Chapter 5

Pleistocene Sahul and the Origins of Seafaring

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Most prehistorians take seafaring — defined as deliberate, place-to-place, open-ocean voyaging — to be a relatively recent phenomenon, dating no earlier than the terminal Pleistocene, 10–15,000 years ago (10–15 kya BP). Others regard this assessment as too conservative, drawing attention to evidence of a more remote origin, associated with the initial colonization of Sahul (Pleistocene Australia-New Guinea) 45–46 kya BP. Solid as this evidence seems to be, it is commonly ignored or dismissed, partly through unfamiliarity with Sahul prehistory, but more importantly because of a narrowly inductive approach to the archaeological record and a reluctance to credit the technological capabilities of early Sahul indigenes.

Here we develop an argument for the origin of Sahul seafaring and the coastal and marine economies that underlie it. We begin with background on regional geography, the initial colonization date for Sahul, and the identities of the colonists. We then review recent debate on the colonization process, focusing on evidence for long-distance voyaging and pelagic fishing from 45–46 kya BP onward. We argue that these practices are best understood by reference to optimal-foraging models designed to explain resource choice and related developments in technology. We use these models along with ethnographic data to develop predictions about the initial practice of seafaring and later variation in reliance on marine and littoral resources. We assess the match between predictions and archaeological data and identify possible reasons for inconsistencies. We speculate on the factors that may have limited recent Australian Aboriginal investment in watercraft, and conclude with comments on the limits of induction in archaeology and the impact of the idea of progress on the study of Sahul prehistory.

Background

Geographic setting

The area of interest has four parts (Fig. 5.1). At the centre is *Sahul*, currently represented by Australia and its continental islands. Over the last few million years, fluctuations in sea level have repeatedly exposed large areas of the surrounding continental shelf, forming a single continuous landmass extending from New Guinea south through Tasmania.

To the west is *Sunda*, now marked by the Malay Peninsula and the islands of western Indonesia. There, past drops in sea level created a broad sub-continent stretching from Southeast Asia east through Borneo and Java.

Between Sunda and Sahul lies the 1500 km-wide *Wallacean Archipelago*. Though falls in sea level have periodically reduced its overall extent and increased the size of its islands, it has never been bridged by dry land during the period of interest here. Even at maximum low sea levels (–120 m relative to modern), it measured well over 1000 km across. Island-hopping through it required at least eight separate crossings (Birdsell 1977). All routes always included one leg >70 km and at least three >30 km. Prior to the arrival of *Homo sapiens*, no large-bodied terrestrial mammal ever managed a complete transit in either direction, at least not in numbers large enough to leave a record, let alone establish a persistent population.

Northeast of Sahul are the islands of *Near Oceania*, notably the *Bismarck Archipelago* and the *Solomons* chain. Water gaps between New Guinea and the Bismarcks, and between neighbouring islands in the Bismarcks and Solomons are generally <100 km across. Exceptions include the New Ireland-Bougainville and Manus-New Hanover divides of 140–170 km and 200–300 km, respectively, the distances in each instance varying with sea level.

Human colonization: dates and identities

Sahul and the Bismarcks were first occupied by humans about 45–46 kya BP (Table 5.1). Some commentators advocate a 60 kya BP arrival date (e.g. Bulbeck 2007; Chappell 2000; Gillespie 2002), but there is no reliable archaeological support for this claim (O'Connell & Allen 2004). Colonizing populations

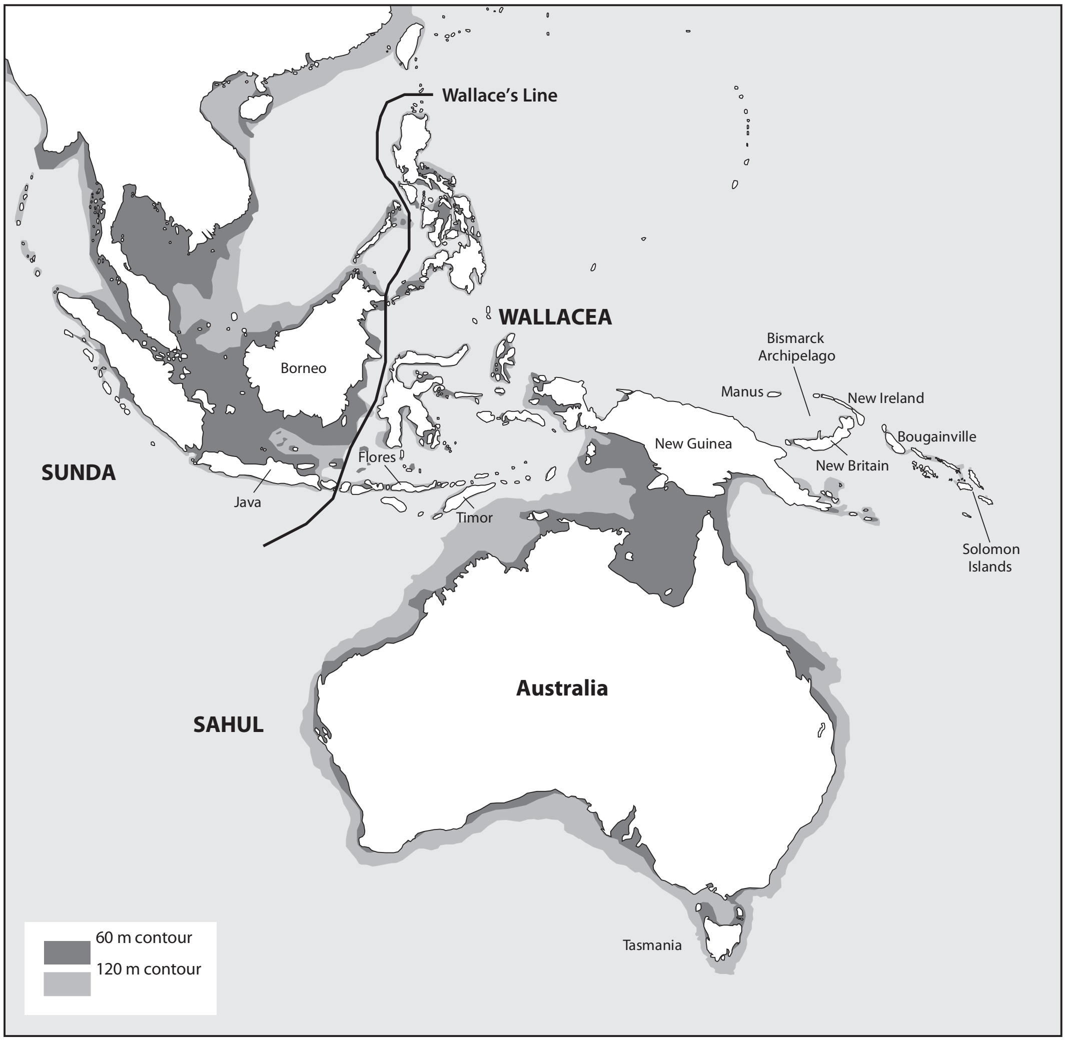

Figure 5.1. *Map of Sunda and Sahul. Sea levels shown at modern, –60 m and –120 m.*

included representatives of at least three mitochondrial and two Y-chromosome macro-haplogroups (van Holst Pellekaan 2008), the former defined by basal mutations that appeared in East Africa or South Asia 45–50 kya BP (Kivisild *et al*. 2006). The geographic distribution of 'daughter' lineages evolving within these haplogroups indicates rapid migration across South Asia (Macaulay *et al*. 2005), consistent with the earliest archaeological dates from Sahul.

Models of colonization

Ideas about Sahul colonization fall into two categories: *accidental vs deliberate*. An extreme example of the first is Calaby's (1976) 'pregnant-woman-washed-ashore-on-a-log' scenario. Smith (2001) offers a more plausible model, arguing that small groups on Sunda were occasionally washed offshore during storms, then carried east on drifting mats of vegetation until they reached Sahul. Anderson (2000) thinks accidental crossings might have been more successful if the people involved used bamboo rafts in connection with near-shore foraging. Their reliance on rudimentary watercraft may have increased the odds of being swept away in bad weather; subsequent survival may have been aided by whatever water, food and gear happened to be on board.

There are two important problems with these arguments:

- If Smith were right, then one might expect pre-modern humans, present on Sunda for more than a million years, to have reached Sahul; yet none managed a demographically successful transit east of Flores (Morwood *et al*. 1998). By contrast, *Homo sapiens* crossed the entire 4500-km-long Sunda-Bismarcks arc in an archaeological 'instant'. The earli-

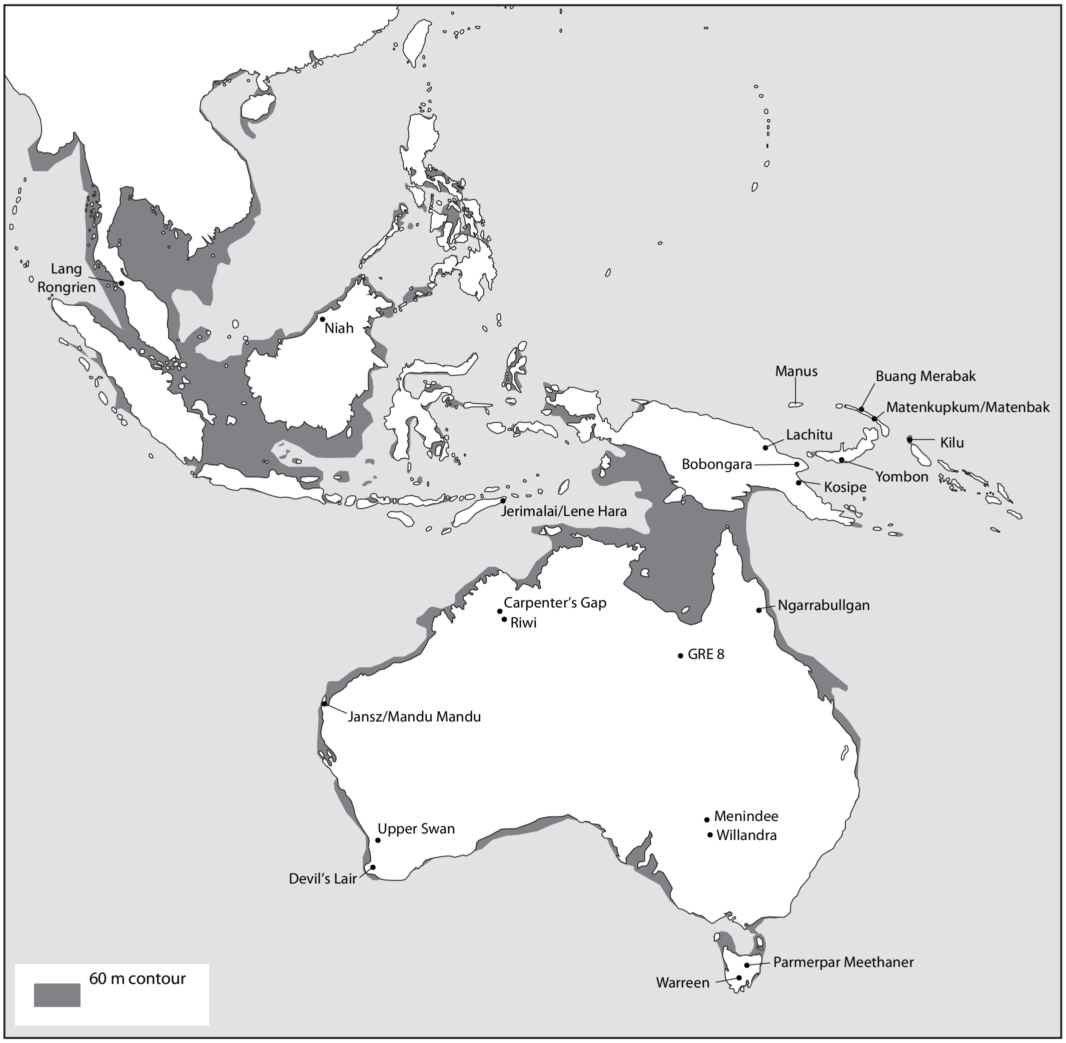

Figure 5.2. *Locations of archaeological sites mentioned in text and Table 5.1.*

est uncontested dates for humans throughout this region, and in fact across large parts of Australia, fall within a narrow time range, roughly 44–46 kya BP (Table 5.1; Fig. 5.2). These data strongly suggest something more purposeful than a series of accidental drift events.

- Given the constraints imposed by birth and death rates, sibship composition, and the availability of suitable mates, successful colonization of an uninhabited landfall probably requires the near-simultaneous arrival of several groups, each including at least 5–10 women of reproductive age (Moore 2001). Continuing contact with the source population(s) further enhances the probability of demographic success. Deliberate voyaging is implied. The odds that members of one small group cast adrift by chance could later generate a persistent population — the scenario envisioned by Anderson and others — are slim. The chances of this outcome being repeated *several times* in the space of a few centuries — the process required to cross Wallacea and colonize Sahul and the Bismarcks in the time frame indicated — are very remote.

Arguments in favour of purposeful colonization, supported by marine-capable watercraft, are more promising (Allen & O'Connell 2008; Bulbeck 2007; Davidson & Noble 1992). Irwin (1992, 18–30) in particular makes a strong, if speculative, case for deliberate crossings using wind- or paddle-powered boats. He describes the zone from Sunda east to the Bismarcks as a 'voyaging corridor … [marked by] predictable seasonal reversals of wind and current, a sheltered equatorial position between bands of cyclones and a large measure of inter-visibility' between neighbouring islands, all of which favoured purposeful seafaring and related developments in marine technology. Birdsell (1977,

Table 5.1. *Sites in Sunda, Wallacea, Sahul and the Bismarck Archipelago dated or estimated ≥40 kya* BP *and containing remains of* Homo sapiens *or archaeological materials thought to have been produced by* Homo sapiens *(O'Connell & Allen 2004; see also Barker* et al. *2007; Cosgrove 1995; Cupper & Duncan 2006; Fairbairn* et al. *2006; Leavesley & Chappell 2004; O'Connor 2007; Przywolnik 2005; Slack* et al. *2004). Luminescence dates are taken to be the equivalent of solar years. Radiocarbon dates are reported in both C14 and solar years, the latter estimated by reference to Fairbanks (2007), a controversial exercise for dates >25 kya* BP *(Esat & Yokoyama 2008). Estimates in this range should be viewed with caution, although consistency with available luminescence dates reinforces confidence in their accuracy. The discrepancy between C14 and luminescence dates for Ngarrabullgen is unexplained.*

Region/site	Location	Earliest archaeological dates (yrs x10^3 BP)		
		C14	C14: solar est.	Luminescence
Sunda				
Lang Rongrien	Peninsular Thailand	37.1±1.8	42.2±1.6	
Niah	Borneo	42–46	45–>46	
Wallacea				
Jerimalai	Timor	38.3±0.6	43.2±0.5	
Lene Hara	Timor	34.7±0.7	40.0±0.7	
Sahul - Far North				
Bobongara	Northeast New Guinea			>44
Buang Merabak	New Ireland	39.6±0.6	44.4±0.5	
Kosipe	Southeast New Guinea	35.0±0.7	40.4±0.7	
Matenkupkum	New Ireland	35.4±0.4	40.7±0.4	
Yambon	New Britain	35.6±0.5	40.9±0.5	
Sahul - Mid-North				
Carpenter's Gap	Kimberley	40.6±0.8	45.3±0.7	
GRE 8	Carpenteria	37.1±3.0	42.2±0.3	
Jansz	Cape Range	35.2±0.5	40.6±0.5	
Mandu Mandu	Cape Range	34.2±1.1	39.6±1.0	
Ngarrabullgen	Cape York	35.2±0.7	40.5±0.7	34–35
Riwi	Kimberley	41.3±1.0	45.9±0.9	
Sahul - Mid-South				
Devil's Lair	Southwest Australia	41.4±1.3	46.0±1.2	44.4±2.1
Menindee	Darling Basin	41.5±1.3	46.0±1.5	45.3±1.5
Upper Swan	Southwest Australia	39.5±2.0	44.3±1.8	
Willandra	Darling Basin	38.1±1.1	43.1±1.0	45.4±2.5
Sahul - Far South				
Parmerpar Meethaner	Southwest Tasmania	33.9±0.5	39.2±0.5	44.2±8.6
Warreen	Southwest Tasmania	34.8±0.5	40.1±0.5	

123) drew essentially the same inference from a similar set of observations, arguing that successful colonization of Sahul must have entailed the use of watercraft '*superior to those found in recent times in Australia and Tasmania*' (emphasis added).

Empirical support for this model includes:

- the speed of regional colonization;
- evidence for the occupation of Buka >34 kya BP and Manus >25 kya BP (Spriggs 2001; Wickler & Spriggs 1988; solar years estimated from radiocarbon dates as in Table 5.1). Reaching Buka required an open ocean voyage of at least 140 km. Crossing to Manus entailed a minimum 200 km trip on which travellers were beyond sight of land for distances of 60–90 km. Purposeful voyaging is clearly implied. Though these dates fall well after the initial colonization of Sahul, their still appreciable ages make the notion of deliberate seafaring earlier in time more plausible than might otherwise have been the case.
- evidence of deep-sea fishing from sites in the 30–45 kya BP range. At Buang Merabak (New Ireland), remains of tuna and deep-water shark are reported in deposits dated 35–45 kya BP (Leavesley 2004); at Kilu Cave (Buka), pelagic taxa represent nearly 20 per cent of 323 fish remains (NISP) in deposits dated >30 kya BP (Wickler 2001, 224–6); at Jerimalai (Timor), tuna are found in deposits dated >42 kya BP (O'Connor 2007). These data are best read to indicate angling from boats, well offshore (Wickler 2001, 226; Smith & Allen 1999).

Though clearly provocative, these observations are widely ignored or discounted. Lack of familiarity with the regional record is partly to blame, but allegiance to the idea of progress (Nisbet 1994) as a dominant theme in human affairs is also involved. Jones (1989, 754), reacting to Birdsell's suggestion about Pleistocene watercraft, expressed this attitude succinctly: 'It would be *perverse* (emphasis added) to assign to … [these early colonists] a superior maritime technology than that used by their descendants once they had arrived in Australia/New Guinea'.

Cultural 'regressions' are of course not uncommon in human history. Jones (1977) himself drew attention to an excellent example, the 'simplification' of Tasmanian technology and economy in the late Holocene. Still, his comment on Birdsell raises an important question. If early Sahul colonists *were* sophisticated voyagers and capable pelagic fishermen, *why isn't* evidence of these capabilities more widely encountered? As Beaton (1985) and others have observed, indications of littoral resource use are rare across most of Sahul until the middle Holocene. Markers of deep-sea fishing and marine watercraft are almost entirely absent from the prehistoric record of Australia, a pattern mirrored in most of the ethnographic literature (Birdsell 1977; Jones 1976). Why should this be the case?

Foraging and technology

We assume that developments in Pleistocene marine technology were primarily subsistence-related. This allows us to make use of concepts from behavioural ecology including optimal foraging theory, a family of models used to investigate variation in patterns of food acquisition (Stephens & Krebs 1986). Two of these models, *diet breadth* and *marginal value*, are of special interest here. Both assume that maximizing the rate of nutrient acquisition enhances reproductive success.

The *diet breadth model* identifies the subset of resources likely to be taken from the array available in a given foraging locale or 'patch'. It makes a distinction between *search* and *handling*, the latter including activities associated with the post-encounter pursuit, capture or collection of prey and their preparation for consumption. It assumes that resources can be ranked on the basis of post-encounter nutrient return rates. The model predicts that resources of the highest rank will always be taken on encounter. Lower-ranked prey will be added to the diet in descending order until the expected post-encounter return from the next lowest-ranked type falls below that earned from *searching for and handling* resources of higher rank. If encounters with the latter decline in frequency, then overall average foraging returns will decline as well. If they drop below the post-encounter returns available from items not previously taken, the latter will be added to the diet, increasing diet breadth. If encounter rates for higher-ranked items increase, overall average foraging returns will rise as well. As they do, low-ranked prey are increasingly likely to be dropped from the diet, reducing diet breadth.

The *marginal value theorem* stipulates the point at which foragers should abandon the patch they are exploiting in favour of another. In-patch resources are always finite and may be depleted by collecting pressure. If they drop to the average available from travelling between patches and exploiting them, the forager should leave that patch and move to another. If average returns from all patches fall over time, the opportunity costs of remaining in place will fall as well, leading to longer in-patch stays and broader diets. Changes in the cost of travelling between patches are also pertinent: all else being equal, lower travel costs imply narrower diets and more rapid patch abandonment, higher travel costs the reverse. The longer the travel-time between patches, the greater the incentive for improving travel technology (Hawkes & O'Connell 1992).

Among social organisms, including humans, diet breadth and patch choice may be complicated by conflicts of interest among group members. One pervasive conflict stems from the fact that reproductive success in males and females is achieved in very different ways. For women, fitness is especially dependent on a steady nutritional stream for themselves and their children. All else equal, localities and resources offering high mean returns but also low risk of procurement failure and low variance in daily return rates are likely to be preferred. For men, fitness depends on access to women. Men usually live in the same residential sites as women, but are likely to target resources that come in large, potentially shareable packages that draw favourable attention to their acquirers (Hawkes & Bliege Bird 2002).

Seafaring and Sahul colonization

These models help us address four questions:
- Given the evidence of long-distance voyaging and pelagic fishing in the period 30–45 kya BP, why adopt either practice at such an early date?
- How were these practices linked with the move across the Sunda-Bismarcks arc?
- Why does evidence of voyaging and deep-sea fishing remain uncommon until as recently as the middle Holocene?
- Why were Indigenous Australian watercraft used historically not more sophisticated?

Mid-Upper Pleistocene human ecology and the origins of seafaring

The mid-Upper Pleistocene movement of *Homo sapiens* beyond Africa was associated with a relatively high-cost subsistence strategy, probably adopted because of an increase in human population size (Rogers

1995). Key elements of this strategy included pursuit of a broader range of prey and the use of more elaborate handling technologies (Henshilwood & Marean 2003; Stiner *et al*. 2000). Some of these practices are reported from sub-Saharan Africa by 60 kya BP, but they were increasingly common from 45–50 kya BP onward, beginning with the spread of *Homo sapiens* into Eurasia.

The earliest evidence of high-cost subsistence economies in Sunda coincides with the arrival of *Homo sapiens*. At Niah Cave (Borneo), macrofossils of toxic yams and nuts are dated 40–46 kya BP (Barker *et al*. 2007). These items require extensive processing before they can be eaten safely: they are relatively low-ranked. Under these circumstances, innovations that reduced travel time between patches would have been especially advantageous and should have been adopted wherever possible.

Modelling movement across the Sunda–Bismarcks arc

Homo sapiens travelling east of Sunda probably pursued a two-component economic strategy, men focusing primarily on larger, more mobile prey, including pelagic fish, women emphasizing smaller, less mobile items, including molluscs. Marine watercraft would have been crucial to this strategy: essential for men's pelagic fishing, important to women insofar as they reduced the cost of movement to previously unexploited coastlines (O'Connell & Hawkes (1984) report a recent central Australian analogue involving the use of motor vehicles).

Changes in residential site location were probably driven by serial depletion of high-ranked resources. Declines in men's fishing returns may have been a factor, but among low-latitude hunter-gatherers, it is usually *women's* foraging that underwrites day-to-day household nutrition; thus declines in women's return rates may have been the primary catalyst for relocation. Mannino & Thomas (2002) show that encounter rates for high-ranked inter-tidal molluscs may fall sharply under sustained collecting pressure. Large-bodied, slow-maturing bivalves, some of which generate post-encounter returns >10^4 kcal/hr (Bird & Bliege Bird 1997; Thomas 2007), are especially at risk. If shellfish such as these were a critical resource for humans operating along the Sunda–Bismarcks arc, then even small drops in encounter rates may have been enough to prompt moves to previously unoccupied sections of that arc (Allen & O'Connell 2008; Beaton 1991). The low variance anticipated in women's daily foraging returns would have facilitated prompt recognition of those drops.

Inter-site movement may have been relatively rapid. If women operated as central place foragers over distances of up to 10 km from their residential bases (a commonly reported ethnographic pattern), and if it required no more than a decade to reduce the encounter rates from high ranked prey within each site 'catchment' to the point that shifting to an unexploited locality made good economic sense, then the entire Sunda–Bismarcks arc, including perhaps 200–250 shoreline catchments, could have been crossed in 2000–2500 years. Foragers targeting only those catchments yielding above average return rates — as the marginal value theorem leads us to expect — would have moved more rapidly. Faster depletion of high-ranked prey would have had a similarly accelerating effect. Access to marine watercraft would have been key, allowing travel to otherwise inaccessible island patches and reducing the cost of coast-wise inter-patch movements. These calculations, though simple, suggest that passage along the entire 4500-km-long arc in less than a thousand years should have been possible, consistent with available chronometric data (Table 5.1).

Uneven record of marine resource use

Data on early Sahul subsistence patterns are partly consistent with these expectations. As indicated above, Buang Merabak and Jerimalai have both yielded remains of marine and littoral resource use dated 40–45 kya BP. Kilu has produced similar evidence from deposits with an estimated age >34 kya BP. Matenkupkum and Matenbek (New Ireland) estimated at 38 kya BP and 24 kya BP, respectively, provide evidence of fishing and shellfish collecting as well as indications of angling in the form of possible fishhook manufacturing debris (Gosden & Robertson 1991; Smith & Allen 1999). Lachitu, on the north shore of New Guinea, has evidence of early shellfishing, although the initially reported date of about 40 kya BP (estimated) is now uncertain (S. O'Connor pers. comm.; cf. Gorecki *et al*. 1991).

These data notwithstanding, evidence of coastal foraging is still patchily distributed across prehistoric Sahul: present almost exclusively in the tropical north until after the Last Glacial Maximum (20–24 kya BP), more widespread thereafter, but abundant only from the mid-Holocene onward (O'Connor & Chappell 2003). Moreover, large-bodied bivalves are not reported from the earliest middens other than at Buang Merabak (Leavesley & Allen 1998, 67–8). The question posed earlier re-emerges: if these tactics — shellfishing in particular — were as productive as we suggest, why is evidence of their practice not more widespread? And why is there so little early evidence of large bivalve exploitation?

Three factors contribute to the apparent mismatch. *First*, sea levels were lower during most of the

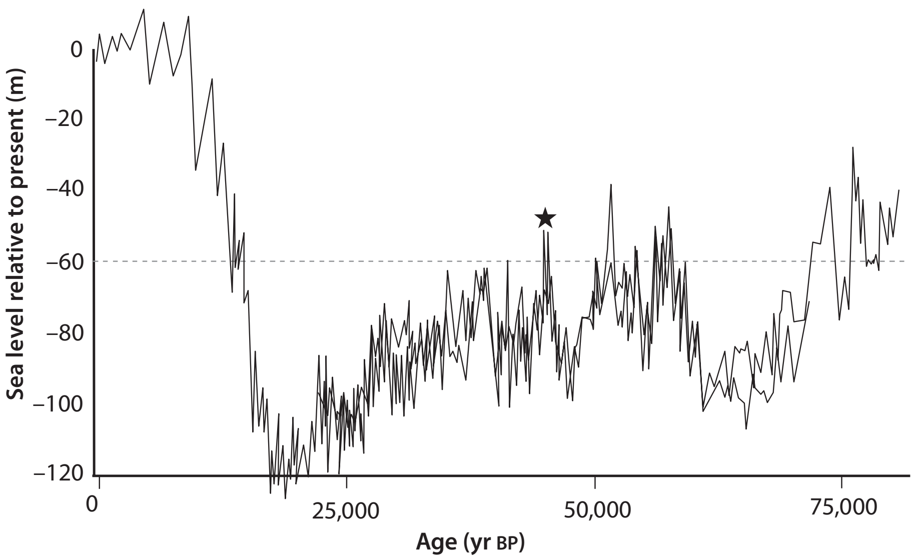

Figure 5.3. *Sea-level fluctuations 80 kya* BP*–present (modified after Siddall* et al. *2003). Multiple lines at various points on the sea level curve (notably in the 30–40 kya and 60–75 kya* BP *ranges) indicate uncertainties in sea-level estimates. The star at the 45 kya* BP *peak indicates the sea-level rise along which initial colonization of Wallacea, Sahul and the Bismarcks probably took place, beginning in the interval 45–47 kya* BP.

last glacial cycle (Fig. 5.3) meaning that most evidence of Late Pleistocene littoral and marine resource use is now under water. Readily recoverable data will be found mainly where offshore profiles are steep and lateral shoreline movement due to sea-level change has been limited. All currently available evidence of pre-Holocene coastal and marine economies comes from such locations.

Second, the attractiveness of coastal habitats to human foragers is determined partly by changes in sea level. Generally speaking, stable and rising levels favour development of economically productive coral reefs, lagoons, littoral swamps and estuaries; falling levels inhibit their formation and persistence (Chappell 1993). Figure 5.3 shows a recent reconstruction of sea-level changes over the last 80 millennia. The pattern is complex: marked by a broadly downward trend punctuated by high-amplitude oscillations (±10–40 m) on sub-millennial time scales from 60–20 kya BP, followed by a relatively steady rise to modern levels at mid-Holocene, with comparatively little fluctuation thereafter.

These changes imply a highly unstable array of coastal habitats across the first 40 kya of human history in the region, and a parallel instability in human diet breadth and degree of investment in littoral and marine resource-related technology. Falls in sea level would have reduced access to higher-ranked coastal habitats and resources throughout Sahul, and so favoured increasingly intensive patterns of resource exploitation in areas that remained attractive for human occupation, including greater reliance on terrestrial resources where possible. Habitats where these options were limited — smaller islands in particular — may have been abandoned. Rising sea levels should have reversed this trajectory, favouring access to higher-ranked coastal patches, narrower diets, and simpler collecting and processing technologies, depending on the rates at which productive littoral habitats developed, and on how closely human population growth tracked their emergence (Beaton 1995). If those habitats evolved slowly and population growth kept pace, there might have been little or no change in diet breadth, although a broader distribution of human populations along coastlines and intermittently renewed investment in marine watercraft that facilitated access to previously unoccupied or abandoned islands should have followed. Even if coastlines had not been flooded by the Holocene sea-level rise, a patchy record of earlier littoral resource use would still be anticipated.

The lack of detailed information on changes in coastal habitats and the still-limited nature of the archaeological record preclude comprehensive assessment of these expectations, though some general observations are possible. Developments consistent with the predicted increase in diet breadth associated with falling sea levels include evidence of terrestrial habitat modification at Bobongara on the north coast of New Guinea after 45 kya BP (Groube 1989), the use of high-cost taro in the northern Solomons after 34 kya BP (estimated) (Loy *et al*. 1992), and the introduction of exotic terrestrial animals to parts of the Bismarcks by 23 kya BP (Flannery & White 1991). Long-distance transport of high-quality tool-stone across the Bismarck Archipelago, also by about 23 kya BP, may be a further measure of economic intensification (Summerhayes & Allen 1993). The presence of some of these markers on islands may reflect the relatively limited arrays of terrestrial resources typically available in such settings (Allen 2000). Indications of the dispersal of human populations in association with rising sea levels include the initial colonization of the region coincident with or shortly preceding the 45 kya BP high-stand, and the occupation of the northern Solomons by 34 kya BP or before, possibly coincident with a pronounced rise in period 35–40 kya BP. And though it merits much more comprehensive treatment than can be afforded here, the sharp increase in reliance on coastal resources all across Sahul from the mid-Holocene onward clearly tracks the development of productive littoral habitats (Beaton 1985; Pope & Terrell 2008).

Thirdly, regarding the relative absence of evidence for high-ranked bivalve exploitation: central place foragers generally seek to maximize the rate at which edible tissue is carried back to their residential base (Metcalfe & Barlow 1992). Given a limit on the size of the load they can move on foot, and a resource that contains both high- and low-value parts, they face a trade-off: *either* collect as much of the resource as possible in the time available, *or* spend time in-patch removing the low-utility parts in order to carry home more high-value components, which means less time available for collecting. The decision turns on the time required to process each item and the gain in load utility earned as a result. Prey that contain relatively large, easily removed, low-utility parts are more likely to be processed in-patch; those that are harder to handle relative to size and so yield little increase in load utility will be carried home intact.

Bird & Bliege Bird (1997) and Thomas (2002) provide ethnographic examples of these trade-offs among southwest Pacific shellfish collectors. Both show that adult foragers almost always process large bivalves — notably tridacnids — in-patch, but generally handle gastropods — notably *Turbo*, *Trochus* and *Cypreaea* — at base. As a result, tridacnids are underrepresented in base camp middens relative to their importance in the diet while gastropods are disproportionately common (Bird *et al*. 2002). These observations suggest that while large-bodied bivalves were probably taken whenever possible and should have figured prominently in early coastal diets, they will be relatively uncommon in residential site accumulations. Gastropods like *Trochus*, *Turbo* and *Cypraea* should also have been targeted, depending on their respective post-encounter returns relative to higher-ranked bivalves. Where taken, they will often have been carried home for processing: Bird & Bliege Bird's data show fewer than 30 per cent handled in-patch.

Data from Buang Merabak, Jerimalai, Kilu and Matenkupkum match up well with these expectations (Gosden & Robertson 1991; Leavesley 2004; O'Connor 2007; Wickler 2001). Larger gastropods are present at all four sites. The especially large sizes of *Turbo* at Matenkupkum indicate low levels of human predation, consistent with the low human population densities and high rates of residential mobility implied by the low rate of refuse deposition, not only there but in other early coastal sites as well (Allen 2000; Gosden & Robertson 1991). The flaked fragments of tridacnid shell, present throughout the Pleistocene layers at Buang Merabak and initially interpreted as stone tools or tool-production debris, indicate that giant clams were present within the site catchment while it was occupied and (given their likely post-encounter return rates) almost certainly taken as food (Leavesley & Allen 1998). The absence of tridacnid shell debris other than that associated with tool production fits our expectations.

Watercraft

Attention to the costs and benefits of prey and patch choice may also help explain the modest nature of traditional watercraft reported from many parts of Sahul at the time of European contact. Large, ocean-going, sail-powered canoes, suitable for transporting sizable cargoes over long distances (Anderson 2000) were found in the north; but around most of Australia, watercraft were smaller and simpler in form, often poorly constructed, fragile, and restricted to use in quiet waters (Birdsell 1977). Such craft could not have supported the rapid, purposeful, mid-Upper Pleistocene transit of the Sunda–Bismarcks arc implied by the archaeological record. If better boats were used in the past, why were those encountered at contact, specifically in Australia, so simple?

We think the answer lies in the relative costs and benefits of coastal and marine resource exploitation. Jones's (1976) discussion of Tasmanian watercraft suggests the direction an analysis might take. These were simple 'canoe rafts', up to 5 m long, made of bundled bark, reeds and grass, and propelled by pole, paddle, or by people swimming alongside. Load capacity was generally limited to 3–4 people, the largest carrying no more than 10–12. All but the very best examples fell apart quickly in rough seas and even in quiet waters lost buoyancy in a day or two. Maximum travel distances were generally in the 8–15 km range. Trips to offshore islands were sometimes undertaken, but only in calm conditions. Routine use was restricted to slow-moving rivers and estuaries. Interestingly, these boats were deployed *only* on the western and southern coasts of the island, *never* on the north and east.

Jones rejects the idea that ecological factors determined the spatial pattern of boat use, but our reading of his review suggests otherwise. Simple watercraft were well-suited to the broad bays and island-studded estuaries that mark parts of the southern coast; generally rougher seas along the west coast probably counted against their use. On the other hand, the relative lack of access to terrestrial resources in the densely forested western country inland may have made strand-looping and occasional forays to nearby islands the only attractive subsistence options. Seas may have been somewhat calmer on the north and east coasts, but terrestrial foraging opportunities were apparently much more abundant there as well. The trade-off may have counted against the use of watercraft, even where offshore islands were relatively close at hand. In short, local opportunity costs arguably determined investment in watercraft. This suggestion is clearly speculative, but consistent with our argument about the origin of seafaring, and so in our view worth pursuing, not only with respect to Tasmania, but in broader form for mainland Australia as well.

Conclusion

Archaeological evidence and demographic modelling indicate that seafaring was central to the colonization of Sahul and parts of Near Oceania roughly 45,000 years ago. Models of diet breadth and patch choice combined with ethnographic data on coastal resource use suggest a series of hypotheses about the factors responsible for that initial colonization and the subsequent evolution of coastal economies across Sahul, the Bismarcks and northern Solomons. Early investments in marine technology were arguably prompted by the high cost of subsistence on Sunda relative to foraging opportunities available in previously unoccupied areas further east. Initial movement across the Sunda–Bismarcks arc was facilitated by rising sea levels that favoured the development of productive shoreline habitats region-wide at about 45–47 kya BP. It was propelled by a series of predation-related declines in women's foraging returns from high-ranked coastal resources. Subsequent human population growth and a longer-term trend toward lower sea levels and less productive littoral habitats limited opportunities for continued relocation, forcing increasingly intensive exploitation of local resources in areas already occupied. The use of high-cost plant foods, the modification of terrestrial habitats in order to increase resource availability, and the introduction and subsequent cultivation of exotic species in island settings where terrestrial prey were always limited were among the results. Smaller islands where these options were unavailable may have been abandoned. Periodic rises in sea level that interrupted the general downward trend, particularly those that resulted in relatively stable high-stands, prompted new rounds of population dispersal, including the occupation of relatively remote islands not previously colonized and the reoccupation of others. After the Last Glacial Maximum, the overall pattern was reversed. Sea level rose fairly steadily, ultimately stabilizing in the middle Holocene, creating the highly productive littoral habitats that supported the development of coastal economies known historically.

As we noted at the outset, this model is at odds with the widely held view that seafaring and marine economies are mainly Holocene phenomena, a perception especially notable among specialists in Sahul prehistory, some of whom have until recently continued to characterize the initial colonization of this region as accidental, and to downplay the growing body of evidence indicating that coastal and marine economies were practiced, at least intermittently in parts of northern Sahul and Island Melanesia, from the mid-Upper Pleistocene onward (e.g. Chappell 2000; O'Connor & Chappell 2003; O'Connor & Veth 2000; cf. O'Connor 2007). We attribute this attitude to two factors. One is a deep-seated scepticism about theoretically driven arguments and predictive modelling exercises, and a corresponding devotion to archaeological evidence, narrowly defined and inductively read. The other is a continuing allegiance to the idea of progress — in this case, to the notion that useful innovations once developed are unlikely to be put aside until something 'more sophisticated' comes along. From this perspective, ancient technology cannot have been more complex than it was in the ethnographic present.

Contrary to the first point, research over the last three decades has repeatedly illustrated the utility of a deductively oriented, theoretically driven approach — specifically one grounded in behavioural ecology — to the study of human prehistory (Bird & O'Connell 2006). It has also shown the importance of attending to the processes that determine the relationship between human behaviour and its archaeological consequences, a finding that seems especially crucial in cases involving long-term littoral and marine resource use, where key segments of the archaeology will inevitably be inaccessible. Failure to take advantage of these findings risks developing incomplete, often seriously misguided inferences about the human past.

Reliance on the idea of progress compounds the risk by assuming a pattern of development that should instead be the object of inquiry. In the Sahul case, that assumption is obviously challenged by many elements of the regional record (O'Connell & Allen 2007). Pleistocene Sahul lithic technology, for example, was simpler than its presumed African Middle Stone Age progenitors, simpler still than its Late Stone Age and West Eurasian Upper Paleolithic collaterals (Holdaway & Stern 2004; cf. McBrearty & Brooks 2000). Late Holocene Tasmanian technology as a whole was simpler than its Pleistocene antecedents (Cosgrove & Allen 1996). These patterns present important problems for the idea of progress as a pervasive theme in human evolutionary history. Some have attempted to explain them away by reference to such factors as a loss of genetic diversity among populations travelling across South Asia to Sahul, a failure of information transmission mechanisms, and ultimately as examples of maladaptive behaviour (e.g. Henrich 2004; Jones 1977; Mellars 2006).

In our view, it is more productive to see these various patterns — including the probable simplification of seafaring technology across much of Australia following initial colonization — as positive, fitness-related responses to local ecological conditions, bounded only by characteristically human capacities for opportunistic adjustment. Further pursuit of this hypothesis, guided by theoretically informed predictive modelling and an understanding of the processes governing the formation of the archaeological record, should be rewarding.

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