Holocene coastal occupation of western Arnhem Land

Peter Hiscock

Surrounding the Van Diemen Gulf is the broad curve of land that comprises western Arnhem Land (Fig. 1). Within the catchment of the Van Diemen Gulf are a range of coastal landscapes that have been dramatically altered during the Holocene. Today coastal lowlands in this area are dominated by a series of rivers flowing south to north across seasonally flooded plains, each separated by undulating surfaces of sandy laterite. At the western end of the Van Diemen Gulf is the deep embayment of Darwin Harbour, while at the eastern end Cobourg Peninsula extends northward. Although the northwestern boundary of the Van Diemen Gulf is marked by Melville Island, that land is archaeologically unknown and will not be discussed here.

Holocene human occupation of the catchment area for the Van Diemen Gulf is the subject of this paper. Hunter-gatherer use of the lands surrounding the Van Diemen Gulf extends back to the Pleistocene, and although archaeological research has focussed on the Alligator Rivers region in the southeast, recent investigations have revealed something of the human history throughout the entire area. It is now clear that the creation of the Van Diemen Gulf by sea level rise initiated widespread and long-term alterations in the landscape, and that changing patterns of settlement, foraging and technology reveal human responses to those transformations in their environment. Combined with an outstanding palaeoenvironmental record for the Alligator Rivers region, the growth of archaeological information about prehistoric economies in this region makes it feasible to examine aspects human ecology in the past. In this paper I discuss some of the consequences of the marine transgression for human occupation of the coastal and near coastal landscapes of this intriguing region.

LANDSCAPE CHANGE DURING THE HOLOCENE

Over the last decade a remarkable record of palaeoenvironmental change in western Arnhem Land has been revealed (summarised in Hiscock and Kershaw 1992). Holocene landscape alterations in the Alligator Rivers region (see Fig. 2) have been described as a succession of phases in which different geomorphic processes created drastically different environments (Woodroffe et al. 1986, 1988). This descriptive framework has proven useful in exploring chronological change in economic activities depicted in the archaeological sequence. These landscape phases can be illustrated using the South Alligator River valley as an example, although they broadly apply to other rivers in the Kakadu region, and to a lesser degree to other major river systems in western Arnhem Land (Woodroffe and Mulrennan 1993).

Transgressive phase

Marine intrusion into South Alligator River valley occurred when the sea reached 10-12 m below the level of today's flood plain, approximately 8500-8000 BP (Woodroffe et al. 1986). Marine flooding is indicated in the pollen sequence by large proportions of aquatics and Poaceae, indicating fresh-brackish swamps. Myrtaceous pollen is common, indicating the closeness of the eucalypt woodland. Mangroves were present but restricted in distribution. Woodroffe and others (1985, 1986, 1988) have inferred that for the next 1000 years the valley contained a broad shallow marine embayment with a mangrove fringe perhaps 500 m wide, bordered by woodland. It is likely that the estuary contained intertidal flats, and perhaps multiple tidal channels towards the river mouth. Towards the end of this phase, after 7000 years BP, there are hints in the palynological cores of mangrove expansion leading to the next phase.

Big swamp phase

By 6800 BP mangroves were established across most of the inundated valley/embayment, covering virtually all of the area of the current flood plains. The main evidence for this pattern is the distinctive mangrove muds that are now found 2-7 m below the surface of the flood plain throughout the South Alligator River valley. Woodroffe et al. (1986, 1988) have labelled this period of extensive mangrove development, the 'big swamp phase'. This was a landscape that does not exist in the region today comprising a mangrove forest 5-12 km across and more than 100 km long, with a meandering river running through the centre. Although the mangrove margins were a mosaic environment, containing freshwater lagoons (Allen 1989:110), the big swamp was the feature dominating the river valleys.

Department of Archaeology and Anthropology, The Australian National University, Canberra, ACT 0200, Australia.

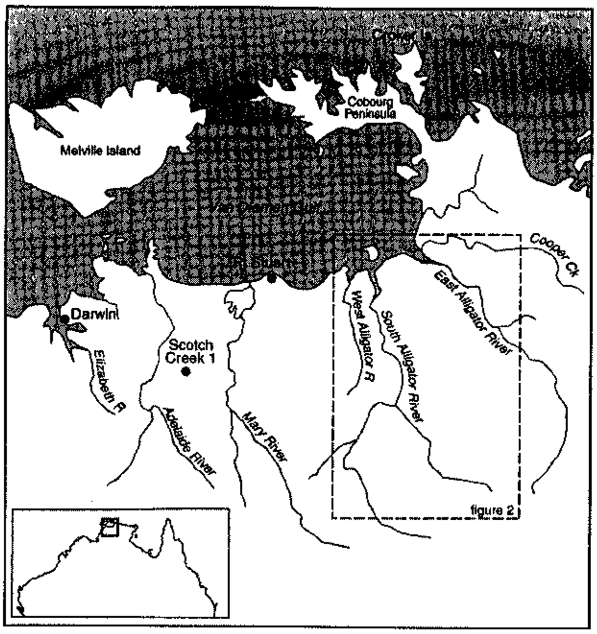

Figure 1 Map of western Arnhem Land, showing the location of the Alligator Rivers area (see Map 2).

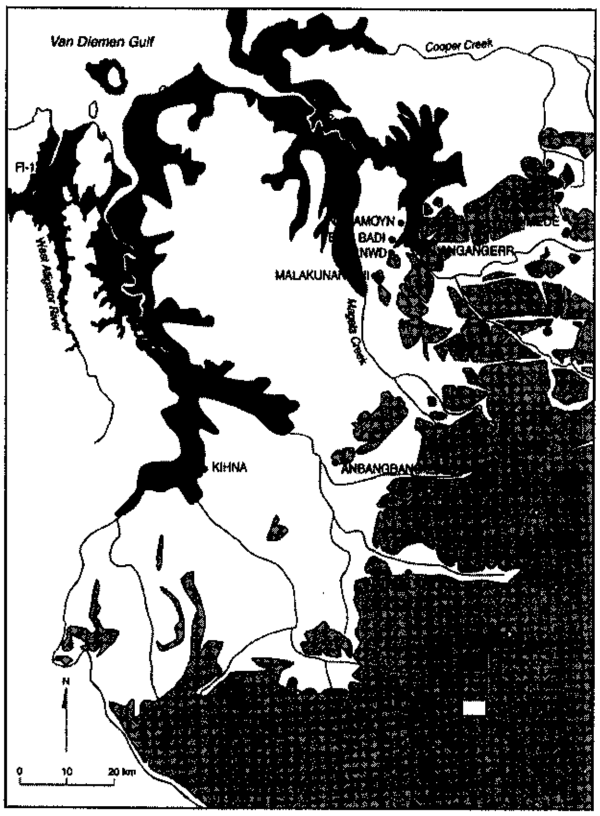

Figure 2 Map of the Alligators Rivers region showing sites mentioned in the text.

This big swamp existed for several thousand years, and evidence for it is found vertically through 3-4 m of sediment which accumulated through high discharge down the rivers, and the sediments were readily trapped in the extensive mangrove forest. During this accumulation mangrove communities persisted because there was continuing sea level rise. Sedimentation was rapid, probably about the same rate as sea level rise, thereby maintaining the shallow tidal conditions that allow mangroves (Woodroffe et al. 1986).

Pollen data shows that the mangrove forest changed during this period (Woodroffe et al. 1986). The early big swamp was dominated by *Rhizophora*, and in the central South Alligator River was succeeded by an *Avicennia* community after 6000 BP. By 5300 BP the pollen sequence reveals growing dominance of Poaceae and Cyperaceae, indicative of freshwater flood plains, at the expense of mangroves. Over the next thousand years there was a reduction of the extent of mangrove forests and replacement by plains covered by sedges and grasses. These transitions were probably caused by sedimentation changing the gradient of the plain and thereby reducing tidal inundation (Woodroffe et al. 1986).

A precise date for the cessation of a big mangrove swamp has not been obtained, and it is likely that the decline of mangroves was part of a process covering several hundred years. What we do know is that the big swamp was gone by 4000 BP, although smaller areas of mangrove still existed in the north.

The big swamp was restricted to the river valley and during the mid-Holocene mangroves were not extensively distributed in the estuarine funnel or along the coast. More open conditions probably existed in these areas. Along the coast between the East Alligator River and South Alligator River there were sandy-silty beaches backed by sand ridges. These open conditions along the coast persisted because sediment was being trapped within the South Alligator River rather than being discharged to the coast, resulting in little progradation.

Sinuous phase

Beginning about 4000 years ago is a period labelled the sinuous phase which represented the transition to dry land or freshwater swamp vegetation (Woodroffe et al. 1986). This phase is characterised by meandering river channels and the creation of associated ox-bow or palaeochannel features. Sediments accreted on the inside of the river bends, forming shallow water where localised mangrove forests developed. Outer bends were cliffed and contained few mangroves. This sinuous system consisted of a grassy, seasonally flooded plain, much like today, but with a river of large loops meandering slowly across the plain. The meanders migrated laterally at an average rate of about 1 m per year.

Existence of a sinuous meandering tidal river is demonstrated by palaeochannels that are visible in the current flood plains. Woodroffe et al. (1986:139) argue that many, if not all, of the palaeomeanders were defunct by 2000 BP. However, several channels have basal fill dated to 1400-1300 BP. Obviously a number of palaeochannels were not filled immediately after abandonment, and existed as lagoons for some time.

In the central South Alligator River area Hope et al. (1985) document the development of high soil salinity at the end of this phase. They argue that as sediment built up, flooding became less common. Hypersaline conditions occurred and little vegetation existed on the flood plain except along the river channel.

During this phase the coast changed markedly (Woodroffe et al. 1986; see also Sullivan and O'Connor 1993:781). The sinuous river appears to have acted as a conduit for sediment discharge, transporting large quantities of sediment through the valley to the coast. Consequently, coastal progradation accelerated and much of the coastal plain accumulated from 4000 BP to about 2000 BP as silts were deposited to form plains of black clay and salt-rich mudflats. By 2000 BP, or shortly afterward, the coast had formed in its current position. During the last 2000 years there has been no noticeable progradation. This cessation of progradation is a matter of some debate, but probably reflects a change in river form and reduction in sediment supply.

Cuspate phase

Over the last 1500-2000 years the middle and upper reaches of the South Alligator River have taken their current cuspate form, consisting of wide reaches and bends that are pointed. Erosion, leading to river widening is also a feature of this phase in the landscape evolution. Today mangroves exist only as fringes along the river channel.

As noted above, some flood plain areas suffered hypersaline conditions by the start of this phase (2000 BP or before). At least in the middle reaches of the South Alligator River system saline flooding ceased before 1400 BP and salt leached from the profile, enabling invasion by grasses and formation of organic rich soils (Hope et al. 1985). In this area billabongs were created through the formation of levee banks and the reduction of salt meant that they then held fresh water.

Transitional environments, such as the hypersaline one described for the middle South Alligator River, varied in duration and timing around the region. For example, in the Magela flood plain hypersaline soils may not have been extensive (Clark et al. 1992b:88), and current freshwater conditions were in place by 1700 BP (Clark et al. 1992a:48).

Variation within and between river systems in this manner would have reduced the stressfulness of these transformations on the human occupants of the landscape. Nevertheless, the creation of the present flood plains was the result of a chain of environmental change stretching back to the marine transgression. The detailed Holocene archaeological record available for the region reveals alterations in human exploitation of the landscape that parallel these environmental changes.

EFFECTS OF THE TRANSGRESSION DURING THE MID-HOLOCENE

Evidence for mollusc exploitation, and hence foraging in coastal mangroves, occurs almost simultaneously with the creation of the mangrove habitats near the scarp. At Malakunanja II marine shell dates to 6360±100 (SUA-264/SI), and at Nawamoyn there is a charcoal date of 7110±130 (ANU-53) from the base of the midden level taken by Schrire (1982:118) to indicate the initiation of the estuarine midden. These dates are broadly coincident with geomorphic evidence for formation and operation of the big swamp. Coastal groups of people were obviously exploiting this mangrove landscape soon after its creation.

Initiation of estuarine shell midden deposition occurs at very different times in each site (Fig. 3). The earliest midden yet dated is at Nawamoyn, the site closest to the current coast, and mangroves may have been locally abundant near this site before they were present near other sites. Thus, some of the variation in the basal dates for estuarine middens may reflect the gradual encroachment of mangrove environments. However, the geomorphic evidence favours a rapid and widespread development of the big swamp. Consequently, this variation in the initiation of estuarine middens, and in particular the relatively late initiation of shell accumulation at sites such as Ngarradj Warde Djobkeng, also indicates differential use of the region for marine foraging. While this variation may relate to local environmental conditions, it may also reflect minor shifts in the focus of foraging and settlement.

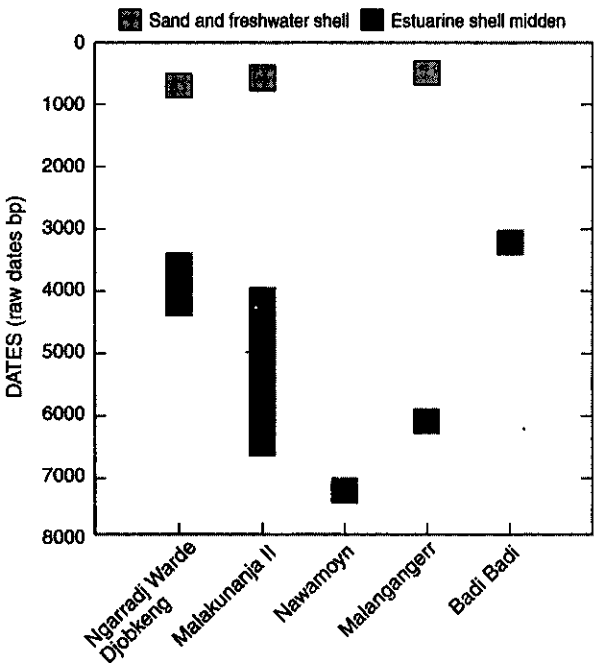

Figure 3 Antiquity of midden deposits established through radiocarbon dating.

Discussions of mid-Holocene economic strategies have focussed on mollusc exploitation since the shell midden levels of rockshelter deposits provide a relatively well dated, well preserved, and archaeologically visible record of subsistence activities during that period. Midden deposits in rockshelters east of the South Alligator River are dominated by the large mangrove bivalve *Geloina coaxans*, and the mangrove gastropods *Telescopium telescopium* and *Cerithidea anticipata*. Because of their small size the abundance of *Cerithidea*, rather than larger and meatier molluscs, has been seen as a puzzling feature of the faunal assemblage. In these middens other mangrove gastropods, such as *Cassidula* sp., *Ellobium* sp. and *Nerita* sp., were often present, but only as minor elements. This molluscan fauna is consistent with the notion that prehistoric people were primarily exploiting the mangrove margins rather than penetrating into the mangroves far enough to reach zones dominated by different plant species. If this is the case then change in the species composition of the mangrove margins might be reflected in the archaeological sequence found in rockshelter middens (see below).

Mid-Holocene shell middens in the coastal lowlands near the mouth of the West Alligator River have a variable composition, reflecting the different landscapes in which they are found (Mowat 1995). Shell deposits 4000-5000 years old, such as FI-1 and FI-2, are dominated by taxa such as *Anadara*, *Marcia* and *Circe*, reflecting foraging along the open mud-sand beaches that dominated the coast at that time. A similar pattern is found on the Cairncurry Plain, where *Anadara*-dominated middens occur in sandy beach ridges dating from a similar time period (Hiscock and Mowat 1993). As discussed below, the implication of dissimilar midden composition on the coastal flats and in escarpment rockshelters is that environmental and archaeological changes are not uniform throughout the region, and that separate economic changes may be evident in each sub-region (see Mowat 1995).

Despite the abundance of marine shell in rockshelter deposits near the East Alligator River it is clear that diet was diverse and that, in these areas at least, the mangrove fringe was not the only environmental zone in which foraging occurred. Mid-Holocene midden levels at Nawamoyn and Malangangerr contain medium and small mammals living in woodland and rainforest habitats, with bandicoots (*Isoodon macrourus*), possums (*Trichosurus arnhemensis*), and wallabies (*Petrogale brachyotis*, *Macropus agilis*) being particularly common. Exploitation of freshwater lagoons and streams is evidenced by remains of water-rat (*Hydromys* sp.), freshwater turtle, freshwater mussel (*Velesunio angasi*), catfish (*Neosilurus* sp.), and magpie geese (*Anseranas semipalmata*). Since the mid-Holocene mammalian assemblage at Nawamoyn resembles the suite of animals retrieved from Pleistocene levels, it seems likely that in the period 7000-3000 BP exploitation of mangroves and freshwater lagoons was added to a subsistence strategy previously based on woodland flora and fauna.

Diversification of diet during this period reflects the creation of a more diverse environment, containing locally resource-rich patches. This mosaic of mangrove, freshwater and terrestrial habitats is one without analogue in northern Australia today (Allen and Barton n.d.:104), and its appearance may have been associated with increased population density in light of land reduction associated with the marine transgression. Although there are hints of more intense occupation in some rockshelters, such as increased artefact discard rates in the midden levels of Ngarradj Warde Djobkeng, coincident changes in site function and artefact technology make demographic inferences unreliable. Additionally, most of the open sites that must have existed at that time are buried under late Holocene sediments, preventing estimates of overall site numbers (see Woodroffe et al. 1988:96). However, if it is difficult to identify demographic and settlement changes connected to the onset of the big swamp, there is not such a problem identifying change brought on by the disappearance of the mangroves.

Faunal succession

One of the models of mid-Holocene economic change has focussed on the succession of molluscan fauna reported at some sites. Five rockshelters containing estuarine middens have been excavated near the East Alligator River. Two sites positioned in large mesas are Ngarradj Warde Djobkeng and Malakunanja II. These sites have been well dated by Allen and Barton (n.d.), but their midden composition remains undescribed. Schrire (1982) has detailed the evidence from three rockshelters occurring in small isolated rock outcrops within the flood plain further north. For these sites, Malangangerr, Nawamoyn, and Badi Badi (sometimes spelt Pari Bari or Pady Pady), we have information on shell abundance measured as weight per genus per excavation unit. Within these midden deposits Schrire identified a number of chronological changes in marine mollusc exploitation. At Malangangerr the lower two-thirds of the midden is dominated by the large bivalve *Geloina coaxans* but in the upper spits *Geloina* decreases sharply in abundance and is replaced by the small gastropod *Cerithidea* (Fig. 4). Similar trends are found at Badi Badi and Nawamoyn, although at the latter site the large gastropod *Telescopium telescopium* is also abundant in the lower levels of the midden and replaced by *Cerithidea* towards the top.

Allen and Barton (n.d.:88) see this switch toward *Cerithidea* as illusory, arguing that if abundance is

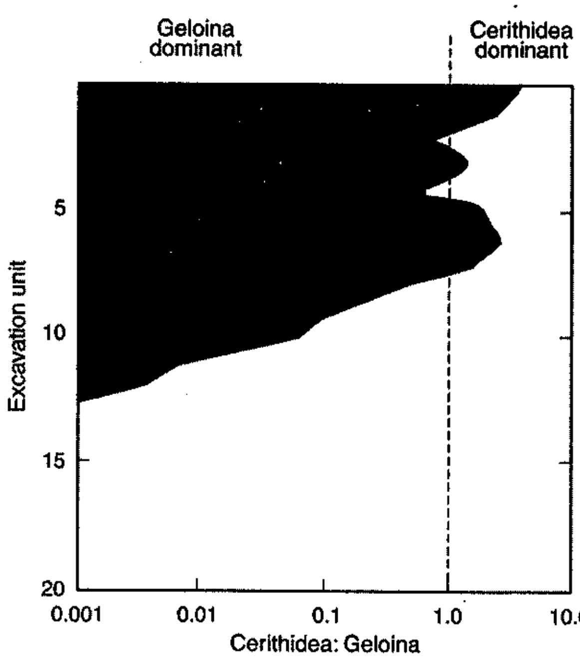

Figure 4 Vertical changes in the ratio of Cerithidea: Geloina in Malangangerr.

calculated using MNI rather than weight, *Cerithidea* would be dominant throughout. While this may be the case for Ngarradj Warde Djobkeng, it cannot account for the patterns visible in sites such as Malangangerr. In many of the lower excavation units the weight of *Geloina* fragments is up to fifty times the weight of *Cerithidea* fragments, and must represent more individual shells. Thus, although Schrire's excavated shell is no longer available for re-examination, it is clear that *Geloina* was more abundant toward the base of the deposit. To illustrate this point Figure 5 plots the estimated numbers of whole individuals in each taxon represented in Malangangerr column sample two. This estimate is based on the average weight of whole *Cerithidea* (1.4±0.4 g) in samples available at the Northern Territory Museum and *Geloina* (12.1±7.8 g) in the Malangangerr collection. The trend from a *Geloina*-dominated assemblage towards a *Cerithidea*-dominated one, is apparent even when this correction for size difference between the species is made. Since Allen and Barton (n.d.) claim that *Cerithidea* dominates all levels of the Ngarradj Warde Djobkeng midden, the archaeological trends at this site are different to those at Malangangerr, Nawamoyn and Badi Badi. This fact suggests local difference in palaeoenvironments and foraging behaviour.

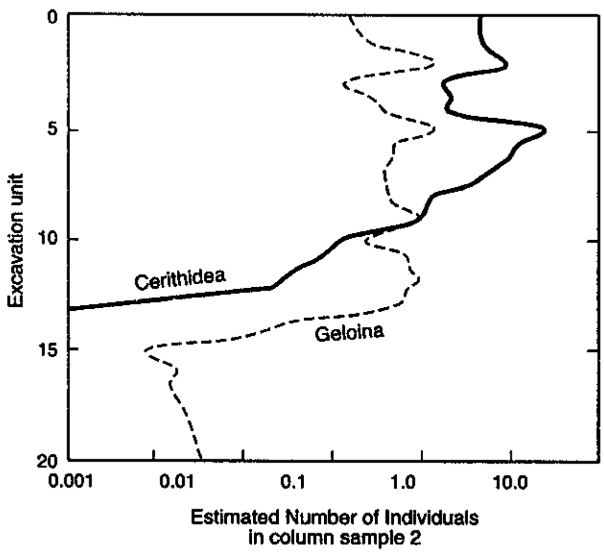

Figure 5 Vertical changes in estimated number of individuals of Cerithidea and Geloina in column sample 2, Malangangerr.

In the lower levels of Malangangerr, Nawamoyn and Badi Badi the dominance of *Geloina* has sometimes been seen to result from a preference for this large meat-rich bivalve over the smaller mudwhelk *Cerithidea*. Schrire (1982: 233-4) describes the mudwhelk as '... time-consuming to collect and tedious to separate from the shell'. She therefore suggests that the shift towards *Cerithidea* may not reflect choice; instead it may have been forced by a reduction in the availability of *Geloina* and *Telescopium* but not *Cerithidea*. Believing that *Cerithidea* is better adapted to open mudflats rather than mangrove forests, Schrire attempted to explain the trend from *Geloina* to *Cerithidea* through the devegetation of coastal flats resulting from buffalo trampling during the last two hundred years.

Although the *Geloina-Cerithidea* shift may relate to environmental change, Schrire's model of buffalo-induced devegetation is not plausible. *Cerithidea* is not characteristically found in open mud beach conditions. More typically *Cerithidea* lives within mangrove forests (Macnae 1968:167). Hence, the collection of *Cerithidea* as a large fraction of the prehistoric mollusc catch does not relate to the replacement of mangroves with unvegetated mudflats.

A more likely environmental explanation is to be found in a change from one type of mangrove forest to another. *Cerithidea* prefers mangroves dominated by the genera *Avicennia* and *Bruguiera*, where they shelter by clinging to the shady side of trees during low tides (Macnae 1968). *Telescopium telescopium* is typically the dominant gastropod in *Rhizophora* sp. forests (Macnae 1968:177), and *Geloina* is normally associated with small streams draining mangrove forests and is likely to be more abundant in *Rhizophora* forests (Morton 1983:82). Transformation of moist *Rhizophora*-dominated forests into relatively dry *Avicennia*- and *Bruguiera*-dominated forests may therefore increase the abundance of *Cerithidea* relative to both *Telescopium* and *Geloina*.

Geomorphological investigation along the South Alligator River indicate a late Holocene transition of precisely this sort (Woodroffe et al. 1986, 1988). Pollen cores from two localities in the central South Alligator River valley indicate that *Rhizophora* initially dominated the big swamp, but that towards the end of that phase of mangroves *Ceriops* and *Bruguiera* became more abundant, and finally *Avicennia* dominated (Woodroffe et al. 1986:131-2). Such a sequence is expected because in this region *Rhizophora stylosa* is less salt tolerant than some species of *Bruguiera* and *Ceriops*, and *Avicennia marina* tolerates extremely high salt levels and low soil water content (Ball 1988). These salt-tolerant mangrove forms of *Bruguiera/Ceriops* and *Avicennia* typically conserve water through small leaf size, resulting in forests with open canopies that allow large amounts of sunlight to be transmitted to the forest floor (Ball 1988:96). Under such conditions *Cerithidea* populations are successful because of their capacity to shelter from the sun by climbing the shaded side of the trunks of mangrove trees.

Similar trends are also apparent in the environmental data from the Magela Creek flood plain, close to Malangangerr, Nawamoyn and Badi Badi. As an example, pollen core M8, near Jabiluka Billabong, shows a dramatic shift towards non-*Rhizophora* mangroves prior to 1650 BP (Fig. 6). Sediments in this core show the characteristic change from blue-grey clay containing mangrove wood to grey-brown clay exhibiting mottling due to oxidation (Clark et al. 1992a:46-7). This pattern represents vegetation changes associated with the transition from estuarine to freshwater conditions. Palynological data supports this interpretation, indicating a chronological succession in mangrove communities in response to increasing salinity and dryness. Accompanying those changes in plant communities would have been an increase in the relative abundance of *Cerithidea*, a trend that is reflected in the

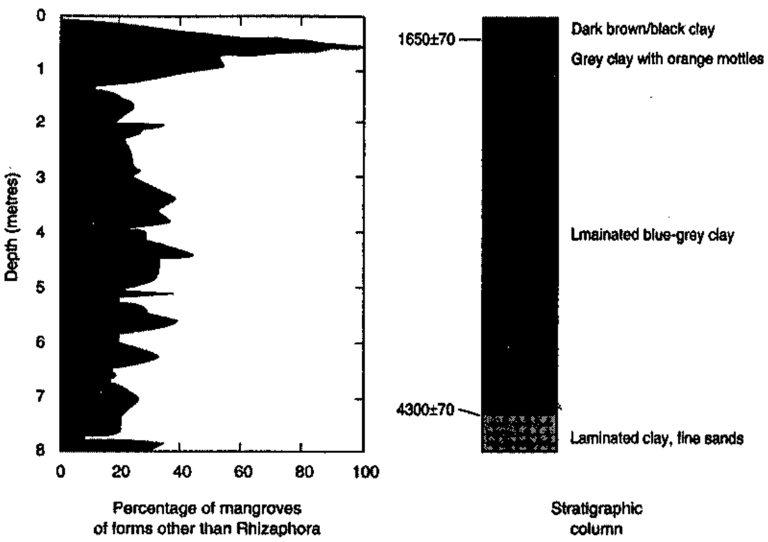

Figure 6 Changes in mangrove pollen and stratigraphy in core M8, Jabiluka Billabong.

nearby archaeological shell middens. One implication of this argument is that the composition of the prehistoric mollusc catch broadly mirrored the availability of these animals within the closest mangrove environment. A second implication is that the change from *Geloina*-dominated midden levels to *Cerithidea*-dominated midden levels predates the arrival of the water buffalo. In all instances where pollen cores have been dated the shift from *Rhizophora* to other mangroves occurs prior to 1500-2000 years ago, and is a response to increased salinity rather than devegetation by buffalo. Such an environmental change may have had consequences beyond an alteration in diet.

Reorganisation of settlement patterns

Increasing siltation and salinity during the sinuous phase eventually resulted in the retreat of mangroves to river channels in the centre of the South Alligator River valley. Disappearance of mangrove habitats across the newly formed flood plain must have caused mollusc exploitation near the escarpment to cease, but the date of that economic shift probably varied locally. Attempts to define the timing of that economic change have been made by Allen and Barton (n.d.), who hypothesise that shell middens in rockshelters near the East Alligator River and Oenpelli do not contain late Holocene occupation. They suggest that estuarine molluscs were collected from abundant mangrove forests during the big swamp phase, and that mollusc gathering ceased early in the sinuous phase, more than 3000 years ago. This model is based on a series of radiocarbon age-estimates from Ngarradj Warde Djobkeng and Malakunanja II. The upper levels of these two middens are dated to 4050±50 years BP. (SUA 2264) at Malakunanja II and 3390±195 (SUA 225) at Ngarradj Warde Djobkeng. Allen and Barton interpret these samples as the terminal dates for the accumulation of the estuarine midden, implying that discard of marine shell had ceased by 3000 BP. They argue that the rockshelters were abandoned at that time, and sediments overlying the midden represent reoccupation in the last 1000 years. Figure 3 illustrates the midden dates on which this model is based.

The Allen and Barton model represents a substantial advance in understanding rockshelter occupation near the East Alligator River, but it does not fit all sites in the area and may be overly rigid in assigning abandonment dates. Archaeological data indicates not only the abandonment of some shelters, but also a high degree of variation between these sites in the timing of mollusc exploitation.

In Ngarradj Warde Djobkeng and Malakunanja II, minimal sediment accumulation above midden levels, together with the three late Holocene radiocarbon dates, led Allen and Barton to infer an extended hiatus between 3500 BP and 1000 BP. This 2500 year hiatus is the maximum possible period of abandonment, but it is feasible that the abandonment was substantially shorter. Samples from the top of the midden layer may not necessarily represent the last occupation of the shelter prior to abandonment. Clearly there is substantial intra-site variation in at least some of the sites, making the interpretation of the few upper samples uncertain. For example, in Ngarradj Warde Djobkeng radiocarbon dates of 3500-4000 BP come from 10 cm below the surface near the drip line and may provide a reliable indicator of midden cessation in that part of the site. But towards the rear of the rockshelter radiocarbon dates of this age (SUA-164 and SUA-2409) were recovered from samples more than 50 cm deep, and here it is possible that the midden continued to accumulate until a later time.

In addition, not all of the sites fit neatly into a pattern of abandonment at 3000 BP. For example, the upper midden deposits in Malangangerr and Nawamoyn are not dated, and it is not clear that they represent abandonment at or before 3000 BP. Furthermore, Badi Badi yielded a basal date for the estuarine midden of 3120±100 (ANU-17). Mangrove shells are dominant right through this midden-level, and in the base of the non-midden level, indicating that at this site mollusc gathering continued for some time after 3000 BP (or 2550 BP with the recommended -450 year correction for the marine reservoir effect). In other words, the dates suggest that at Badi Badi shell gathering begins at the time it may be finishing at Ngarradj Warde Djobkeng and Malakunanja II. This strongly indicates local differences in economy and settlement in response to an increasingly mosaic environment at this time, just as Schrire (1982:233) thought.

Nevertheless, this abandonment model has been useful in describing the relationship of rockshelter sites to the open wetland sites. Cessation of estuarine midden build-up in the rockshelters implies that as mangroves gradually retreated from their maximum distribution during the big swamp phase, the focus of human activity shifted from the escarpment out onto the flood plains and coast. While one consequence of this settlement shift may have been the relatively late use of rockshelters in some outliers, such as Badi Badi, the focus of human occupation in the region probably moved even further northwest, away from the scarp and toward the coast and estuarine funnel of the West and South Alligator Rivers. In the period after 4000 BP the coast was rapidly prograding, and was probably a productive landscape. At a number of locations 3-12 km from the current coastline we have geomorphic evidence for the mid-Holocene coast, at the beginning of the period of progradation. Archaeological sites associated with these landscape features bear witness to the extent of human exploitation of the coast from 4500 years BP.

Near the mouth of the West Alligator River some of the mid-Holocene sites still intact are extremely large. For example the FI-2 site recorded by Mowat (1995) is a long shell mound (200 m) containing approximately 3000-4000 m^3 of material. Its interpretation is complicated because archaeological midden material rests on a shelly chenier and it is difficult to quantify the amount of anthropogenic shell. Nonetheless, evidence from this and other nearby sites clearly indicates substantial human activity along the coast 4000-4500 years ago.

Another example of coastal occupation during the mid-Holocene comes from the edge of the Cairncurry Plain, where there are large mounds and middens dominated by the bivalve *Anadara* in coastal beach ridges and silt flats dating to this time, suggesting extensive occupation of the coast (Hiscock and Mowat 1993).

Further west, at Point Stuart and the eastern end of Chambers Bay, Baker (1981) has recorded shell middens in geomorphic contexts dating to the mid-Holocene. A test pit in Site 11 demonstrated that much of the midden was dominated by *Marcia*, indicating foraging on sandy mudflats (Baker 1981:78; Mowat 1995). The position of this midden on a chenier ridge dated at 4500 BP by Clarke et al. (1979), led Baker (1981:79) to the conclusion that the site may date to that time. These data reinforce the image of widespread foraging along the coast by the terminal phase of the big swamp phase.

Geomorphic investigations also dated shell middens and earth mounds near the mouth of the South Alligator River to less than 4500 BP (Woodroffe et al. 1988). A number of the large mounds are close to palaeochannels of the river, but date to a period in which the channels had been cut off and may have been fresh or brackish lagoons. The archaeological implication of these sites is difficult to evaluate, since the descriptions provided by Woodroffe et al. (1988) are both vague and inaccurate (see Mowat 1995). However these sites probably add to the impression of human occupation of the coastal plains after 4000-5000 BP.

Therefore, at a broad level, the late occupation of the coastal plains might be a reversal of the rockshelter sequences near Oenpelli, for which there is evidence for abandonment of some sites by 3000 BP. A simple explication of this pattern is that the focus of exploitation is drawn away from the scarp and onto the forming plains by the retreat of the mangroves. However, if a simple demographic shift from east to northwest occurred we might expect to see a distinct increase in sites along the present coastal plain after 3000-4000 BP, when occupation near the escarpment is thought to have decreased. Figure 7 illustrates the chronological change in midden abundance within the coastal plains of the Alligator Rivers region. This histogram is calculated by plotting one calibrated date from each open shell midden for which dates are currently available, to yield a picture of the numbers of sites per unit time. Although more than one date is available from a few sites this procedure is justified because in any single site radiocarbon age-estimates are within hundreds of years of each other, suggesting that occupation of these coastal sites may be limited to a single temporal unit (perhaps 500-1000 years in duration). This histogram shows no distinct increase at the end of the big swamp phase (post-4000 BP until say 2000 BP) such as might be expected if the coastal plains became the focus of regional activity at that time.

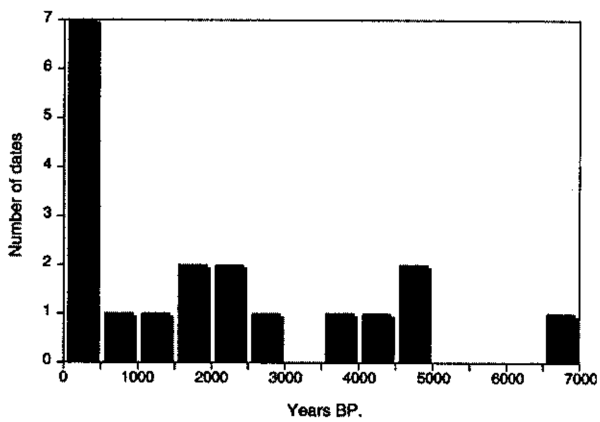

Figure 7 Histogram of the age of dated midden sites on the coastal floodplains of the Alligator Rivers.

Interpreting this pattern is difficult, and while a shift in the focus of settlement 4000-2000 BP is not evidenced by these data, neither is it unambiguously denied. Some of the dated sites are completely subsurface and were only discovered in the course of drilling (Woodroffe et al. 1988). This fact suggests that there may be many more sites within the estuarine funnel of the South Alligator River dating to the period 4000-1000 BP than have yet been recorded. More extensive exploration of the coastal zone is required to clarify this issue.

Technological change during the mid-Holocene

With settlement and foraging strategies changing dramatically in response to environmental transformations it might be expected that the technological strategies which people used to exploit the environment might also have altered. Despite the amount and quality of research carried out in Kakadu, there has been little discussion of the organisation of technological activities within the landscape. Schrire proposed that assemblage variation resulted from seasonal tranhumance between lowlands and the uplands, and was due to manufacture of stone points in one sub-region but not the other (White and Peterson 1969; White 1971). Although this model is now unable to deal with the environmental and archaeological diversity that has been identified (see Allen and Barton n.d.:117; Brockwell 1989; Clarke 1987; Schrire 1982:250, 1984), it highlights the short term environmental variations to which prehistoric hunter-gatherers along the tropical coastline had to respond. Schrire's approach, treating assemblage variation in Kakadu as a technological response to economic and logistical changes, is one that should be explored in a re-analysis of archaeological assemblages.

Temporal variation in implement form during the Holocene is generally thought to have followed a coherent trend throughout western Arnhem Land. Focussing on unserrated unifacial and bifacial stone points, most researchers agree that such implements appear for the first time at or before 5000 BP, and that points become relatively abundant in many deposits approximately 4000-2000 years ago (Smith and Brockwell 1994:101). Within the Alligator Rivers region large-scale production and use of stone points is seen to be a mid-Holocene phenomenon, ceasing before 1500 BP (Allen and Barton n.d.:95). A summary of dating and temporal variation in points reveals a pattern that closely parallels environmental change in the region.

Appearance of points

Changes in stoneworking become apparent during the big swamp phase, shortly after the marine transgression. Precisely shaped bifacial points are recovered from many rockshelters in mid-Holocene levels. Dating of the appearance of the implements in the regional sequence is inexact. White (1971) obtained points from the basal midden unit in Malangangerr and Nawamoyn. She originally argued that these specimens dated to the time when the estuarine middens began to form, some 6000-7000 years ago. Imprecise control over the spatial location of specimens within the midden deposits was used by White and O'Connell (1982:118) to argue that points only appeared in the last 5000 years. This conclusion was motivated more by a belief in a late appearance than by the available data. In retrospect it would have been more accurate to conclude that points first appear 5000-7000 BP, and accept that a more precise estimate could not be given at that time. Nevertheless, in an intellectual climate that demanded precise dates, Schrire (1982:238-9) revised her estimate to a younger appearance at 4000-5000 BP.

More recently, Jones and Johnson (1985a) obtained a bifacial point in a level of Nauwalabila 1 that dated to approximately 5700 BP. While points are most abundant after 5000 BP, this find again suggested that the implement type was in use before that time. While doubts have been expressed about the association of that point with the dated charcoal sample (Allen and Barton n.d.:93; Bowdler and O'Connor 1991), there are equally strong arguments that the specimen may be in situ and that even older examples are likely to be found by further excavation (Hiscock 1993a). Although Australian archaeologists have been determined to date these new implement forms precisely, it must be admitted that we still cannot define their chronology beyond an initial occurrence in the mid-Holocene, between 5000 and 7000 BP.

Despite this imprecision in dating, what emerges is a picture of a change in the structure of stoneworking technologies during the big swamp phase, when dramatic environmental changes took place. Flooding of the river valleys, and the subsequent creation of a landscape consisting of a massive mangrove forest, drastically altered distribution and type of resources within the landscape. Outcrops of rock suitable for artefact manufacture would have been buried, and a mosaic environment created. As described above, this was an unstable landscape that changed rapidly, at least in the distribution and composition of mangrove forests and palaeochannels.

Peak of point production

Not only the appearance of points, but their increasing abundance in the archaeological record parallels a period of environmental change. During the sinuous phase of the environmental sequence, several rockshelters in the Alligator Rivers portion of western Arnhem Land show a dramatic increase in the number of discarded points. At Ngarradj Warde Djobkeng the discard rate of stone points was greatest in Layer 2, probably dating to roughly 3000-3500 BP. At Nauwalabila 1 points are most abundant 25-45 cm below the surface of the shelter, broadly corresponding to the period bracketed by charcoal samples dating to 2970±80 (ANU-3178) and 2180±80 (ANU-3177), indicating a phase of relatively high point abundance 2000-3000 BP. Unfortunately, the dating at other rockshelters, including all five reported by Schrire (1982), is inadequate to discuss the magnitude or timing of changes in point abundance. Nevertheless, Ngarradj Warde Djobkeng and Nauwalabila 1 both suggest that the peak of point production and discard occur during the transition of the big swamp to dry land and at least the initiation of the formation of hypersaline flats.

Similar patterns are found in other parts of western Arnhem Land. For example, Scotch Creek 1 is a stratified artefact scatter on the bank of a tributary of the Adelaide River. Within the deposit a concentration of points may represent their manufacture from local rocks, primarily Gerowie Tuff that crops out nearby. Smith and Brockwell (1994:93) consider it unlikely that the black sandy clay loam from which these artefacts were recovered could have accumulated more than 4000 years ago (see Smith 1995). They note that the period 4000-2000 BP was one of substantial landscape change, involving the local equivalent of the sinuous phase in the geomorphic sequence. As noted above, the contraction of mangrove swamps probably left bare or nearly bare saline mudflats as a dominant terrain type. Drawing a connection between the existence of environmental uncertainty and the manufacture of points Smith and Brockwell (1994:102) hypothesised that increased intergroup tension and conflict is being reflected in stone points hafted in duelling spears (see also Smith 1995).

Technological change as risk reduction

Political tension may reflect underlying shifts in the settlement and foraging strategies of people, and may be only one dimension of stress suffered by hunter-gatherers of this period. Rapidly changing environments, involving extensive sedimentation and developing salinity, could create problems in predicting lowlands resource distributions over the long term. Patterns of foraging may have been difficult to establish, and may have been useful for only a few years before shifting resource distributions made them ineffective. In these circumstances it would be advantageous to adopt strategies that reduced risks associated with a lack of familiarity with resource locations. The model I have advanced elsewhere (Hiscock 1994) proposes that during the mid-Holocene new forms of stoneworking were adopted as an aid in reducing risk. As noted above, in western Arnhem Land the primary innovation in stoneworking that has been documented is the manufacture of unifacial and bifacial points. While the stone points themselves are unlikely to have been used directly in the exploitation of the mangrove forests, they were probably part of a standardised and reliable composite toolkit unlike any used in the region previously. As part of composite tools points may have enhanced the success rate of resource capture, by providing readily maintainable, multi-functional extractive tools with an extendable uselife, and by decreasing the need to constantly supply replacement raw material (Hiscock 1994:277-8). Consequently it is suggested that points are likely to have been part of a technological strategy which yielded reliable tools that could provide a buffer against environmental uncertainties. Within this changing and unfamiliar environment such a toolkit may have aided the subsistence strategy by helping to minimise foraging risk. If this is true, then the technological changes often recognised in Holocene western Arnhem Land are as much a consequence of the marine transgression as any shift in diet.

SETTLEMENT AND SUBSISTENCE STRUCTURES IN THE LATE HOLOCENE

Over the last 1500-2000 years humans in western Arnhem Land have been exploiting landscapes that were broadly the same as today. In many locations in this region the coastline has been in its present position for much of the last two millennia, with lateral movement in the form of progradation being limited to tens of metres at most. However, environmental alteration in the nature of both coastal and subcoastal provinces has continued, and is reflected in the archaeological record. Economic reorganisation can be documented in this late Holocene period, and although the scale of change may have diminished it often remained significant. Hence economic responses to landscape changes induced by the marine transgression continue to occur in the late Holocene. Two examples of alterations to late Holocene economic practices that are unambiguously related to environmental transformations are presented here. The first example is of changing exploitation of the coast at the western end of the region; while the second example is the development of settlement strategies for the new subcoastal wetlands along the South Alligator River. In both of these examples the environment has probably looked something like it does today for less that 600-800 years.

Settlement patterns in the coastal zone

At the western end of the Van Diemen Gulf the city of Darwin overlooks a relatively deep embayment. Here archaeological investigations have documented a phase of coastal foraging that appears to have been intensive but short-lived. On the eastern side of the harbour there are a number of mounded archaeological middens composed largely of *Anadara* shells (Burns 1994; Hiscock 1997; Hiscock and Hughes in press). All six of the middens that have been radiocarbon dated ceased accumulation approximately 700-1000 years ago (Hiscock 1997). Extensive excavations at one of these middens, Bayview Haven 3, revealed that it began to accumulate about 1400 years ago. Recent radiocarbon dating of excavations into a second shell mound by Burns (pers. comm.) has yielded a very similar basal date. Consequently, existing archaeological research suggests that most, if not all of the shell mounds near Darwin formed during the period 1500-700 years ago.

These mounds are dominated by shells of *Anadara*, which occurs in high density, and in some cases in high volumes. Minor elements in the faunal assemblage include a number of gastropod genera (*Telescopium, Terebralia, Nerita, Chicoreus, and Cassidula*) indicative of mangrove habitats. Midden composition in the period 1500-700 BP period suggests that human foraging along the coast focussed on open beaches, with some minor exploitation of mangrove stands. Hiscock (1997) has suggested that such an economic system ceased 700-1000 years ago because of rapid environmental change in which mangroves expanded at the expense of open beaches, eventually leading to the disappearance of the productive *Anadara* beds. What happened to hunter-gatherers at the end of this period is unclear, although a shift in emphasis away from foraging along the coast, to an economy focussed on exploiting subcoastal resources remains a possibility.

Settlement patterns in the subcoastal flood plains

Intensive exploitation of the subcoastal flood plains has been claimed for the eastern portions of the region, particularly the seasonally inundated freshwater flood plains on the central South Alligator River. While the quantity of occupation debris in this area is impressive, it is poorly defined chronologically and difficult to unambiguously interpret. Open artefact scatters occur in abundance on the flood plain margins and have been described by Jones (1988:18) as,

> Huge open sites occur on the wetland edges. These have millions of stone tools on their surfaces, and they were probably dry season sites, when people came to congregate to exploit the abundant plant and animal foods.

Artefacts are typically restricted to the top 10-20 cm of alluvium, indicating a late Holocene date (Meehan et al. 1985:147), which is broadly consistent with the geomorphic evidence. A recent time period for these sites is also indicated by excavations of an 80 cm deep earth mound on the Kihna site, which yielded a radiocarbon determination of 280±140 (ANU-3212) from near the base of the deposit (Meehan et al. 1985:152). Different interpretations of this evidence for large-scale recent occupation are possible.

In view of their recent chronology, and the large number of artefacts they contain, one interpretation of these sites is that they are base-camps for large groups, of perhaps several hundred people, and were occupied for at least several months each year (Meehan et al. 1985: 135). In this model these large groups located themselves at resource-rich backwater swamps for prolonged periods, and throughout the year moved sequentially between swamps on the flood plain margin. In this way the inferred seasonal pattern is thought to have taken the form of spatial relocation of the large group(s), without it necessarily fissioning or moving out of the lowlands altogether.

A different interpretation of these sites is based on a more sceptical evaluation of the idea that these scatters necessarily represent camps for large numbers of people (see Hiscock et al. 1992). Some observers have suggested that the guesstimate of millions of artefacts per site is likely to be an overestimate (Brockwell 1989; Hiscock et al. 1992). This raises the possibility that it is not large group size but perhaps recurring occupation of smaller groups with long residence time that is the key to explaining a high archaeological signal from the flood plain margins.

Despite such debates about residential group size, there is a persistent image of increased sedentism in the late Holocene. Centred upon spatially restricted but rich swamps and lagoons, it is often considered that recent sites on the South Alligator River flood plain are likely to have been long-term camps in the very late Holocene. In the view of Meehan et al. (1985) low residential mobility is suggested by the testimony of Aboriginal informants, by the ethnohistorical documents, and by a range of archaeological data. Brockwell (1989:210) has argued for intensive, long-term occupation at a number of late Holocene sites containing a diverse range of artefact types, high densities of stone artefacts, and assemblages consisting of hundreds of thousands of stone artefacts. This interpretation of low residential mobility on wetlands sites along the South Alligator River is supported by analyses of the composition of the artefact assemblages. These late Holocene assemblages suggest that increasingly sedentary settlement patterns are associated with economic stresses best solved by extensive reduction of rock to yield small sharp edges (Hiscock 1996). At these sites on the flood plain margin, large earth mounds containing abundant artefactual and faunal material reinforce the impression of sedentism (Meehan et al. 1985).

This emphasis on sedentism rather than large group size when interpreting individual sites on the flood plain margin is paralleled by the different interpretations of the significance of these sites for regional prehistory during the very late Holocene. While some interpretations focus on the distribution and mobility of people across the landscape, others concentrate on interpretations of increasing population size linked to increasing carrying capacity of the wetlands environment.

One model, proposed by Jones (1985:291-3), is that these sites are indicative of a several-fold increase in regional population size during the last 800-1000 years, as a result of the emergence of large freshwater flood plains during the cuspate phase of environmental changes. Since this population increase is seen to be regional in nature, and not limited to a small stretch of the central South Alligator River, this model implies a uniformity in environmental and demographic trends in many of the wetland zones of subcoastal western Arnhem Land. Until other wetlands areas have been archaeologically examined this proposition cannot be adequately evaluated. However, the apparent decline in productivity of other heavy exploited landscape zones during the last 1000 years, such as the *Anadara* beds in Darwin harbour (see above), may indicate that the increased population density in some localities was largely counterbalanced by decreased population densities in other localities.

An alternate model therefore suggests that these sites on the South Alligator River are indicative of the latest phase of major shifts in landscape use that can be identified since the marine transgression. During the big swamp phase there was extensive exploitation of the mangrove margins as documented by Allen and Barton (n.d.), together with the exploitation of available freshwater features (Allen 1989:110). During the sinuous phase occupation focussed on the coast, estuarine funnel, and palaeochannel lagoons in the north. In at least one portion of the region, on the shores around Darwin Harbour, occupation was intense in the coastal zone for several hundred years, until about 700-1000 years ago. Finally, at some point in the last 2000 years, perhaps in the last 1000 years, a concentration of occupation is visible in the southeast of the region where people take advantage of the newly formed wetlands on the central South Alligator River. From this regional perspective, what Jones (1985) observed on the South Alligator River may well be a reorganisation of population distribution and resource use, rather than an overall increase in human numbers throughout the region.

A very different interpretation for the abundant archaeology of the South Alligator River wetlands has been contemplated with the suggestion that intensive occupation of the wetlands may have been a product of cultural changes induced by the effects of European or Macassan contact (see below), rather than, or in addition to alterations in environmental productivity (Hiscock and Kershaw 1992). This proposition was considered because the radiocarbon chronology at Kihna can be interpreted as revealing change in the human economy or demography only 200-300 years ago. However, the large number of late Holocene sites now known from the wetlands are difficult to reconcile with such a short chronology, and Jones estimate of a millennium of occupation on the South Alligator River wetlands seems more plausible. Hence the late Holocene trends in the subcoastal zone must be explained in terms of local environmental changes.

Nevertheless, it is clear that the dramatic economic changes along the coast during recent centuries have been largely a response to change in the cultural landscape of the region.

CULTURE CONTACT AND COASTAL ECONOMIES

Archaeological investigations have indicated the extent and rate of historic and proto-historic change in coastal economy and settlement in western Arnhem Land. The best example of such change comes from the work of Mitchell (1994a, 1994b) who documented sites along the northern coastline of the Cobourg Peninsula (see Fig. 1). By employing a combination of approaches to absolute and relative chronology he was able to separate late Holocene sites which predate regular visits by Macassans from those sites that were created after 1720 AD when contact with Macassans, Dutch and British gradually intensified. These sites were assigned to what Mitchell called 'pre-contact' and 'post-contact' periods. Evidence of substantial modification to the organisation of settlement and subsistence practices in the post-contact phase generally confirms the conclusions Macknight (1972) drew about Macassan contact, while demonstrating the depth of economic reorganisation that occurred with a hunter-gatherer economy.

Mitchell (1994a:377-98) found that the size of post-contact middens was often substantially larger than that of pre-contact ones (Table 1). This increase in midden debris was not only visible near foreign settlements as predicted by Schrire (1972), but also found away from such settlements. A broad change of this kind is better explained as a shift in the entire settlement structure of hunter-gatherer groups in the region, than by the suggestion that foreign settlements attracted attention from hunter-gatherers whose patterns of landscape use was elsewhere unchanged.

	Pre-Contact	Post-Contact
Mean surface area of middens (m^2)	747	1941
Proportion of middens with turtle and/or dugong	3.6%	52.9%
Frequency of turtle bone at Barlambidj (NISP)	8.7%	44.4%
Proportion of middens with imported stone	7.1%	41.2%

Table 1 Summary of changes in the contact period (data from Mitchell 1994a, 1994b).

These changes in site size probably represent increased size of residential groups and decreased residential mobility. Alteration in residential strategies reflects a number of political, technological and economic changes as follows:

1. Increased levels of inter-group conflict following Macassan contact may have encouraged larger population congregations if they conferred a defensive benefit.
2. Adoption of the dugout canoe increased the scale and efficiency of marine travel, and provided the means to transport far more food to a base camp, thereby effectively increasing the foraging radius of a group. Mitchell (1994a:398) has described the advent of effective water craft as transforming residential patterns from a 'forager' form (pace Binford 1980) to a structure closer to a 'logistical' pattern. A direct outcome of this technological innovation was decreased residential mobility, while the consequences for economic activity created indirect influences on settlement structure.
3. A series of related economic changes underlay the reorganisation of coastal settlement in the post-contact period. Mitchell (1994a) has documented the introduction of a new extractive toolkit focused around dugout canoes and metal harpoon-heads. With this new toolkit coastal hunter-gatherers appear to have dramatically increased the rate at which they captured large marine mammals, particularly dugong and turtle. The economic shift towards the exploitation of these marine mammals during the post-contact period is demonstrated archaeologically. Increased representation of dugong and turtle bone is apparent in post-contact sites along the coast of the Cobourg Peninsula, and similar quantitative changes in the archaeological fauna are observable in the Barlambidj stratified midden (see Table 1). In addition to these modifications in food acquisition, Mitchell (1994b) has also demonstrated the elaboration and intensification of trade networks in coastal Arnhem Land during the contact period. One archaeological measure of this increased transportation and exchange in non-food resources is the far higher rate at which inland stone arrived in coastal sites (see Table 1). With the targeting of larger, energy-rich animal species and the enhanced trading system, the economy was substantially re-shaped in the post-contact period.

CONCLUSIONS

Archaeological material in western Arnhem Land documents long-term changes in the patterns of coastal settlement, resource procurement and technology. Many of these economic changes must have represented marked alterations in the lifestyles of prehistoric hunter-gatherers in this region, and in the majority of instances these were clearly responses to altered environmental and cultural circumstances. While the rate of environmental changes, and of human response, may have varied at different periods change seems to have been ongoing since the marine transgression.

This depiction of significant economic, demographic and technological change in response to continuing environmental and cultural change implies that recent observations of Aboriginal activities in the contemporary landscape may make poor analogues for the economic strategies that were in place at earlier times. Recent systems centred on strategies of low mobility and a demographic concentration on freshwater resources in the subcoastal zone may have an antiquity of no more than 500-1000 years. Economic systems reflected in the early or mid-Holocene archaeological record were adjusted to landscapes for which there is no counterpart in the region today, and it seems likely that the subsistence and technological strategies may have no local counterpart today. Certainly the repertoire of economic behaviour displayed in western Arnhem Land since the marine transgression was more diverse than that observable in the recent past.

ACKNOWLEDGEMENTS

Several researchers working in northern Australia read and commented on sections of this paper. I especially thank Sally Brockwell, Fiona Mowat and Richard Willan. I also benefited greatly from discussions with Harry Allen.

REFERENCES

Allen, H. 1989 Late Pleistocene and Holocene settlement patterns and environment, Kakadu, Northern Territory, Australia. *Indo-Pacific Prehistory Association Bulletin* 9:92-117.

Allen, H. and Barton, G. n.d. *Ngarradj Warde Djobkeng: White Cockatoo Dreaming and the Prehistory of Kakadu. Oceania Monograph* 37.

Baker, R. 1981 The Aboriginal and environmental history of the Chambers Bay coastal plains. Unpublished B.A.(Hons) thesis, The Australian National University, Canberra.

Ball, M. 1988 Organisation of mangrove forests along natural salinity gradients in the Northern Territory: An eco-physiological perspective. In D. Wade-Marshall and P. Loveday (eds) *Floodplains Research*, pp.84-100. Canberra: The Australian National University.

Binford, L.R. 1980 Willow smoke and dog's tails: Hunter-gatherer settlement systems and archaeological site formation. *American Antiquity* 45:4-20.

Bowdler, S. and O'Connor, S. 1991 The dating of the Australian small tool tradition, with new evidence from the Kimberley, WA. *Australian Aboriginal Studies* 1:53-62.

Brockwell, C.J. 1989 Archaeological investigations of the Kakadu wetlands, Northern Australia. Unpublished M.A. thesis, The Australian National University, Canberra.

Burns, T. 1994 Mound over matter. Origins of shell and earth mounds of northern Australia: An evaluation of mounds on Channel Island and Middle Arm mainland, Darwin Harbour. Unpublished B.A.(Hons) thesis, Northern Territory University, Darwin.

Clark, R.L., East, T.J., Guppy, J., Johnston, A., Leaney, F., McBride, P. and Wasson, R.J. 1992a Late Quaternary stratigraphy of the Magela Plain. In R.J. Wasson (ed.) *Modern Sedimentation and Late Quaternary Evolution of the Magela Creek Plain*, pp.28-80. Supervising Scientist for the Alligator Rivers Region, *Research Report* 6.

Clark, R.L., Guppy, J., Mahon, P., McBride, P. and Wasson, R.J. 1992b Late Quaternary evolution of the Magela Plain. In R.J. Wasson (ed.) *Modern Sedimentation and Late Quaternary Evolution of the Magela Creek Plain*, pp.81-157. Supervising Scientist for the Alligator Rivers Region, *Research Report* 6.

Clarke, A.F. 1987 An analysis of archaeobotanical data from two sites in Kakadu National Park, Northern Territory. M.A. dissertation, University of Western Australia, Perth.

Clarke, M.F., Wasson, R.J. and Williams, M.A. 1979 Point Stuart chenier and Holocene sea levels in Northern Australia. *Search* 10:90-2.

Hiscock, P. 1993 The distribution of points within Nauwalabila 1. *The Beagle* 10:173-8.

Hiscock, P. 1994 Technological responses to risk in Holocene Australia. *Journal of World Prehistory* 8:267-92.

Hiscock, P. 1996 Mobility and technology in the Kakadu coastal wetlands. *Bulletin of the Indo-Pacific Prehistory Association* 15:151-7.

Hiscock, P. 1997 Archaeological evidence for environmental change in Darwin Harbour. In R. Hanley, G. Caswell, D. Megirian and H.K. Larson (eds) *Proceedings of the Sixth International Marine Biological Workshop. The Marine Flora and Fauna of Darwin Harbour, Northern Territory*, pp.445-9. Darwin: Museum and Art Galleries of the Northern Territory and the Marine Sciences Association.

Hiscock, P. and Hughes, P. in press Prehistoric and World War Two use of shell mounds in Darwin Harbour. *The Beagle*.

Hiscock, P. and Kershaw, P. 1992 Palaeoenvironments and prehistory of Australia's tropical Top End. In J. Dodson (ed.) *The Naive Lands*, pp.43-75. Melbourne: Longman Cheshire.

Hiscock, P. and Mowat, F. 1993 Midden variability in the coastal portion of the Kakadu region. *Australian Archaeology* 37:18-24.

Hope, G., Hughes, P.J. and Russell-Smith, J. 1985 Geomorphological fieldwork and the evolution of the landscape of Kakadu National Park. In R. Jones (ed.) *Archaeological Research in Kakadu National Park*, pp.229-40. Canberra: Australian National Parks and Wildlife Service *Special Publication* 13.

Jones, R. 1985 Archaeological conclusions. In R. Jones, (ed.) *Archaeological Research in Kakadu National Park*, pp.291-8. Canberra: Australian National Parks and Wildlife Service *Special Publication* 13.

Jones, R. and Johnson, I. 1985 Deaf Adder Gorge: Lindner Site, Nauwalabila 1. In R. Jones (ed.) *Archaeological Research in Kakadu National Park*, pp.165-228. Canberra: Australian National Parks and Wildlife Service *Special Publication* 13.

Macknight, C.C. 1976 *The Voyage to Marege: Macassan Trepangers in Northern Australia*. Melbourne: Melbourne University Press.

Macnae, W. 1968 A general account of the fauna and flora of mangrove swamps and forests in the indo-west-Pacific region. *Advances in Marine Biology* 6:73-270.

Meehan, B., Brockwell, S., Allen, J. and Jones, R. 1985 The wetlands sites. In R. Jones (ed.) *Archaeological Research in Kakadu National Park*, pp.103-54. Canberra: Australian National Parks and Wildlife Service *Special Publication* 13.

Mitchell, S. 1994a Culture contact and indigenous economies on the Cobourg Peninsula, Northwestern Australia. Ph.D. dissertation, Northern Territory University, Darwin.

Mitchell, S. 1994b Stone exchange network in north-western Arnhem Land. In M. Sullivan, S. Brockwell and A. Webb (eds) *Archaeology in the North*, pp.188-200. Darwin: North Australia Research Unit, The Australian National University.

Morton, B. 1983 Mangrove bivalves. In K.M. Wilbur (ed.) *The Mollusca*, Vol. 6, pp.77-138. New York: Academic Press.

Mowat, F.M. 1995 Variability in Western Arnhem Land shell midden deposits. Unpublished M.A. thesis, Northern Territory University, Darwin.

Schrire, C. 1972 Ethno-archaeology models and subsistence behaviour in Arnhem Land. In D.J. Clarke (ed.) *Models in Archaeology*, pp.653-69. London: Methuen.

Schrire, C. 1982 *The Alligator Rivers: Prehistory and Ecology in Western Arnhem Land.* Canberra: Department of Prehistory, Research School of Pacific Studies, The Australian National University. *Terra Australis* 7.

Smith, M. 1995 Radiocarbon dates for bifacial points at Scotch Creek 1, Northern Territory. *Australian Archaeology* 41:40-1.

Smith, M. and Brockwell, S. 1994 Archaeological investigations at a stratified open site near Humpty Doo, northern Australia. In M. Sullivan, S. Brockwell and A. Webb (eds) *Archaeology in the North*, pp.84-106. Darwin: North Australian Research Unit, The Australian National University.

Sullivan, M. and O'Connor, S. 1993 Middens and cheniers: Implications of Australian research. *Antiquity* 67:776-88.

White, C. 1971 Man and environment in northwest Arnhem Land. In D.J. Mulvaney and J. Golson (eds) *Aboriginal Man and Environment in Australia*, pp.141-57. Canberra: ANU Press.

White, C. and Peterson, N. 1969 Ethnographic interpretations of the prehistory of western Arnhem Land. *Southwestern Journal of Anthropology* 26:45-67.

White, J.P. with O'Connell, J.F. 1982 *A Prehistory of Australia, New Guinea and Sahul.* Sydney: Academic Press.

Woodroffe, C.D. and Mulrennan, M.E. 1993 *Geomorphology of the Lower Mary River Plains Northern Territory.* Darwin: North Australia Research Unit, The Australian National University.

Woodroffe, C.D., Chappell, J.M.A. and Thom, B.G. 1988 Shell middens in the context of estuarine development, South Alligator River, Northern Territory. *Archaeology in Oceania* 23:95-103.

Woodroffe, C.D., Chappell, J.M.A., Thom, B.G. and Wallensky, E. 1986 *Geomorphological Dynamics and Evolution of the South Alligator Tidal River and Plains, Northern Territory.* Darwin: North Australia Research Unit, The Australian National University. *Mangrove Monograph*, No. 3.

Woodroffe, C.D., Thom, B.G. and Chappell, J.M.A. 1985 Development of widespread mangrove swamps in mid-Holocene times in northern Australia. *Nature* 317: 711-13.