

A ZOOLOGIST WITH A TASTE FOR THE PAST: THE EARL OF CRANBROOK'S CONTRIBUTION TO ZOOARCHAEOLOGICAL RESEARCH IN SOUTHEAST ASIA

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ABSTRACT. — The Earl of Cranbrook (V) (then Lord Medway) was first introduced to archaeological research in 1958 when he participated in excavations at the Niah Caves, Sarawak Borneo. In that same year he published a paper entitled 'Food bone in Niah Cave excavations (-1958)' in the Sarawak Museum Journal. Unbeknownst to him at the time, his individual and intuitive research was on a par with, if not methodologically ahead of, burgeoning studies in the field of zooarchaeology that were taking place at leading academic institutions in Europe and the United States. This paper recounts and lauds the significant contributions the Earl of Cranbrook has made to the establishment and furtherance of a discipline over more than 50 years.

KEY WORDS. — Cranbrook, zooarchaeology, Borneo, Southeast Asia, fossils, Niah Caves

INTRODUCTION

It was in 1955 over a drink with friends in common at Nic Hill's apartment in Cambridge that Lord Medway (now Earl of Cranbrook V) first met Tom Harrisson—a chance encounter that turned his life '...into completely unexpected pathways' (Medway, 1977a: 66). Harrisson, then Head Curator of the Sarawak Museum in Borneo, apparently in expansive mood that day, offered the prospect of work to anyone present who would travel to Sarawak. The young Medway, then on the point of graduating, took up the offer, arriving in Kuching, Sarawak's capital, via Singapore the following year. In 1957 and in his capacity as the Museum's Technical Assistant, he joined Harrisson in the latter's excavation of the Niah Caves near Miri, but he was mostly excluded from the archaeological work, being encouraged instead to focus on gathering data on swiftlets for a doctoral dissertation (Heimann, 2002: 311). Medway returned to the cave periodically in late summer 1959 and beyond but it was during the first half of the long (4-month) 1958 season and as a senior member of the project team that he took on a much more hands-on role in the archaeological work at Niah (see Harrisson, 1959: 2; Fig. 1). With his background in zoology, Medway was set the

task of recording all of the animal bones recovered during the excavations—a role he took to with characteristic zeal and exactitude, alongside responsibilities to carry out survey work and statistical analysis of excavated finds (Harrisson Archive, Field-season report 1958: 6).

He quickly established new protocols in the recording of recovered bone, shifting away from the existing on-site system of taking bag-counts, first to producing generalised lists, before settling on taxonomically specific bone counts (Medway, 1958: 630). Medway ensured that, so far as it was possible, all fragments retrieved from the excavated sediments were collected and meticulously logged (hand-sifting was practised though not, it is thought, mesh screening: Solheim, 1977: 36). Recovery pace and precision could not always be easily reconciled, though, as Medway writes (14 Mar.1958 [emphasis in original]):

"T.H. [Tom Harrisson] decided to continue bat and fine bone search as far as 72" in [trench] E/W6; in E/W7 to 27". Beyond this fine search abandoned. Bat bone records therefore not valid beyond these depths. E/W8 and 9 will be done in 12" [spits] without fine bone search."
(Harrisson Archive, NCP76: 23)

Even so, he tabulated and quantified material across more than 1020 notebook pages during his time at Niah in 1958. His on-site 'bone books' still exist within the Harrisson Archive at the Sarawak Museum. They contain records of the number of bones recovered by trench and per excavated spit. During re-analysis of the bones in 2003–2005 PJP and RJR were able to compare in many cases their bone counts almost to the last fragment with those that Medway had logged in 1958, and completely correlate our results (Barker et al., 2009; Piper & Rabett, 2009; Fig. 2).

Whilst encamped at Niah that year, Medway would also write his first to be published report on the Niah faunas (Medway, 1958). This crucial piece established the foundations for a long career that has continued for more than 50 years and has resulted in numerous important contributions to the fields of zooarchaeology and palaeoecology in Southeast Asia (e.g., Medway, 1958, 1960a, 1960b, 1963, 1964a, 1964b, 1966, 1972, 1973, 1977; Cranbrook, 2000, 2010; Cranbrook & Labang, 2003; Cranbrook et al., 2006, 2007; Cranbrook & Piper, 2007, 2008a, 2008b, 2009, 2013; Piper & Cranbrook 2007a, 2007b; Piper et al., 2007a, 2007b). Although unable to participate closely in the excavations after departing from Sarawak, Medway continued to be actively involved in Niah and went on to study many of the animal bones collected, as one of the numerous international specialists working on different datasets from the project (Harrisson Archive, Report by B. Harrisson 31 Jul.1959). Some of the protocols he had established for the recovery and collection of bones were maintained in future seasons at Niah, although his system of comprehensive field recording would be less evident; the importance of recovered bone appears to have slipped down

the priority list (e.g., see editorial footnote, Medway, 1966: 185). However, his enthusiasm for studying the bones and the information he was able to generate from their study resulted in hundreds of thousands of bone fragments being collected, bagged and retained, making the Niah faunal collections archived at the Sarawak Museum probably the largest and most comprehensive in the entire region. More than this, the research techniques then and subsequently employed by Medway in the study of this material would break new ground.

To place the Earl of Cranbrook's insights into context, zooarchaeology in the late 1950s and early 1960s, when the young Medway embarked on his work on the Niah fauna, had hardly developed as a distinct branch of archaeological enquiry. Faunal research in archaeology had actually begun in the 19th century with studies of the animal bones from French Palaeolithic caves, Danish Mesolithic 'kitchen-middens' and the prehistoric 'lake villages' of the alpine region. However, its major role in prehistory was as a chronological marker, Westropp (1872), for example, separating the Barbarous Stage of Man (the Palaeolithic) from the Hunting Stage (the Mesolithic) by the occurrence of mammoth, rhinoceros, cave bear, hyaena, and reindeer in association with the former, and the red deer, wild boar, and wild ox with the latter. The studies by the veterinarian Rütimeyer (1862) of the animal bones from Swiss lake villages were remarkable for the time for his comments not just on the zoology and ecology of the animals represented, but also the zooarchaeological information he provided about hunting and farming. The research potential of animal bones from archaeological sites was more commonly noted by zoologists than archaeologists



Fig. 1. Lord Medway taking site notes during the 1958 season (Sarawak Museum Archive na371; left), and standing over one of the many trestle tables set up in the cave mouth across which all recovered material passed (Sarawak Museum Archive na179; right). Photographs reproduced with courtesy of the Sarawak Museum.

(e.g., Wintemberg, 1919), bones commonly being thrown away by excavators except specimens clearly modified into tools. In the first half of the 20th century studies of Pleistocene material continued to focus primarily on information that could be gleaned from species frequencies about climate change, as in Bate's study of fallow deer and gazelle in the Mount Carmel caves (Bate, 1937), and animal bone research generally made little contribution to the culture historical paradigm that dominated the archaeology of later periods. In many respects the pioneer of modern zooarchaeology was Theodore White, who published a series of classic methodological papers on quantification methods and butchery studies through the 1950s with a focus on Plains archaeology (e.g., White, 1952, 1953a, 1953b, 1954, 1955, 1956), but his work was not picked up quickly outside North America. For example, Fraser & King's careful study of the fauna from the Mesolithic site of Star Carr in northern England (Fraser & King, 1954) still consisted largely of zoological descriptions, with few comments on the inferences that could be drawn about hunting practices. The first major zooarchaeological textbook, *Bones for the Archaeologist*, published by Cornwall (1956) just the year before Lord Medway joined Harrisson's team at Niah, was primarily a manual for identification and conservation, with just seven pages at the end devoted to 'Study and Interpretation', the primary topics identified being, for wild animals, the information they provided about environment and seasonal abundance and, for domestic animals, what species were represented, their size in relation to modern animals, their possible racial/breed affinities, and whether there was evidence in the mortality data for autumn slaughtering.

In the light of the nascent development of zooarchaeology, even in archaeologically well-studied regions of the world such as Europe and North America in the late 1950s, Gathorne Cranbrook's work on the Niah fauna posed biologically interesting questions of the archaeological material, and developed effective methods to tackle them. Quite aside from element and taxonomic identification, from the outset his papers (and some he co-authored with Tom Harrisson) tackled facets of study that were the exception rather than the norm in (the then) current zooarchaeological

practice: bone taphonomy and its links to spatial and temporal distributions of skeletal elements; quantification indices such as the Minimum Numbers of Individuals (MNI) represented; experimentation into bone fracturing characteristics; the creation and use of reference collections; formalised definitions for classifying bone tools; and the reconstruction of the subsistence activities of past societies and the impact of these on the lowland rainforest. In the rest of this paper we review and contextualise these contributions to zooarchaeology. Working far away from what were then the mainstream theatres of archaeological enquiry, Lord Medway was using state of the art methodologies, indeed he was developing the state of the art, and in this respect he must now be recognised as one of the pioneers of modern zooarchaeology.

ASSESSING THE ZOOLOGICAL EVIDENCE FROM THE NIAH CAVES

Tom Harrisson's campaign at Niah ran discontinuously from 1954 to 1965 and paralleled other large-scale projects of the time, predominantly in western Eurasia but also the New World, in being explicitly multi-disciplinary. Alongside specialists working on pollen, soil chemistry and on human remains, zoologists came to feature strongly: the Earl of Cranbrook (IV) (Linnean Society, London: bat bones); R. Inger (Chicago Natural History Museum: fish and reptile bone); R. W. Sims (British Museum of Natural History: bird bone); Lord Medway (Birmingham University: animal bone); and G. H. R. von Koenigswald (Utrecht University: 'special' bone) (Harrisson Archive, Report by B. Harrisson 31 Jul. 1959). To this list we can add others, such as W. King (University of Chicago: reptile and amphibian bone), Edwards Hill (British Museum: squirrel bones), D. D. Lyons (University of Michigan: turtle bones), D. A. Hooijer (Rijksmuseum van Natuurlijke Historie, Leiden: primate and pangolin remains), J. Clutton-Brock (Institute of Archaeology, London: domesticated dogs), Tom Harrisson himself because of his particular interest in the molluscan fauna recovered from the site (details of which he diligently recorded in his notebooks over the years), and the zoological as well as archaeological advice that M. W. F. Tweedie (Director of the Raffles Museum) brought to the project. As Solheim (1977: 37) pointed out, 'probably the greatest quantity of publication that came out on Niah has to do with the zoological materials'. Effort went into taxonomic identification of extant but also extinct fauna from the site, such as a species of giant pangolin (see Hooijer, 1960; Piper et al., 2007a); into using the antiquity of the bone assemblages to trace evolutionary change or relatedness to populations in other parts of the region (e.g., Cranbrook, 2000; Hooijer, 1961, 1962; Medway, 1964a); and into using fauna to help reconstruct past environments (e.g., Medway, 1963, 1964b). This was not zooarchaeology, it remained primarily a zoological concern, but it embodied questions and ideas already being seen to be of potentially mutual interest to zoologists and archaeologists (e.g., Gilmore, 1946, 1949). They were also being drawn together in the context of an excavation that was being promoted for its potential



Fig. 2. Philip Piper (leftmost) and Ryan Rabett (rightmost) with the Earl of Cranbrook working on faunal remains at the Niah Caves field station in Apr. 2003. (Photograph by: Graeme Barker).

importance to understanding the evolution of humanity (Harrisson & Tweedie, 1957) and in a regional landscape replete with indigenous knowledge about life in tropical rainforests, another of Harrisson's many interests (see e.g. in connection to the zoological work at Niah: Harrisson, 1972: 390–396). These factors may not have dictated the lines of investigation or innovative approaches to zoology that the young Lord Medway adopted, but Niah undoubtedly provided a crucible for their development, as the title to his 1977 paper “*The Niah excavations and an assessment of the impact of early man on mammals in Borneo*” exemplifies (see also Medway, 1964b; Cranbrook, 1988, 2000, 2010). In the following sections we explore the different elements of this synergy between zoology and archaeology that the Earl of Cranbrook's work came to embody in relation to modern established zooarchaeological themes.

Distinguishing between indigenous post-depositional processes and anthropogenic modification. — During the 1958 field season at Niah the excavation team established their camp in what is known as the ‘Trader's Cave’ (so named as it formally held the camp of people trading the birds' nests harvested from the West Mouth of Niah) and located just to the north and slightly downslope from the West Mouth, where the main archaeological work was taking place. The only surviving evidence of the Harrisson team's habitation of the Trader's Cave (remarkably) is the scoured outline of the badminton court they set up about mid-way along the cave's interior.

It was whilst encamped here that Lord Medway collated field notes for the first of his many papers on the animal bones from Niah that would be published in the *Sarawak Museum Journal*. The 1958 paper perhaps owes much to the long hours spent coming to grips with identification, quantification and interpretation of the growing faunal assemblage that was being uncovered at Niah. His time in the field allowed Lord Medway to begin establishing a bone reference collection from modern game taken in the vicinity of the caves ‘on a need to know’ basis, a task that also provided an unparalleled opportunity for him to observe animal behaviour first hand. What is also immediately apparent in the 1958 paper is an intellectual curiosity not only for the species of animals represented in the archaeological record, but also in how they might have got there. For example, the introductory paragraphs of the paper are dedicated to using differences in bone condition and appearance to determine the relative age of various assemblages, and the types of sub-aerial and post-depositional processes that might have influenced the preservation/destruction of skeletal elements (including occasional minor disturbance by digger wasps, which he would have observed boring into the sediment and standing sections on-site). He argued that the bones had probably been discarded in and around the cave entrance and had eventually entered the archaeological record through a number of complex pathways following deposition. He interpreted the scarceness of bones around the fringes of what he termed ‘the occupation zone’ (the thick cultural deposits laid down in the most well illuminated part of the

cave mouth) as likely resulting from differential destruction by extremes of environment rather than variations in the amount of bone originally deposited (Medway, 1958: 269). He also interpreted the spatial and temporal distributions of bones within different occupation layers. By interpreting the taphonomic histories of the various bone assemblages encountered in the West Mouth, Medway was able to make inferences about the entire archaeological record of the site, about where human activity was concentrated or which archaeological deposits were likely to contain mixed materials of different ages—astute observations that were critical to postulating a taphonomically-informed assessment of site formation.

Together with Tom Harrisson, Lord Medway also evaluated natural and anthropogenic activities that could leave distinctive marks on bones. They noted that discarded bones could be of interest to a wide range of scavenging animals that re-distribute, modify and even collect bones, particularly in a country like Borneo. They described how tooth marks attributable to dogs in the form of ‘small pricks and pits’ were found only in the upper levels of the West Mouth associated with Neolithic/Metal Age activity on the site, and that this corresponded with the distribution of dog bones recovered from the site (see Clutton-Brock, 1959; Medway, 1964b). Distributed more widely in time and space were bones showing the characteristic parallel double grooving associated with rodent-gnawing, modifications that result from a rodent's need to keep the continuously growing incisors worn down. Several examples could be attributed to a known bone accumulator, the porcupine (Harrisson & Medway, 1962: 337 and pl. IIIc). These insights into rodent behaviour and their potential impact on the structure and composition of animal bone assemblages came 20 years before the publication of C. K. Brain's seminal contribution to animal bone taphonomy, where he outlined similarities and differences between hominin and other predator/scavenger behaviours that can be identified in the paleontological record (Brain, 1981).

Harrisson and Medway (1962: 336 and pl. Ia) and Medway (1966: 186) also discussed employing experiments in bone breakage in order to determine whether it was possible to differentiate unmodified bone tool ‘blanks’ produced from large mammal long bone shaft fragments from bone broken for other reasons, such as marrow extraction. They acknowledged that many functional-looking shapes like ‘sharp points, scoops or blades’ could be mimicked by simple breakage of fresh pig and deer long bones through undirected blows to the shaft. From close examination of numerous excavated bone fragments, they noted that most demonstrated no signs of abrasion or rounding that could be related to deliberate human modification, and that there was no reason to consider these as tools or tool blanks. As a result, they opted only to consider those specimens with clear evidence of anthropogenic modifications ‘showing either accessory grinding, or decoration, or polished or use-worn edges’ (Harrisson & Medway, 1962: 337) as tools or tool fragments.

Given that their study was undertaken in the wider intellectual context of the Javanese ‘bone culture’ (van Es, 1930: 333; van Heekeren, 1957)—referring to the occasional recovery of apparent bone implements from layers within archaeological sites in Java and elsewhere on the mainland; and, further afield, Raymond Dart’s claims for the existence of an ‘osteodontokeratic’ culture among Australopithecines of southern Africa (e.g., Dart, 1949, 1959)—the fact that Harrisson’s and Medway’s analysis should have taken a critical line, and was not to be swayed by prevailing ideas, stands as significant. So much so that they employed the Niah evidence to refute the theory that there should have existed a ‘bone culture’ in Southeast Asian prehistory. In the event, their approach to bone tool identification and classification would only be applied to one assemblage outside of Niah, the cave of “Gua Bintong” on the west coast of Peninsular Malaysia (Collings, 1937). Although the years that followed were not devoid of influential publications on the subject of bone modification—perhaps most particularly Semenov’s (1957/1964) excellent experimental study into bone-working—the same critical attention towards distinguishing pseudo-tools from genuine ones and using defined parameters would not appear again until the 1980s (e.g., Johnson, 1985; Lyman, 1982; Myers et al., 1980).

Zoology and Zooarchaeology.— The period from the late 1960s to the early 1980s saw a flurry of contributions towards an emerging zooarchaeological discipline, particularly in relation to questions of animal domestication (e.g., Clason, 1967; Higham, 1967; Bökonyi, 1969; Ducos, 1969; Flannery, 1969; Grigson, 1969; Herre, 1969; Reed, 1969; Chaplin, 1971; Carter & Flight, 1972; Jarman & Wilkinson, 1972; Legge, 1972, 1981; Payne, 1972a, 1972b; Perkins, 1973; von den Driesch, 1976; Noe-Nygaard, 1977; Barker, 1978; Bay-Peterson, 1978; Wing, 1978; Clutton-Brock, 1979, 1981; Maltby, 1979; Sakellaridis, 1979; Uerpmann, 1979; Meadow, 1981; Rowley-Conwy, 1981; Gautier & Van Neer, 1982; Wilson et al., 1982; Grant, 1982; Bailey, 1983; Voigt, 1983). Despite these pioneering efforts, however, analysis of faunal remains was seen at the end of this period as ‘still in infantile theoretical stage’ (Lyman, 1982: 334). In Southeast Asia in particular, the taxonomic lists of species that Smith (1976) referred to as the ‘twitching’ approach to faunal analysis, whereby the primary emphasis lay in creating species lists, or what have also been called ‘laundry lists’ (Olsen, 1972), remained the principal feature of the zoological section of most archaeological site reports. As already shown to be the case with respect to Niah, more often than not such work generally fell to zoologists. Smith (1976: 279) explains that this had the consequence that archaeologists who were only gradually coming to terms with the idea that skeletal elements from animal species lay within their analytical domain were prone to ‘accept such reports as presenting all the information that could be extracted from such faunal samples’. While such lists had the utility of providing insights into the biogeography of a species and could be used to infer the use of game as food items, their entirely descriptive nature offered little in the way of interpretative value and, in the case of human subsistence strategies, no demonstrable linkage.

By the mid-seventies, straight lists and occasional use of MNI (minimum numbers of individuals) and meat yields—approaches originally advocated by White (1953)—were being replaced with more complex procedural approaches that considered identification by element, side, portion, sex, age and size as well as taxonomy; and which paid closer attention to taphonomy. Nonetheless, even these reports, though more detailed, remained almost entirely descriptive, without serious attention to interpretation or explanation (Smith, 1976: 283). It is in this respect that Lord Medway’s faunal reports again stand out. From early on he had been acutely aware of the need to identify ways to quantify the faunal remains that were accumulating from Niah—including most of those indices listed above—and through them to accurately determine which taxa were the most commonly occurring. Intuitively, however, he also saw the need to place those descriptive statistics into a wider explanatory context.

It was without prior knowledge of then recent advances in zoological research (see White, 1953, 1956) that Medway adopted an MNI system alongside and derived from one used to quantify the ‘number of identified specimens’ (NISP) of each taxon. By these means he was able to determine the relative contributions of different taxa represented in the cave’s archaeological record, determining that the bearded pig (*Sus barbatus*) and various species of leaf monkey and macaque (Cercopithecidae) comprised the greatest proportion of medium to large-bodied mammal remains at the site. These represented the principal taxa hunted by the human inhabitants of the caves from the Late Pleistocene onwards (Medway, 1958), a conclusion corroborated by the current authors’ own studies of the vertebrate faunas from Niah (e.g., Barker et al., 2007; Rabett & Barker, 2007; Piper & Rabett, 2009; Piper & Rabett, in press).

As noted in the list of specialists at the head of this section, most zoologists by that time specialised in a very limited number of species (see also Reitz & Wing, 1999). This included Medway’s father the Earl of Cranbrook IV, who made an important contribution to the Niah story through detailed studies of the numerous mega- and microchiropteran mandibles recovered from the Late Pleistocene deposits in the West Mouth, and through producing a useful key to the identification of bat genera (Aldridge & Cranbrook 1963; Cranbrook, 1966). Unlike many, though, Medway’s own knowledge base was broader and, given the diverse faunal spectrum of Bornean rainforest, of necessity expanding all the time as he worked, whether through analysis or collecting comparative specimens. He also did not limit his focus to just the larger mammals introduced to the caves by people (e.g., see Medway, 1960a, 1978), but also sought to identify many of the smaller members of the community as well, such as squirrels, rats, shrews and even molluscs (Medway, 1960c, 1960d, 1964a). In a review of his previous studies and a discussion of post-Pleistocene changes in the faunal communities of Borneo (Medway, 1964b) he lists 39 mammal taxa (from a total of 58 taxa identified throughout the Pleistocene and Holocene sequences) identified in the Pleistocene Niah assemblages (those recovered from below 48° on site). In this, the first of several papers written on

the palaeo-environment of Borneo (see also Medway, 1977a; Cranbrook, 1988, 2000, 2010), he concluded that, with the exception of an extinct giant pangolin, the Niah material consisted entirely of extant species found in the region today. Nonetheless, the constituents of the Niah fauna indicated notable differences between past and present environmental conditions. This was evidenced through reductions in body-size among several taxa relative to modern comparatives for murids, orangutan, leaf monkeys and macaques, Sumatran rhinoceros and barking deer (Medway, 1959, 1964a, 1964b, 1966; Hooijer, 1961, 1962). In some instances it also became apparent that the presence of species found archaeologically at Niah did not correspond to their modern geographic distributions. For example, the bones of orangutan (*Pongo pygmaeus*) feature prominently in the deposits at Niah, whereas this animal does not occur within hundreds of kilometres of the cave today (Harrisson, 1958). Even more so, the discovery on archaeological sites in Sarawak of the remains of the Malay tapir (*Tapirus indicus*), an animal confined today to parts of Myanmar, the Thai-Malay peninsula and Sumatra, was testament to its survival in the north of the island well into the Holocene, to possibly as recently as the 1930s (Medway, 1960a; Piper & Cranbrook, 2007a; Cranbrook & Piper, 2009, 2013). Although the Malay tapir was almost certainly hunted, even at Niah (where the numbers of bones exceeds all other instances), only 19 pieces have been recovered out of a total number of identifiable bones from large and medium-sized mammals that exceeded 10,000, suggesting that encounters were rare.

Medway argued in 1964 that the current patchy distribution of both orangutans and tapirs were characteristic of residual enclaves from once widespread regional populations. Rather than putting the disjuncture between past and present patterns of occurrence down wholly to human predation or disruption, extensive though these factors have been—he argued that the tapir 'is poorly adapted to prevailing conditions, and is naturally declining' (Medway, 1964b: 36). This was a position he also saw as affecting the orangutan, detailed surveys of which had only begun in Borneo in 1959 (B. Harrisson, 1961; Yoshioka, 1964), and even allowing for the impact that intensive historic persecution of this animal had on its population density (e.g., Meijaard et al., 2010). This process of decline he later linked to floristic changes between Pleistocene and Holocene vegetation, brought about by reduced seasonality and rising mean ambient temperatures (Medway, 1972). Although forays into the role of ecological change on species decline since the Pleistocene had been made before this time (e.g., Eisely, 1943; Gill, 1955), Medway's ideas in 1964 appear to have developed independently, but contemporaneous with the first systematic treatment of this topic in other parts of the world (e.g., Skeels, 1962; Guilday, 1967; Slaughter, 1967; Dreimanis, 1968; Guthrie, 1968a, 1968b; Reed, 1970; Wolberg, 1970; see also Martin & Wright, 1967).

The disappearances from Borneo's Pleistocene record of other large mammals remain enigmatic. These include the tiger (*Panthera tigris*), no longer present on the island, but evidenced by two finds from the West Mouth of Niah (Hooijer,

1963; Piper et al., 2007a) and one from Madai Cave, Sabah (Bellwood, 1988); and the Javan rhinoceros (*Rhinoceros sondaicus*), now also confirmed from subsurface levels at Niah (Cranbrook & Piper, 2007). Both are among the ten species present at Niah that Cranbrook (2010) describes as survivors from the region's Middle Pleistocene fauna, and whose eventual (local) extinction he attributes to a combination of maladaptation to wet interglacial climate and, ultimately, the effects of selective hunting pressure in the comparatively recent past.

One of the most revealing inclusions in the Niah fauna was the presence of the ferret-badger (*Helictis orientalis*) and lesser gymnure (*Hylomys suillus*) (Medway, 1958; the lesser gymnure would later be struck from the list of species recorded at Niah by the Earl of Cranbrook as mis-identified). The presence of the ferret-badger provided compelling evidence that cooler, submontane conditions likely prevailed in the vicinity of the caves at times. Medway (1964b) probably used the then recent geological evidence from Africa that suggested much lower ambient temperatures regionally during the Pleistocene (no reference was given but this evidence is likely from Büdel, 1955). Although the concept of altitudinal depression had long been known, it had rarely been examined for low latitudes before this time (Flint, 1963). Medway deduced that a reduction of 5°C would have resulted in the lowering of the montane/submontane ecosystems by 3,000 ft (914 m), bringing upland species into settings otherwise dominated by lowland taxa (Medway, 1964b: 37). Though there cannot be a straightforward application of typical temperature lapse rate with altitude, Medway's approximation, based on the known ecology of the ferret-badger, was proved not far off the mark. Evidence of Quaternary vegetation change in Southeast Asia was slow to build: with rare exceptions such as Tsukada's study of Late Pleistocene climate in Taiwan (Tsukada, 1966) and Petersen's (1969) study of Würm II climate at Niah Cave, detailed study of regional vertical shifts in altitudinal zonation only started to appear after the mid-1970s (e.g., Verstappen, 1975; Hope, 1972; Walker & Flenley, 1979; Morley, 1982). The significance of his faunal data was recognised and incorporated (e.g., Verstappen, 1975, 1980).

The importance of Medway's early scientific contributions lay not only with the statistical or taphonomic approaches he devised, nor only with the breadth of faunal knowledge he quickly assembled, nor even with the palaeo-environmental reconstructions the data afforded. Reading through Medway's many publications one gets the sense that, if Tom Harrisson's approach to archaeological (and zooarchaeological) material was more anthropological—for example, he was interested in determining how the ancestors of modern indigenous groups managed and prospered in the rainforest (e.g., Harrisson, 1966: 222) and whether they were the cause of faunal extinctions (T. Harrisson, 1961)—then Medway's was to bring humans into zoology. His observations and explanations about changes in species occurrence and faunal biometrics do not suffer from any human-centric hyperbole, but nor do they shy away from exploring human agency. Alongside his essays about human impact on tropical faunal communities,

it is through his studies of dog and pig domestication in Borneo that the relationship between faunal change and human action is perhaps most clearly expressed.

The introduction of domestic animals.—Canid domestication in mainland Southeast Asia may date back to at least c. 4,200 bp (Higham et al., 1980), though evidence remains limited from Borneo. Three fragments from Neolithic levels in the West Mouth of Niah (Clutton-Brock, 1959) are noticeably small with a reduced dental structure, indicative of an extended period of selective breeding and are unmistakably that of *Canis lupus familiaris*. The presence of a single lower first molar from a similar-sized specimen taken from subsurface (0–3") deposits at Gua Sireh (c. 480 km southwest of Niah) and of 26 lower mandibles from the historic period at Lobang Kudih, about 48 km in the opposite direction (Woodfield, 2005), and possibly the remains of ceremonial consumption (Medway, 1977b), support his earlier suggestion (Medway, 1959) that one or more breeds of small dog may have been widespread across northwest Borneo from the Neolithic onwards. Interestingly, this timing accords well with genetic evidence for a substantial expansion of dogs from mainland Southeast Asia at around this time (Sacks et al., 2013). Although the dogs Medway reported do not equate with the larger hunting dogs of modern Penan hunters—folklore accords these latter a comparatively late introduction (Harrisson, 1972)—his survey of published accounts from the mid-19th century to the 1950s suggested that the smaller breeds were still present among Dayak and some Penan communities and used primarily for hunting. Inter-breeding with imported stock in the years since, he argued, appears to have submerged these lineages in Borneo, though they seem to have survived on the Southeast Asian mainland, with reports into the 1960s from Malaysia (Medway, 1977b). Potential close relatives may still be present in modern-day northern Vietnam (Fig. 3; Rabett, pers. obs.). While in the late 1970s there was no evidence forthcoming about

the existence of wild dogs in Borneo—a position that is still presumed by some modern genetics studies into dog domestication—Cranbrook (1988) identified two isolated specimens (a calcaneum and a canine) from early Holocene midden deposits in the mouth of Agop Sarapad cave, Sabah, as most likely belonging to a dhole (*Cuon alpinus*). As none of the other food bone in the midden exhibited signs of carnivore gnawing, he reasoned that the *Cuon* itself may have been predated by people rather than kept as a hunting companion. Recent support for Medway's assertion that the dhole itself may have once inhabited Borneo has been forthcoming from the Philippine island of Palawan, where canid remains in association with another locally extinct species, the tiger, have been recovered from early Holocene archaeological sequences at Ille Cave (Piper et al., 2011).

From his analysis, early human groups appear to have had a limited effect on large mammal populations. The eventual local or regional demise of certain species was most likely due to their already being in a state of natural decline through maladaptation to changed conditions. He affirms, however, that hunting probably played a part in that process. Certainly, the use of dogs had important repercussions for the effectiveness of hunting practice in the latter part of the Holocene (e.g., Sloan, 1975; Brosius, 1986, 1991). As Puri (2005: 250) explains with reference to the Penan, 'one important advantage of using dog is that anywhere along...[a hunting] route the dogs may find other game than the preferred pigs, especially nocturnal animals asleep in their burrows'. The introduction of even a single shot-gun, however, gives every indication of having increased hunting pressure rapidly on pigs to an unsustainable level (Cranbrook & Labang, 2003); the same is unfortunately probably true for other game as well.

In 1973 Medway started to investigate the introduction of other domesticated animals into Sarawak. His initial



Fig. 3, 'Liu', Tràng An, Ninh Bình Province, Vietnam, 2009. (Photographs by: J. Appleby, reproduced with permission).

study included the pig mandibles associated with burials from two archaeological sites: Lobang Kudih, near Beluru, which contained imported Chinese ceramics of late Sung and Ming date (AD 136–1644) and Lobang Magala (cave mouth 'E'), Niah, which included a date on human bone of 1165 ± 240 BC, and with reference to two other caves, both also at Niah: Upising and Lobang Tulang (Medway, 1973; Woodfield, 2007). Amongst other indices Medway used body part representation to calculate how many pig mandibles were represented in the complete assemblage. Tooth dimension, wear stage and occlusal attrition were used in order to match mandibles and aid in calculating the overall number of pigs represented in the assemblage. He also used differences in the mesiodistal length of the only known wild pig in Borneo, the bearded pig, and the specimens from Lobang Kudih, to argue that the relatively small size of the latter indicated that they were derived from introduced domestic stock. In addition to metric traits, Medway identified certain non-metric features in pig mandibles as related to the domestication process including foreshortening of the snout, resulting in tooth cramping and misalignment (see Clutton-Brock, 1981). Used together with a simple but effective scheme to determine the age at death of individual pigs in the assemblage, he concluded that a wide range of age stages was represented, but with a propensity towards a kill-off pattern between 5–13 months of age. The results left little doubt that the specimens recovered from Lobang Kudih and from Lobang Magala were of a domestic breed of pig that had been selectively slaughtered towards the middle or end of their first year of life.

In 1976 Medway turned his attention back to the pig remains from the West Mouth excavations at Niah, in order to reassess his early assertion that the only species present there was the bearded pig. Using a substantial comparative sample ($n = 286$) of *Sus barbatus* and *Sus scrofa* and dental biometrics, Medway (1978) concluded that, with the exception of three very much smaller specimens from sub-surface levels that were from likely domestic stock, only the bearded pig was present throughout the deposits. This conclusion was recently confirmed from the examination of teeth from the Late Pleistocene to mid-Holocene using geometric morphometrics (Cucchi et al., 2009); though Piper et al. (in press) recently identified several specimens of domestic affinity from the Metal Age (c. 1,500 cal. BP) deposits from the east facing entrance to the Niah Caves, Gan Kira. On the basis of the Magala specimen Cranbrook argued that domestic pigs were introduced to Borneo in the first half of the second millennium BC. Although there is some doubt about the provenance of the Lobang Magala pig mandibles, recent research has demonstrated that domestic pigs arrived in the Philippines c. 2000 cal. BC (Piper et al., 2009; Amano et al., in press). Until recently, Medway's comparative pig studies have been the only available detailed zooarchaeological studies of this crucial game animal from the islands of the Sunda Shelf. His work continues to represent the only major such study into the introduction of domestic pigs west of Wallace's Line (modified by Huxley); while his study into the dental biometrics of the bearded pig (Cranbrook & Labang, 2003),

based on fieldwork undertaken in 1977–1978, still remains the only such comparative data-set in existence for this animal.

CONCLUSIONS

In this paper we have endeavoured to highlight not only the long-term engagement that the Earl of Cranbrook has had with the prehistoric fauna of Borneo, but also the way in which his work has created an enduring legacy. The contents of that legacy represent an invaluable guide and incentive to those of us following in his footsteps, while its proportions extend to the whole modern discipline of zooarchaeology. The zoological studies at Niah were especially well provisioned, with a wealth of expertise that made it a rarity in archaeological research in the 1950s and since. However, it has been the Earl of Cranbrook's contribution that has lain at the heart of that work from the outset, from his initial documentation and quantification of remains on-site and first publication in 1958. His work, more than any other of those studying the fauna during Harrisson's campaign at Niah, has dovetailed the discipline of zoology with that of archaeology, be it through innovating approaches to statistical analysis, taphonomy and bone modification, the use of experimentation and comparative studies, environmental reconstruction, or the exploration of human impacts on wild fauna and the origins of domestic animals. The Earl of Cranbrook's research has been and shall remain the benchmark in Southeast Asian zooarchaeology.

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LITERATURE CITED

Aldridge, P. M. & Earl of Cranbrook, (IV), 1963. Deep bat remains from Niah cave excavations, 1954–61. Part 1: 1954–60. *Sarawak Museum Journal*, **11**(New Series 21–22): 201–213.

Amano Jr, N., P. J. Piper, H-c Hung, & P. Bellwood, in press. Introduced domestic animals in the Neolithic and Metal Age of the Philippines: Evidence from Nagsabaran, Northern Luzon. *Journal of Island and Coastal Archaeology*.

Bailey, G. N. (ed.), 1983. *Hunter-Gatherer Economy in Prehistory*. Cambridge University Press, Cambridge.

Barker, G., 1978. Economic models for the Manekweni zimbabwe, Mozambique. *Azania*, **13**: 71–100.

Barker, G., H. Barton, M. Bird, P. Daly, I. Datam, A. Dykes, L. Farr, D. D. Gilbertson, B. Harrisson, C. O. Hunt, T. Higham, L. Kealhofer, J. Krigbaum, H. Lewis, S. McLaren, V. Paz, P. A. Pike, P. Piper, B. Pyatt, R. Rabett, T. E. G. Reynolds, J. Rose, G. Rushworth, M. Stephens, C. Stringer, G. Thompson, 2007. The 'human revolution' in tropical Southeast Asia: The antiquity and behaviour of anatomically modern humans at Niah Cave (Sarawak, Borneo). *Journal of Human Evolution*, **52**: 243–261.

Barker, G., P. Piper & R. Rabett, 2009. Zooarchaeology at the Niah Caves, Sarawak: Context and research issues. *International Journal of Osteoarchaeology*, **19**(4): 447–463.

Bate, D. M. A., 1937. Palaeontology: The fossil fauna of the Wadi el-Mughara caves. In: Garrod, D. A. E. & D. M. A. Bate (eds.), *The Stone Age of Mount Carmel*. Clarendon Press, Oxford. Pp. 137–240.

Bay-Peterson, J., 1978. Animal exploitation in Mesolithic Denmark. In: Mellars, P. (ed.), *The Early Postglacial Settlement of Northern Europe*. Duckworth, London. Pp. 115–145.

Bellwood, P., 1988. *Archaeological Research in South-eastern Sabah*. Kota Sabah Museum Monograph, Volume 2. Kinabalu.

Bökonyi, S., 1969. Archaeological problems and methods in recognising animal domestication. In: Ucko, P. & G. W. Dimbleby (eds.), *The Domestication and Exploitation of Plants and Animals*. Duckworth, London. Pp. 219–229.

Brain, C. K., 1981. *The Hunters or the Hunted? An Introduction to African Cave Taphonomy*. The University of Chicago Press, Chicago.

Brosius, J. P., 1986. River, forest and mountain: The Penan Gang landscape. *Sarawak Museum Journal*, **36** (New Series 57): 173–184.

Brosius, J. P., 1991. Foraging in tropical rain forests: The case of the Penan of Sarawak, East Malaysia (Borneo). *Human Ecology*, **19**: 123–150.

Büdel, J., 1955. Relieftypen und plio-pleistozäner Klimawandel im Hoggar-Gebirge (Zentral Sahara). *Erdkunde*, **9**: 100–115.

Carter, P. L. & C. Flight, 1972. A report on the fauna from the sites of Ntereso and Kintempo rock shelter six in Ghana, with evidence for the practice of animal husbandry in the second millennium BC. *Man*, **7**: 277–82.

Chaplin, R. E., 1971. *The Study of Animal Bones from Archaeological Sites*. Seminar Press, London.

Clason, A., 1967. *Animal and Man in Holland's Past*. J. B. Wolters, Groningen.

Clutton-Brock, J., 1959. Niah's Neolithic Dog. *Sarawak Museum Journal*, **8** (New Series 13–14): 143–145.

Clutton-Brock, J., 1979. The mammalian remains from the Jericho Tell. *Proceedings of the Prehistoric Society*, **45**: 135–57.

Clutton-Brock, J., 1981. *Domesticated Animals from Early Times*. Heinemann and the British Museum (Natural History), London.

Collings, H. D., 1937. An excavation at Bukit Chuping, Perlis. *Bulletin Raffles Museum*, Series B, **1**: 94–119.

Cornwall, I., 1956. *Bones for the Archaeologist*. Phoenix, London.

Cranbrook, Earl of (IV), 1966. Bat remains from Niah Cave excavations. *Sarawak Museum Journal*, **14** (New Series 28–29): 224–228.

Cranbrook, Earl of (V), 1988. The contribution of archaeology to the zoogeography of Borneo, with the first record of a wild canid of early Holocene age. *Fieldiana*, **42**: 1–7.

Cranbrook, Earl of (V), 2000. Northern Borneo environments of the past 40,000 years: Archaeozoological evidence. *Sarawak Museum Journal*, **55** (New Series 76): 61–110.

Cranbrook, Earl of (V), 2010. Late Quaternary turnover of mammals in Borneo: The zooarchaeological record. *Biodiversity Conservation*, **19**: 373–391.

Cranbrook, Earl of (V) & D. Labang, 2003. Bearded pigs (*Sus barbatus*): Tooth wear and aging wild populations in Sarawak. *Sarawak Museum Journal*, **55** (New Series 76): 61–110.

Cranbrook, Earl of (V) & P. J. Piper, 2007. The Javan rhinoceros *Rhinoceros sondaicus* in Borneo. *Raffles Bulletin of Zoology*, **55**: 229–232.

Cranbrook, Earl of (V) & P. J. Piper, 2008a. Sarawak through the ice ages to present time: Environmental change and human impacts on the past and present distribution of mammals. In: Stuebing, R. B., J. Unggang, J. Ferner, B. Gimant & Kee Kum Ping (eds.), *Proceedings of the Regional Conference: Biodiversity Conservation in Tropical Planted Forests in South East Asia*. Forest Department, Sarawak Forest Corporation, Kuching. Pp. 81–104.

Cranbrook, Earl of (V) & P. J. Piper, 2008b. Post-Pleistocene evolution of Bornean shrews *Crocidura foetida* (Mammalia, Soricidae). *Biological Journal of the Linnean Society*, **94**: 413–419.

Cranbrook, Earl of (V) & P. J. Piper, 2009. Borneo records of the Malay tapir, *Tapirus indicus* Desmarest: A zooarchaeological and historical review. *International Journal of Osteoarchaeology*, **19**: 491–507.

Cranbrook, Earl of (V) & P. J. Piper, 2013. Paleontology to policy: The Quaternary history of Southeast Asian tapirs (Tapiridae) in relation to large mammal species turnover, with a proposal for conservation of Malayan tapir by reintroduction to Borneo. *Integrative Zoology*, **8**: 95–120.

Cranbrook, Earl of (V), A. P. Currant & G. W. H. Davison, 2006. Quaternary mammal fossils in Borneo: Retraction and review. *Sarawak Museum Journal*, **62** (New Series 83): 107–119.

Cranbrook, Earl of (V), J. Payne & C. M. U. Leh, 2007. Origin of the elephants *Elephas maximus* L. of Borneo. *Sarawak Museum Journal*, **63** (New Series 84): 95–125.

Cucchi, T., K. Dobney, M. Fujita, 2009. New insights into pig taxonomy, domestication and human dispersal in Island Southeast Asia through molar shape analysis: The *Sus* remains from Niah, and Lobang Kudih caves in Sarawak. *International Journal of Osteoarchaeology*, **19**: 508–530.

Dart, R. A., 1949. The predatory implemental technique of *Australopithecus*. *American Journal of Physical Anthropology*, **7**(1): 1–38.

Dart, R. A., 1959. Further light on Australopithecine humeral and femoral weapons. *American Journal of Physical Anthropology*, **17**(2): 87–93.

Dreimanis, A., 1968. Extinction of Mastodons in eastern North America: Testing a new climatic environmental hypothesis. *The Ohio Journal of Science*, **68**(6): 257–272.

von den Driesch, A., 1976. *A Guide to the Measurement of Animal Bones from Archaeological Sites*. Harvard University, Peabody Museum Bulletins 1, Cambridge, Mass.

Ducos, P., 1969. Methodology and results of the study of the earliest animals in the Near East (Palestine). In: Ucko, P. & G. W. Dimbleby (eds.), *The Domestication and Exploitation of Plants and Animals*. Duckworth, London. Pp. 265–275.

Eisely, L. C., 1943. Archaeological observations on the problem of post-glacial extinction. *American Antiquity*, **8**(3): 209–217.

van Es, L. J. C., 1930. The prehistoric remains in the Sampoeng cave, Residency of Ponorogo, Java. *Proceedings of the Fourth Pacific Science Congress, Java, 1929*. Volume III: Biological papers, Batavia-Bandoeng. Pp. 329–340.

Flannery, K. V., 1969. Origins and ecological effects of early domestication in Iran and the Near East. In: Ucko, P. & G. W. Dimbleby (eds.), *The Domestication and Exploitation of Plants and Animals*. Duckworth, London. Pp. 73–100.

Flint, R. F., 1963. Pleistocene climates in low latitudes. *Geographical Review*, **53**: 123–129.

Fraser, F. C. & J. E. King, 1954. Faunal remains. In: Clark, J. G. D., *Excavations at Star Carr*. Cambridge University Press, Cambridge. Pp. 70–95.

Gautier, A. & W. van Neer, 1982. Prehistoric fauna from Ti-n-Torha (Tadrart Acacus, Libya). *Origini*, **11**: 87–127.

Gill, E. D., 1955. The problem of extinction, with special reference to Australian marsupials. *Evolution*, **9**: 87–92.

Gilmore, R. M., 1946. To facilitate cooperation in the identification of mammal bones from archaeological sites. *American Antiquity*, **12**: 49–50.

Gilmore, R. M., 1949. The identification and value of mammal bones from archeological excavations. *Journal of Mammalogy*, **30**: 163–169.

Grant, A., 1982. The use of tooth wear as a guide to the age of domestic ungulates. In: Wilson, B., C. Grigson & S. Payne (eds.), *Ageing and Sexing of Animal Bones from Archaeological Sites*. British Archaeological Reports, British Series 109, Oxford. Pp. 91–108.

Grigson, C., 1969. The uses and limitations of differences in absolute sizes in the distinction between the bones of aurochs (*Bos primigenius*) and domestic cattle (*Bos taurus*). In: Ucko, P. & G. W. Dimbleby (eds.), *The Domestication and Exploitation of Plants and Animals*. Duckworth, London. Pp. 277–294.

Guilday, J. E., 1967. Differential extinction during Late-Pleistocene and recent times. In: Martin, P. S. & H. E. Wright Jr. (eds.), *Pleistocene Extinctions: The Search for a Cause*. Yale University Press, New Haven. Pp. 121–140.

Guthrie, R. D., 1968a. Paleoecology of the large-mammal community in interior Alaska during the Late Pleistocene. *American Midland Naturalist*, **79**: 346–363.

Guthrie, R. D., 1968b. Paleoecology of a Late Pleistocene small mammal community from Interior Alaska. *Arctic*, **21**: 223–244.

Harrison, B., 1961. Orang-utan: What chances of survival? *Sarawak Museum Journal*, **9** (New Series 17–18): 238–261.

Harrison, T., 1958. The caves of Niah: A history of prehistory. *Sarawak Museum Journal*, **8** (New Series 12): 549–595.

Harrison, T., 1959. New archaeological and ethnological results from Niah Caves, Sarawak. *Man*, **59**: 1–8.

Harrison, T., 1961. Prehistoric faunal changes and losses in Borneo. Nature conservation in western Malaysia, 1961. Special issue of the *Malayan Nature Journal*. Pp. 89–92.

Harrison, T., 1966. Lobang Angus, a frequentation cave at Niah-I. *Sarawak Museum Journal*, **14** (New Series 28–29): 217–223.

Harrison, T., 1972. The Borneo Stone Age: In light of recent research. *Sarawak Museum Journal*, **20** (New Series 40–41): 385–412.

Harrison, T. & Lord Medway, 1962. A first classification of prehistoric bone and tooth artifacts (based on material from Niah Great Cave). *Sarawak Museum Journal*, **11** (New Series 19–20): 335–362.

Harrison, T. & M. W. F. Tweedie, 1957. Commentary: Archaeology in Southeast Asia. *Science*, **125**: 1238.

van Heekeren, H. R., 1957. *The Stone Age of Indonesia*. Den Haag: Martinus Nijhoff, Verhandelingen Van Het Koninklijk Instituut Voor Taal-, Land- En Volkenkunde 21.

Heimann, J. M., 2002. *The Most Offending Soul Alive: Tom Harrisson and his Remarkable Life*. Aurum Press Ltd., London.

Herre, W., 1969. The science and history of domesticated animals. In: Brothwell, D. & E. S. Higgs (eds.), *Science in Archaeology 2nd Edition*. Thames and Hudson, London. Pp. 257–272.

Higham, C. F. W., 1967. Stock-rearing as a cultural factor in prehistoric Europe. *Proceedings of the Prehistoric Society*, **33**: 84–106.

Higham, C. F. W., A. Kijng, & B. F. J. Manly, 1980. An analysis of prehistoric canid remains from Thailand. *Journal of Archaeological Science*, **7**: 149–165.

Hooijer, D. A., 1960. The giant pangolin (*Manis palaeojavanica* Dubois) from Niah. *Sarawak Museum Journal*, **9** (New Series 15–16): 350–355.

Hooijer, D. A., 1961. The Orang-Utan in Niah Cave prehistory. *Sarawak Museum Journal*, **9** (New Series 15–16): 408–421.

Hooijer, D. A., 1962. Prehistoric bone: The gibbons and monkeys of Niah Great Cave. *Sarawak Museum Journal*, **9** (New Series 15–16): 408–421.

Hooijer, D. A., 1963. Further Hell mammals from Niah. *Sarawak Museum Journal*, (New Series 21–22): 196–200.

Hope, G. S., 1976. The vegetational history of Mt Wilhelm, Papua New Guinea. *Journal of Ecology*, **64**: 627–663.

Jarman, M. R. & P. Wilkinson, 1972. Criteria of animal domestication In: Higgs, E. S. (ed.), *Papers in Economic Prehistory*. Cambridge University Press, Cambridge. Pp. 83–96.

Johnson, E., 1985. Current developments in bone technology. *Advances in Archaeological Method and Theory*, **8**: 157–235.

Legge, A. J., 1972. Prehistoric exploitation of the gazelle in Palestine. In: Higgs, E. S. (ed.), *Papers in Economic Prehistory*. Cambridge University Press, Cambridge. Pp. 119–124.

Legge, A. J., 1981. Aspects of cattle husbandry. In: Mercer, R. (ed.), *Farming Practice in British Prehistory*. Edinburgh University Press, Edinburgh. Pp. 169–181.

Lyman, R. L., 1982. Archaeofaunas and subsistence studies. *Advances in Archaeological Method and Theory*, **5**: 331–393.

Maltby, M., 1979. *The Animal Bones from Exeter 1971–1975*. Exeter Archaeological Reports 2. Sheffield University, Department of Prehistory and Archaeology, Sheffield.

Martin, P. & H. E. Jr. Wright, 1967. *Pleistocene Extinctions: The Search for a Cause*. Yale University Press, New Haven.

Meadow, R. H., 1981. Early animal domestication in South Asia: A first report of the faunal remains from Mehrgarh, Pakistan. In: Härtel, H. (ed.), *South Asian Archaeology 1979*. Dietrich Reimer Verlag, Berlin. Pp. 143–179.

Medway, Lord, 1958. Food bone in the Niah Cave excavations (-1958), a preliminary report. *Sarawak Museum Journal*, **8** (New Series 12): 627–636.

Medway, Lord, 1959. Niah animal bone II: (1954–8). *Sarawak Museum Journal*, **9** (New Series 13–14): 151–163.

Medway, Lord, 1960a. The Malay tapir in late Quaternary Borneo. *Sarawak Museum Journal*, **9** (New Series 15–16): 356–360.

Medway, Lord, 1960b. Niah cave bone III: Hell bone (–1959). *Sarawak Museum Journal*, **9** (New Series 15–16): 361–363.

Medway, Lord, 1960c. Niah cave bone IV: Shrew (*Crocidura*). *Sarawak Museum Journal*, **9** (New Series 15–16): 364–367.

Medway, Lord, 1960d. Niah shell: 1954–58. *Sarawak Museum Journal*, **9** (New Series 15–16): 368–379.

Medway, Lord, 1963. Niah cave animal bone VI: New records. *Sarawak Museum Journal*, **11** (New Series 21–22): 188–191.

Medway, Lord, 1964a. Niah cave bone VII: Size changes in the teeth of two rats, *Rattus sabanus* Thomas and *R. muelleri* Jentink. *Sarawak Museum Journal*, **11** (New Series 23–24): 616–623.

Medway, Lord, 1964b. Post-Pleistocene changes in the mammalian fauna of Borneo: Archaeological evidence from the Niah Caves. *Studies in Speleology*, **1**: 33–37.

Medway, Lord, 1966. Animal remains from Lobang Angus, Niah. *Sarawak Museum Journal*, **14** (New Series 28–29): 185–216.

Medway, Lord, 1972. The Quaternary mammals of Malesia: A review. In: Ashton, P. & M. Ashton (eds.), *The Quaternary Era in Malesia*. Transactions of the 2nd Aberdeen-Hull symposium on Malesian ecology, series 13, University of Hull, Department of Geography Misc, Aberdeen. Pp. 63–98.

Medway, Lord, 1973. The antiquity of domesticated pigs in Sarawak. *Journal of the Malaysian Branch Royal Asiatic Society*, **46**: 169–178.

Medway, Lord, 1977a. The Niah excavations and an assessment of the impact of early man on mammal in Borneo. *Asian Perspectives*, **20**: 51–69.

Medway, Lord, 1977b. The ancient domestic dogs of Malaysia. In memory of Tom Harrisson: Life member, former member of council and prolific contributor to our journal. *Journal of the Malaysian Branch of the Royal Asiatic Society*, **50**: 14–27.

Medway, Lord, 1978. The wild pig remains from the west mouth, Niah Cave. *Sarawak Museum Journal*, **25** (New Series 46): 21–39.

Meijaard, E., A. Welsh, M. Ancrenaz, S. Wich, V. Nijman & A. J. Marshall, 2010. Declining orangutan encounter rates from Wallace to the present suggest the species was once more abundant. *PLOS One*, **5**(8): 1–8.

Morley, R. J., 1982. A palaeoecological interpretation of a 10,000 year pollen record from Danau Padang, Central Sumatra, Indonesia. *Journal of Biogeography*, **9**: 151–190.

Myers, T. P., M. R. V oorhies & R. G. Corner, 1980. Spiral fractures and bone pseudotools at paleontological sites. *American Antiquity*, **45**(3): 483–490.

Noe-Nygaard, N., 1977. Butchering and marrow fracturing as a taphonomic factor in archaeological deposits. *Paleobiology*, **3**: 218–237.

Olsen, S. J., 1972. *Zooarchaeology: Animal Bones in Archaeology and their Interpretation*. Current topics in Anthropology. Addison-Wesley, Reading, Massachusetts.

Payne, S., 1972a. Partial recovery and sample bias: The results of some sieving experiments. In: Higgs, E. S. (ed.), *Papers in Economic Prehistory*. Cambridge University Press, Cambridge. Pp. 49–64.

Payne, S., 1972b. On the interpretation of bone samples from archaeological sites. In: Higgs, E. S. (ed.), *Papers in Economic Prehistory*. Cambridge University Press, Cambridge. Pp. 65–91.

Perkins, D., 1973. The beginnings of animal domestication in the Near East. *American Journal of Archeology*, **77**: 279–80.

Petersen, R. M., 1969. Würm II Climate at Niah Cave. *Sarawak Museum Journal*, **17** (New Series 34–35): 67–79.

Piper, P. J. & Earl of Cranbrook (V), 2007a. The potential for large protected areas for the secure re-introduction of Borneo's lost 'megafauna': A case for the Malay tapir *Tapirus indicus*. In: Stuebing, R. B., J. Unggang, J. Ferner, J. Ferner, B. Gimant & K. P. Kee (eds.), *Proceedings of the Regional Conference: Biodiversity Conservation in Tropical Planted Forests in South East Asia*. Forest Department, Sarawak Forest Corporation, Kuching. Pp. 161–168.

Piper, P. J. & Earl of Cranbrook (V), 2007b. Niah cave bone IX: First Pleistocene record of Hose's pygmy shrew *Suncus hosei*. *Sarawak Museum Journal*, **63** (New Series 84): 227–232.

Piper, P. J. & R. J. Rabett, 2009. Disentangling the Harrisson archive to interpret the spatial and temporal distribution of vertebrate remains at Niah Caves, Borneo. *International Journal of Osteoarchaeology*, **19**: 464–475.

Piper, P. J. & R. J. Rabett, in press. The vertebrate fauna. In: Barker, G. (ed.), *Rainforest Foraging and Farming in Island Southeast Asia: The Archaeology and Environmental History of the Niah Caves, 1954–2004*. Niah Cave Project Monographs. McDonald Institute Monograph Series.

Piper, P. J., Earl of Cranbrook (V) & R. J. Rabett, 2007a. Confirmation of the presence of the tiger *Panthera tigris* (L.) in Late Pleistocene and Early Holocene Borneo. *Malayan Nature Journal*, **59**: 259–267.

Piper, P. J., R. J. Rabett & Earl of Cranbrook (V), 2007b. New discoveries of an extinct Giant Pangolin (*Manis cf. palaeojavanica* Dubois) at Niah Cave, Sarawak, Borneo: Biogeography, palaeoecology, and taxonomic relationships. *Sarawak Museum Journal*, **63** (New Series 84): 205–226.

Piper, P. J., H-c Hung, F. Z. Campos, P. Bellwood & R. Santiago, 2009. A 4000 year old introduction of domestic pigs into the Philippine Archipelago: Implications for understanding routes of human migration through Island Southeast Asia and Wallacea. *Antiquity*, **83**: 687–695.

Piper, P. J., J. Ochoa, E. Robles, H. Lewis & V. Paz, 2011. Palaeozoology of Palawan Island, Philippines. *Quaternary International*, **233**: 142–158.

Puri, R. K., 2005. *Deadly Dances in the Bornean Rainforest: Hunting Knowledge of the Penan Benalui*. KITLV Press, Leiden.

Rabett, R. & G. Barker, 2007. Through the looking glass: New evidence on the presence and behaviour of Late Pleistocene humans at Niah Cave, Sarawak, Borneo. In: Mellars, P., C. Stringer, O. Bar-Yosef & K. Boyle (eds.), *Rethinking the Human Revolution: New Behavioural and Biological Perspectives on the Origins and Dispersal of Modern Humans*. McDonald Institute Monographs, Cambridge. Pp. 383–394.

Reed, C. A., 1969. The pattern of animal domestication in the prehistoric Near East. In: Ucko, P. & G. W. Dimbleby (eds.), *The Domestication and Exploitation of Plants and Animals*. Duckworth, London. Pp. 361–380.

Reed, C. A., 1970. Extinction of mammalian megafauna in the Old World Late Quaternary. *BioScience*, **20**(5): 284–288.

Reitz, E. J. & E. S. Wing, 1999. *Zooarchaeology*. Cambridge Manuals in Archaeology, Cambridge University Press, Cambridge.

Rowley-Conwy, P., 1981. Mesolithic Danish bacon. In: Sheridan, A. & G. N. Bailey (eds.), *Economic Archaeology*. British Archaeological Reports, International Series, **96**: 51–55.

Rütimeyer, L., 1862. Die Fauna der Pfahlbauten der Schweiz. *Neue Denkschriften der Allgemeinen Schweizerischen Gesellschaft für die Gesammten Naturwissenschaften*, **19**: 1–248.

Sacks, B. N., S. K. Brown, D. Stephens, N. C. Pedersen, J.-T. Wu & O. Berry, 2013. Y Chromosome analysis of dingoes and Southeast Asian village dogs suggests a Neolithic continental expansion from Southeast Asia followed by multiple Austronesian dispersals. *Molecular Biology and Evolution*, **30**: 1103–1118.

Sakellaridis, M., 1979. *The Mesolithic and Neolithic of the Swiss Area*. British Archaeological Reports, International Series 67, Oxford.

Semenov, S. A., 1964 [1957]. *Prehistoric Technology: An Experimental Study of the Oldest Tools and Artefacts from Traces of Manufacturing and Wear*. (Trans. M. W. Thompson). Cory, Adams & Mackay Ltd, London.

Skeels, M. A., 1962. The mastodons and mammoths of Michigan. *Papers of the Michigan Academy of Science, Arts, and Letters*, **47**: 101–133.

Slaughter, B. H., 1967. Animal ranges as a clue to Late Pleistocene extinction. In: Martin, P. S. & H. E. Wright Jr. (eds.), *Pleistocene Extinctions: The Search for a Cause*. Yale University Press, New Haven. Pp. 155–168.

Sloan, C., 1975. A study of the Punan Busang, III: Punan hunting methods. *Malayan Nature Journal*, **28**: 146–151.

Smith, B. D., 1976. "Twitching": A minor ailment affecting human paleoecological research. In: Cleland, C. E. (ed.), *Cultural Change and Continuity*. Academic Press, New York. Pp. 275–292.

Solheim, W., 1977. The Niah research program. *Journal of the Malaysian Branch of the Royal Asiatic Society*, **50**: 28–40.

Tsukada, M., 1966. Late Pleistocene vegetation and climate in Taiwan (Formosa). *PNAS*, **55**: 543–548.

Uerpmann, H.-P., 1979. *Probleme der Neolithisierung des Mittelmeerraums*. Ludwig Reichert Verlag, Beihefte zum Tübinger Atlas des vorderen Orients, Reihe B, Nr. 28, Weisbaden.

Verstappen, H. Th., 1975. On palaeo climates and landform development in Malesia. *Modern Quaternary Research in Southeast Asia*, **1**: 3–36.

Verstappen, H. Th., 1980. Quaternary climatic changes and natural environment in SE Asia. *GeoJournal*, **4**: 45–54.

Voigt, E. A., 1983. *Mapungubwe: an Archaeozoological Interpretation of an Iron Age Community*. Transvaal Museum, Pretoria.

Walker, D. & J. R. Flenley, 1979. Late Quaternary vegetational history of the Enga Province of upland Papua New Guinea. *Philosophical Transactions of the Royal Society of London, Series B*, **286** (1012): 265–344.

Westropp, H., 1872. *Prehistoric Phases*. Bell and Daldy, London.

White, T. E., 1952. Observations on the butchery techniques of some aboriginal peoples: 1. *American Antiquity*, **17**: 337–338.

White, T. E., 1953a. A method of calculating the dietary percentage of various food animals utilized by aboriginal peoples. *American Antiquity*, **18**: 396–398.

White, T. E., 1953b. Observations on the butchery techniques of some aboriginal peoples no. 2. *American Antiquity*, **19**: 160–164.

White, T. E., 1954. Observations on the butchery techniques of some aboriginal peoples nos 3, 4, 5 and 6. *American Antiquity*, **20**: 254–264.

White, T. E., 1955. Observations on the butchery techniques of some aboriginal peoples nos 7, 8 and 9. *American Antiquity*, **21**: 170–178.

White, T. E., 1956. The study of osteological materials in the Plains. *American Antiquity*, **21**: 401–404.

Wilson, B., C. Grigson & S. Payne (eds.), 1982. *Ageing and Sexing of Animal Bones from Archaeological Sites*. British Archaeological Reports, British Series 109, Oxford.

Wing, E. S., 1978. Animal domestication in the Andes. In: Browman, D. L. (ed.), *Advances in Andean Archaeology*. Mouton, The Hague. Pp. 167–189.

Wintemberg, W. J., 1919. Archaeology as an aid to zoology. *Canadian Field Naturalist*, **33**: 63–72.

Wolberg, D. L., 1970. Late Pleistocene extinction: A note. *American Anthropologist*, **72**: 106–107.

Woodfield, C. C., 2005. Lobang Kudih: The excavation of a Ming Period burial cave, near Beluru, Miri Division, within the Baram basin. *Sarawak Museum Journal, Special Issue 61* (New Series 82).

Yoshiba, K., 1964. Report of the preliminary survey on the Orang-utan in North Borneo. *Primates*, **5**: 11–26.