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Colonisation and coastal subsistence in Australia and Papua New Guinea: different timing, different modes?

Introduction

The prehistoric colonisation of Australia and New Guinea involved the earliest voyages by modern humans beyond the sea horizon. Recent dating of critical sites in both northern and southern Australia indicates that this occurred before 50,000 and possibly as early as 60,000 years ago (Roberts *et al.* 1990; 1994; Thorne *et al.* 1999; Turney *et al.* 2001; but see also Bowler *et al.* 2003). While the new dating adds up to 15,000 years to the previous chronology for human arrival in Australia and has been extensively debated, there has been little attempt to assess the prehistoric implications of this longer chronology for migration to, or colonisation patterns and rate of spread of populations following entry into Sahul (the expanded Pleistocene landmass consisting of Australia and New Guinea).

Regardless of the routes taken from Asia to Sahul, the maritime journeys required several major water crossings of distances up to 120 km. This fact has prompted the logical view that the first colonists must have been mariners, adapted for their livelihood to coastal and estuarine environments. However, evidence for coastal use following colonisation is non-existent in Australia, where the earliest dated sites are found at inland locations. The earliest evidence for exploitation of coastal environments in Australia is at least 15,000 years younger than the time of initial settlement; even then, the usage of readily procurable coastal resources was not impressive. Early Holocene use of coastal resources appears to be similarly generalised and was largely restricted to those of the intertidal zone. There is some evidence for increasing maritime specialisation in the late Holocene, when the use of offshore islands becomes fairly widespread, and new types of coastal sites and more specialised marine technology appear. In contrast, fish and shellfish appear to have been an important part of the resource base in PNG and Island Melanesia, from first occupation onwards.

This paper re-examines the archaeological data for Pleistocene migration and colonisation in Australia, New Guinea and the Bismarcks; a reassessment that leads us to conclude that, once established, colonisation proceeded rapidly but not equally into all geographic or environmental zones. We find little evidence for the continuity of maritime economies following landfall in Pleistocene Australia, where Pleistocene subsistence strategies rely on a broad range of resources, dominated by terrestrial game. Subsistence in PNG and Island Melanesia featured marine resources from the earliest occupation, including the exploitation of fish species that suggest the usage of specialised fishing technology. We also note that northern Australia and PNG may not have been colonised at the same time; indeed, presently available dating evidence suggests that colonisation of PNG may have lagged behind Australia by at least 10,000 years. Finally, there is some evidence in northern Australia for diversification in the use of coastal resources in Late Holocene times, including technical innovations such as fish hooks, dugout canoes and detachable harpoons that probably were introduced from elsewhere, but this is minor compared with the specialised strategies of Island Melanesia and the Pacific.

Chronology[1]

The question of when humans first arrived in Sahul is an important one, essential to an understanding of their subsistence and geographic dispersal, and the rates at which subsequent adaptations occurred. The chronology of these events has largely been based on radiocarbon dating but the timing is near the limit of the radiocarbon method, and other methods may be more reliable. Allen and Holdaway (1995) and O'Connell and Allen (1998) argue that radiocarbon ages indicate initial colonisation of Australia at about 40,000 b.p., whereas thermoluminescence (TL) and optically stimulated luminescence (OSL) dates reported by Roberts *et al.* (1990, 1994, 1998a) indicate that occupation began around 55,000 years ago (55 ka) at Malakunanja II and Nauwalabila I in northwest Arnhem Land. However, the association between dated materials and cultural materials at Malakunanja and Nauwalabila has been questioned (Hiscock 1990; Bowdler 1990a, 1991, 1993; O'Connell and Allen 1998). Ages of 56-68 ka, obtained by uranium-series (U-series) and electron spin resonance (ESR) techniques from a human skeleton at Lake Mungo (Simpson and Grün 1998; Thorne *et al.* 1999), were later questioned and an age of 40 ka has been assigned to the skeleton and occupation is considered to have begun around 50 ka, on the basis of OSL results of the associated sediments (Bowler and Magee 2000; Bowler *et al.* 2003). O'Connell and Allen (1998) also argue that occupation of Australia around 60,000 years ago is inconsistent with the chronology of dispersal of modern humans elsewhere in the world, but here, too, the chronology continues to be revised (Grün and Stringer 1991; Mercier *et al.* 1995). It appears that many objections to the "long" chronology reflect a reluctance to break the moulds into which prehistory has been poured, rather than a critique of the technicalities of the age measurements themselves.

Setting aside questions about association of dated materials and human occupation, the problem is to identify the reliable dates amongst the many radiocarbon, TL, OSL, ESR and U-series measurements reported from early Australian sites. Allen and Holdaway (1995) infer that most archaeologic radiocarbon dates around 40,000 b.p. are likely to be reliable because geologic deposits have yielded dates exceeding 45-50,000 b.p. This is not persuasive. The relevant geologic dates mostly come from carbon-rich deposits where contamination through chemical exchange is less likely than in sites where carbonaceous particles are small and sparse, which is the case in older levels of many Australian archaeologic sites. Indeed, many of the geologic dates over 40,000 b.p. cited by Allen and Holdaway have been shown to be quite erroneous (Chappell *et al.* 1996). Furthermore, recent stepped-combustion AMS radiocarbon measurements of refractory, oxidation-resistant charcoal support previous radiocarbon ages around 40,000 b.p. for some key sites but show that others, discussed below, are significantly too young (Bird *et al.* 1999; Turney *et al.* 2001).

Radiometric ages are reliable only when no chemical exchanges have occurred between the dated materials and their surroundings. Such closed system behaviour is essential where an age can be seriously falsified by small traces of contaminant, as with radiocarbon beyond 35-40,000 b.p. Many materials of the highest archaeologic importance (e.g. bone; teeth) rarely behave as closed systems, but U-series and ESR age estimates based on open system models have been shown to be acceptable by crossdating (e.g. Grün and Stringer 1991; Simpson and Grün 1998; Thorne *et al.* 1999). These and other dating methods are not immune from error, as was illustrated by the Jinmium fiasco where TL dates exceeding 120 ka reported by Fullagar *et al.* (1996) were later shown to be less than 20,000 years old, both on internal evidence (Spooner 1998) and by OSL dating (Roberts *et al.* 1998b). Similarly, the archives of U-series dates derived from shells and bone, which take up uranium from groundwater, are shot through with erroneous results. However, with appropriate materials and practice, each method has produced impressive series of results that have withstood the test of careful crossdating. Calibrated radiocarbon ages have been successfully replicated by U-series dates from corals (Bard *et al.* 1990); TL and OSL have been successfully crossdated with radiocarbon at many sites including both Malakunanja and Lake Mungo to about 30,000 b.p. (Roberts *et al.* 1990; Bowler and Price 1998; Gillespie 1998). Cross dating studies from the Lake Eyre basin have shown excellent accordance between OSL and U-series in the range 50-100 ka (Magee *et al.* 1995; Magee and Miller 1997) as well as with AMS ^{14}C from 0 to over 50 ka (Miller *et al.* 1999).

Considering that this paper is concerned with early archaeological sites in Australia, PNG and Island Melanesia that have been dated by a variety of methods, something must be said about radiocarbon calibration. For radiocarbon ages beyond ~30,000 b.p., this is problematic because there are major differences amongst the various sets of potentially useful data. On one hand, measurements from varved sediments at Lake Suigetsu, Japan, suggest that the divergence of ^{14}C and calendar years increases fairly smoothly to maximum of 3-4000 years at ~38 ka and decreases beyond that (Kitagawa and van der Plicht 1998); on the other, major spikes with ^{14}C temporarily more than 100% above modern levels appear in different places in detailed cross-dated sequences from speleothems (Beck *et al.* 2001), corals (Yokoyama *et al.* 2000) and marine cores (Voelker *et al.* 2000). Such is the level of disagreement amongst these records that to attempt even rough calibration beyond ~30 ka, such as the informal calibration of some Australian dates by Gillespie (1998), almost certainly is meaningless (Pettit and Pike 2001). Thus, in the following review of early dates from Australia and Papua New Guinea we avoid calibration but, in order to cast radiocarbon and other determinations into broad age-bins, we do refer to the cross-dating series referred to above.

Questions of timing

We review here the basal or near-basal age estimates from the oldest late Pleistocene sites from Australia and the northern PNG region, bearing in mind that preparation techniques and validation criteria vary not only between methods but within any given dating method. The sites are listed in Table 1.

Taking the PNG dates first, the original reports give no reasons to doubt the radiocarbon ages from Kosipe (White *et al.* 1970), Nombe (Mountain 1991), Kilu (Wickler 2001), Buang Merabak (Balean 1989), Yambon (Pavlides 2000; Pavlides and Gosden 1994) and Matenkupkum (Gosden and Robertson 1991; Allen 1994), all of which are from good charcoal or well preserved shells in well stratified sites. The same may be true for Lachitu, although the 35,000 b.p. date is published without standard deviations or Laboratory Code and needs verification (Gorecki 1993). At the Huon Peninsula site, large waisted stone blades were

Site	Type	^{14}C b.p x1000	Other methods[1], ka	Age bin ka[2]	Authors[3]
Mungo 3 burial	Open		61±4, U,OD,ES	55-65	S&G 1998; T. *et al.*1999
			45±2, 14C, TL	40-50	Gillespie 1998; B&P 1998
Nauwalabila	Shelter		57±3, OD	50-60	Roberts *et al.* 1994
Malakunanja II	Shelter		55±2, TL, OD	50-60	Roberts *et al.* 1990; 1998a
Devil's Lair	Cave	47±2		45-55	Turney *et al.* (2001)
Carpenter's Gap 1	Cave	42±2		40-50	McConnell & O'Connor 1999
Riwi	Shelter	41±1		40-50	Balme 2000
Upper Swan	Open	38±1		35-45	Pearce & Barbetti (1981)
Ngarrabullgan	Shelter	37±1		35-45	David *et al.* 1997
Huon Peninsula	Open		40±5, TL	35-45	Groube *et al.* 1986
Lachitu	Shelter	35±1		35-45	Gorecki 1993
Yambon	Open	35±1		35-45	Pavlides 1999
Matenkupkum	Shelter	35±1		35-45	Allen 1994
Buang Merabak	Shelter	32±1		30-40	Balean 1989
Kilu	Shelter	28±1		25-35	Wickler 2001
Nombe	Cave	26±1		25-35	Mountain 1991
Kosipe	Open	26±1		25-35	White *et al.* 1970

Notes: 1. U=Uranium-series, TL=thermoluminescence, OD=optical dating (optically-stimulated luminescence), ES=electron spin resonance. 2. Radiocarbon calibration is not established for this age-range but in order to compare dates from different methods, 3±2 ka is added to ^{14}C dates and results are put into age-bins of width 10 ka. This conservative approach is consistent with detailed cross-dating results cited in the text. 3. Abbreviations: S&G = Simpson & Grun 1998; T. *et al.* = Thorne et al. 1999; B&P = Bowler & Price 1998.

TABLE 1. Sixteen earliest archaeological sites in Australia and PNG.

recovered from beneath two tephras dated by thermoluminescence as 36±6 and 38±6 ka but the potassium contribution to the radioactive dose is uncertain, and the ages could be greater (Groube *et al.* 1986).

Turning to the Australian sites in Table 1, the near-basal layer at Ngarrabullgan has been intensively dated by conventional and AMS ^{14}C, which were accordant, as well as by OSL (David *et al.* 1997). The Upper Swan site was dated by accordant conventional ^{14}C measurements from charcoal and cycad resin (Pearce and Barbetti 1981). The base of Carpenter's Gap 1 and Riwi are dated by accordant conventional and AMS ^{14}C (McConnell and O'Connor 1999; O'Connor 1995; Balme 2000), which have been confirmed by stepped combustion AMS ^{14}C (Bird *et al.* 1999). The lowest occupation levels of Devil's Lair in southwest Western Australia, re-dated by stepped combustion AMS ^{14}C, prove to be 47±2 ka yrs b.p., which is substantially greater than previous estimates based on conventional ^{14}C (Turney *et al.* 2001). Luminescence dating of Malakunanja II (TL: Roberts *et al.* 1990: OSL Roberts *et al.* 1998a) and Nauwalabila (OSL: Roberts *et al.* 1994) have basal ages around 55±5 ka. At Malakunanja II, ^{14}C dates in the sequence down to ~30,000 b.p. match the TL chronology (Roberts *et al.* 1990), but at Nauwalabila both conventional and stepped combustion AMS ^{14}C show age inversions beyond about 20 ka and are unreliable (Dr M.Bird pers. comm.). As indicated earlier, the timing of events at Lake Mungo is contentious: the Mungo-3 cranium was dated directly at 61±4 ka by U-series methods (Thorne *et al.* 1999) but sediment coeval with the cranium gives OSL ages of 40±2 ka (Bowler *et al.* 2003); the same authors consider 50 ka to be the limit for earliest occupation of Mungo. However, in reaching his age estimate of 61 ka, Grün (in Simpson and Grün 1998; Thorne *et al.* 1999) exhaustively examined various modes of open system behaviour and, even though the results of Bowler *et al.* (2003) are compelling, it is difficult to disagree with Grün's result on technical grounds. For these reasons, two sets of ages for Mungo are shown in Table 1.

Table 1 represents the oldest available dates for early occupation from Australia and PNG. While recognising the uncertainty about Mungo we consider that there are no clear grounds for faulting any of these ages, although technical details are not examined in depth by all authors. These represent the 7 oldest known ages from Australia and the 8 oldest from PNG. According to the primary reports, the associations of reported dates and cultural materials are now accepted[2]. The ages span a range from ~35 ka to at least 55 ka and probably 60 ka. As discussed below, we believe it is significant that none of the Australian sites in Table 1 are 'maritime' or located near the Pleistocene coast, whereas five of the PNG and Bismarck sites lie very close to their contemporary coastlines and preserve evidence of maritime exploitation.

A conspicuous feature of Table 1 is that in terms of their binned ages, four and perhaps five of the Australian sites are older by up to 10-15 ka than the earliest dates from PNG, and the other two or three overlap with the earliest PNG results. We must stress that almost certainly the data suffer from sampling bias: archaeologic investigation of PNG has been conducted on more of an expeditionary basis than Australia, where both the search for and dating of early sites has been more systematic. Further work may well throw up a number of sites beyond 40 ka in PNG. Offsetting this, it is reasonable to expect that the very earliest sites in both Australia and northern PNG would be near ancient coasts: the likelihood of discovering these is higher on the precipitous coasts of northern PNG where there is no continental shelf, than

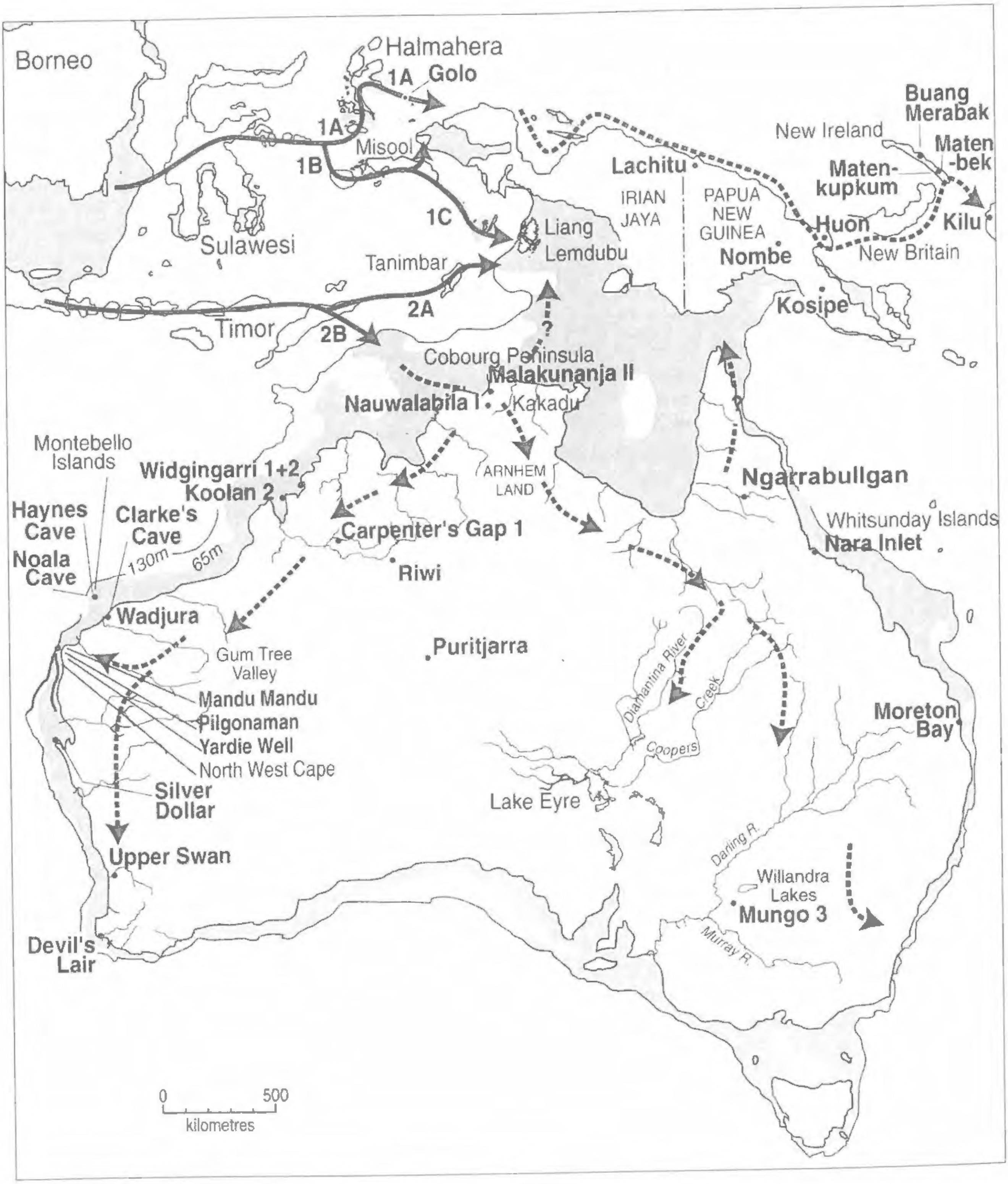

FIGURE 1. Map showing places and sites mentioned in the text and Birdsell's (1977: 122) proposed migration routes from Southeast Asia to Sahul. Dashed arrows show Pleistocene migration routes following first entry into Autralia, PNG and Island Melanesia as hypothesised by the authors. The approximate position of the expanded Last Glacial lowstand coastline is also shown.

on the wide shelves of northern Australia. At face value, the dates in Table 1 suggest that colonisation of northern PNG commenced around 40 ka whereas Australia was colonised around 55 ka. Add to this the time it must have taken for descendants of the first arrivals to migrate to the non-maritime dated sites, after arrival at the now-submerged middle or outer continental shelf, and the difference in timing is yet more striking.

Opportunity: Passage and arrival

On the basis of the archaeological dates, Bellwood (1998: 196) suggested that colonisation into Sahul may have been staggered and that Australia may have been settled earlier than the eastern Indonesian Islands, the Philippines and Melanesia. The data in Table 1 support this view and indicate that there may have been separate migrations by separate routes at different times: first to Australia through Timor from Flores or Alor, and later to northern PNG – probably through the Moluccas. Both are hypothetical routes identified by Birdsell (1977): the Timor path is his route 2B from Java, which, as Bellwood (1993) points out, is very easily traversed to Alor once the 19 km Lombok Strait is crossed. The Molucca path is Birdsell's northern route 1A (Fig. 1). Indeed, on the basis of the dates alone, colonisation of PNG from Australia and even back-colonisation from PNG to the Moluccas, where present data indicate occupation from about 33,000 b.p. (Bellwood *et al.* 1998), cannot be ruled out.

Traditionally, initial migration has been thought to have been most probable when sea level was low (Birdsell 1977; Flood 1983). According to the dates in the table migrations to Australia commenced around 55-65 ka. Sea level was low (-85 to -90 m) from 68 to 62 ka and then rose substantially, reaching -55 m at ~59 ka (Fig. 2), but the presence of Australia may have been detectable (horizon distance from the mountains of Timor is up to ~170 km). Today's wind regime in the region is strongly vectored towards the southeast from Timor in the north Australian wet season (Hellerman and Rosenstein 1983) and probably was similar around 60 ka.

The passage could have been crossed in a few days in optimum conditions with simple watercraft. However, sea level change may indirectly affect the likelihood that coastal people possess watercraft of any sort, because coastal ecosystems differ according to whether sea level is rising or falling. Tropical coastal resources – coral reefs, lagoons, mangroves, estuarine plains and wetlands – become well established when sea level is rising (Woodroffe *et al.* 1989; Chappell 1993) but are much more restricted when sea level is falling, because rivers then become entrenched and coasts tend to be steep and simple, with negligible coastal plains.

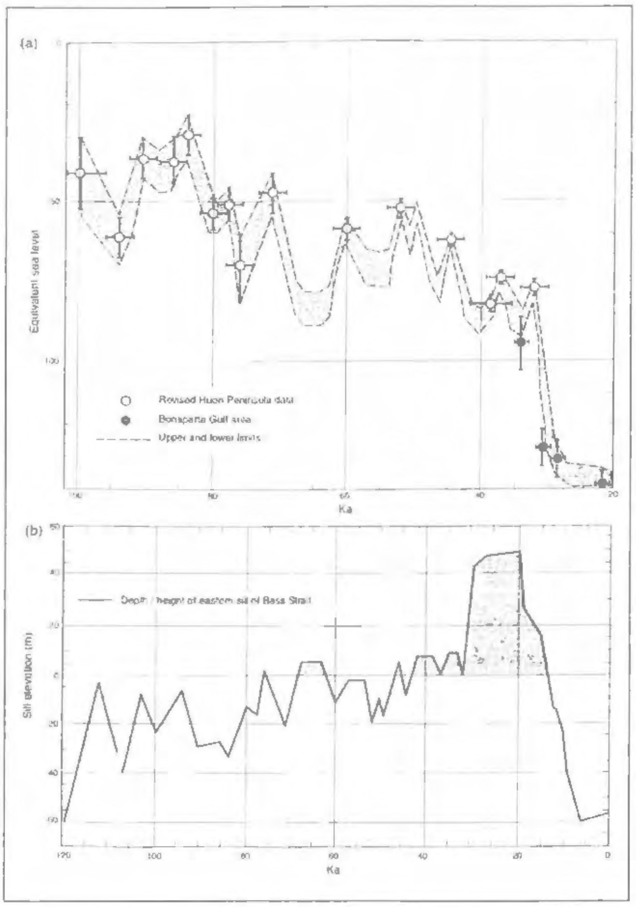

FIGURE 2. (a) Sea levels during the period of prehistoric colonisation of Sahul. (b) Windows of opportunity for Late Pleistocene land-passages to Tasmania (from Lambeck and Chappell 2001).

Under falling sea level, reef and sedimentary ecosystems including mangrove, estuarine plains and backwater swamps would have been minor features on the islands from Lombok to Timor, the Moluccas and much of northern PNG. As simple watercraft are less useful for subsistence on rocky tropical coasts than in lagoons and estuaries, people were most likely to have been equipped for voyaging at times of rising sea level. If opportunity is the only consideration, the rising sea level of 62-59 ka is a likely time for migration across the Timor Sea.

Colonising Sahul

After entering Australia, humans quickly reached the southern part of the continent but did not enter Tasmania until ~40 ka, when the Bassian land bridge had begun to emerge. Had they reached the southeast region before 62 ka, people could have entered Tasmania at this earlier time, as the land bridge also existed from ~70 to ~62 ka (Figure 2). Thus, it seems unlikely that the first migrations occurred much before that. Having arrived, distance appears to have been no obstacle to human dispersal: there is little difference between basal dates from Nauwalabila, Devil's Lair and Mungo, at opposite extremities of Australia (Fig. 1). The same appears to be true, about 10-15,000 years later (according to presently-available dates), for the northern route into PNG, where basal dates in the Bismarcks are similar to if not older than basal dates reported by Bellwood *et al.* (1998) from the northern Moluccas.

In addition to the matter of timing of initial colonisation, the presently-known archaeological record suggests that after ~35 ka, the population expanded more rapidly in Australia than in PNG. Figure 3 shows a cumulative plot of basal ages from all dated sites older than 20 ka, for both regions. Three straight lines are fitted: A1 and A2 for Australian data prior to 35 ka and post 35 ka, respectively, and NG for the PNG data. Taken at face value this plot suggests that between 35 and 20 ka the rate of site establishment was about three times faster in Australia than in PNG (again, we stress that these conclusions are based on presently available dates and would be overthrown if, or when, more early sites are discovered in PNG). Significantly, in both regions, the rate of site occupation is very low compared, say, with Lapita-led Holocene migrations into Oceania. For the early periods in Australia (55 - 35 ka) and northern PNG (40 - 20 ka), the rate at which sites were established is about 1.2 per thousand years; but data for Late Holocene Oceania compiled by Spriggs and Anderson (1993) and Spriggs (1996) give 10 sites per thousand years if we count whole island groups as single "sites", and is much higher based on islands within groups. Clearly, processes of late Pleistocene colonisation of Australia and northern PNG, although maritime in the sense that people departed from and arrived at coastal sites, bear no comparison in terms of rates or mobility with later Holocene migration into Oceania.

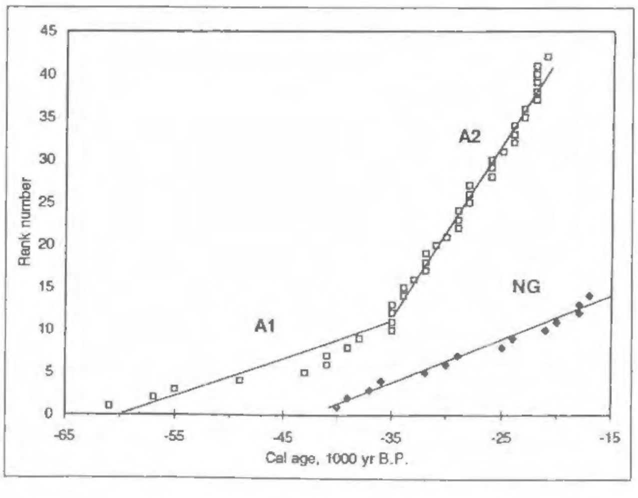

FIGURE 3. Cumulative graph of basal dates of early archaeologic sites in Australia and PNG. The graph includes the sites listed in Table 1, using central 'bin' ages for radiocarbon dates and published results for OSL/TL/U-series dates, together with the data set published by Smith and Sharp (1993) (after Chappell 2000).

Colonisation models

Considering that all prehistoric migrants to Australia and New Guinea arrived on the coast, it was perhaps inevitable that many models of Australia's colonisation include a major, early phase of maritime subsistence and coastwise dispersion. Bowdler (1977) for example, argued that as colonisation was accomplished by mariners, earliest subsistence would have been maritime and aquatic and dispersal would have followed the coasts and later would have moved up the major rivers, where the roots of the new subsistence patterns lay in the prior coastal economies. Bowdler (1990b) has since allowed that adaptation to, and occupation of, the savannah took place earlier than she initially proposed, but has maintained that earliest colonisation would have followed the coast; that the earliest economies would have been maritime, and that the earliest sites would have lain on the Pleistocene coastal plain.

Bowdler's concept of up-river migrations from the coasts is one of a growing number of colonisation models that have been proposed for the Australian continent.

The most generalised are one-dimensional curves of prehistoric population growth, such as that of Birdsell (1977) in which the early growth-rate is rapid but decreases negative-exponentially, and the population reaches saturation at carrying capacity within 5000 years of first arrival. In contrast, Beaton (1985) proposed a "logistic" model of slow early growth, accelerating later to rapid growth and finally slowing to saturation. In the geographic plane, Jones (1979; 1987) and O'Connell and Allen (1998), for example, considered that all environmental niches were occupied relatively rapidly, while Butlin (1993: 65) argued that "extreme aridity after 20,000 b.p. forced Aborigines out of the interior into the...margins of the continent... to seek the security of coasts and estuaries". On the ecologic front, models range from low-impact ones where the Pleistocene inhabitants are envisaged as small, mobile groups, in well-watered inland savannahs with abundant game and plant foods (Horton 1981, 1999), to high-impact models of colonisation accompanied by irreversible transformation of vegetation and extinction of a naive megafauna, either as a direct consequence of hunting or through elimination of megafaunal habitats (Flannery 1996).

Setting aside the question of population growth, most of these models can be tested, as they imply the presence or absence of archaeological sites in different environments at different times. Bowdler's model predicts that early sites, being coastal, would most readily be found where the Pleistocene coastline was close to its present position and that 'transliterated coastal' sites on rivers and lakes would be occupied next. Birdsell (1977), Jones (1979; 1987) and O'Connell and Allen (1998) predict early use of all environments including coasts, uplands and deserts, so that there should be little difference between the dates for early settlement between these regions. Hallam (1987), Butlin (1993) and Horton (1981), although different in detail, imply that the majority of early sites will be found in better watered inland regions, and that interior sites should become less common while coastal sites should increase after ~25-30 ka, as conditions deteriorate inland. Beaton's (1985) model predicts only slowly increasing numbers of sites in all environments prior to the mid-Holocene, with coastal locations virtually unrepresented in the Pleistocene.

Coastal sites and the maritime factor in the Pleistocene

PNG and Island Melanesia

There is no question that early colonists in PNG and Island Melanesia used maritime resources and that these resources provided a significant component of the diet (Table 2). In Table 1 evidence of maritime subsistence is prominent in the early sites other than at the open sites at Huon Peninsula (Groube *et al.* 1986) and Yambon in southwest New Britain (Pavlides 1999), where only stone artifacts are preserved within stratified tephras and tephric soils.

To summarise, the westernmost shell-rich site, Lachitu, is a rock shelter in coral limestone and lies 150 m from the present coast: the earliest occupation is dated at ~35,000 b.p. (Gorecki 1993: 155) and includes a range of marine shellfish (Gorecki, pers. comm., unpubl. data),while an occupation phase from 14,000 to 12,000 b.p. includes some 15 species of shellfish together with a variety of terrestrial fauna (Gorecki *et al.* 1991). Similarly, the Matenkupkum (New Ireland) cave site overlooks the beach, and was intermittently occupied from 33,000 to 10,000 b.p. The early deposits are dominated by subsistence shellfish with accessory terrestrial fauna (Gosden and Robertson 1991): the shellfish are large individuals of large-shell species indicating a focused subsistence strategy (Allen 2000: 149). Marine resources also are important at the other New Ireland Pleistocene sites of Buang Merabak (Allen 2000: 148; Balean 1989: 40-42) and Matenbek (from ~ 21,000 b.p.; Allen *et al.* 1989) and at Kilu (Buka, north Solomons) (Wickler 2001) (locations, Fig. 1), all of which contain both shellfish and fish bone, including large pelagic fish, thus providing very early evidence for systematic fishing (Wickler 2001: 235; Leavesley pers. comm.). Clearly, a strong maritime factor pervaded the subsistence base of coastal colonists in northern PNG and Island Melanesia, from their arrival onwards.

Australian Pleistocene near-coast sites

Evidence for maritime subsistence begins to appear at a number of Australian sites when sea level approached the Last Glacial lowstand (shown in Fig. 2 as 28-20 ka, approximately equivalent to 25–17,000 b.p.). Amongst sites on the mainland, Mandu Mandu and Pilgonaman near Northwest Cape, today 1-2 km from the shore, lie nearest the edge of the continental shelf, which at most was a mere 10 km distant, and provide a rare opportunity to examine maritime exploitation during the Late Quaternary (Morse 1993a; 1993b).

The better dated site, Mandu Mandu (Fig. 4), was occupied from 34,000 to 20,000 b.p., abandoned, and reoccupied around 5,500 b.p. Marine resources occur throughout and are regarded by Morse as fairly uniformly distributed; however, there is a significant difference between the earliest assemblages and those deposited after 22,000 b.p. The lowest levels almost exclusively contain *Melo* sp. (baler shell), *Pinctada* sp. (pearl shell), *Dentalium* and *Conus*, none of which are likely to have been procured as dietary items. The *Conus* are definitely drilled for threading (Fig. 5) (Morse 1993b: 158), and the *Dentalium* were probably threaded and used

	Period, b.p.	Distance to coast, km	Subsistence Base
PNG			
Lachitu	35,000	<5	mixed terrestrial & maritime
Matenkupkum	from 33,000	<5	mixed terrestrial & maritime
Buang Merabak	from 32,000	<5	mixed terrestrial & maritime
Kilu	from 28,000	<5	mixed terrestrial & maritime
AUSTRALIA			
Devil's Lair	from 47,000	8-10	terrestrial (2 shell fragments)
Mandu Mandu	34-22,000	7	terrestrial (marine shell ornaments)
Mandu Mandu	22-20,000	10	mixed terrestrial & maritime
Noala Cave	27-12,000	20-35	terrestrial, sparse maritime
Noala Cave	12-8,500	<20	increasing maritime

TABLE 2. Subsistence base in early near-coastal sites in Australia and PNG.

FIGURE 4. The entrance of Mandu Mandu Creek rockshelter, Northwest Cape, WA (Photo courtesy Kate Morse).

for personal decoration, as they have been until recent times on the Kimberley coast. Although baler and pearl shell are edible, the sizes of the fragments suggests that they derive from decorative items or bowls. In contrast, terrestrial fauna are comparatively well represented in the earliest layers, whereas dietary molluscs become significant only later: *Turbo* spp. and the chiton *Acanthopleura gemmata* appear at 22,000 b.p. together with fish, crab and sea urchin, and reach a peak at ~ 20,000 b.p. (Morse 1993a: 149,187), but terrestrial fauna is less well represented at this time (Morse 1993a: 153-4). The Pilgonaman site shows a similar pattern.

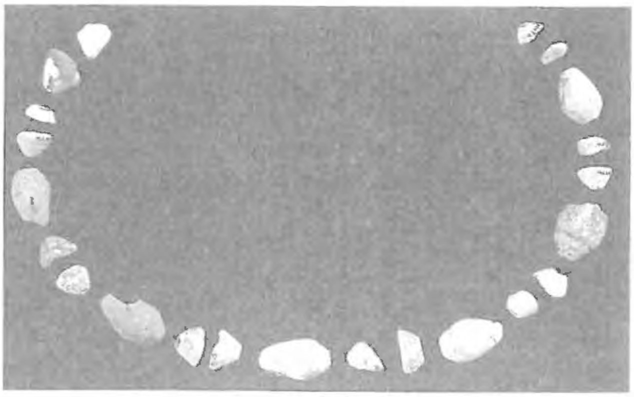

FIGURE 5. The *Conus* sp. shell beads from Mandu Mandu Creek rockshelter, Northwest Cape, WA reconstructed to form full necklace (photo courtesy WA Museum).

The semi-arid Montebello Islands lie ~100 km offshore from the Pilbara coast (Fig. 1) and were part of the mainland until isolated by rising sea level, about 7,500 b.p. Although at the time of low sea level the islands were more distant than Northwest Cape from the shelf edge, Late Pleistocene occupants used maritime resources. Noala Cave, a small limestone chamber first occupied at ~27,000 b.p. when the coast was about 35 km distant (Table 2), contains a range of terrestrial and marine fauna: medium to small marsupials dominate the earliest assemblages but include sparse intertidal shells, including *Polymesoda (Geloina) coaxans* (Veth 1993: 45). Much further south and somewhat closer to the shelf edge, the Devil's Lair site (Fig.1) contains a thick, fauna-rich record of continual human usage from ~47,000 to 12,000 b.p. (Dortch 1979: 42-48; 1984; Turney *et al.* 2001). The fauna overwhelmingly reflect subsistence on resources of the surrounding woodland, scrub, wetlands and streams (Dortch 1984: 72-4) and contains so little marine material as to contribute nothing for or against our argument: a fragment of marine bivalve was found in Layer 32 (dated by stepped combustion AMS ^{14}C to ~45,000 b.p. and by OSL to ~47 ka [Turney *et al.* 2001]) but whether for food or finery is not known. The shore would then have been about 25 km west of Devil's Lair.

Australian Pleistocene coast-distant sites

Widgingarri 1 and Koolan 2 (Fig. 1, Fig. 6) rockshelters in the southwest Kimberley region, although dominated by terrestrial fauna, show evidence for early contact with the coast between ~28,000 and 19,000 b.p. Shells of *Melo* (baler), *Pinctada* (pearl shell) and *Geloina coaxans* (mud clam) are considered to have been 'value goods' rather than dietary items (O'Connor 1999: 121). When first occupied, Koolan 2 was probably within 10 km of the coast but Widgingarri Shelter 1 was at least 50 km inland. Both shelters were abandoned around 19,000 b.p. but Koolan 2 was reoccupied at ~10,500 b.p., when the coast again became proximal, and shows a mixed terrestrial-marine based economy (O'Connor 1999: 122). The fact that reoccupation of these shelters coincides so closely in time with the arrival of the sea suggests that by the end of the Pleistocene people using the resources of the coastal fringe and plain were following the fluctuating coastline landwards. There is no indication of a lag between the time an area becomes coastal and the signal for its occupation and some use of marine resources. Importantly, however, there is no evidence of occupation at ~37 or 44 ka at the Kimberley sites, when the coast would have been about as close as at 10,500 and much closer than at 20,000 b.p. Riwi Cave in the southern Kimberley also contains segments of *Dentalium* shells in its Pleistocene levels which "are smooth at the openings suggesting their use as beads" (Balme 2000: 4). At the time these beads entered the cave, it would have been well over 400 km from the coast (Balme 2000: 4).

Finally, a few other sites suggest echoes of dwellers on distant coasts. The Silver Dollar open site, Shark Bay, included a baler shell (*Melo amphora*) dated to 18,730 b.p. (Bowdler 1990c), and a cave site at Gum Tree Valley, Burrup Peninsula, yielded a specimen of *Syrinx aruanus*, dated to 18,510 b.p. (Veth *et al.* 1993). The coast would have been more than 100 km distant from both sites at the time.

Inland Australia: Pleistocene subsistence

Amongst the very earliest Australian sites, the western Arnhem Land sites – Malakunanja and Nauwalabila (Roberts *et al.* 1990; 1994) – contain no organic materials but the region almost certainly was as ecologically rich as it is today. Summer rains reached far into the continental interior more frequently around 50-60 ka than today, to judge from evidence from the Lake Eyre basin (Magee and Miller 1997; Miller *et al.* 1999) and from the central Australian playas of Lake Amadeus (Chen *et al.* 1993) and Lake Lewis (Chen *et al.* 1995). Thus, Jones (1999) considered that the Arnhem Escarpment and Alligator Rivers region was then, as now, a diverse sclerophyll woodland interspersed with swamp and rainforest savannah rich in resources. Somewhat later around 40,000 b.p., subsistence in the somewhat-drier Kimberley region rested on a similar resource-base, to judge from organic remains in the Carpenter's Gap 1 shelter (O'Connor 1995; McConnell & O'Connor 1999).

Far to the south, faunal remains in the deep, well-stratified deposits of Devil's Lair testify to subsistence based on resources of forest and woodland (Dortch 1979; 1984). Furthest inland amongst the early sites, artifacts, hearths and human remains mingle in the lunette at Lake Mungo with skeletal remains of fish, molluscs, reptiles, and marsupials, together with eggs of emu and other birds. Irrespective of uncertainty about the exact age of the oldest human remains at Mungo, the Willandra lakes before 40 ka enjoyed much moister conditions than at the end of the Pleistocene, supporting "abundant vegetation and filling the basin with permanent water" (Miller *et al.* 1999: 207). The occupants subsisted on the rich resources of the savannah and the lake together.

The fact that the Willandra Lakes were populated early probably reflects a high potential at the time for subsistence and population movement throughout much of the continental interior. Evidence cited above from the Lake Eyre basin shows that the core of the continental interior was much better watered before 50-55 ka than it is today. There is increasing evidence that pioneer colonists altered the Australian environment about 50,000 years ago leading to the final demise of the large fauna (eg. *Genyornis newtonii* [Miller *et al.* 1999]). Miller *et al.* (1999) believe that this most likely occurred as a result of the impact of frequent fire on the vegetation, rather than direct predation.

Technology in the Pleistocene in Australia, PNG and Island Melanesia

Savannah-based subsistence from earliest times is reflected not only by the distribution of sites but also in the

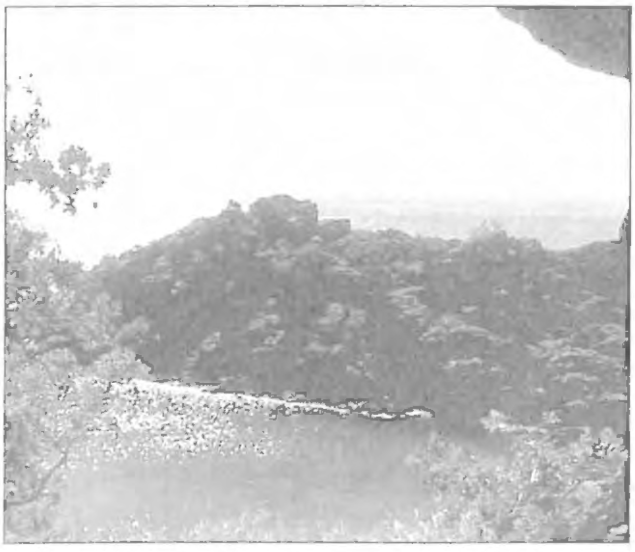

FIGURE 6. Koolan Shelter 2, west Kimberley.

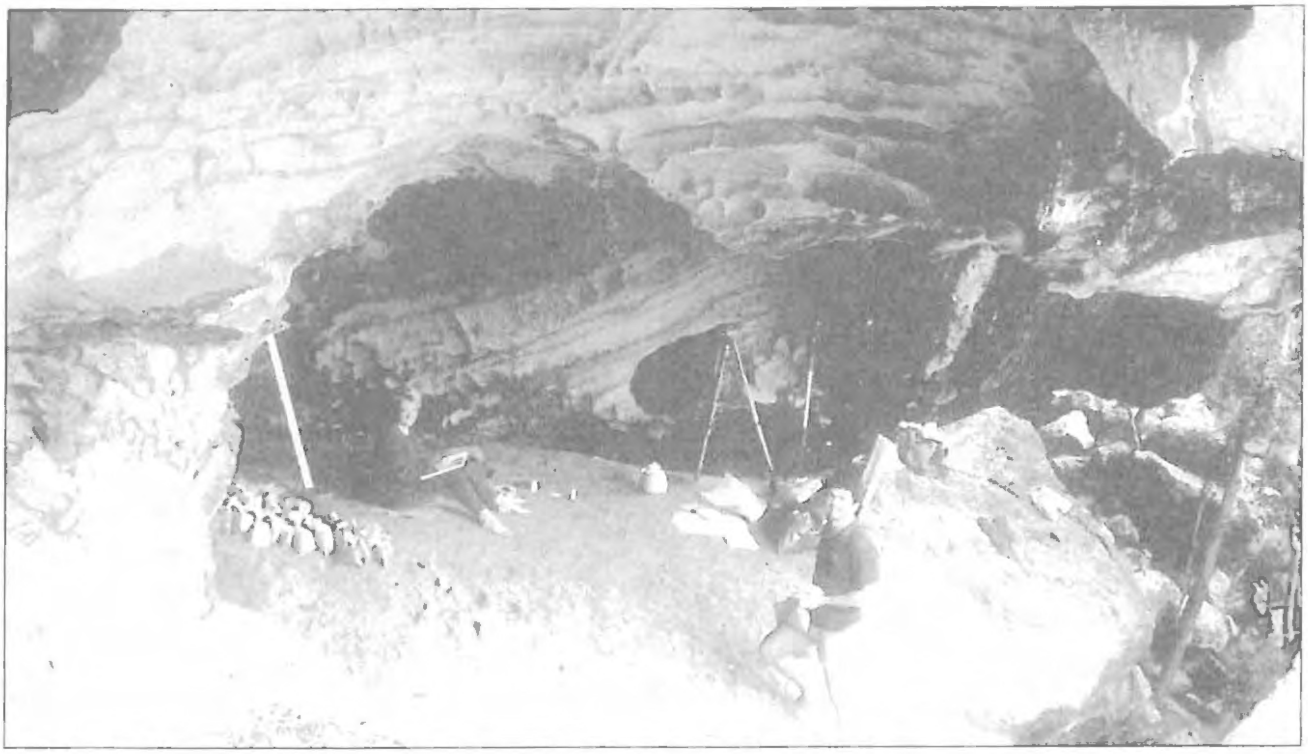

FIGURE 7. Nara Inlet 1, Whitsunday Islands, Queensland (Photo courtesy Bryce Barker).

Pleistocene tool kits. Assemblages from north Australia are dominated by small unretouched and retouched flakes (cf. Dortch 1977: 121; McCarthy and Setzler 1960: 275; O'Connor 1999). Edge-ground axes or hatchets are the only specialised tool-type in the earliest levels of several sites (Morwood and Trezise 1989; O'Connor 1999: 75; C.White 1967) and like their ethnographic equivalents, are thought to have been used both for cutting timber to make implements and extracting tree-dwelling animals and honey from wooded environments. There are no items specifically designed to exploit coastal resources, such as fish hooks and spear barbs, even in sites that lie close to former coasts like Mandu Mandu and which preserve fragile shell beads and small bones (Fig. 5).

Conversely, in Island Melanesia there does appear to be some evidence for the early development of specialised maritime technology. Although no definite fish hooks have been found in the Pleistocene sites in New Ireland, Smith and Allen (1999) have argued that the repeated evidence of circular drilled tabs from *Turbo* sp. shells indicate that this is highly likely. Technology may also be assessed from the species of fish exploited. The presence of pelagic fish species in the earliest levels of Buang Merabak and Kilu indicates that deep water fishing was practised and that trolling technology was in use (Leaveslley pers. comm.; Wickler 2001: 235).

The Holocene: Continuity and change

Amongst all known sites that contain both Late Pleistocene and Holocene deposits, only a few lay close to the coast throughout the entire period: Mandu Mandu and Pilgonaman on the Exmouth coast, Noala Cave in the Montebello Islands, Lachitu in northern PNG, and Matenkupkum, Buang Merabak and Matenbek in the Bismarck archipelago. As with many other rock shelters, archaeologic sequences in these sites are discontinuous, which makes it difficult to exactly determine changes of subsistence strategies from the late Pleistocene and through the Holocene. However, other types of sites such as open middens provide additional data.

The Bismarck sites

Matenkupkum, Buang Merabak and Matenbek lie on a steeply shelving coastline, such that their distance to the coast would have been little affected by changing sea level. After abandonment during the Last Glacial Maximum, the sites were reoccupied in the terminal Pleistocene or early Holocene, and were most intensively occupied from about 10,000 b.p. to about 6-8,000 b.p. Evidence includes dense shell deposits which have a greater range of species and more variably-sized individuals, perhaps indicating heavier predation on nearby shell beds than in the Late Pleistocene occupation; the range of shell artefacts also is greater (Allen 2000: 157). By the mid Holocene, most of the shelter sites were abandoned or only intermittently used but this probably reflects a change to settlement in built villages and agricultural activities, rather than to decreasing emphasis on maritime environments *per se*.

The fishing technology associated with the Melanesian Lapita sites indicate fish and shellfish continued to be important elements in the diet, and specialised fishing technology was well developed.

Australian Holocene: maritime intensification?

A number of changes have been detected in the mid to late Holocene Australian archaeological record, including increases in site numbers and deposition rates. New environments also became utilised and new types of sites appear, as do new technologies and extractive equipment. Together with lingistic evidence, all these factors contribute to the view that cultural changes, perhaps initiated in Arnhem Land, spread throughout Australia in the last 6000 years (Evans and Jones 1997). Some researchers interpret such changes as expressions of 'intensification' (Lourandos 1985), although the exact meaning of this term has been hotly debated for the better part of two decades (eg. Lourandos and Ross 1994). As outlined below, many of the more noted indications of change occur in coastal areas and are considered by some as expressions of internal social processes, while others view them as responses to changes of coastal environments and resources. Moreover, taphonomic factors probably confound the record.

It is beyond the scope of this paper to examine the matter in detail but some examples of Holocene usage of maritime resources are discussed here, for comparison with the Pleistocene evidence for maritime subsistence. These include new types of coastal sites such as large shell mounds, new maritime technologies, usage of offshore islands, and evidence for 'intensification' in the use of certain marine resources. The longest records of coastal resources usage tend to occur in regions with steep offshore profiles, and some extend to 9-10,000 b.p. Typical sites include Koolan Shelter 2 and Widgingarri Shelter 2 (west Kimberley coast, NW Western Australia: O'Connor 1999) and Nara Inlet rockshelter 1 (Whitsunday Islands, central Great Barrier Reef: Barker 1991) (Fig. 7, 8). Open middens appear from 8000 b.p. in other regions of northwest Western Australia (eg. Bradshaw 1995; Clune 2002; Kendrick and Morse 1982).

Overall, the record indicates that people were on the coastal plain at the end of the Pleistocene and shifted with the coast, as it moved landwards with rising sea level. Sites in the west Kimberley region were occupied (or reoccupied) progressively as sea level rose (Koolan 2 at 10,500 b.p.; the Widgingarri sites at ~8000 and 7000 b.p.) (O'Connor 1999), by people using a range of marine resources including fish, crocodile and diverse shellfish from mangrove and rocky environments. However, terrestrial fauna is well represented throughout these records, and the occurrence of turtle in the last 500 years is the only suggestion of increasing usage of marine resources. Thus, O'Connor (1999: 92) concluded that "species are derived from an extensive catchment around the shelter which includes freshwater, estuarine coastal fringe and terrestrial environments, ...[but] there is no evidence for selective or specialised hunting in any of these". Similar patterns occur elsewhere in northwest Australia. Sites near Northwest Cape contain diverse marine resources together with terrestrial fauna throughout the Holocene, but fish and turtle occur mainly in the late Holocene. Morse (1993a, b) recognises late Holocene expansion of the marine suite but attributes it to larger sample sizes, rather than to increased marine specialisation by the occupants. A similar picture of broad-based hunting and gathering emerges in the Montebello Islands where Noala Cave and Hayne's Cave, occupied between 8500 and 7500 b.p., include diverse shellfish and fish remains, together with a wide range of small to medium-sized arid sand plain marsupials and reptiles (Veth 1993).

In contrast, a change of coastal subsistence within the last 4000 years or so is suggested by the widespread occurrence in northern Australia of large shell mounds dominated by a few species, most commonly *Anadara granosa*. Almost all of these are younger than 4000 b.p., and the highest densities and

FIGURE 8. Excavation at Nara Inlet 1, Whitsunday Islands, Queensland (Photo courtesy Bryce Barker).

FIGURE 9. High Cliffy Island, northwest Kimberley, WA.

largest mounds are younger than 2000 b.p. Moreover, at sites where the environmental history has been documented, it appears that the shellfish communities and their habitats were established 2-3000 years before mound-building came into practice (Beaton 1985; Bailey *et al.* 1994). Some have argued that these mounds signal a more intensive maritime focus by coastal-dwelling peoples, who focussed their attention on high yielding species, and that this is in some way linked to pan-Australian intensification (eg. Veitch 1996, 1999). However, Clune (2002) has presented a convincing case that such mounds – at least on the Pilbara coast of Western Australia – are the end product of a change in logistical mobility that was a strategic response to increased relative aridity, in the last 4000 years or so.

On the east of the continent, Walters (1986, 1989) inferred that fishing intensified in Late Holocene times in southeast Queensland, citing evidence for the establishment of new fishing territories, and increase in the number of sites containing fish bone and in the amount of fish remains discarded. Similarly, Barker (1989, 1991) argues for greater use of maritime resources over the last 2000 years, based on a late broadening of the marine subsistence base at Nara Inlet 1 rockshelter, on Hook Island in the Whitsunday group[3]. Marine resources were important throughout the Hook Island sequence, but turtle and cetacean remains in the uppermost layers indicates a widening of maritime subsistence.

Opinion varies as to the causes and indeed the question of intensification. From examining some 23 Queensland sites, Ulm (2002: 88-90) concluded that not only is there no general trend towards intensifying marine fish production, but also that some sites demonstrate *decreasing* rates of fish bone discard. Late Holocene broadening of the subsistence base, represented at Nara Inlet by turtle and whale, is seen by Barker not as the direct outcome of new technology[4], but as the outcome of internally generated social change. However, others such as Rowland (1986: 83) have realistically noted that the "use of outriggers in this area suggests that diffusion of ideas from the north may have extended at least this far down the coast ... material culture items of Papuo-Melanesian origins were finding their way down ..., particularly items relating to coastal resource exploitation". Mitchell (1996) reached a similar conclusion for the Cobourg

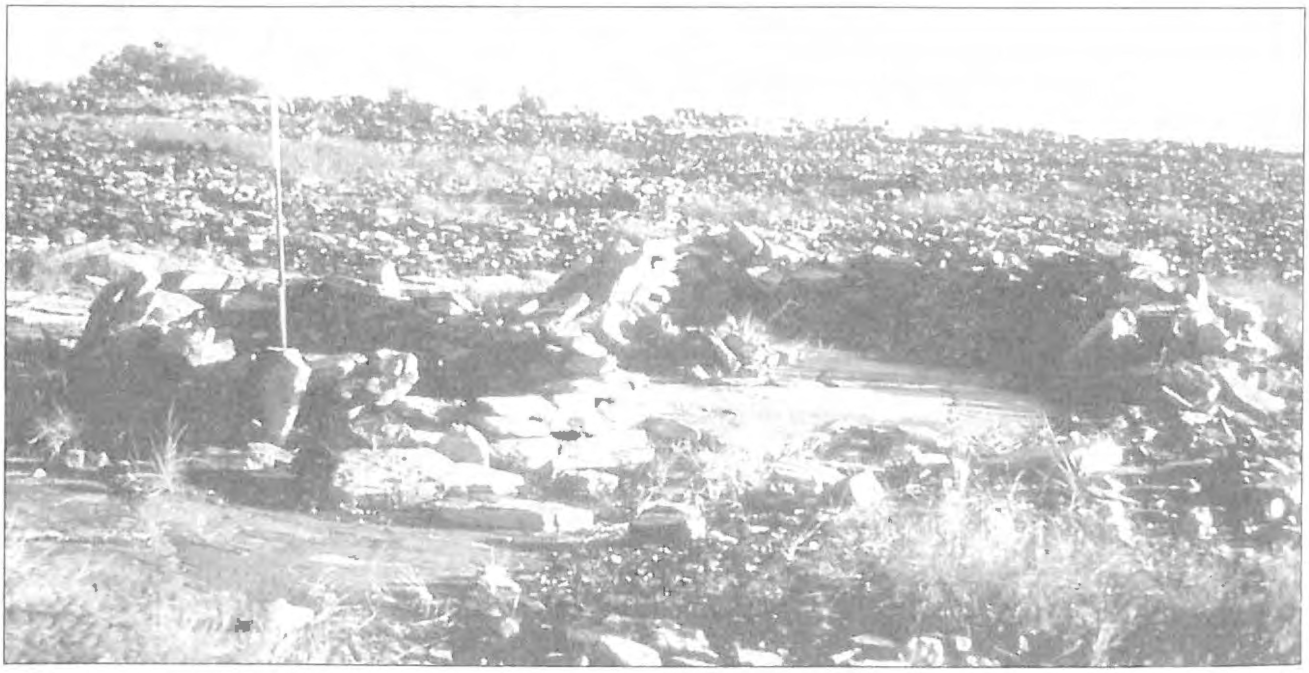

FIGURE 10. Stone house bases on High Cliffy Island, northwest Kimberley, WA.

Peninsula, Arnhem Land, where dugout canoes and metal harpoon heads were introduced by Macassan visitors and, he argues, enabled more effective hunting of turtle and dugong. This may also be the case for the Kimberley coast (O'Connor 1999: 95-117). While there is sparse evidence for early post-transgression use of offshore islands in this region (O'Connor 1999: 111), there appears to have been an acceleration in island use immediately preceding European contact. The adoption of the metal harpoon head, acquired from Macassan trepangers, may have led to greater efficiency in hunting marine mammals and reptiles and may in turn have allowed the permanent occupation of very small islands as documented in the European contact period. On some of these small islands such as High Cliffy (Fig. 9), dozens of stone house bases have been recorded (Fig. 10). Some of these contain grinding stones with rust residues, resulting from the grinding of metal harpoon heads (Fig. 11) (O'Connor 1999: 113-117). Similarly, technologic innovation may underlie the usage of small offshore islands by Aboriginal groups along the east coast of Australia in the last 2000 years (Bowdler 1995) but, once again, whether this reflects intensification of coastal subsistence is debated.

FIGURE 11. Grinding stones with rust residues from grinding metal harpoon heads, High Cliffy Island, northwest Kimberley, WA.

Conclusions in summary

The more surprising conclusion from present evidence is that Pleistocene coastal populations in Australia only became significant some 25-30 ka after colonisation of the savannah, despite that sea levels were lower and coasts were further off than in the preceding period. Setting aside the original landfalls, of which there is no trace, the evidence is readily interpreted as showing that coastal Australia in the terminal Pleistocene largely was populated by movements from the savannah, rather than the reverse. This is supported by a number of features in the available data. Although the oldest Australian sites lie too far inland to be hinterland components of coastally-based economies, the early sites that do lie within touch of Pleistocene shorelines contain few remains of coastal resources. Indeed, evidence for significant maritime subsistence is younger than 25,000 b.p., even where the opportunities owing to site location were much better before 25,000 b.p. This systematic use of the coastal zone occurs at a time when continental aridity was deepening.

There is no reason to expect that maritime resources became more plentiful at this time; indeed, coastal diversity is likely to have decreased during the fall of sea level around 28-30 ka. Nor is resource availability likely to underlie the virtual absence of traces of maritime subsistence prior to 25 ka, which contrasts so strikingly with the situation in Island Melanesia, because the Australian shores not only lay closer to the present coast, but also are likely to have passed through several episodes when diversity was comparable to that in the Holocene, during the phases of rising sea level shown prior to 33 ka.

As coastal subsistence intensified, links with inland groups appear to have extended through trade or exchange, as shown by pearl, baler, mud clam and *Dentalium* shells from the Kimberley (Koolan 2, Widgingarri 1 and Riwi); *Syrinx* from the Pilbara coast (Burrup Peninsula), and baler shell from the Silver Dollar site at Shark Bay. Around 18,000 b.p., soon after the appearance of evidence for coastal contact, occupation ceased at many inland sites, which then remained largely unoccupied through the period of maximum continental aridity, until ~12,000 b.p. when the coastline was moving rapidly landward. Finally, although the record of coastal usage over the last 8,000 years is very good, it gives no clear indication of increasing specialisation in the use of marine resources or maritime technology in Australia until the Late Holocene. When such evidence does appear, it is at least in part a result of new introductions in marine technology from outside Australia.

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Notes

1. All radiocarbon dates in this paper are conventional ages, and use b.p. following the recommendation by *Antiquity* for citation of uncalibrated dates.

2. we note that Bowdler [1993] preferred to remain skeptical about Upper Swan, Malakunanja II and Huon Peninsula.

3. Fig. 1: Hook Island separated from the mainland about 6500 b.p. but the rockshelter was used throughout the last 8000 years.

4. Turtle and whale probably were captured using harpoons with detachable heads as described by Roth (1907): Barker 1991: 104.

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