur in Neolithic layers at Minanga Sipakko in central West Sulawesi dated to between 3700±70 cal. BP (WK-14651) and 2676±139 cal. BP (P3G-97) (Simanjuntak *et al*. 2008).

In the Philippines, the earliest record of bone implements comes from the site of Balobok rockshelter, Tawi Tawi in the Sulu Sea. Three cultural layers were identified here; all contained osseous artefacts and all produced on pig bone (Bautista 2001; Ronquillo *et al*. 1993). However, the available radiocarbon dates are problematic as these were carried out on shell, and there is some concern that the deposits are significantly disturbed (Spriggs 2000; 2003). The earliest layer contained flake tools and no pottery and is provisionally dated by this means to between 8760±130 uncal. bp (no lab code provided) and 8000±100 uncal. bp (no lab code provided). In the Peňablanca region of northern Luzon, another site, Musang Cave, was found to have been occupied intermittently over a period of, provisionally, 12,000 years (Thiel 1990a). The earliest occupation here, Cultural Layer 1 dated by a shell sample (and hence must be viewed with caution) to 12,650–11,050 cal. BP (ISGS-496), produced no bone implements, though three were recovered from Cultural Layer 2, along with pottery and equally provisional shell dates of 6095–5385 cal. BP (GaK-7044) and 5040–4320 cal. BP (GaK-7043) (Thiel 1990a). Arku Cave, also in Peňablanca, reportedly produced eighteen bone artefacts associated with Neolithic and Metal Age burials (Thiel 1990b). These consisted (in Thiel's terminology) of five 'blunted' type, two finely-ground broken points made of horn or bone, six bone awls, and five barbed points. The two earliest associated radiocarbon dates from this site are 3660–2890 cal. BP (GaK-7041) and 3225–2645 cal. BP (GaK-7040). More reliably dated are three pieces of ground bone from Ille Cave, northern Palawan. Heavy polish and rotational striations would suggest that one of these, the distal end and shaft of a pig fibula, was used as an awl. All three were recovered from the Mid-Holocene shell midden layers and date to *c*. 6565±57 cal. BP (OxA-16095) (Lewis *et al*. 2008; Ochoa 2008). Several other Philippine sites have also produced bone artefacts tentatively dated to between 4000 BP and AD 1500 (Hutterer 1973; Legaspi n.d.; Peterson 1974) — indication of the continued existence and presumed utility of this technology from the Early Holocene even well into the Historic Period.

Further to the east, Pasveer and Bellwood (2004) have reported a total of 78 bone artefacts, including a particular abundance of point-forms, from the upper pre-ceramic phase at Golo Cave, Gebe Island in the north Moluccas, dating to between 7965–7743 cal. BP (ANU-9449) and 3691–3244 cal. BP (ANU-9448) (CALIB 5.0.1) (see Szabó *et al*. 2007). Pasveer and Bellwood (2004) proposed that the main use-context for the pieces in this assemblage was possibly as perforators (awls and piercing implements). Bone technology also appears in the Aru Islands on the margin of the Sahul Shelf at the site of Liang Lemdubu during this period, as well as another site, Liang Nabulei Lisa. At the former, 37 bone artefacts, mostly points, have been recovered from the top of the sequence (0–5 cm, spit 1) to a depth of 20–25 cm (spit 5). Most (n = 21) date to the last two thousand years, but 13 come from spits 2–5; contexts that could date back as far as 10,624±65 cal. BP (OZF-356) and perhaps older (O'Connor *et al*. 2006; Pasveer 2006). At Liang Nabulei Lisa, n = 11/15 bone implements excavated came from contexts dated to between 11,264±68 cal. BP (OZD-699) and 7800±151 cal. BP (ANU-10905). Much more pronounced variability in tool size and shape here was taken as a possible indication that they performed functions that may have been specific to this location. Some incidence of use as projectile points is surmised while other pieces again appear to carry wear-traces suggestive of use as perforators (Pasveer 2006). Finally, the appearance of a point-dominated bone tool assemblage (n = 92) at Kria Cave on the Bird's Head Peninsula, Papua New Guinea also dates to a comparatively brief interval during the Mid-Holocene: 7680–7510 cal. BP (GrA-9103) to 5210–4840 cal. BP (GrA-9100) using CALIB 4.3 (after Stuiver *et al*. 1998); after which time it disappears again. Use-wear analysis of these points suggested use as tools rather than as decorative pieces, with perforating being the proposed likely use-context (Pasveer 2004).

Turning to the northern and western margins of Southeast Asia, there are several sites where bone tools have been reported from this period, usually in small numbers (Rabett 2005, table 1). For example, fifteen points were recovered at Sai Yok 1 in western Thailand (Sørensen 1988; van Heekeren & Knuth 1967) from undated but probably Early Holocene levels; while an undisclosed number of artefacts were identified at Da But in northern Vietnam. The latter site dates to between *c*. 6500–5500 uncal. bp (on freshwater molluscs), though basal deposits remain unexcavated and greater antiquity is anticipated at this site (Nguyen Viet 2005). Occasionally, larger collections have been reported, such as at Da Phuc in northern Vietnam (e.g. Ha Van Tan 1976) and on the Malaysian side of the Thai/Malay peninsula at Gua Bintong (Collings 1937). Located in the state of Perlis, excavations at Gua Bintong uncovered a mixed midden of shells from several species of mollusc (coastal and freshwater), abundant fragmentary faunal remains — including soft-shell turtle — and crustacea, together with ceramics, lithics

Figure 4. *Southeast Asia showing a range of sites containing bone technology, and wherever possible the dates of the occupational sequence when such technology first appears. Most dates are presented calibrated. Occurrences commence in the Late Pleistocene, but are concentrated between the second half of the Last Termination and Holocene. The dates for Hagop Bilo, Madai 1/28, 2 and Balobok are uncalibrated values (see Bellwood 1984; 1988). (Illustration: R. Rabett & D. Kemp.)*

Table 1. *Radiocarbon and calendar dates for Late Pleistocene and Early Holocene bone tool assemblages mentioned in the text from Island and Mainland Southeast Asia, presented in chronological sequence. [a] Calibrated using the CALIB 3.4 curve (O'Connor* et al. *2006); [b] calibrated using the CALIB 5.0.1 with marine 04 calibration data (Szabó* et al. *2007); [c] calibrated using the CALIB 4.3 curve (Pasveer 2004); [d] calibrated using the IntCal04 curve (Morwood* et al. *2008). All other calibrated dates have been obtained using the Fairbanks_0107 curve (Fairbanks* et al. *2005).*

Pleistocene/ Holocene epoch	Site (Island Southeast Asia)	Uncalibrated date (years bp)	Reference(s)	Calibrated date (years BP)	Lab code
Pre-Last Termination	Niah Caves (Hell)	41,200±400	Barker *et al.* 2007	44,941±329	OxA-15630
		35,690±280	Barker *et al.* 2007	40,984±305	OxA-V-2076-16
		35,000±400	Barker *et al.* 2007	40,344±415	OxA-15126
	Lang Rongrien	37,265±1000	Anderson 1988; 1997	42,358±885	PITT-1248
		37,000±1780	Anderson 1988; 1997	42,108±1589	SI-6819
Last Termination	Xom Trai	18,420±150	Nguyen Viet 2000	22,012±211	Bln-3472
	Liang Lemdubu	16,570±510	O'Connor *et al.* 2006	19,720±530	OZD-460
	Gua Balambangan	16,530±160	Zuraina Majid *et al.* 1998	19,651±180	Beta-109143
	Xom Trai	16,130±90	Nguyen Viet 2000	19,259±114	Bln-3042
	Niah Caves (Area A)	13,745±55	Pritchard *et al.* 2009	16,000±125	OxA-15162

Table 1. *(cont.)*

Pleistocene/ Holocene epoch	Site (Island Southeast Asia)	Uncalibrated date (years bp)	Reference(s)	Calibrated date (years BP)	Lab code
Last Termination *(cont.)*	Liang Lemdubu	13,300±300	O'Connor *et al.* 2006	15,487±365	OZC-777
	Niah Caves (Lobang Hangus)	12,500±50	Piper & Rabett 2009a	14,484±131	OxA-13936
	Gua Braholo	12,060±180	Simanjuntak & Asikin 2004	13,873±181	None provided
	Hang Boi	11,741±43	This article	13,601±43	UBA-14887
	Liang Lemdubu	11,700±130	O'Connor *et al.* 2006	14,057–13,183[a]	ANU-10792
	Gua Musang	11,450±170	Thiel 1990a	Uncalibrated	ISGS-496
	Moh Khiew	11,020±150	Pookajorn *et al.* 1996	12,893±128	OAEP-1284
	Agop Atas (Madai 1/28)	10,800±120	Bellwood 1988	Uncalibrated	ANU-3088
	Niah Caves (Lobang Hangus)	10,450±45	Piper & Rabett 2009a	12,373±95	OxA-13939
	Agop Sarapad (Madai 2)	10,450±110	Bellwood 1988	Uncalibrated	ANU-2554
	Con Moong	10,330±70	Nguyen Viet 2000	12,136±132	Bln-3485
Early Holocene	Gua Balambangan	9960±190	Zuraina Majid *et al.* 1998	11,453±319	Beta-109141
	Niah Caves (Area A)	9995±40	Pritchard *et al.* 2009	11,429±109	OxA-15157
	Song Gupuh	9961±60	Morwood *et al.* 2008	11,410±180[d]	Wk-14650
	Con Moong	9905±150	Nguyen Viet 2000	11,351±229	ZK-340
	Liang Nebulei Lisa	9870±70	O'Connor *et al.* 2006	11,264±68	OZD-699
	Niah Caves (Area D)	9560±60	Barton *et al.* 2009	10,886±148	OxA-12391
	Liang Lemdubu	9400±50	O'Connor *et al.* 2006	10,624±65	OZF-356
	Gua Balambangan	8930±150	Zuraina Majid *et al.* 1998	10,007±227	Beta-109140
	Song Keplek	8870±210	Simanjuntak & Asikin 2004	9952±299	None provided
	Balobok rockshelter	8760±130	Ronquillo *et al.* 1993; Bautista 2001	Uncalibrated	None provided
	Song Terus	8350±100	Forestier 1999; Sémah *et al.* 2004	9362±125	Beta-124008
	Gua Lawa	8190±170	Simanjuntak & Asikin 2004	9141±232	None provided
	Niah Caves (Area D)	8005±50	Barton *et al.* 2009	8915±103	OxA-11864
	Balobok rockshelter	8000±100	Ronquillo *et al.* 1993; Bautista 2001	Uncalibrated	None provided
	Niah Caves (Area D)	7948±39	Barton *et al.* 2009	8793±109	OxA-18358
	Sakai Cave	7620±160	Pookajorn *et al.* 1996	8421±151	OAEP-1364
	Niah Caves (Area A)	7606±35	Pritchard *et al.* 2009	8400±20	OxA-15161
	Ulu Leang 1	7170±650	Olsen & Glover 2004	8019±660	ANU-606
	Liang Nebulei Lisa	6970±160	O'Connor *et al.* 2006	7800±151	ANU-10905
	Golo Cave	7400±10	Szabó *et al.* 2007	7965–7743[b]	ANU-9449
Mid-Holocene	Kria Cave	6760±50	Pasveer 2004	7680–7510[c]	GrA-9103
	Da But	6540±60	Nguyen Viet 2005	Uncalibrated	Bln-3509 II
	Song Terus	6390±80	Forestier 1999; Sémah *et al.* 2004	7316±80	Beta-124009
	Ille Cave	5769±37	Lewis *et al.* 2008	6565±57	OxA-16095
	Gua Musang	4980±150	Thiel 1990a	Uncalibrated	GAK-7044
	Gua Bintong/Bukit Chuping	5200±200	Haile 1971	5960±224	None provided
	Song Keplek	5174±160	Forestier 1999	5930±183	None provided
	Gua Kechil	4800±800	Dunn 1964	5457±967	GX-0418
	Kria Cave	4370±50	Pasveer 2004	5210–4840[c]	GrA-9100
	Gua Musang	4110±130	Thiel 1990a	Uncalibrated	GaK-7043
	Moh Khiew	4240±150	Pookajorn *et al.* 1996	4795±203	OAEP-1290
	Gua Braholo	4120±100	Simanjuntak & Asikin 2004	4640±155	None provided
	Niah Caves (Lobang Hangus)	3945±40	Piper & Rabett 2009a	4404±50	OxA-13940
Late Holocene	Khok Phanom Di	3560±60	Higham & Thosarat 2004	3852±80	ANU-5493
	Minanga Sipakko	3446±51	Simanjuntak *et al.* 2008	3700±70	WK-14651
	Golo Cave	3230±80	Szabó *et al.* 2007	3691–3244[b]	ANU-9448
	Arku Cave	3040±130	Thiel 1990b	3660–2890[e]	GaK-7041
	Khok Phanom Di	3310±128	Higham & Thosarat 2004	3542±149	ANU-5482
	Song Keplek	3260±110	Simanjuntak & Asikin 2004	3484±122	None provided
	Gua Sireh	3220±190	Ipoi Datan 1993	3441±225	ANU-7047
	Ban Lum Khao	3120±50	Higham 2004	3346±49	Wk-4511
	Gua Lawa	3040±90	Simanjuntak & Asikin 2004	3242±123	None provided
	Arku Cave	2740±120	Thiel 1990b	3225–2645[e]	GaK-7040
	Ban Lum Khao	3000±80	Higham 2004	3188±120	Wk-4509
	Minanga Sipakko	2570±110	Simanjuntak *et al.* 2008	2676±139	P3G-97

and 42 bone implements (Collings 1937). Upon the original publication of the Gua Bintong material, as well as subsequently (e.g. Tweedie 1953), these artefacts too were compared favourably to the Javanese and Vietnamese material, which were collectively considered to be of 'Mesolithic' age (Erdbrink 1954). While there are still no dates available specifically for the Gua Bintong assemblage, a marine terrace in a neighbouring cave in the same massif has been dated to 5960±224 cal. BP (no lab code provided) (Haile 1971), suggesting that a Mid- to Late Holocene age for the sequence at Gua Bintong is likely.

While a low-input approach to unit-manufacture persists on the Mainland (as it does in Island Southeast Asia), it appears that, during the Mid- to Late Holocene, bone tool inventories occasionally became larger and/or were sometimes supplemented with much more invasively worked forms. These included tanged and barbed bone arrow- or harpoon-heads, as evidenced at a number of sites, such as Gua Kechil in Malaysia — dated early for the Neolithic, to *c.* 5457±967 cal. BP (GX-0418) (after Dunn 1964; 1966; see also Bulbeck 2003) — and Khok Phanom Di, from 3852±80 cal. BP (ANU-5493) to 3542±149 cal. BP (ANU-5482) (Higham & Thosarat 2004); and in the form of 'waisted' flat-bone implements at Ban Lum Khao in Thailand, from 3346±49 cal. BP (Wk-4511) to 3188±120 cal. BP (Wk-4509) (Higham 2004). Thus far, similar finds have only been reported at one site in Island Southeast Asia: a tanged arrow and eyed needle from Gua Sireh, Borneo dated to 3441±225 cal. BP (ANU-7047) (see Ipoi Datan 1993).

To summarize, the first major shift in the frequency-of-occurrence of bone tools appears then to have occurred in eastern Island Southeast Asia, commencing during the period approximately equivalent to GIS-1, when there is a marked increase, especially point forms. Some of these were probably used as perforators; others show breakage patterns consistent with use as projectile armatures; a conclusion supported by evidence of cordage wear and worked hafting surfaces. By the beginning of the Holocene, the likelihood that hafted and probably composite implements were being used is very strong, through the innovative use of sting-ray spines at Niah, but also in relation to extractive implements at Gua Balambangan (Rabett 2005). From this time onwards, sites yielding a bone tool component appear from as far apart as New Guinea, to the southern half of the Thai/Malay Peninsula at Gua Bintong and into Java (Fig. 4). Multiple factors are likely to have been involved in the timing and geographic distribution of this technology. The explanatory model we present below attempts to take account of as many of these as possible but does not claim to be authoritative at this stage.

Southeast Asian bone technologies in regional context

At the end of the last glacial period Island Southeast Asia witnessed profound changes in climate and geography. The huge landmass of Sundaland that joined the islands of Borneo, Sumatra and Java to each other and the Mainland started to disappear as a result of global sea-level rise. Between 19,000 and 14,600 cal. BP the average lateral rate of transgression was about 0.41 m per 100 yrs and may have been as much as 5.3 m per 100 yrs during Meltwater Pulse 1A between 14,600 and 14,300 cal. BP (Hanebuth *et al.* 2000; Hanebuth & Stattegger 2003; Lambeck *et al.* 2002). Approximately 75 per cent of the land mass of the continent of Sundaland was ultimately lost to the sea (Bird *et al.* 2005; Sathiamurthy & Voris 2006); a fact that we cannot doubt would have had a dramatic effect on human settlement and subsistence, as well as on regional climate systems. Caves that were previously unoccupied when they were far inland during the LGM become the focus for habitation at the end of the Pleistocene (e.g. Lewis *et al*. 2008; Sémah *et al*. 2004). It has been argued that these dramatic changes in the geography of Southeast Asia were the catalyst for large-scale movements of peoples across the region and they are linked to developments in sailing technologies (Meachum 1984–85; Oppenheimer 2004; Solheim 2006).

Almost certainly innovations in technology will have been tied to associated shifts in resource availability as part of the process of groups adapting to these far-reaching environmental changes. Rabett (2005) postulated a possible link between the rise in bone tool occurrences and the exploitation of expanding mangrove forest resources; a proposition based both on archaeological near-coastal associations at Southeast Asian sites and on parallel evidence from the Early Holocene in the north Arnhem Land area of Australia (Allen 1986; White & Peterson 1969; Woodroffe *et al.* 1988). Another evident association, as noted above, appears to link the rise in the frequency of bone technology with an increase in the exploitation of arboreal rainforest fauna, particularly Cercopithecidae (leaf monkeys and macaques). To what extent this was driven by greater primate abundance and how much by technological innovation and hunting choice is not yet clear as the correlation between bone technology and this faunal staple is not a perfect one.

The Niah Caves faunal assemblages are among the most extensive in the region (a sample of *c.* 200,000 fragments from the most secure contexts were studied by the authors) and illustrate this well. Primates had always figured in hunting strategies at Niah, high incidence of bone technology had not. Even during the oldest occupation (Phase I) and using raw unadjusted NISP (Number of Identified Specimens) values, cercopithecids made up *c*. 10 per cent of NISP, *n* = 216/2072). The small component of bone tools from this period was not being made predominantly on primate bone, nor does it contain confirmed evidence of projectile points. Perhaps more importantly, the high incidence of cercopithecids from the GIS-1 occupation at Lobang Hangus (*c*. 22.5 per cent of total NISP, *n* = 737/3281), is not matched by such high levels during the main contemporary occupations in the West Mouth entrance to Niah, where they account for *c*. 12.4 per cent NISP, *n* = 257/2070; comparable to that seen during Pre-LGM. This contrasts again with the small Early Holocene assemblage excavated by the Niah Caves Project (Barker *et al*. 2002; 2003) in the West Mouth (Area D), where primate remains account for a full *c*. 48.5 per cent of an albeit small total NISP, *n* = 127/262; twice as high as that in Lobang Hangus. Most of the 31 osseous point fragments from Area D are mostly not made on primate bone and are as likely to have been used in fishing activities as arboreal hunting (Barton *et al*. 2009). Further afield, at the upland cave site of Hang Boi, Vietnam 14.3 per cent (unadjusted NISP) of the vertebrate fauna assemblage are cercopithecids during the period from 12,182±83 cal. BP (UBA-8373) to 10,620±64 cal. BP (UBA-8371) (Rabett *et al*. 2011). For this period only one enigmatic fragment of worked bone has been recovered. Work on-site in 2009 brought to light a bone point from *c*. 13,601±43 cal. BP (UBA-14887). Even so, correlation between the occurrence of primate remains and bone tools here is not strong. Finally, of the six sites listed in Bulbeck (2003) as showing a rise in the hunting of arboreal game during the Holocene, only one, Moh Khiew, contained any bone tools from this period.

This may be partly a taphonomic issue (see e.g. Langley *et al*. 2011), but part of the answer may also lie in the use of hunting technologies that were made on non-preserving organic materials, such as wood or particularly bamboo — long supposed to have been a mainstay of material culture in this region (e.g. Mijares 2008; Pope 1988). For example, ethnographically, bamboo or wooden blowpipes are frequently employed to hunt smaller to medium-sized game: squirrels, monkeys, bamboo rats, birds and civets (Bennett *et al*. 2000; Endicott 1984; Noone 1936; Rambo 1978). Darts are usually made from the leaf stalks of the sago — the species *Eugeissona tristis* is mentioned by Evans (1937). In this particular case, the antiquity of the blowpipe is a matter of debate. Some authorities see its first appearance in Borneo as coinciding with the arrival Austronesian-speaking people *c*. 4000 bp (King 1995; Sloan 1975) others favour an earlier regional heritage (e.g. Oppenheimer 1998), though evidence is inconclusive. Irrespective, components are unlikely to preserve unless under exceptional conditions. Some suggestion has been made that bone points might have served as blowpipe darts, though this seems unlikely on two counts — firstly, darts are characterized by their redundancy of form (e.g. Yost & Kelley 1983), something rarely apparent with bone points; secondly, there is no indication that hafting devices are ever used, while these are apparent on many bone points.

That there was a change in hunting strategy to one favouring a greater dependency on arboreal game *is* evident, but it is noteworthy that the timing of this 'arboreal-shift' is not uniform across the region: it happens earliest in Borneo, during GIS-1, during the Early Holocene in Java (Morwood *et al*. 2008; Sémah *et al*. 2004; Sémah & Sémah in press), and seemingly the Late Holocene on the Thai-Malay Peninsula (Bulbeck 2003, 148). Prevailing opinion certainly suggests that conditions across the Sunda Shelf were not uniformly forested during the Upper Pleistocene (Bird *et al*. 2005; Heaney 1991; Wurster *et al*. 2010) with both Java and to an extent the Thai-Malay Peninsula located within the proposed savanna corridor, and this may have been a factor in the timing for changes in hunting strategies across the region. It leads us to conclude that while primate abundance was probably a factor in the occurrence and distribution of bone technology as it rose in importance that rise is unlikely to have been governed by this variable alone.

The insularization of the region during the post-glacial presents another factor that may be expected to have helped shape its archaeological record from this period: namely, population movement. Although the full story is still far from clear, human genetic evidence does suggest that a local Southeast Asian ancestry for the greater proportion of people in the region extends back to between 5000 and 25,000 uncal. bp (e.g. Hill *et al*. 2007). The same authors also raise the possibility that considerable population movement had taken place several millennia before more familiar migrations associated with this region's Neolithic (e.g. Bellwood 2006). Communities bearing Haplogroup E genetic ancestry are thought to be almost entirely restricted to Southeast Asia and Taiwan, making this a particularly powerful marker with which to track any early population movements. Using data from a large cross-section of populations from Island Southeast Asia, west Papua and Taiwan, Soares *et al*. (2008) have shown that Haplogroup E has an age depth of *c*. 30,000 uncal. bp. They suggested that because Haplogroup E contains only three branches that extend into the

Late Pleistocene, and with only two of these older than *c*. 12,000 uncal. bp, the haplogroup appears to have undergone a significant bottle-neck event prior to a phase of regional dispersal. They also proposed that the most likely cause of this constriction and possibly subsequent diaspora was to be found in the consequences of deglaciation, and perhaps the rapid sea-level rise associated with the onset of GIS-1 (Hanebuth *et al*. 2000).

The increasing significance and abundance of bone tools from Island Southeast Asia and continued presence in Mainland Southeast Asian sites through the second half of the Last Termination and into the Holocene, together with possible association with coastal and sub-coastal sites fits comfortably with the genetic story of population dispersal and its point of northeastern origin during this same period. It can be considered only a superficial fit, however, until such a time as more concrete associative lines can be drawn. Models that equate Palaeolithic technology with early human population dispersals are well-known from other parts of the world — for example Clovis in North America, or the Aurignacian in Europe. The generally low-input nature of Southeast Asian bone technology (especially prior to the Mid-Holocene) may be considered distinctive in its own right (Rabett & Barker 2007), though this fact does make it difficult to support a dispersal argument based on the kind of stylistic or formal grounds used in the aforementioned regions with respect to stone tools.

An element of the doctoral research of one of us (RR) included the description and classification of bone tool assemblages according to levels and types of identifiable surface modification. Traces were quantified as expressions of primary (blank-shaping), secondary (principal manufacture) and tertiary (repair/re-use) manufacture and different forms and distribution of use-wear (see Barker *et al.* forthcoming; Rabett 2005). While this level of analysis was not extended to all site inventories containing bone tools across the region, some inter-site variation in production, use and repair regimes was hinted at through the sample of twelve assemblages that were studied in Rabett (2002). Little is yet known in detail about early settlement systems in Southeast Asia (Rabett & Barker 2010; Shoocongdej 1996; 2000); consequently such patterns could be symptomatic of differences in site function as readily as being individual tool reduction and use traditions.

The heterogeneous make-up of the tropical rainforest and the impact of the varied synchronous and asynchronous peaks in resource abundance within it are thought likely to have exerted positive selection pressures on the feeding habits of migratory tropical vertebrates (Leighton & Leighton 1983). Following from this, one might also expect that early tropical foragers likewise adopted mobility strategies which enabled them to exploit punctuated abundance in a range staples (Rabett & Barker 2010). If this was the case, locally-contingent patterns to subsistence may be a peculiar feature of the archaeological record of this region compared to that from more northerly latitudes, even during early population dispersal, simply because of differences in the structure of high- and low-latitude environments and people's approaches to living in them.

Development in bone technology in Island Southeast Asia may be on the threshold of joining several other lines of evidence that suggest the establishment of early and extensive communication networks across the wider region. These include the earliest tentative evidence of animal translocation, in the form of the northern common cuscus (*Phalanger orientalis*) moving from New Guinea to New Ireland perhaps as early as 20,000 years ago (Allen *et al*. 1989). This same species was then transported to the Solomon Islands, Bismark Archipelago and islands in the Moluccas (Heinsohn 2003). The furthest location of the common cuscus from its homeland is the island of Timor, where it arrived around 10,000 uncal. bp (Anderson & O'Connor 2008; Bulbeck 2008; O'Connor 2006; O'Connor & Aplin 2007). At the same time the brown dorcopsis (*Dorcopsis muelleri*) was introduced to Gebe and Halmahera Islands, the northern pademelon (*Thylogale browni*) to New Britain and New Ireland and the common spotted cuscus (*Spilocuscus maculates*) to New Ireland, Ambon, Pandar and Seram (Flannery *et al*. 1998; Heinsohn 2003). These early translocations from New Guinea indicate complex movements of people to and from here, presumably to increase the resource base on impoverished oceanic islands. Pig genetic studies have also shown that by *c*. 7000 cal. BP the Sulawesi warty pig (*Sus celebensis*) was translocated to Flores, the Moluccas and other islands in Wallacea (Dobney *et al.* 2008; Larson *et al*. 2007a,b; van den Bergh *et al*. 2009).

Another source of information on human contact and information transmission comes through the distribution of cultivated bananas (*Musa* spp.). Recent genetic evidence suggests that rather than being peripheral to the centres of banana domestication, New Guinea was the source. The crucial first step in the banana-domestication process, which involves the development of parthenocarpic forms, has been linked with the wild species *Musa acuminata banksii*, native to New Guinea (Kennedy 2009). Archaeological evidence dated between 6900 and 6400 cal. BP suggests the cultivation of bananas was already taking place at Kuk in the New Guinea Highlands, based on the relative frequency of banana phytoliths from the site and their distinctive shape, which matches *Musa acuminata banksii* (Denham *et al*. 2003; 2004). Edible diploid bananas derived from *Musa acuminata banksii* hybridized with other wild species of Island Southeast Asia, including *Musa acuminata errans*, native to the Philippines. The distributions of hybrid cultivated forms of banana suggest that New Guinea played an integral role in complex networks that included early east-to-west links connecting Melanesia and the Philippines with the rest of Island Southeast (Kennedy 2008).

Archaeological evidence for a substantial change in culture and ideology that does occur across the region comes with the appearance of new and similar human mortuary practices. The earliest-known modern human remains in Island Southeast Asia come from Tabon Cave (Détroit *et al.* 2004) and the Niah Caves (Barker *et al.* 2007), and on the Mainland from Moh Khiew (Matsumura & Pookajorn 2005). These show no categorical evidence of having been deliberately interred. The completeness of the last of these specimens makes it the most plausible for burial. The most well-dated — the 'Deep Skull' at Niah and the few post-cranial elements broadly associated with it (Krigbaum & Ipoi Datan 2005) — was mixed within a substantial refuse midden, including the remains of several partial animal carcasses (see Rabett *et al*. 2006; Piper *et al*. 2007; Rabett & Barker 2007; Piper & Rabett 2009b). Nothing survives to suggest that these early human remains were treated in any more special way than the other material in the midden, though clearly we cannot demonstrate an absence of purpose or ritual from this evidence.

The earliest clearly orchestrated burial in the region comes from Liang Lemdubu on the Aru Islands, at the edge of the Sahul Shelf. Here, a young female was interred sometime between 16,000 and 18,000 cal. BP, apparently in a seated position (Bulbeck 2006). On the Sunda continent the earliest known expression of this emerging burial tradition is again from the Niah Caves, and dates to *c*. 10,000 cal. BP (Lloyd-Smith 2008; Barker *et al*. 2011). Several individuals from here were also buried in a seated position. Other cases have been reported from the western and eastern margins of the Archipelago — e.g. at Gua Lawa, Song Keplek and Gua Braholo in eastern Java (Simanjuntak & Asikin 2004) and Ille Cave in northern Palawan, Philippines (Lewis *et al*. 2008). As all date from the Early to Mid-Holocene, this may suggest that particular stylistic traditions of mortuary practice were now emerging and becoming widely adopted, possibly marking a 'conceptual shift in the way people thought about life and death' (Lloyd-Smith 2008). The sudden appearance of such burials across this wide geographic area could suggest further evidence of population movements and/or the diffusion of cultural and social ideologies related to death and burial along established channels, though its relationship to proposed earlier movements is to be established.

From the current data, interactions between populations on different islands and the translocation of plants and animals increased in intensity, and possibly even the distances travelled between geographic locations broadened during the period from the Late Pleistocene to the Mid-Holocene. As Bulbeck (2008) has demonstrated, pre-Neolithic maritime connections were complicated spheres of interaction that may well have existed throughout Island and Mainland Southeast Asia. We tentatively propose that the rise in importance of bone technology and innovations associated with it may have been influenced not simply by changes in resource availability and access, but also as a result of intra-regional group interaction precipitated by those same changes.

Conclusions

In this article we have sought to examine the distribution and role of early bone technology from a specifically regional perspective. We have shown that occurrences can be traced back to at least *c*. 45,000 cal. BP at the Niah Caves in Borneo, and a similar age at Lang Rongrien in Peninsular Thailand. With particular reference to the Niah Caves, the variety of osseous artefacts recovered from this early phase of settlement suggests utilization in a range of different activities, though there is no clear evidence that this included composite projectile pieces (Rabett *et al*. 2006). By the end of the Pleistocene the amount of bone tools recorded from sites in the region increases significantly, while their site distribution also broadens considerably. It is conceivable that northern Borneo and parts of Wallacea featured prominently as an important locus of innovation in this technology. Although this equates quite well with intra-regional dispersal, as expressed in the genetics, direct association between these two lines of evidence is not yet proven. On the Mainland a different trend is observed: there is initially greater continuity in the low incidence of bone technology, as seen during the Late Pleistocene followed, it appears, by occasionally larger assemblages and/or the addition of much more intricate and standardized forms later on.

The wider occurrence and range of osseous implements through the Last Termination and into the Holocene suggests that no single pattern of use was associated with this technology, even when it was in its ascendancy. One specific and possibly new role for it, though, does appear to have been in composite range weapons. Use-wear analysis of bone points suggests that many (though not all) were employed as projectile armatures (Pasveer 2004; Pasveer & Bellwood 2004; Rabett 2005; Rabett & Piper in press). At some sites, intensification in bone tool use appears to have been accompanied by a broadening in the diversity of animals hunted — with a noticeable increase in arboreal taxa — but this is a neither universal nor a simple correlation, and the use of other organic media cannot be discounted. At Niah, the presence of discarded articular ends of monkey long bones exhibiting the groove-and-snap fracturing technique indicates that production of bone tools was likely happening on-site. In this instance, the increase in primate-hunting evidence from Lobang Hangus does imply that procurement was at least partly with an eye to acquiring a preferred raw material for tool production. At Gua Balambangan, the bone tool assemblage is dominated by edged forms made on much denser bone, with very few points, and procurement activities look to have been directed at resources in the mangrove swamps near to the site at this time (Rabett 2005; Zuraina Majid *et al*. 1998). In further contrast, at Kria Cave in the Birds Head, New Guinea and Golo Cave on Gebe Island bone tools appear to be dominated by perforators and awls. At Liang Nabulei Lisa, Pasveer (2006) has argued that the diverse range of tools suggests they were produced to serve particular functions specific to that site.

Finally, it is worth briefly comparing the Southeast Asian record to those emerging in other parts of Asia, where locally contingent patterns are also being documented. For example, the Sri Lankan site of Batadomba-lena (Perera 2010; Perera *et al*. 2011) contains a large bone point assemblage (*n* = 194); the earliest instances of which date to *c*. 35,977±409 cal. BP (Wk-19963), but most are again concentrated in the period covered by the Last Termination. Cercopithecidae bones were used in point fabrication and the possibility that many represent projectile armatures is proffered (Perera 2010), though their wide metrical variation is taken as evidence that they probably served a range of different functions. Where Batadomba-lena differs from a site like Niah is that rainforest cercopithecids are the dominant hunted fauna through-out the archaeological sequence, perhaps implying the use of more than one technology over time to acquire them. There is also more overt evidence of symbolic practice in shell and other media than is seen at Niah during this period. The use of bone as a tool medium and possibly for projectiles carries intriguing parallels and timing with the Southeast Asia record, but does so as part of a suite of behaviours and adaptations that exhibit their own local distinctiveness (Perera *et al*. 2011).

A perhaps more visible contrast is that with trends in bone technology seen in north Asia, where confirmed bone tools also begin to appear at about the same time. For example, a wide range of pieces have been recorded from Layers 9 and 11 at the site of Denisova Cave in southern Siberia (e.g. Derevianko 2010), dating to *c*. 42,332±885 cal. BP (SOAN-2504) (after Dolukhanov 2002). The emphasis and spheres of innovation in this region included the development of bone perforators (including eyed needles), carvings and pieces of adornment; trajectories that continue through the late glacial (e.g. Kuzmin 2008) — similar forms appear in Southeast Asia, but only in the context of the region's Neolithic and Metal Age. The use of bone as projectile armatures is also to be found in Siberia, particularly so after the LGM when it is linked to the development of microlithic technology and inset weapons; innovations that are considered to have been part of a northern adaptation towards enhancing provisioning and averting risk under harsh winter conditions and low resource abundance (Elston & Brantingham 2002).

The apparent inter-site variability in bone-tool occurrence and use in Southeast Asian sites may reflect localized subsistence practices, themselves prompted by environmental heterogeneity. The rise to prominence of this technology also took place within the context of significant changes to landscape and resource availability. Notable developments in projectile forms were likely to have been closely tied to human responses to these changes — in particular, it appears, in those settings that were becoming increasingly insular through deglaciation at higher northern and southern latitudes.

Orthodoxy would suggest that such developments were occurring outside, later than, and remote from the genesis of this technology (considered to have been in Africa) and that they were, therefore, not directly related to the emergence of species-defining behavioural traits. We would argue, however, that early human colonization and settlement of different environments came about through the process of adaptation rather than the imposition of a set of faculties attained in one region and then disseminated around the world without significant change. We would suggest that 'humanity' was (and will continue to be) defined by multiple contributing and emerging traits; and that the local and temporal distinctiveness of these, including the use of and innovations in bone technology, should be viewed as no less important to its characterization.

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