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The zooarchaeology of carnivores in Borneo, with a proposal for continuing collection

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Abstract. Excavations in the Borneo states of Malaysia, notably but not solely at Niah caves, Sarawak, have provided samples of the mammals that lived over the past 50,000 years, confirming close relations with a wider Sundaic subregional fauna. Most attention has been paid to the abundant remains of primates, pigs and perissodactyls. Carnivore zooarchaeology is less rich. While 17 species have been recognised positively, most specimens are identifiable only to family (e.g., civet [Viverridae] or cat [Felidae]), or genus (e.g., mongoose *Herpestes*). Through a period of climate change, records of species such as sun bear *Helarctos malayanus* and binturong *Arctictis binturong* reinforce evidence that a forest refugium persisted in northern Borneo. During the Last Glacial Maximum (LGM), a central zone of savannah separated forest-adapted carnivores of the east and west of the Sunda subregion. Post LGM, the land link was finally severed by rising sea levels about 10,000 years ago. Unexpected discoveries were three osteological specimens of tiger *Panthera tigris* dated from about 14,000 years ago to the Metal Age. Among small carnivores, a mixed assemblage suggests incidental additions to the diet of human cave visitors in which bearded pig *Sus barbatus* and primates predominated. Of carnivores, only binturong is represented in numbers indicating directed hunting policy. Within a long tradition of bone tools, projectile tips appeared from the 12th millennium before present. Probably carrying a toxin, their use may account for large carnivores appearing in the zooarchaeological record at this time and was reflected also by an increase in the proportion of arboreal mammals, including civets, among human quarry. No clear identification of carnivores in burials was noted until a 15th century CE funereal cave, where lower jaws suggested that domestic dogs *Canis familiaris* had been eaten. Metal Age human burials, however, were the source of carnivore teeth bored through the root, notably binturong, Sunda clouded leopard *Neofelis diardi* and sun bear, showing usage as strung 'beads' or as ear plugs, paralleling modern custom among interior people. A scenario has been proposed linking Mid-Holocene post-cranial remains of a canid, and later undisputed dental remains of domestic dog, to show an early, pre-Neolithic introduction of this companion carnivore to Borneo. Future development of the regional zooarchaeology of carnivores depends on improved comparative collections in museums, for which policies including a programme for the acquisition of road kill specimens would make a useful contribution.

Keywords. binturong, domestic dog, Holocene, Late Pleistocene, Metal Age, Mustelidae, otters, road kill, tiger, Viverridae

Abstrak (Bahasa Indonesia). Penggalian di negara bagian Borneo, Malaysia, terutama di Gua Niah, Sarawak, mendapatkan berbagai spesimen mamalia yang hidup 50.000 tahun yang lampau. Ini membuktikan hubungan yang dekat dengan fauna di wilayah dataran Sunda. Perhatian lebih ditujukan pada spesimen yang berlimpah, dari bagian-bagian tubuh primata, babi serta perisodaktila. Zooarkeologi spesimen karnivora tidaklah banyak. Sejumlah 17 spesies telah diidentifikasi, namun kebanyakan spesimen hanya dapat diidentifikasi pada tingkat suku (musang Viverridae, kucing Felidae) atau marga (garangan, *Herpestes*). Melalui periode perubahan iklim, catatan keberadaan spesies seperti Beruang Madu *Helarctos malayanus* dan Binturong *Arctictis binturong* memperkuat bukti keberadaan hutan pengungsian yang ada di Borneo utara. Pada periode akhir glasial maksimum, wilayah pusat savana memisahkan karnivora teradaptasi hutan antara bagian timur dan barat dataran Sunda. Pasca periode akhir glasial ini hubungan antara daratan akhirnya terpisah dengan menaiknya garis pantai pada 10.000 tahun yang lalu. Penemuan tidak terduga adalah tiga spesimen tulang belulang Harimau *Panthera tigris* dari masa 14.000 tahun yang lalu hingga Periode Besi. Diantara serpihan spesimen karnivora, menunjukan bahwa manusia pengunjung gua kadang memanfaatkannya sebagai sumber makanan mereka, dengan babi *Sus barbatus* dan primata yang paling dominan. Diantara karnivora, hanya Binturong yang tampak jelas sebagai sumber makanan mereka. Sebagai alat tradisional berbahan tulang, ujung tombak telah digunakan sebelum masa milenium ke 12. Kemungkinan menambahkan racun, penggunannya pada masa itu tampaknya banyak diperuntukkan untuk karnivora besar, dan semakin jelas dengan semakin meningkatnya proporsi mamalia arboreal buruannya, diantaranya musang. Keberadaan karnivora di kuburan manusia dalam gua mulai tampak jelas pada era abad ke 15, dimana rahang bawah yang diduga berasal dari Anjing Domestik *Canis familiaris* juga menjadi santapan mereka. Pada kuburan di Periode Besi, ditemukannya gigi karnivora yang dilubangi bagian akarnya, khususnya dari kelompok Binturong, Macan *Neofelis diardii* serta beruang madu menunjukkan adanya pemanfaatan sebagai hiasan penutup telinga, suatu perhiasan yang dipakai manusia modern. Suatu skenario telah dibangun yang mencoba menghubungkan bagian-bagian rahang kelompok anjing, dan kemudian gigi Anjing Domestik, yang menunjukkan perkembangan pemanfaatan hewan sebagai pendamping manusia. Perkembangan pemahaman zooarkeologi dari kelompok karnivora sangat bergantung dari adanya perbandingan diantara koleksi museum, termasuk kebijakan pengumpulan semua spesimen mati akibat kecelakaan di jalanan, akan memberikan kontribusi yang berguna.

Abstrak (Bahasa Malaysia). Penggalian di negeri-negeri Malaysia di kepulauan Borneo, terutama tetapi tidak hanya di Gua Niah, Sarawak, telah memberikan contoh mamalia yang hidup sejak 50,000 tahun dahulu, dan mengesahkan hubungan rapat dengan kumpulan haiwan di perantauan Sunda. Tumpuan lebih diberikan kepada tinggalan yang banyak daripada primat, babi dan binatang berkuku angka ganjil (perissodactyls). Kajian tinggalan haiwan (zooarchaeology) jenis karnivora kurang banyak. Walaupun 17 spesis diidentifikasi secara positif, namun kebanyakan spesimen hanya dapat diidentifikasi hingga ke peringkat keluarga (contohnya musang [Viverridae] atau kucing [Felidae]) atau genus (contohnya bambun/garangan Herpestes). Melalui zaman perubahan iklim, rekod-rekod spesis seperti Beruang Madu *Helarctos malayanus* dan Binturong *Arctictis binturong* mengesahkan bukti yang sesuatu hutan perlindungan telah wujud di utara Borneo. Semasa zaman glasial maksima terakhir (Last Glacial Maximum, LGM), suatu zon sentral yang terdiri dari padang savana mengasingkan karnivora yang teradaptasi terhadap hutan antara bahagian timur dan barat perantuan Sunda. Selepas LGM, hubungan darat akhirnya terpisah akibat kenaikan paras air laut kira-kira 10,000 tahun dahulu. Penemuan yang tidak terduga adalah tiga specimen tinggalan tulang (osteological) dari Harimau *Panthera tigris* dari zaman kira-kira 14,000 tahun dahulu hingga ke zaman logam (Metal Age). Serpihan spesimen karnivora kecil yang terdiri daripada kumpulan yang bercampur-aduk menunjukkan bahawa ianya digunakan sebagai sumber makanan sampingan bagi manusia pengunjung gua, di mana Babi Hutan *Sus barbatus* dan primat yang paling banyak. Di antara karnivora, hanya Binturong dijumpai dengan angka yang jelas menunjukkan ianya menjadi sasaran pemburu. Dalam tradisi lama penggunaan peralatan yang dibuat daripada tulang, hujung mata pelontar hanya muncul dari alaf ke 12 sebelum zaman sekarang. Mungkin membawa toksin, penggunaanya mungkin menerangkan terjumpanya karnivora besar di kalangan rekod-rekod tinggalan haiwan pada ketika itu, dan semakin jelas dengan peningkatan kadar mamalia arboreal (atas pokok), termasuk musang, di antara hasil pemburuan manusia. Tiada tinggalan karnivora jelas dikesan di perkuburan manusia sehingga abad ke 15, di mana rahang bawah dari Anjing Domestik *Canis familiaris* menunjukkan yang ianya juga menjadi bahan makanan. Dari kubur manusia daripada zaman logam terjumpanya gigi karnivora yang digerek hingga ke akar, khususnya dari Binturong, Harimau Dahan Sunda *Neofelis diardi* dan Beruang Madu, menunjukkan penggunaannya sebagai manik rantai atau perhiasan telinga, serupa dengan adat moden Orang Ulu. Suatu senario telah dicadangkan yang mengaitkan rangka tulang dari keluarga anjing dari zaman pertengahan Holocene, dan kemudiannya tinggalan gigi Anjing Domestik, yang menunjukkan perkembangan awal dari zaman pra-Neolithic penggunaan haiwan ini sebagai haiwan dampingan manusia di Borneo. Perkembangan di masa depan dalam bidang kajian tinggalan haiwan serantau bergantung kepada peningkatan koleksi perbandingan di antara muzium-muzium, di mana polisi-polisi termasuk program untuk mendapatkan bangkai jalanan (road-kill) akan menjadi suatu sumbangan yang berharga.

INTRODUCTION

The generally alkaline nature of Borneo cave soils (Wilford, 1964), when coupled with dry conditions in cave mouths and rock shelters, can preserve mammal bones and teeth in good condition for many thousands of years. In Borneo, by far the greatest quantity and diversity of mammal remains have been recovered from Niah caves, Sarawak, Malaysia, reflecting the unmatched volume and depths of the archaeological deposits, and the resources applied to the task (Leh & Datan, 2013). Excavations in this multi-mouthed cave system were initiated by the Sarawak Museum in 1954 (Harrisson, 1958) and continued until 1965, revisited by Majid (1982) and again by the Niah Caves Project in 2000–2004 (Barker et al., 2007). Results from this important site have been reviewed comprehensively and evaluated by contributors to an impressive first volume of a projected two-volume report (Barker, 2013), from which much of the information below is drawn.

Studies have concentrated mainly on larger mammal species: primates, pigs *Sus* Linnaeus, and perissodactyls. The Carnivora are less well represented. Yet identifications of carnivore remains from Niah and other archaeological sites offer perspectives on a range of subjects including climate change and zoogeography, and human use of this resource, from the Late Pleistocene to the present (i.e., the past 50,000 years). Osteological remains of tiger *Panthera tigris* (Linnaeus), occurred from Early Holocene to Metal Age, posing the unsolved problem of the subsequent extinction of this largest cat. Zooarchaeology has also defined the characteristics of early domestic dog *Canis familiaris* Linnaeus, in Borneo. It is likely that further study, especially of post-cranial remains in the zooarchaeological collection of the Sarawak Museum, will improve on the information summarised below.

Conventions. Useful abbreviations are NISP (number of identifiable specimens), and MNI (minimum number of individuals). The abbreviation 'BP' denotes age before present based on calibrated C_{14} dates, when available, the abbreviation 'ka' denotes thousands of years (ago) and 'Ma', millions of years. As defined in the text, LGP is the Last Glacial Period, i.e., following the end of the Eemian interglacial around 115 ka, and LGM the Last Glacial Maximum, roughly 23–18 ka. 'BC' and 'CE' bear their conventional meanings in relation to the common dating system. Systematic names of carnivores, as used elsewhere in this volume, are given in Table 1, and at first mention in the main text, together with conventional English names. Thereafter, the latter are used.

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Table 1. Carnivores identified in archaeological excavations in Sarawak and Sabah from four periods of prehistory.

Order **Species**	**Late Pleistocene**	**Note**	**Terminal Pleistocene**	**Note**	**Early Holocene**	**Note**	**Neolithic – Metal Age**	**Note**
AGE (years ago)	50,000–35,000		35,000–11,500		11,500–4500		4500 – Present	
NISP all mammals (Niah)	1379		2990		2791		118	
Carnivora (Caniformia)								
Helarctos malayanus	0.15%		X	2	0.21%	4	X	9
Canis familiaris							X	7, 8
Canidae indet.					X	8		
Martes flavigula			0.07%	3				
Mustela nudipes			X	2				
Melogale everretti			X	2				
Mustelidae indet.	0.07%	1	0.10%	3				
Lutra sumatrana			X	2	0.11%	4		
Aonyx cinereus			0.03%	3				
Carnivora (Feliformia)								
Viverra tangalunga			0.10%	3	0.04%	4	X	2
Paradoxurus hermaphroditus	0.22%	1	0.10%	3				
Paguma larvata	0.44%	1	0.27%	3				
Arctictis binturong	0.73%	1	4.62%	3	1.18%	4	0.85%	5
Arctogalidia trivirgata			0.03%	3				
Hemigalus/Diplogale indet.			0.07%	3	0.04%	4		
Viverridae indet.	0.44%	1	3.28%	3	1.61%	4		
Herpestes indet.			0.07%	3	0.14%	4		
Panthera tigris			X	8	0.04%	4	X	6
Neofelis diardi			0.03%	3	0.21%	4	X	2
Catopuma badia			0.03%	3				
Prionailurus planiceps			0.03%	3				
Prionailurus bengalensis	0.07%	1	0.30%	3	0.18%	4		
Felidae (small cats) indet.	0.51%	1	1.37%	3	0.72%	4		

Notes:Late Pleistocene 50,000–35,000 years ago, represented by 'Hell' trenches in the West Mouth, Niah cave; Terminal Pleistocene, 35,000–11,500 years ago; Early Holocene, 11,500–4500 years ago; Neolithic and Metal Age, 4500 years ago to (near) present. X denotes presence; % denotes proportion of the total NISP (Number of Identifiable Specimens) of all mammals from a specific site.

(1) Percentages of NISP (Number of Identifiable Specimens) of 1379 identifiable mammal specimens listed by P.J. Piper and R.J. Rabett in their Table 4.2 – *Identified vertebrate fauna from the Hell Trench and associated deposits [West Mouth, Niah caves]* (Barker, 2013: 160). *(2)* Medway, 1958. *(3)*. Percentages of NISP 2409 mammal specimens listed by PJP and RJR in Table 5.10 as '*represented in the Late/Terminal Pleistocene deposits from West Mouth areas A & B and Lobang Hangus, Niah caves*'; including identifications by Medway (1958), (Barker, 2013: 200). *(4)* Percentages of NISP 2663 mammal specimens listed by PJP and RJR in Table 6.5 as '*represented during the Early Holocene occupation of the West Mouth ... and Early to Mid Holocene at Gan Kira',* Niah caves (Barker, 2013: 342). *(5)* Percentages of NISP 117 mammal specimens listed by PJP and RJR in Table 7.13, likely to be of Neolithic age (4000–2000 years ago) from West Mouth, Niah caves (Barker, 2013: 295). *(6)* Hooijer (1963). *(7)* Cranbrook (2014). *(8)* Medway (1973). *(9)* Harrisson & Medway (1962).

ZOOARCHAEOLOGY OF BORNEO CARNIVORES

The presence of osseous remains in an archaeological deposit is affected by a mix of factors. Included are the habits of the animal itself. Animals that naturally frequent caves may be 'trogloxenes' (= cave guests), i.e., habitually shelter in caves but depend on resources outside (e.g., bats), or 'troglophiles' (= cave lovers), i.e., may use the resources of caves but can live equally well outside. Natural casualties among both groups are of zooarchaeological interest.

The default decision of the zooarchaeologist is that the remains of mammals other than proven trogloxenes and troglophiles, especially those of large species, were brought into the cave by people for purposes including consumption as food. An indeterminate example may be leopard cat *Prionailurus bengalensis* (Kerr). At Niah remains of wild cats (probably mostly leopard cat) were comparatively abundant in the central area of the West mouth excavated in 1954–1958 accounting for NISP 34 (10%) of 341 mammal specimens (Medway, 1958: Table II). In the wider frame of all excavations at Niah caves, leopard cat and Felidae indet. were moderately abundant through all Pleistocene and Early Holocene contexts (Table 1). This level of representation probably reflects the troglophile habits of this ground-dwelling carnivore, which enters caves in search of fallen bats or swiftlets (*Collocalia* Gray, or *Aerodramus* Oberholser), or other casualties. The sparse records of carnivorous civets, e.g., Malay civet *Viverra tangalunga* Gray may reflect similar habits (Table 1). Regardless of these behavioural characteristics, all occurrences contribute zooarchaeological information.

Palaeobiogeography and palaeoecology. The present tally of wild mammals of Borneo is some 285 terrestrial and freshwater species, including 55 endemics recognised by Wilson & Reeder (2005). At the level of family and genus, this assemblage is obviously related to the mammals of peninsular Malaysia, Sumatra, Java and Bali, together constituting a subregional Sundaic fauna. Borneo, however, at present (but see below) lacks several large mammals that occur elsewhere in the Sunda subregion, including tiger, leopard *Panthera pardus* (Linnaeus), and dhole *Cuon alpinus* (Pallas). Conversely, the smaller carnivores include three endemic species, bay cat *Catopuma badia* (Gray), Hose's civet *Diplogale hosei* (Thomas), and Bornean ferret badger *Melogale everetti* (Thomas). The status of the unique specimen of Hose's mongoose *Herpestes hosei* Jentink, is equivocal, but this name was synonymised with short-tailed mongoose *Herpestes brachyurus* Gray, by Corbet & Hill (1992) and most subsequent workers.

Living Bornean carnivores are adapted to the prevailing humid equatorial environment, but archaeology has shown that the present climate is not representative of past environments. From about 2.7 Ma, during the period of emergence of many living carnivore species, the world has undergone repeated, oscillating patterns of climate change during which cold phases (or 'glacials') lasting around 100,000 years, have alternated with briefer warm periods ('interglacials') of 10,000–15,000 years. During glacials the expansion of polar and high-altitude ice sequestered much of the world's finite supply of free surface water, with consequent global lowering of sea level and expansion of exposed land surface, including the bed of the South China Sea. Rainfall was generally reduced, and wind velocities increased, resulting in enlarged arid zones in many parts of the world (Wilson et al., 2000).

The last glacial period (LGP) began about 115 ka, after which global ambient temperatures cooled by stages. The final, coldest stage began at about 35 ka and reached extreme conditions about 23–18 ka (the Last Glacial Maximum, LGM) when global mean temperatures were around 5–6°C below present (Kershaw et al., 2007), and sea levels lowered by 124–130 m (Hanebuth et al., 2009). For about 40% of the LGP, the Greater Sunda Islands, the Thai–Malay Peninsula and Indochina were united in a land area of subcontinental dimensions (Voris, 2000; Woodruff, 2010), thereby permitting faunal exchange within the Sundaic subregion. Eastward, at all times the Macassar Straits (Selat Makasar) formed a permanent deep sea-barrier between Borneo and Sulawesi.

During glacial maxima, including LGM, Sundaic rainforest was reduced to refugial areas: along the west coast of Sumatra, and in northern and eastern Borneo (Bird et al., 2005). Zooarchaeology provides evidence that Niah fell within such a refugial forested area. The Late Pleistocene fauna of 50,000–35,000 years ago included mammal species characteristic of rainforest habitat, such as arboreal primates: orang-utan *Pongo pygmaeus* (Linnaeus), long-tailed macaque *Macaca fascicularis* (Raffles), and langurs of the genus *Presbytis* Eschscholtz. Also present were sun bear *Helarctos malayanus* (Raffles), and binturong *Arctictis binturong* (Raffles), together with less specialised semi-arboreal civets (Table 1). Although large ungulates favoured by a more open environment with copious browse and grazing were included, as well as bearded pig *Sus barbatus* Müller (Barker, 2013: Table 4.2), this assemblage of forest-adapted primates and carnivores confirms the persistence of forest cover in the vicinity of Niah caves.

At the LGM, the Sumatran and Bornean forest refugia were separated by a zone of savannah vegetation running obliquely through the centre of the exposed Sundaic subcontinent through the Malay Peninsula to Java, possibly impinging on central and west Kalimantan (Bird et al., 2005; Wurster et al., 2010). This imposed an ecological barrier to the movement of forest-adapted carnivores, and isolated the Bornean endemics. Simultaneously, under the cooler, drier climate of the LGM, the upper altitudinal boundary of lowland forest may have been lowered locally by as much as 1000 m (Cannon et al., 2009). On botanical grounds, Ashton (2014: 435) has argued that cooling of this extent is improbable, because it would have led to the extinction of much of the lowland flora, including Mixed Dipterocarp Forest, now the prevalent forest cover in Borneo. None the less, it is indisputable that there were changes in the composition of the forest in the neighbourhood of Niah, affecting resources for frugivorous carnivores. For example Medway (1958) identified the Bornean ferret badger from the Niah excavation, a species which is today restricted to the higher altitudes of Kinabalu Park, Crocker Range Park and the surrounding areas of Sabah (Wilting et al., 2016), corroborating lowered ambient temperatures in the Late Pleistocene.

From 18 ka, interrupted by a final cool period shortly before the onset of the Holocene era, the world re-warmed, ice-fields shrank and the seas filled again. Using data from Voris (2000), Cranbrook (2000) estimated that the last land-bridge connecting Kalimantan Barat (West Kalimantan) to Sumatra (through Belitung and Bangka) was flooded about 10 ka, after which unassisted exchange of carnivore species would have been prevented. The glacier on the summit of Gunung [=Mount] Kinabalu melted about 9000 years ago (Jacobson, 1978). During the mid-Holocene, the climate warmed to its greatest extent. Locally, at 4850–4450 years ago, South China Sea levels peaked at about 5 m above present mean datum (Horton et al., 2005), invading much of the land now under lowland peat swamp forest, which would have become a scarce habitat.

An unexpected zooarchaeological discovery was the presence of tiger, shown by three distinctive items: a broken left 4th metacarpal (fore-foot bone) found among a rich accumulation of the debris of butchery, beneath a rock overhang adjoining the central occupation zone of the West mouth, Niah caves, securely dated within the Terminal Pleistocene at 13,745±55 BP (Piper et al., 2007); a navicular (foot bone) from Madai cave, Sabah, in a deposit of Early Holocene age, 10,500–3000 years ago (Harrison, 1998); and the crown of a canine tooth, in the process of erupting and therefore from a very young animal, at a superficial level of Neolithic or Metal Age in the West mouth, Niah caves (Hooijer, 1963). None of these remains is likely to have been an item of trade or value, and the occurrence of adult foot bones implies that these were slaughtered animals processed in the cave, probably for food. Tigers survived into the 20th century in Java and Bali, and still exist in Sumatra (Corbet & Hill, 1992). Present day tiger canines in ethnic artefacts in Borneo, real or faked, may include imports from elsewhere in the Sunda subregion. On the other hand, the variety of local dialect names for tiger, the associated folklore, and even some suspect photographs (Medway, 1977a) point to a recent date for the final extinction of this top predator (Piper et al., 2007). Zooarchaeology cannot yet provide a satisfactory reason for the disappearance of tigers.

The variety of civets (Viverridae Gray) among the identified mammal remains from Niah caves increased in diversity in the Terminal Pleistocene (Table 1). The least common was the most ground-dwelling, Malay civet, and the increased representation of more arboreal species is attributed to technological advances among human cave visitors (below). Records of mongooses (Herpestidae Bonaparte) were few and inadequate for species identification.

Carnivores as food. When evident, charring of animal bone indicates the use of fire in cooking or other treatment, and implies use as food. More positive such indication is proof of butchery with the use of sharp tools. A characteristic sign is one or more short nicks on a shaft bone, just below the head, at the point where the attachment of a large muscle or a tendon is severed.

The most feared large carnivore still extant in Borneo, the sun bear, is represented in the zooarchaeological record from Late Pleistocene to Metal Age (Table 1). With NISP 5, sun bear formed 1.5% of the identified mammal specimens from the excavations at Niah of 1954–1958 (Medway, 1958, 1959). The early specimens were presumably food remains but with burials of Neolithic/Metal Age in Gan Kira, Harrisson & Medway (1962) found canine teeth of bears bored for ornamental function (see below), and it is possible that at this time sun bears were targeted for their canines as value objects.

Other members of the Suborder Caniformia have been identified in small numbers (Table 1), including the two otter species, hairy-nosed otter *Lutra sumatrana* (Gray), and Asian small-clawed otter *Aonyx cinereus* (Illiger), the yellow-throated marten *Martes flavigula* (Boddaert), and Malay weasel *Mustela nudipes* Desmarest. All have anal scent glands, emitting strong, offensive smells and may have been incidental by-catch from passive trapping methods, rather than chosen human quarry.

The largest cat (Suborder Feliformia) now present in Borneo, Sunda clouded leopard *Neofelis diardi* (Cuvier), is represented at Niah from Terminal Pleistocene and subsequently (Table 1). Further afield, a foot bone (metapodial) was identified in Sireh cave, south-west Sarawak (Cranbrook, 2012). Although not charred, the context implies that this individual was processed in the cave, and therefore probably represented food remains.

The only civet (Viverridae) represented in sufficient number to confirm other evidence that it was preferentially targeted as human quarry is the largest and, with a prehensile tail, among the most arboreal, the binturong, with NISP 17 (out of 19 Viverridae) in the 1954–1958 sample (Medway, 1958: Table II). Among 30 examples of cut and chop marks on bones from an assemblage of Late Pleistocene age, 50,000–35,000 years ago, one was binturong (PP & RR, in Barker, 2013, Table 4.3) proving that the earliest human cave visitors successfully hunted this arboreal carnivore, and ate its meat. In binturong remains dated 35,000–11,500 years ago, multiple transverse cut marks at the distal end of humerus or proximal ends of radius and ulna were particularly prominent. These butchery marks reflected the hard, repetitive strokes necessary to sever the strong forelimb muscles adapted for climbing (RR & PP, in Barker, 2013: 207).

Bone tools. At Niah in particular, and in other Borneo cave sites, there are numerous artefacts of bone or, less often, teeth (notably pigs' tusks) showing deliberate shaping, and often wear by use. The functions of such 'tools' of bone or tooth are not always self-evident but, in a preliminary classification, Harrisson & Medway (1962) gave utilitarian names to the variety of morphological types found at Niah caves West Mouth, during excavations of 1954–1958: drifts & rods (four in number), awls (five), simple points (32), gouges (41), spatulas (10), with pig tusk tools (19) and cut fragments of turtle carapace polished or ground for some purpose.

Overall, ‘Simple points’ accounted for the most frequent type of bone tools at Niah, not necessarily all performing the same function. A worked bone tool of this type is among the oldest found at Niah, in context dated around 45 ka, and has been identified as an ’awl’ (Rabett et al., 2006). A simple bone tool of this form was found elsewhere, in a Neolithic context in Sireh cave, Serian (Datan, 1993: 113). Excavations in the Lubang Hangus mouth of Niah cave yielded 43 bone points securely dated between 14,206–15,061 cal. BP (OxA-13936) and 12,444–12,811 cal. BP (OxA-14038). Fourteen of these had definite signs of manufacture and use-wear as projectile tips; one had transverse striations consistent with being bound or hafted to a shaft (HB, PP & RR in Barker, 2013: 209). More sophisticated versions became common later (RR in Barker, 2013: 234).

Small-scale excavations undertaken in the West mouth in 2001–2002 produced a new suite of 31 osseous point-forms, of which half were made from sting-ray spines that had clearly been modified for hafting. The contexts that yielded these pieces were dated between 10,886±148 cal. BP (OxA-12391) and 8,793±109 cal. BP (OxA-18358), i.e., Early Holocene. The comparative frequency of sting-ray spines and bone points implied that both were projectile heads that were removed or fell out of game as it was being butchered in the cave mouth (Barton et al., 2009).

Complementing this evidence of a projectile armature was an increase in the proportion of arboreal mammals, including civets, relative to ground-dwelling species (Piper & Rabett, 2009; Rabett & Piper, 2013). Because the sting-ray spine tips appear to lack the weight to cause a fatal wound, and the thicker, round-edged points manufactured from mammal bone were unlikely to penetrate deeply into vulnerable tissue, it is probable that both carried a toxin. It appears that a distinctive (chemo-)technology among present Borneo rural communities was already familiar some 11,000 years ago, providing an explanation for the appearance in the zooarchaeological record at that time of large carnivores: sun bear, tiger and Sunda clouded leopard (Table 1).

A second change noted during the Terminal Pleistocene – Early Holocene was an increase in nocturnal mammals, including leopard cat, binturong and masked palm civet *Paguma larvata* (Smith). However, this was attributed to the likely use of snares or nooses (Barker, 2013: 209) to which small carnivores would have been susceptible. Evidently, there may be also a deep history to the traditional ingenious traps, baited or unbaited, nooses, snares, nets etc. made of natural materials, and set by Borneo hunters on the ground or on or between the branches of trees (Roth, 1896).

Funereal associations. Sireh cave, Sarawak, was famously the site of a murder, with the victim’s corpse left in place (St John, 1862, 1: 214–216) but it was used also for the reverent disposition of the dead, as were so many caves throughout Borneo. The comparatively small entrance chamber was used for shallow inhumations and the secondary deposition of human remains, in many cases after incineration (Datan, 1993). Much animal bone of great variety was also recovered, mainly in the forward area of the cave, whereas human bone was concentrated in the rear zone (Cranbrook, 2012). While this cave may have served both as cemetery and shelter, some at least of the animal remains surely represent the residue of funereal feasts, or of offerings for the dead. At the West mouth, Niah cave, compared with the richly and varied mammal faunas of Late Pleistocene to Early Holocene (Table 1) the sparse NISP of 117 mammal remains of the Neolithic period (PP and RR, in Barker, 2013: Table 7.13), may represent only funereal feasts or offerings associated with the use of this mouth as a cemetery at this time, rather than a refuge or temporary residence.

The association of carnivore remains with funereal ceremony was clear in Lubang Kudih, Beluru, Sarawak, a small cave (37.2 m²) high in a limestone cliff above a river, excavated by Woodfield (2005). This cave offered no attractions as a shelter and had been used solely as a repository for the remains of 150–170 people, originally in wooden coffins. Accompanying grave goods and personal ornaments of the deceased were dated to late 15th century CE. The principal mammal remains were lower jaws of small dogs (MNI 24) (Medway, 1977b) and small domestic pigs (MNI 94) (Medway, 1973). The retention of lower jaws as trophies, or mementos of significant feasts, can be compared to modern custom among Orang Ulu (see also Barker, 2013: Fig. 6.31), and as evidence that both pigs and dogs at Lubang Kudih were cooked before being dismembered and, presumably, eaten.

Adornment and art. The dead interred in caves were frequently accompanied by personal adornments made from parts of mammalian skeleton. Among grave goods found at Niah, notably at Gan Kira, were small carnivore canines bored with a single hole in the mesio-distal plane near the apex of the root, generally showing wear round the edges of the boring as evidence of being strung, and in some instances found in situ with beads. The majority of those that could be identified were teeth of binturong (Harrisson & Medway, 1962), once again showing the multiple functions derived from the remains of this civet. Another example was found at Jambusan (Cranbrook, 2013).

Even the sophisticated and wealthy community of the Ming era using Lubang Kudih took with them to the grave not only ornamental items of metal, and a hoard of antique beads, but also a small carnivore canine, its root pierced to be suspended from a string, with holed bearded pig tusks and four astragulus bones of the hock of chevrotains (mousedeer) *Tragulus* Brisson, also pieced to be strung. Necklaces of such mixtures of teeth and bones are still found in modern use, and for sale in craft and antique shops.

Double-bored canines of large carnivores (Sunda clouded leopard and sun bear) reported from Niah by Harrisson & Medway (1962) also reflect contemporary usage by Orang Ulu groups as ear plugs. Intriguingly, Niah examples (all from Metal Age contexts) included faked Sunda clouded leopard canines manufactured from bone or pig incisors, again paralleled in many modern tourist artefacts.

Domestic dog. Cranbrook (1988) reported a calcaneum (heel bone) and canine of a canid from the Agop Sarapad mouth of Madai cave, Sabah, from a midden dated Early Holocene or later (Bellwood, 1988). These elements are indistinguishable in the skeleton of domestic dog or dhole. The latter ranges across much of Asia to peninsular Malaysia, Sumatra and Java (Corbet & Hill, 1992), but is absent from the present mammal fauna of Borneo. Because no confirmed remains of dhole have ever been found at any archaeological site in Borneo, it is reasonable to attribute the Madai specimens to domestic dog. The earliest occurrence of dog in archaeology in East Asia is at Nanzhungtou, Hebei province, China, dated 8000 BC, i.e. Early Holocene (Yuan, 2010). The Madai specimens are younger, so they plausibly demonstrate a first introduction of dog to Borneo. An upper second molar in a Neolithic context among Everett's material from Jambusan, Sarawak, has been interpreted to show that, in parallel with contemporaries of the South-east Asian continental mainland, the Borneo dog progressively diminished in size (Cranbrook, 2014).

Later remains from Neolithic or Metal Age contexts at Niah and Sireh (Table 1) show more extreme selection towards smaller size (Clutton-Brock, 1960). The 24 mandibles of dogs recovered at Lubang Kudih, Beluru (above), dated by associated artefacts to late 15th century CE, had very short jaws and small, structurally reduced teeth (Medway, 1977b; Woodfield, 2005). Although the archaeological trail is incomplete, a scenario points to a lineage of small hunting dogs emerging in Borneo. Early 19th century travellers reported that interior Dayak people kept small dogs, which were important for hunting large quarry, notably bearded pigs. The distinctive breed, comparable with the 'Telomian' of peninsular Malaysia, survived until the 20th century when it became swamped by the introduction of larger, less well adapted bloodlines in Western breeds (Weller, 1970). The genome is now probably irrecoverable, but a search in remoter longhouses could be rewarding.

CONCLUSION

This brief overview has shown that, although less numerous than the remains of primates and pigs in cave excavations in the Borneo states of Malaysia, carnivores were included in the mammal quarry hunted by people throughout the past 50,000 years. Seventeen carnivore species have been recognised, mainly from dental remains. Further work on the zooarchaeological archive in the Sarawak Museum, especially if focussed on post-cranial remains, is likely to enlarge the sample size of species, and probably add new identifications.

Through the Late Pleistocene and Early Holocene, a period of extreme climate change, continuing occurrence in the zooarchaeological record of forest-adapted carnivores reinforces other evidence that a forest refugium persisted in north-western Borneo. During the Last Glacial Maximum (LGM), a central zone of savannah separated forest-adapted carnivores of the eastern and western Sunda subregion, providing circumstances for isolation and local selection of the Borneo endemics. Unassisted exchange of carnivore species between the western Sundaic subregion and Borneo, or vice versa was finally prevented by rising sea levels, cutting the link from West Kalimantan through Belitung and Bangka to Sumatra about 10,000 years ago. Unexpected discoveries were three osteological specimens of tiger, the oldest dated about 14,000 years ago, i.e., before this severance, to the Metal Age. The extinction of tiger in Borneo has parallels in South America, where widespread extinctions affecting carnivores, among other mammals, occurred from Early Holocene to Recent (Barnosky et al., 2004; Prevosti et al., 2013), but remains unexplained in the local context of Borneo.

Among small carnivores, the mixed assemblage suggests incidental additions to a meat diet in which bearded pig and primates predominated. Only binturong is represented in numbers indicating directed hunting policy. It is likely that passive trapping was initially the means by which small carnivores were obtained, but the development of projectile armament, probably poison-tipped, from the 12th millennium before present could explain the capacity to obtain larger carnivores.

With the Metal Age, carnivores became important sources of ornamental artefacts. Metal Age human burial areas were a source of carnivore teeth bored through the root, notably binturong, Sunda clouded leopard and sun bear, showing usage as strung 'beads' or ear plugs, paralleling modern custom among interior people. No clear identification of carnivores in burials was noted until a 15th century funereal cave, where a collection of lower jaws suggested that young, full grown domestic dogs had been eaten during interment ceremonials. Much earlier, Mid-Holocene, post-cranial remains of a canid have been linked with later undisputed dental remains of domestic dog in a plausible scenario from an early introduction of this companion carnivore to Borneo to the selection of a distinctive miniature Neolithic – Metal Age breed, whose main function was probably in hunting ground game.

The scope of these biogeographical, environmental and cultural interpretations could not be anticipated by the original excavators. The productivity of the post-2000 re-investigation of the Niah animal material by the new generation of zooarchaeologists, testified especially by the accounts in Barker (2013), fully justifies the effort involved more than half a century ago, in cleaning, bagging, labelling and storing the huge quantity of animal remains recovered during the original Sarawak Museum excavations of 1958–1965. These new insights emphasise the need to keep, record and properly respect all excavated animal remains, and not arbitrarily to decide what may or may not be useful.

Also indispensable in any museum or other research centre is a sufficiently diverse collection of comparative material in the form of skeletons. A good reference collection, properly prepared and labelled, is essential for zooarchaeological research. In Borneo, over the last half-century, large areas of forest have been cleared for swidden farming, or logged, and re-logged before conversion to more permanent use for tree-crop plantations of rubber, oil palm or exotic wood-pulp species of acacia or eucalypt. With the loss of natural habitat, opportunities recede for creating a comprehensive reference collection of native mammals (as skeletons), including a representative range of age and gender. With a network of voluntary support, road kill can become a useful source. The future of productive zooarchaeological research on Borneo carnivores depends on a shared effort by volunteers, specialist mammalogists and museums or other repositories of collected material. We must hope that coordinated action can be organised.

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