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From Small Holes to Grand Narratives: The Impact of Taphonomy and Sample Size on the Modernity Debate in Australia and New Guinea

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Abstract

Our knowledge of early Australasian societies has significantly expanded in recent decades with more than 220 Pleistocene sites reported from a range of environmental zones and depositional contexts. The uniqueness of this dataset has played an increasingly important role in global debates about the origins and expression of complex behaviour among early modern human populations. Nevertheless, discussions of Pleistocene behaviour and cultural innovation are yet to adequately consider the effects of taphonomy and archaeological sampling on the nature and representativeness of the record. Here, we investigate the effects of preservation and sampling on the archaeological record of Sahul, and explore the implications for understanding early cultural diversity and complexity. We find no evidence to support the view that Pleistocene populations of Sahul lacked cognitive modernity or cultural complexity. Instead, we argue that differences in the nature of early modern human populations across the globe were more likely the consequence of differences in population size and density, interaction and historical contingency.

Keywords: Sahul; Pleistocene; Behavioural modernity; Site formation; Cultural complexity

Introduction

Sahul, the combined Pleistocene low sea-level landmass of New Guinea and Australia, plays an important role in global debates concerning the origins and spread of modern humans and the characterisation of cultural complexity present among them. As an isolated island continent that was uninhabited by hominin species prior to modern human arrival, Sahul offers a window to the cultural and economic characteristics of early colonising human groups in an unfamiliar environment that was free from inter-specific competition. Despite making a formidable sea voyage to reach Greater Australia, adapting to unfamiliar flora and fauna, occupying most biogeographic zones within a few millennia, engaging in some of the earliest known ritual burials, and rapidly developing advanced and previously unknown lithic technologies (e.g., waisted and edge-ground axes), the Pleistocene archaeological record of Sahul is frequently depicted as simple, unchanging and homogeneous – or as Clark in 1968 put it in reference to the lithic technology: 'crude, colourless and unenterprising' (Clark cited in White, 1977: 13).

A number of reviews of the evidence for cultural complexity among Sahul's earliest societies have appeared in recent years (Brumm and Moore, 2005; Franklin and Habgood, 2007; O'Connell and Allen, 2007; Habgood and Franklin, 2008; Balme et al., 2009). These reviews conclude that while sometimes startling (as in the c.40,000 years BP Mungo ochred burial, early shell beads, long-distance exchange, rock art, axes and grindstones), overall the evidence is sparse and unlike that seen from the Old World. Most agree that these few instances are unlikely to represent the arrival of a complete 'package' of complex behaviours from MSA Africa. All agree that complex behaviour in Sahul shows a slow start, likely reflecting a small founding population and low population numbers with little sustained growth until the Holocene. O'Connell and Allen (2007: 404) even state that Sahul's Pleistocene archaeological record is so unlike that of Europe and Africa that it "does not appear to be the product of modern human behaviour as such products are conventionally defined."

Several commentators note that preservation and sampling may be key factors structuring the present state of knowledge about early cultural complexity and innovation in Sahul (Brumm and Moore, 2005; Davidson, 2007; Balme et al., 2009), yet none have systematically investigated these issues, and some have played down their importance altogether (e.g., Habgood and Franklin, 2008). Yet accurate depictions of cultural change and diversity in Sahul, and hence the place of the Sahul story in the ongoing debate about a mosaic-like or full-blown emergence of cultural complexity in modern human societies (Klein, 1995, 2000; Mellars, 1996, 2005; d'Errico et al., 1998; McBrearty and Brooks, 2000; Wadley, 2001; d'Errico, 2003; Zilhão, 2007), is dependent on how much and how well archaeological evidence is preserved and recovered. The extreme environments and highly variable climates of Sahul dictate that preservation must have played a major role in the survival of archaeological evidence in this region. But how well does the record survive? Similarly, archaeological sampling practices are known to dramatically affect the recovery of certain kinds of evidence needed to identify behavioural modernity, but how large are our samples? Indeed, should we expect to have recovered most kinds of evidence based on our current sampling?

Our goal in this paper is to explore the impact that differential preservation and sample size have had on constructions of Pleistocene lifeways in this region, as well as explore the implications of an incomplete record and variable sampling for the modernity debate in Sahul. We conduct new analyses exploring the impacts of differential preservation over time and space in Sahul, focussing on depositional context and environmental setting. We also examine the effects of sample size and recovery methods on the likelihood of recovering important markers of cultural complexity. In undertaking this analysis, we address three key questions: (1) has the recovery of archaeological materials been sufficient to adequately characterize cultural diversity, complexity and innovation among the earliest colonisers of Sahul? (2) What biases currently exist in the record? (3) what patterns in cultural change and diversity emerge when taphonomic and sampling effects are minimized?

Discussions of the record of symbolism and complexity in Sahul have typically been framed against the backdrop of the 'modernity debate' that currently dominates Palaeolithic research in Africa and Eurasia. The term ' behavioural modernity' has remained strangely ill-defined, leaving open the possibility that this refers either to cognitive modernity, meaning the state of cognitive virtuosity and flexibility observed among living people today, or some form of cultural type or stage serving as a yardstick against which to measure human achievement and capabilities across time and space. We prefer to see the debate as centred on determining the point at which 'modern cognition' first appeared and became fixed within past populations to avoid rigid typological definitions of cultural modernity.

The question of the origins of 'modernity' in Sahul needs to be recast to avoid two unacceptable propositions: (1) that an anatomically modern human population colonised the continent without complete modern cognition, and (2) that those early populations can be compared with a 'cultural type' or trait list as a valid yardstick for measuring cognitive development. Presented with occupation of Sahul by a fully anatomically and cognitively modern population, we must steer the 'modernity debate' in Sahul away from the question of 'When did modernity first appear in Sahul?' (answer: when modern humans arrived) to 'When did complex cultural behaviours appear in Sahul?' Since the modernity debate largely searches for evidence of complex behaviour and other traces of complex mental phenomena as a proxy for modern cognition, we argue this approach can serve both purposes and we have advocated the same approach elsewhere in relation to the question of Neanderthal complexity (Langley et al., 2008).

The emphasis on emerging cultural complexity is also appropriate given that populations likely began small and expanded rapidly across the continent, entering new habitats, climatic zones and crossing major water gaps. The link between population size and cultural innovation and complexity is now well established (Shennan, 2000; Powell et al., 2009; Kline and Boyd, 2010), and means that changes in complexity in Sahul are likely tied in some way to demography and interaction. Reformulating the modernity debate in Sahul as the emergence of a diverse range of complex behaviours lends itself to analysis and modelling of the relationship between complexity and prehistoric demography as revealed from radiocarbon dating and site occupation data.

Methods

Complexity in cultural systems can be usefully defined as the accumulation of "more parts and more connections between parts" (Price, 1995: 140). Placing the emphasis on *diversity of complex behaviours* rather than individual traits indicative of modernity (or cultural complexity) therefore gives rise to a solution to the methodological problems inherent in this debate by taking the focus off any one trait in favour of the overall picture. To develop a measure of diversity, we employ generic categories (listed in Table 1) that reference the criteria typically used to indicate abstract thinking, planning depth, innovativeness, and the appearance of symbolism (e.g., Chase and Dibble, 1987; McBrearty and Brooks, 2000;Wadley, 2001; Klein and Edgar, 2002; d'Errico, 2003; d'Errico et al., 2003; Henshilwood and Marean, 2003; Conard, 2008). These categories have traditionally included archaeological objects and features indicative of personal ornamentation, social communication, ritual disposal of the dead, complex subsistence behaviours, formalised and/or complex technologies, long-distance social interaction, deliberate environmental modification, exploitation of new habitats and long-distance water crossings.

While some of these categories at first glance may seem inappropriate for a comparison concerned only with modern human populations, these categories have been employed in all previous studies of complex behaviours, both in Pleistocene Sahul and Africa and Eurasia (e.g., McBrearty and Brooks, 2000; d'Errico, 2003; Brumm and Moore, 2005; Mellars, 2005; Habgood and Franklin, 2008), therefore necessitating their use in this study in order to make its findings comparable with previous research. We are therefore not making the claim that manufacturing a shell or bone tool is particularly complex in and of itself, but instead, that each category is part of a wider suite of indicators, which can be used to identify complex and diverse cultural behaviours in the archaeological record.

However, to combat this methodological problem, we have separated our dataset into symbolic and non-symbolic instances in order to make more direct comparison between instances more clearly indicative of abstract thought and symbolism versus those more clearly representing forward planning and innovation. This dual system of data exploration allowed both the comparison of our results with those previous and a more rigid analysis of only those symbolic categories, which we felt were a better indication of changes in social complexity.

To examine the spatial and temporal distribution of evidence for complex behaviours in Sahul, artefacts and features identified as representing 'complex cultural behaviour' in the archaeological record (see Table 1) were recorded as separate instances in time and space. For this study, an archaeological instance of complex behaviour was defined as a single type of artefact or feature indicative of one of the items listed in Table 1 from a single site in a securely dated context, regardless of the abundance of that artefact type or feature. Thus, a single incised object or a group of 250 fragments of pigment from the same dated context each represents a single instance in the study. Where several distinct instances occur within a site and are dated by two or more distinct dates, each would represent a separate instance. Our approach therefore favours diversity of artefact types per dated context as opposed to quantity of artefacts, although the two may be correlated. This approach is consistent with Price's (1995) definition above.

The date of first colonisation of Sahul is imprecise and is best estimated as 50,000±10,000 years BP (Hiscock and Wallis, 2005). This level of uncertainty and large error ranges for some dates makes determining both the earliest instances of complex behaviour, as well as rates of initial change in complexity within Sahul, very difficult. To avoid attributing undue precision to early instances of complexity in Sahul, we assign all individually dated instances to 5000-year intervals spanning the period from 55,000 to 10,000 years BP. If an artefact or feature was associated with more than one date or only relative dates were available, a mean for these dates was calculated to determine the appropriate chronological unit. This creates some temporal ambiguity but captures the uncertainty that exists over the age of some instances.

Data were compiled for this study from published and unpublished sources, yielding 2096 absolute ages and 464 instances of complex behaviour from 223 archaeological sites. This dataset dramatically expands earlier compilations undertaken by Jones (1968, 1973, 1979) and Smith and Sharp (1993). As in these earlier reviews, any site (enclosed or open) containing a Pleistocene archaeological deposit (>10,000 years BP) was included in the dataset (Figure 1).

Table 1. Archaeological correlates of complex behaviour in Sahul.

McBrearty and Brooks (2000) principle	Category	Symbolic evidence	Number of instances recorded in Sahul
Symbolic behaviour, abstract thought and innovativeness	Social communication, art, ritual behaviours	Burial Pigment Ornamentation Notational Piece Rock Art Intentional cranial deformation Total	20 63 13 4 22 6 128
		Non-symbolic evidence	
Innovativeness and planning depth	Complex technologies, formal implements, composite technologies	Ground-edge axes Grindstones Thumbnail scrapers Hafting Bone technology Shell technology Wood technology	18 14 13 9 36 12 2
	Exploitation of new environments, environmental modification, complex subsistence	Plant exploitation Avian exploitation Freshwater exploitation Marine exploitation Shellfish exploitation Megafauna exploitation	21 27 5 18 74 8
	Exploration of new environments, social interaction, complex and composite technologies	Colonisation Long-distance transport	4 36
		Other Total	39 336

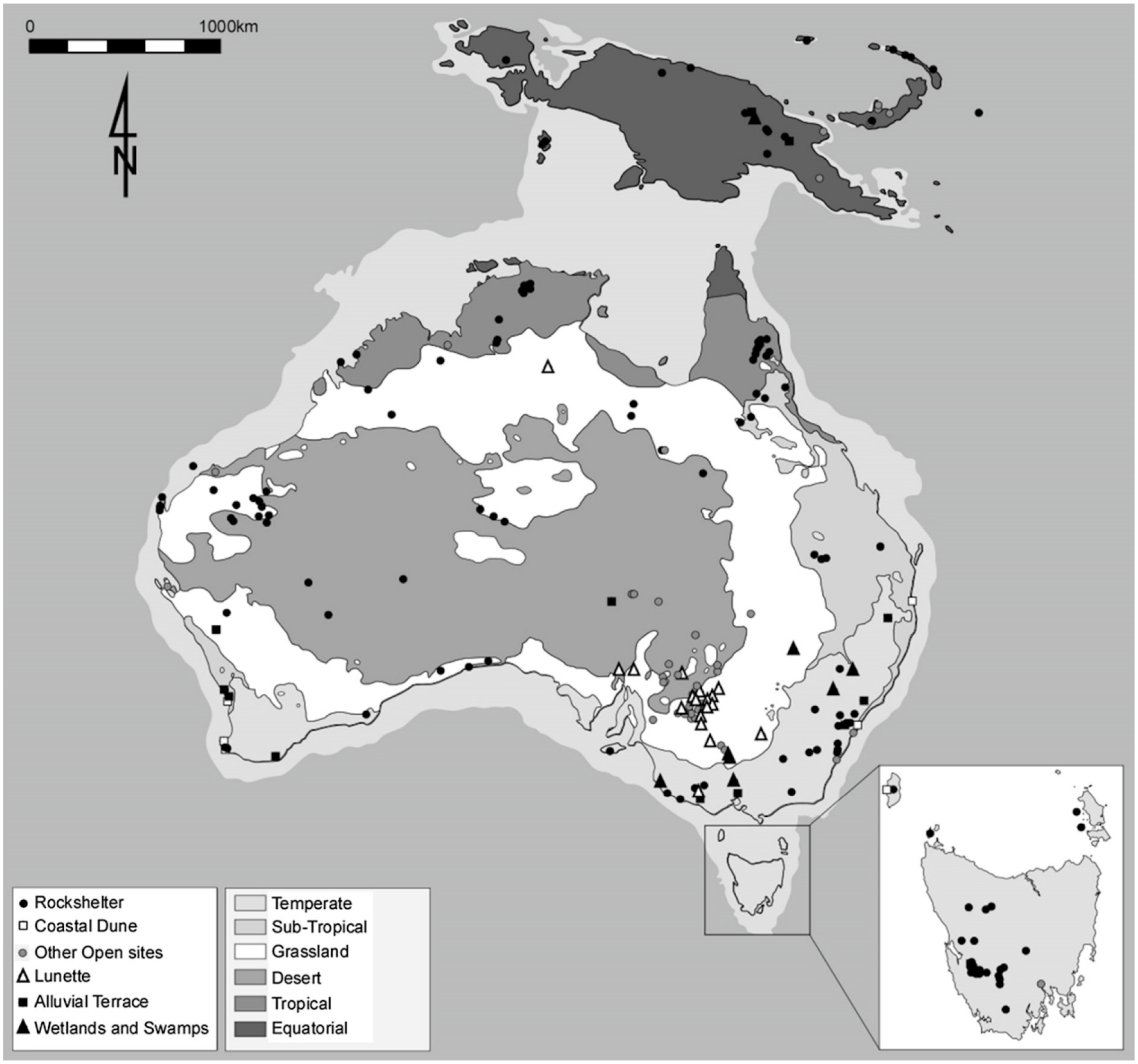

Figure 1. Distribution of Sahul Pleistocene sites showing location of environmental zones. Inset: Tasmania.

Information for each site was systematically reviewed to determine geographic location, excavation history, assemblage composition, and compile absolute (^{14}C, AMS, OSL, U-Series, TL) and relative (ESR, biostratigraphic) ages. Following Smith and Sharp (1993), each site was assigned to one of six depositional contexts; rockshelters/caves, alluvial terraces, coastal dunes, lunettes, wetlands/swamps, or other open sites (artefact scatters etc.). Sites were present in all six depositional contexts and all environmental regions (equatorial, tropical, sub-tropical, semi-arid grassland, temperate and desert), as defined by the Australian Bureau of Meteorology (based on annual rainfall) (http://www.bom.gov.au), thereby providing a sample representative of the diversity of depositional contexts across Pleistocene Sahul. Radiocarbon ages were calibrated using OxCal v.4.1 (Bronk Ramsey, 2009). Atmospheric ages were calibrated using the calibration datasets SHCal04 (McCormac et al., 2004) for ages between 0 and 11,000 years BP and INTCAL09 (Reimer et al., 2009) for ages between 11,000 and 50,000 years BP with a +41±14 southern hemisphere offset (McCormac et al., 2004). Marine ages were calibrated using MARINE09 (Reimer et al., 2009) and the ΔR regional offset recommended by Ulm (2006)

Owing to differences in the detail of available information, not all artefact type, site, excavation and absolute date fields could be completed for every site. The excavators of sites with missing data were contacted directly to address these gaps, however, the required data were often not available either because it was not collected at the time of excavation or had subsequently been lost. This meant that not all 223 sites could be included in every analysis undertaken in this study. Sub-samples of various sizes were used for each analysis, which included as many of the 223 sites as possible.

One of the advantages of this dataset over those employed in previous studies is that both sites containing evidence for complex behaviours and sites without archaeological evidence for complex behaviours are included. This allows us to generate a more complete picture of the frequency and distribution of archaeological indicators of complexity, as well as a better understanding of how complex cultural behaviours are represented in the Pleistocene archaeological record of Sahul.

Results

A total of 464 instances of complex behaviour were identified in securely dated contexts, with 481 Pleistocene instances recorded in total. Symbolic evidence is found in 40% of the 223 sites while non-symbolic evidence is found in 55% of sites. Evidence for complex behaviour is absent in only 33% of Pleistocene sites in our database, suggesting that detection of complex behaviour in Pleistocene sites is the norm and that Pleistocene sites are generally richer in such traces than is commonly expressed in the literature. Despite compiling a much larger sample, our results mirror previous studies in revealing a steady increase in the quantity of evidence for complexity in Sahul through time (Figure 2). The larger dataset has revealed, however, that the temporal distribution of non-symbolic evidence differs from the symbolic evidence. While non-symbolic evidence increases more evenly over time, the distribution of symbolic evidence is more varied, showing a significant increase in quantity and diversity immediately following the LGM.

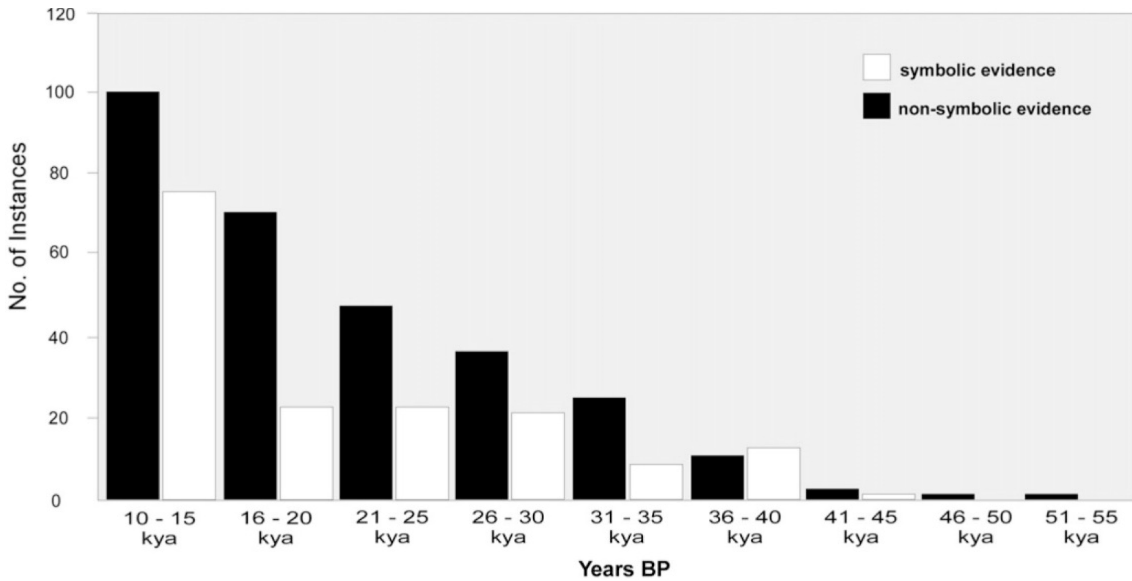

Figure 2. Frequency distribution of symbolic and non-symbolic datasets in Sahul presented in 5000-year time slices.

Evidence for symbolism in Sahul includes 128 instances from six categories incorporating ornamentation, pigment use, notational pieces, rock art, ritual burial, and intentional cranial deformation. While complex behaviours are represented from the earliest time slice, evidence for symbolism does not make its first appearance until 41,000e45,000 years BP. The use of pigment at sites such as Malakunanja II (ochre crayon) (Roberts et al., 1994), Carpenter's Gap 1 (painted roof fall) (O'Connor,1995; O'Connor and Fankhauser, 2001) and Lake Mungo (exotic ochre) (Allen, 1972; Bowler, 1998) are the first evidence for symbolic activities in Sahul. Pigment use provides the most abundant form of symbolic evidence throughout the Pleistocene. The early use of pigment at Lake Mungo is potentially the most significant of these, owing to its use in the WLH3 ritual extended burial and the transport of ochre over 200 km to the burial site (Bowler et al., 2003). The world's earliest cremation is also found at this site, dating to c. 40,000 years BP, together demonstrating the ritual complexity of early populations in southeast Australia (Bowler et al., 1970, 2003).

The first evidence for rock art appears early in the record between 36,000 and 40,000 years BP at Carpenter's Gap 1 (O'Connor and Fankhauser, 2001) and remains one of the main components of the symbolic record throughout the Pleistocene. The decoration and/or transfer of cultural meanings through this medium therefore contributes one of the oldest symbolic behaviours in Sahul, as well as the most frequently identified in the archaeological record.

Burials at Lake Mungo (Allen, 1972; Bowler, 1998) and personal ornamentation from Riwi (pierced shell beads) (Balme, 2000; Balme and Morse, 2006), Mandu Mandu Creek (pierced shell beads) (Morse, 1993; Balme and Morse, 2006) and Buang Merabak (drilled shark's tooth) (Leavesley and Allen, 1998) first appear between 36,000 and 40,000 years BP; however, these traits only contribute sporadically to the record of complex behaviour until 10,000–15,000 years BP. Evidence for notational pieces appears in just three time slices, once at 31,000–35,000 years BP at Spring Creek (tooth with incised grooves) (Vanderwal and Fullagar, 1989), twice at 21,000–25,000 years BP at Devil's Lair (engraved limestone plaque) (Dortch, 1976) and Cave Bay Cave (macropod femur with grooves) (Stockton, 1981) and finally a single instance during the last 5000 year time slice again found at Devil's Lair (engraved limestone plaque) (Dortch, 1976). Finally, intentional cranial deformations along with possible cemeteries at Coobool Creek and Kow Swamp (Brown, 1987; Pardoe, 1993) appear in the last 5000 years of the Pleistocene.

A total of 336 instances of non-symbolic complex behaviours from 16 different categories were identified from 123 Pleistocene sites. Instances appear in all time slices with innovative and complex technologies comprising both the oldest non-symbolic instances and the oldest instances in the total dataset. Waisted axes from Bobongara in Papua New Guinea (PNG) provide the first evidence for complex behaviour in Sahul dated to between c.61,400 and c.44,500 (U-series) (Groube et al., 1986; Roberts, 1997). These examples have been recently joined by a number of waisted axes reported by Summerhayes et al. (2010), recovered from four sites also found in the New Guinea Highlands and dated to >42,500 years BP. It has been suggested that the large size and robustness of these lithic artefacts is indicative of their use for activities such as forest clearance rather than more delicate, wood-working tasks (Groube, 1989). These waisted axes are a regional innovation unknown elsewhere in the world at this time and appear at a number of additional sites in northern Sahul and Melanesia from around 35,000 years BP (e.g., Kosipe: Allen, 1972; Lampert, 1983; Nawarla Gabarnmang: Geneste et al., 2010; Sandy Creek 1: Morwood and Trezise, 1989; Morwood et al., 1995; Widgingarri 1: Morwood, 1989; O'Connor, 1999).

The 20,000 years following the appearance of waisted axes witnesses the appearance of a wide variety of new complex and standardised technologies including ground-edge axes (Geneste et al., 2010), bone tools (points, spatulas, awls), shell tools (adzes, containers, flaked shell tools) and dedicated food processing tools such as grindstones (found at sites including Malakunanja II, Nauwalabila 1 and Willandra Lakes). Standardised hafted retouched stone tools, often made from high quality exotic raw materials (e.g., 'thumbnail scrapers' from southwest Tasmania), appear in the record at around 35,000 years BP and the oldest known wooden projectile technologies appear a little later at around 25,000 years BP (as indicated by imprints of shafts at Lake Mungo; see Webb et al., 2006). Additional evidence for wooden artefacts, along with other perishable technologies such as clothing and textiles are found in rock art, which includes images of elaborate clothing, headdresses, baskets, nets and other textiles (Welch, 1996). Their inclusion in these images demonstrates that these items were part of the material culture repertoire of Pleistocene populations dating back to at least c.20,000 years BP when these images are argued to have been painted (Taçon and Chippindale, 1994; Walsh, 1994; Flood, 1997).

Evidence for forward planning and innovation in subsistence strategies makes up the dominant component of the non-symbolic dataset. These include the exploitation of difficult to obtain resources and demanding environments requiring adaptations to subsistence as well as possible risk reduction strategies. Once entering the Sahul landmass, colonists would have been faced with a wide range of challenging environments, including tropical rainforests in the New Guinea highlands, arid zones in Central Australia, permafrost regions of the Tasmanian highlands and Melanesian islands with low productivity, each requiring unique social, technological and economic adaptations. To successfully exploit these environments colonists developed and undertook a range of activities such as the detoxification of plants (e.g., Macrozamia pits at Cheetup: Smith, 1996; taro at Kilu: Gosden, 1995), exploiting arboreal or flighted animals including cuscus, bats and a wide range of birds (as evidenced at Buang Merabak, Balof 2 and Batari, Steadman et al., 1999), exploiting deep sea resources including several species of large sharks, tuna and mackerel (as at Balof 2: Leavesley, 2007; Kafiavana: White, 1972; Buang Merabak: Leavesley, 2007), and the transportation of staple flora and fauna such as the cuscus (*Phalanger orientalis*), rat (*Rattus mordax*) and bandicoot (*Echymipera kalubu*) to islands previously devoid of these species (Allen et al., 1989; Fredericksen et al., 1993; Leavesley and Allen, 1998).

People also modified their landscape as evidenced by a marked increase in burning that takes place around c.45,000 years BP as seen in the Lynch's Crater pollen core in north Queensland (Turney et al., 2001). This change appears to be independent of any known climatic changes during that period and appears to be the product of human agency. Firing the landscape has been used in ethnographic times for hunting and managing game (Bowman et al., 2001; Bliege Bird et al., 2008), as well as promoting the growth and increasing the density of favoured plant species (Jones, 1969; Gott, 2005). This form of landscape alteration and management is therefore likely to carry with it some element of intentionality even if all the consequences of such practices could not have been anticipated. Denham et al. (2009) also argue that the early use of axes could have contributed to vegetation change through understory clearing and ring-barking of large trees (see also Groube, 1989). The deliberate modification of the landscape together with the introduction of favoured staple species to these landscapes suggests that colonising populations were fully capable of altering their environment to suit their needs.

The first evidence for long-distance social interaction or exchange appears as marine shells, shell beads and ochre transported >200e300 km at sites including Riwi and Lake Mungo from 36,000 to 40,000 years BP (Allen, 1972; Balme, 2000; Balme and Morse, 2006). Other exotic raw materials were also being exploited and moved long distances from this time, such as Darwin glass (>50 km) in western Tasmania and obsidian in Melanesia (Allen et al., 1989; Brown et al., 1991; Jones, 1995; Cosgove, 1999; Torrence et al., 2004). Although ocean-going watercraft are not directly known from Pleistocene sites, and hence are not included in this analysis, obsidian was transported from quarries on the New Guinea mainland to Melanesian islands >23 km away, requiring the manufacture and use of sturdy watercraft around c.35,000–45,000 years BP (Torrence et al., 2004). Allen and O'Connell (2008) additionally argue that watercraft must have been employed from before 40,000 years BP to obtain the deep sea fish found in Melanesian sites (including Buang Merabak, Matenkupkum, Kilu), as well as make journeys of up to 175 km to remote islands such as Manus and the Solomons.

Collectively, the evidence for early complex behaviours in Pleistocene Sahul shows a remarkable degree of flexibility and innovation in symbolism, subsistence and technology. In the next section, we investigate the degree to which this pattern of unidirectional increase in the abundance and diversity of complex indicators could be attributable to taphonomic and sampling factors by reviewing sample size, collection methods, preservation and depositional context as well as the effects of climate change.

The impact of taphonomy and archaeological sampling

The survival of cultural materials in archaeological deposits is a function of various taphonomic processes, influenced by the specific macro- and microenvironmental conditions of each region and the unique depositional processes operating at each site. Both organic and inorganic artefacts and features are used to identify complex behaviours in the archaeological record, and these are subject to processes of weathering and decomposition to differing degrees. The majority of evidence for complexity in Pleistocene Sahul is comprised of organic artefacts (59%), principally objects of bone, shell and wood. The potential implications of differential preservation for the spatial and temporal representation of evidence are significant, as recently discussed by Surovell and Brantingham (2007) and Surovell et al. (2009). We should expect that most Pleistocene organic artefacts will not have survived such a long period of exposure to destructive taphonomic processes and hence robust inorganic evidence will be over-represented. In many ways, this may create the illusion of a simple Pleistocene material culture. We investigate these issues by examining the differential preservation of organic versus inorganic artefacts in Sahul's Pleistocene archaeological record.

Differential preservation

Depositional context Past investigations have shown that archaeological evidence is differentially preserved in enclosed and open contexts (Lourandos, 1996; cf. Ulm, 2004; Goldberg and Macphail, 2006; Ward et al., 2006), while ethnographic and ethnoarchaeological research suggests enclosed and open sites may differ in use (Binford, 1978; Gorecki, 1991; Nicholson and Cane, 1991; Attenbrow, 2006; Goldberg and Macphail, 2006). Archaeologists have historically preferred to excavate rockshelters and caves rather than open contexts, but both contexts must be investigated to arrive at a satisfactory understanding of Pleistocene behaviour.

Our dataset reveals that 62% of recorded Pleistocene sites are enclosed rockshelter or cave deposits, revealing a pronounced bias towards enclosed site types, given that habitable rockshelters are typically uncommon in most regions. As expected, organic evidence for complexity is more commonly preserved in enclosed sites, with 63.6% of all organic instances found in this site type (Figure 3). Organic evidence is slightly more common in lunettes and wetlands than in any other specific open site type (15.3%), but is found in all site types except coastal dunes. This sample is skewed towards the lunettes of the archaeologically rich Willandra Lakes region of southeast Australia, which has seen intensive archaeological research since the 1960s.

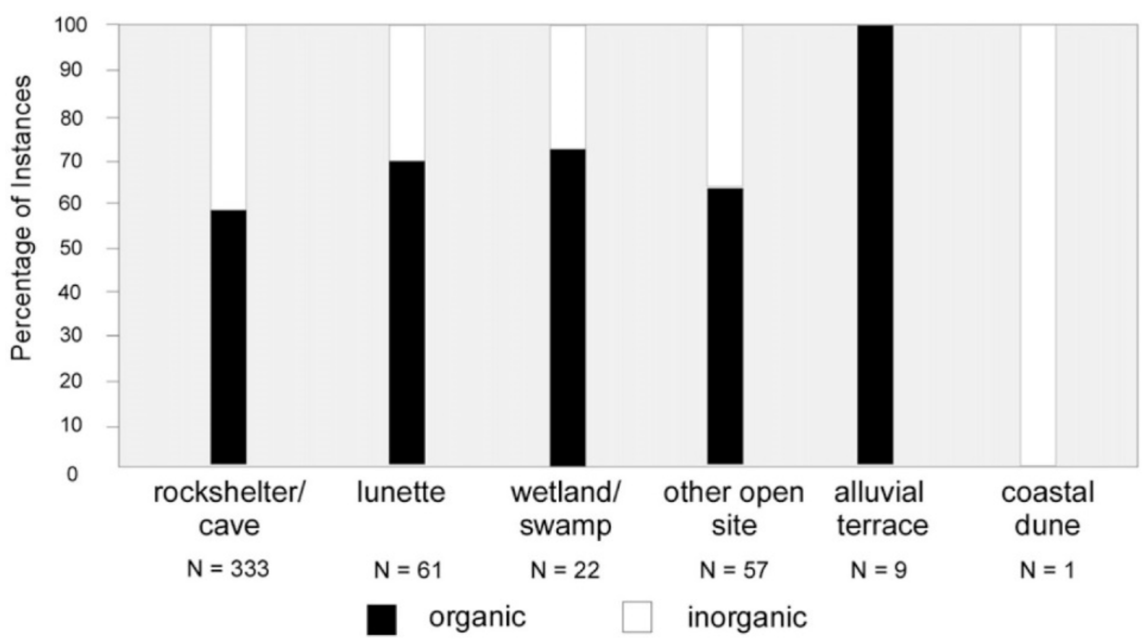

Figure 3. Comparison of the numbers of organic versus inorganic instances in each depositional context.

Geology Of the 138 rockshelters and cave sites recorded in the dataset, 122 reported their geological matrix. Rockshelter and caves are typically formed in limestone (49%) or sandstone (36%), with less than 15% of sites found in other lithologies. Limestone contexts provide an alkaline environment that promotes the preservation of organic items whereas sandstone contexts are typically acidic and hinder organic preservation for long periods (Goldberg and Macphail, 2006). As would be expected, enclosed limestone sites contained 86.4% of the organic evidence while inorganic evidence was present in sandstone and limestone shelters in roughly equal proportions (limestone¼55.81%, sandstone¼ 44.18%). Geological context therefore clearly has a profound effect on the preservation of Pleistocene organic objects. This evidence suggests that most organic artefacts deposited in enclosed sandstone sites probably have not survived.

Given the effects of geology, we should expect that differential preservation will also have affected the survival of organic evidence for complex behaviours through time. The only evidence for complex behaviours until the 36,000–40,000 year time slice consists of inorganic instances from open and enclosed sandstone sites. At 36,000–40,000 BP, the first limestone rockshelters begin to show dateable traces of complex cultural behaviours. Enclosed sites dominate the sample throughout this early period (77%). Open sites do not reach double digits until 26,000e30,000 years BP and hence open air activities are under-represented for at least the first half of the Pleistocene occupation of Sahul.

Climate and environmental zones Sites with fluctuating moisture content create hostile microenvironments for the preservation of organic objects. Such conditions are widespread across Sahul, which is subject to seasonal changes between extended wet and dry periods, particularly in the monsoonal north (Figure1). The east coast of Sahul is dominated by tropical and sub-tropical environments, which also experience regular fluctuations between wet and dry conditions. Environments that are generally more conducive to preservation are the arid centre of Australia where the lack of moisture inhibits decomposition, the temperate regions of southeast and southwest Sahul where cool moist conditions also slow the rate of organic decay, and the climatically stable equatorial zone of the far north where temperature and rainfall are least variable.

Hope et al.'s (2004) map of climatic zones for Sahul during glacial periods makes it possible to explore the potential effects of past climate on site preservation. Eighty-nine sites in the sample were established prior to the LGM (i.e., >20,000 years BP) and several observations can be made about the distribution of these sites in relation to past climate zones:

1. no sites are located in the sub-tropics;

2. sites in climatically unstable regions are mostly located in enclosed contexts (73%); and

3. open sites are largely located in the temperate and grassland regions of the southeast and southwest, or the climatically stable northern equatorial zone.

This distribution pattern suggests that past climatic zones have affected the survival of Pleistocene sites, with site survival far more common in the three places where preservation should be best. The same pattern is found if the distribution of Pleistocene sites is considered in relation to modern environments (Figure 4). Only 5% of sites are located in the sub-tropical and tropical zones, whereas 75% of Pleistocene open sites are located in the grassland and temperate regions of the southeast and the equatorial north, where proportions of organic artefacts actually exceed those of inorganic artefacts. While desert regions contain few Pleistocene sites, the proportion of organic to non-organic objects is likewise higher than for tropical and sub-tropical regions.

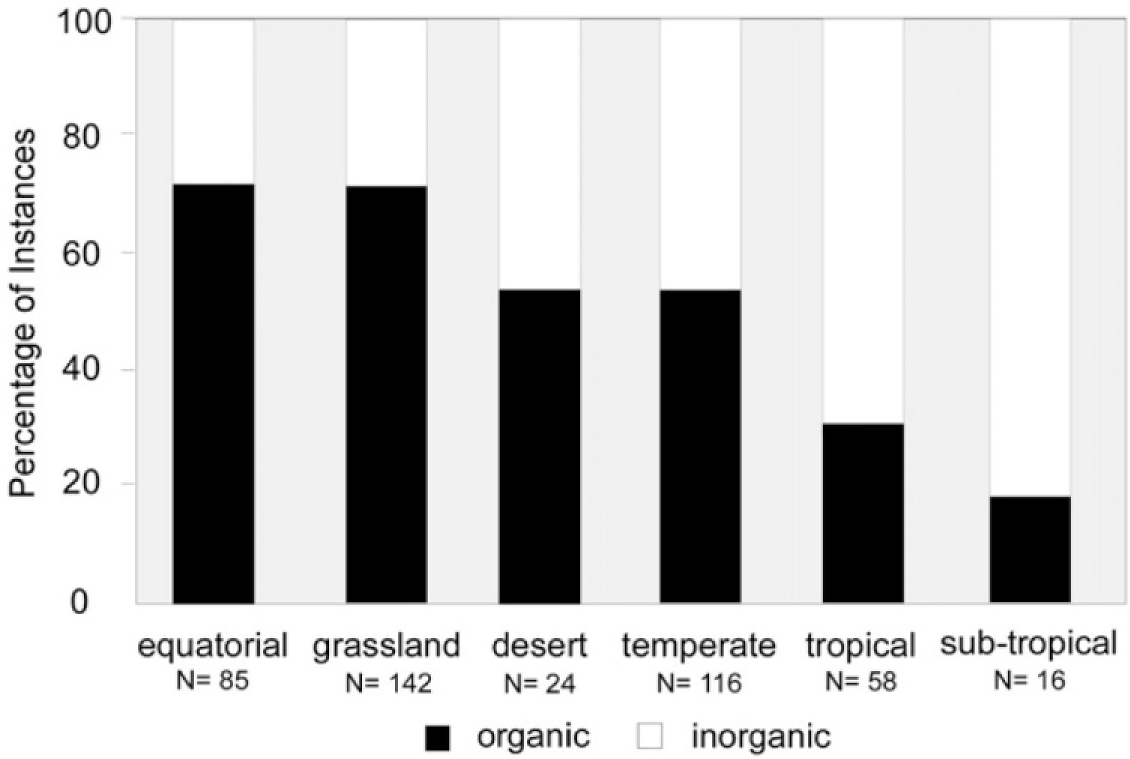

Figure 4. Comparison of organic and inorganic instances found in each environment.

In summary, depositional context clearly creates very different possibilities for the preservation of organic artefacts and the record of organic instances of cultural complexity has clearly been heavily affected by differential preservation. Enclosed limestone shelters in equatorial, arid or temperate landforms provide by far the best preservation, yet these are not represented in the archaeological record until after 40,000 years ago. Sahul's oldest sites are sandstone rockshelters and open sites, which contain demonstrably fewer organic instances and hence possess a lower probability for the survival of organic artefacts. The absence of complex organic artefacts prior to 40,000 years ago in this region might therefore reflect the absence of excavations in suitable contexts for the preservation of organic objects of sufficient age to inform on the activities of early settlers. We now turn to a consideration of the sampling by considering recovery methods and excavated sample sizes.

Sampling

Excavation area and volume A review of archaeological excavation practices for Sahul's Pleistocene sites reveals that the average excavation consists of four squares of either 1x1 m or 50x50 cm in size, excavated to a depth of c.100 cm per square. Based on a sample of 81 Pleistocene sites, the average total excavated volume from a single site was 10.27 m^3 (including both the Pleistocene and Holocene components, which could not be simply differentiated). Mean excavated volume drops markedly after 1990 to only 2.61 m^3. This decrease in excavation volume probably reflects changing research priorities away from establishing cultural sequences towards establishing regional chronologies and land-use patterns, as well as perhaps the increasing cost of fieldwork.

The small size of excavations in Sahul contrasts markedly with many huge Eurasian and African excavations. Consider, for example, Salzgitter Lebenstedt or Abric Romani, where up to hundreds of square meters have been excavated (Gaudzinski and Roebrocks, 2000; Vaquero et al., 2001). Unfortunately, the difficulty of obtaining precise excavation volumes for many sites from Sahul, Eurasia and Africa makes direct comparisons difficult, however, the typically small size of excavations in Sahul may have resulted in a comparatively impoverished record of complex behaviours.

Sieve sizes Sieve sizes play an important role in the recovery of evidence because small items such as beads are vital to the identification of complex behaviours and may be lost if only larger mesh sizes are used. Three millimetre mesh sieves are often cited as the minimum size needed to recover the full range of faunal/artefact diversity present in a deposit (Gordon, 1993; Schaffer and Sanchez, 1994; James, 1997; cf. Vale and Gargett, 2002). An analysis of reported sieve sizes for 93 excavations reveals that 33% of excavations employed sieves greater than 3 mm, suggesting that many small bones, fragments, beads, and other rare items such as exotic raw materials are unlikely to have been retrieved from as much as a third of past excavations.

Sample size Numerous studies have shown that sample size affects the diversity of artefacts recovered from the archaeological record (Grayson, 1981; Nance,1981; Leonard and Jones, 1989; O'Neil,1993; Shott, 2000; Hiscock, 2001). This can be explored for Sahul by examining whether the quantity and diversity of symbolic and the non-symbolic instances is correlated to the number of sites in each time slice. As shown in Figure 5, the quantity of instances and number of sites occupied are highly correlated, strongly linear and significant ($r^2 = 0.954$, d.f. = 9, $p < 0.0005$). This indicates that the quantity of instances in each 5000-year time slice is determined by the size of the sample available. Given that the sample size for early occupation of Sahul is very small, and grows gradually through time, it is not surprising that few signs of complexity are known in Australia and New Guinea.

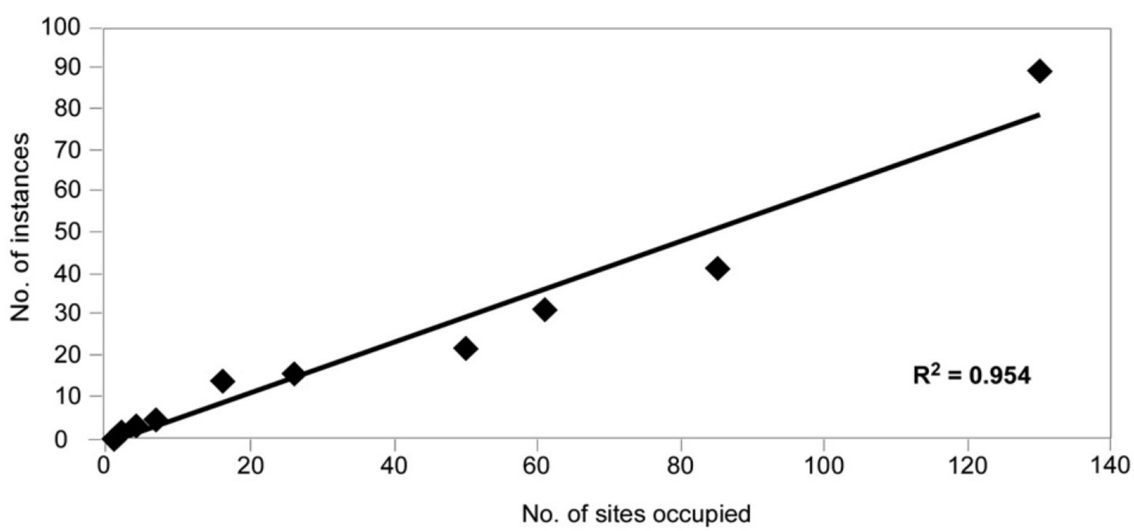

Figure 5. Correlation between the number of sites occupied against the quantity of instances represented in each time slice.

On a smaller, intra-site scale, the volume of excavated deposit shows a moderate correlation with the diversity of complex instances recovered ($r^2 = 0.427$, d.f. = 32, $p < 0.0005$). Hence larger excavations have a higher probability of yielding evidence for complexity, with small excavations of less than 5 m^3 typically yielding one instance, and excavations of >20 m^3 typically yielding two instances. Very large excavations of >40 m^3 may yield as many as five instances of complexity (e.g., Devil's Lair). As the volume data we have includes both Holocene and Pleistocene sediments, we cannot state how this total volume translates into the volume of sediments from Pleistocene-only contexts. We expect that the Pleistocene component of most sites would be less than 30%, but this will vary greatly deal between sites and regions.

Continuing, Figure 6 indicates that the number of occupied sites increases dramatically over time in Sahul. Various explanations can be offered for this trend, including increasing population size, increasing use of marginal landscapes, or increasing site survival. Surovell et al. (2009) have identified this same pattern of exponential increase (or decline) as a likely indicator of differential preservation in both archaeological and geological datasets. Also shown in Figure 6 is the diversity of complex instances from all sites across Sahul through time. While the number of occupied sites continues to rise over time, the diversity of instances plateaus at around 31,000–35,000 years ago. From this point on, site numbers and diversity are decoupled, with site numbers continuing to increase and diversity levelling-off and decreasing slightly at 16,000–20,000 BP, during the LGM. The relationship between diversity and sample size is shown as a scatter plot in Figure 7 and confirms the appearance of a plateau in diversity after 30,000 BP with a slight drop during the LGM.

The relationship between diversity versus numbers of sites occupied suggests either a period of initial population increase, adaptation and innovation took place in the first 30,000 years of occupation with few new innovations after that time, or that earlier innovations are invisible and rapidly lost from the record due to poor preservation. We cannot presently determine which of these is the case, but both are equally plausible given the paucity of sites with good preservation greater than 40,000 years in age and the apparently long 'settling in' period that preceded, for example, the occupation of the arid zone and southwest Tasmania. The absence of limestone shelters from the sample at the time of earliest colonisation may also suggest that preservation factors can be implicated in driving this trend.

Our analyses have so far revealed that depositional context, sample recovery techniques and sample size have all profoundly affected the nature of the evidence for early complexity in Sahul. It would be easy to conclude from these results that the record is so profoundly corrupted by differential preservation and poor sampling as to provide little hope of assessing the nature of early societal complexity in Sahul. In the next section, we explore one means of extracting information about early levels of complexity by examining only the oldest and best preserved sites while keeping several important variables constant.

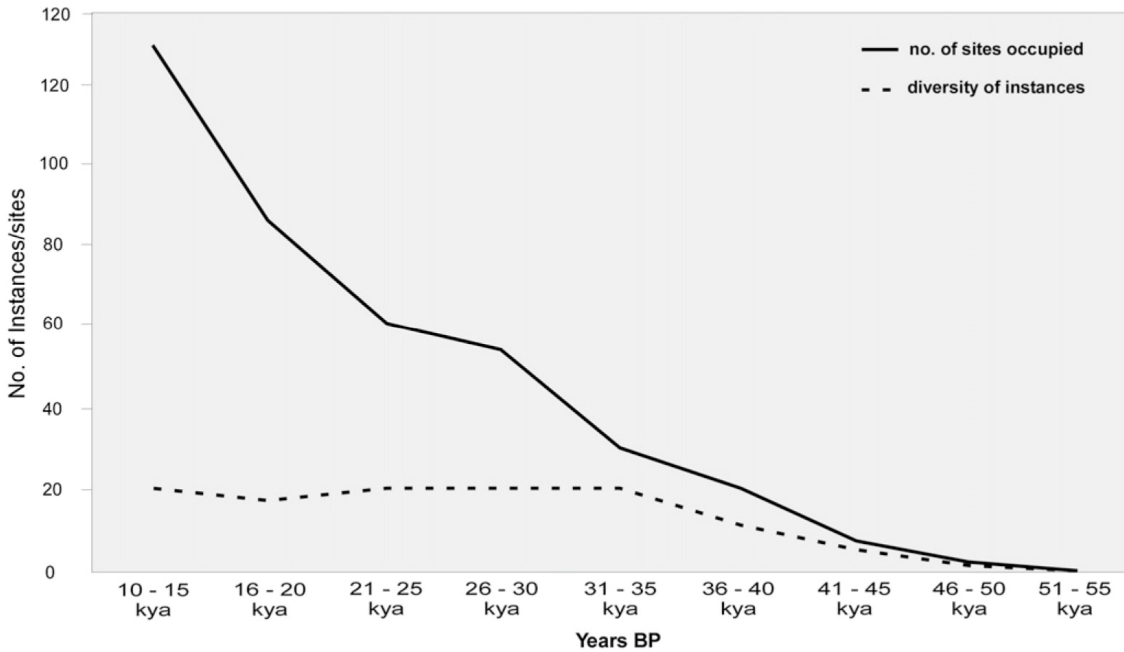

Figure 6. Comparison of the number of sites occupied and diversity of instances in each 5000-year time slice.

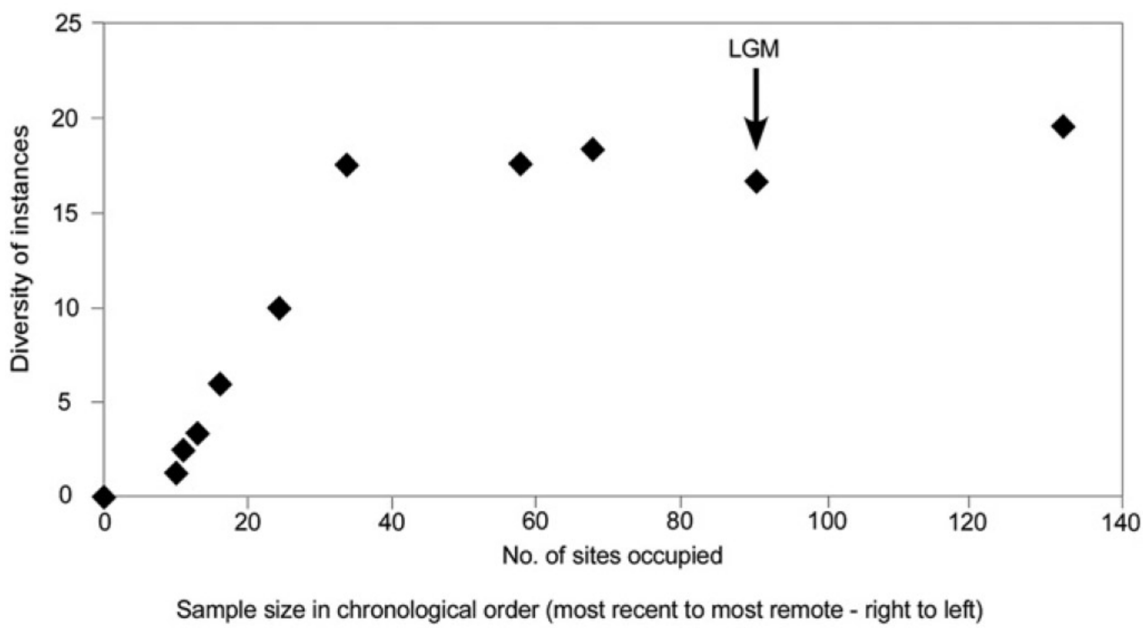

Figure 7. Correlation between the diversity of instances and sample size recovered.

The record of complex behaviour from the oldest preserved sites

In this section, we examine the changing diversity of instances over time for the available sample of continuously occupied sites spanning 40,000–10,000 years ago. The purpose of this analysis is to examine whether the number and diversity of complex behaviours fluctuates through time when only continuously occupied sites are included. This analysis will allow us to test whether all sites show the same trend towards continuous increase in diversity seen in the Figure 2 for the total Australian Pleistocene sample. The sites used in the analysis are Allen's Cave, Carpenter's Gap, Devil's Lair, FABM, GRE 8, Wharton Hill, Lake Mungo, Malakunanja II and Riwi. Only five of these are limestone rockshelters or caves. While the sample is small and preservation conditions may not be uniform at all sites, the advantage of this approach is that we have selected only the oldest continuously occupied sites that have survived intact to discovery (though not necessarily the oldest sites in Australia), and we have eliminated the problem of sample size effects on diversity by maintaining a constant sample size. Because these sites have survived to discovery some 30,000–40,000 years after initial occupation with no obvious breaks in occupation or scouring of sediments, we consider them to be located in microenvironmental contexts with exceptional preservation.

Our results indicate that when only the oldest continuously occupied sites in Australia are plotted, the pattern of diversity in complex indicators departs significantly from the exponential increase seen in Figure 2. The diversity of complex instances is high but fluctuating from 40,000 to 25,000 BP, then shows a pronounced decline over the Last Glacial Maximum period, followed by a subsequent huge rise in diversity in the last 10,000–15,000 years (Figure 8). One way this pattern can be interpreted is as multidirectional changes in cultural complexity over time with a substantial decline in complexity over the LGM, a time of likely population reduction and fragmentation. This might therefore reflect a reduced rate and retention of cultural innovations as well as reduced opportunity for reintroduction of lost traits between fragmented groups during a period of prolonged severe aridity (Shennan, 2000; Kline and Boyd, 2010).

Discussion

Three questions were posed at the start of this paper: (1) whether the recovery of archaeological materials has been sufficient to adequately characterize cultural diversity, complexity and innovation among the earliest colonisers of Sahul, (2) what biases currently exist in the record, and (3) what patterns in cultural change and diversity emerge when taphonomic and sampling effects are minimized. The answers to these questions profoundly affect the interpretation of the Pleistocene archaeological record in Sahul as well as regions outside the Pacific.

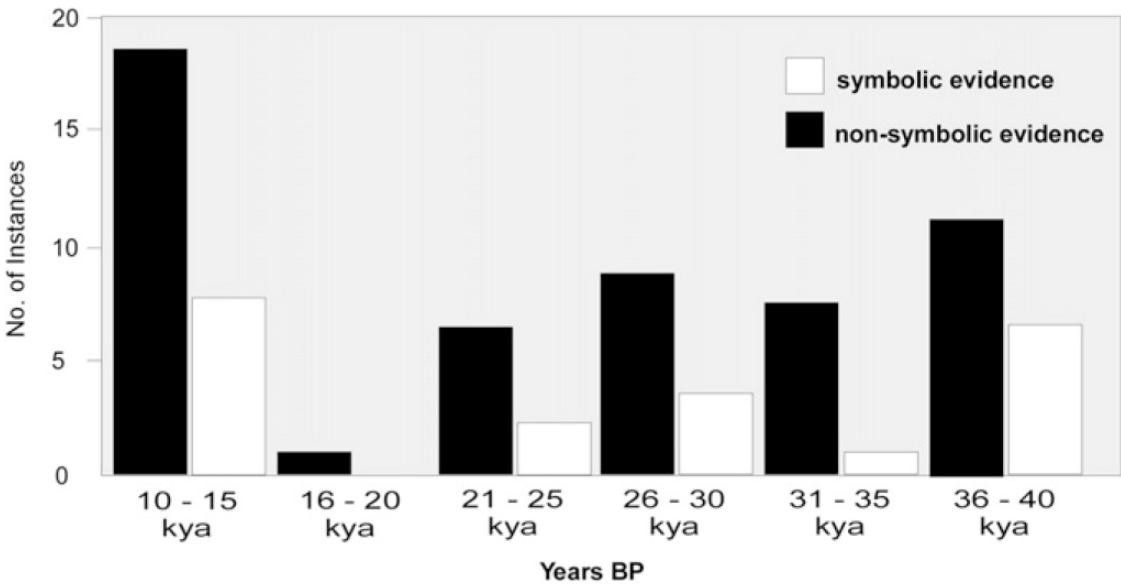

Figure 8. Frequency distribution of symbolic and non-symbolic datasets in Sahul's earliest continuously occupied sites presented in 5000-year time slices.

This study has shown that taphonomy and sample size are significant factors in the patterning exhibited in Sahul's Pleistocene archaeological record. Consequently, while adequate investigative methods have been used by the majority of researchers, the extreme environments, highly variable climates, over-representation of sites in poor preservational environments and small average size of excavations have restricted the recovery of evidence for complex behaviour dating to the first c.20,000 years of occupation. Developing a precise understanding of sampling and taphonomic issues for Sahul means that we are now well-placed to understand the kinds of sites and sample sizes required to retrieve better samples of early complex behaviours in this region. We have found that the earliest sites, and particularly those in the north where the earliest occupation is found, are typically in contexts that do not promote the preservation of organic artefacts and hence we should interpret the lack of organic evidence, and perhaps low diversity in complex instances, as more indicative of poor preservation than the state of cultural complexity at the time. Likewise, the heavy bias towards the excavation of rockshelters suggests that open site activities are under-represented in models of early behaviour. Renewed focus on retrieving larger samples from old open and enclosed sites in contexts that favour organic preservation is required to redress the bias in the record and better understand early cultural complexity in Sahul. We are not advocating complete excavation or unwarranted removal of large quantities of sediments from sites, however we do urge archaeologists to consider sample size and its effects on the recovery of evidence pertinent to the 'modernity debate'.

We assert that reduction in the mean size of excavations in recent decades has stymied attempts to reveal the complex and diverse nature of Pleistocene societies in Sahul. We would hope to see a reversal of this trend in future decades. It is clear that the diversity and quantity of evidence of early complexity is dependent on recovery techniques and sample size. We found that the average total volume of excavations including a Pleistocene component was around 10 m^3 and 2 m^3 for excavations conducted after 1992, and we note that this typically yields an average of only one instance of complex behaviour. We can qualify this still further by adding that instances are more numerous for a given sample size in sites that are conducive to organic preservation.

While our results suggest that caution must be exercised when interpreting the earliest archaeological evidence from Sahul, we are able to draw several important conclusions. First, we find that the gradual increase in diversity and abundance through time is likely the result of differential preservation, revealing the distinctive 'taphonomic curve' predicted by Surovell and Brantingham (2007). Second, non-directional changes are detected when appropriate site types and depositional contexts are analysed. We also find that complexity may be tied to population size. Several recent studies (Shennan, 2000; Powell et al., 2009; Kline and Boyd, 2010) have demonstrated the link between population density, interaction and cultural innovation, where larger populations generate and retain greater cultural diversity than smaller, isolated populations. The drop in quantity and diversity of evidence for symbolic behaviour during theLGM is consistent with a drop in population densities and the retraction of social interaction/exchange systems at this time. The large boost in the number of sites occupied and the evidence for complex behaviour at the end of the Pleistocene supports the notion that fluctuating population density may be driving multidirectional changes in cultural complexity in this region.

With the identification of a diverse range of complex behaviours in Sahul's record by 35,000 years ago, it is evident that this record probably shares many similarities with MSA Africa and Upper Palaeolithic Eurasia, while still retaining a unique artefact set. Sahul's record lacks the mobile figurative art of Upper Palaeolithic Europe (Venus figurines, moulded animal forms, etc.), but presents evidence for early complex figurative depiction in the form of ancient rock art styles such as the Bradshaw and Dynamic figures. d'Errico et al. (2003: 198) likewise remark that there is "little evidence for abstract or depictional representations in the MSA, apart from the Blombos Cave inscribed ochres and slabs with painted animal figures from the Apollo 11 site, Namibia," and although additional artefacts of this kind have surfaced in recent years (e.g., Texier et al., 2010), the core of this statement remains true. It therefore seems that the MSA African and Pleistocene Sahul records are more similar to each other than either is to the European record. Why this is so requires further exploration, but Powell et al. (2009) argue convincingly that this difference may be explained by much higher population densities in Europe, a finding that gathers general support from our study of long-term changes in complexity over the LGM.

Conclusion

Fluctuations in the diversity of complex instances during the Pleistocene are consistent with non-directional changes in many other aspects of Pleistocene societies such as those identified by Hiscock (2008). Far from simple and unchanging, Pleistocene societies of Sahul appear locked in a process of dynamic and continuous change that markedly altered the nature of social and technological activities of populations through time. The Pleistocene archaeological record of this continent therefore holds testament to the adaptive and cultural flexibility of modern human colonists that rapidly modified the cultural components they brought from Africa and Asia to suite dramatically different environments, developing innovative new technologies, subsistence strategies and ritual practices in the process.

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