2

The Physical Environment, Landscape Evolution and Resource Availability

It has been widely acknowledged that environmental changes that occurred during the phase of post-glacial amelioration leading into the Holocene were particularly dramatic, and as such affected the long-term structure of the physical environment. Referring to long-term changes within the north Australian landscape, Sullivan (1996:1) has noted:

> The landscape changes at the end of the Pleistocene involved shifts in the position of the coastline over more than a thousand kilometres, and in the nature of coastal landforms. These landform changes were accompanied by massive changes in climate, and hence vegetation.

Due to the significant effect that these environmental and climatic changes would have had leading into the Holocene, a number of researchers continue to state that the nature and degree of environmental and climatic changes that occurred during the mid-to-late Holocene were comparatively insignificant (primarily Barker 1996, 1999, 2004; but see also Lourandos and Ross 1994 and Lourandos 1997). As this assertion is at odds with the position held by most researchers working on the north Australian coastline and elsewhere in the Pacific (e.g. Bailey 1977, 1999; Beaton 1985; Mowat 1995; Hiscock 1997, 1999; Bourke 2000; Allen 2006), it is important to consider Rowland's (1999a:11) position that those adhering to this opinion tend to underestimate the extent and significance of Holocene environmental change. While it is true that climatic and environmental variability from the mid-to-late Holocene may not have been as formidable as those changes that characterised the post-glacial amelioration, the degree and rate of change would still have had significant implications for human economic behaviour. In addition to describing the environmental and climatic conditions of the mid-to-late Holocene for the study area, the data presented here also address the question as to whether environmental and climatic changes of the mid-to-late Holocene would have significantly affected coastal resources, and by extension human behaviour.

The effects of environmental and climatic change on the formation of the landscape and the structure of the resource base will vary considerably both within and between coastal areas, depending on the nature of shorelines (e.g. steep rocky coasts or low lying coastal plains) and the type of processes acting on them. For these reasons the impact the environment may have on human behaviour can vary considerably on a regional basis (as also noted by Barker 1996:32). In order to gain an understanding of past human-environmental interactions through archaeological evidence, therefore, research needs to be placed within an environmental context. The emphasis here is on the difference between the present-day structure of the physical environment and

climate and those of the mid-to-late Holocene within the Blue Mud Bay region of eastern Arnhem Land. This facilitates the discussion of changes in the range of resources available to the hunter-gatherer population within the region over time, and the effect that long-term climatic and landscape changes may have had on the resource base structure.

The area selected for the focus of this investigation is the Point Blane Peninsula, situated within the coastal plains of Blue Mud Bay, northeast Arnhem Land (Figure 2.1). The study area is located approximately 200km south of the mining town of Nhulunbuy and the former mission settlement of Yirrkala (both on the Gove Peninsula). The Point Blane Peninsula is the central of three peninsulas on the northern coastal margin of Blue Mud Bay. This area is presently inhabited by the Yolngu people, and as previously noted, the region as a whole is defined as a distinct cultural bloc on the basis of cultural affinities and linguistic boundaries (Keen 1997:271–2). The homelands of the Yolngu people cover the area bounded by the Goyder River to the west, the Gulf of Carpentaria to the east, the Wessel Islands to the north and the Walker River to the south. The Yolngu people from the northern Blue Mud Bay region distinguish themselves further, referring to themselves as Dholupuyngu (translated as 'people of the mud') (H. Morphy 2004:3, 54). The study area (Figure 2.1) encompasses part of the traditional lands of a set of closely related Yolngu clans, The Yithuwa, or saltwater, Madarrpa are a large clan of over 100 people. Madarrpa land is concentrated on the Point Blane Peninsula, and the majority of the Madarrpa live at the Yilpara settlement in this area (Barber 2002:2).

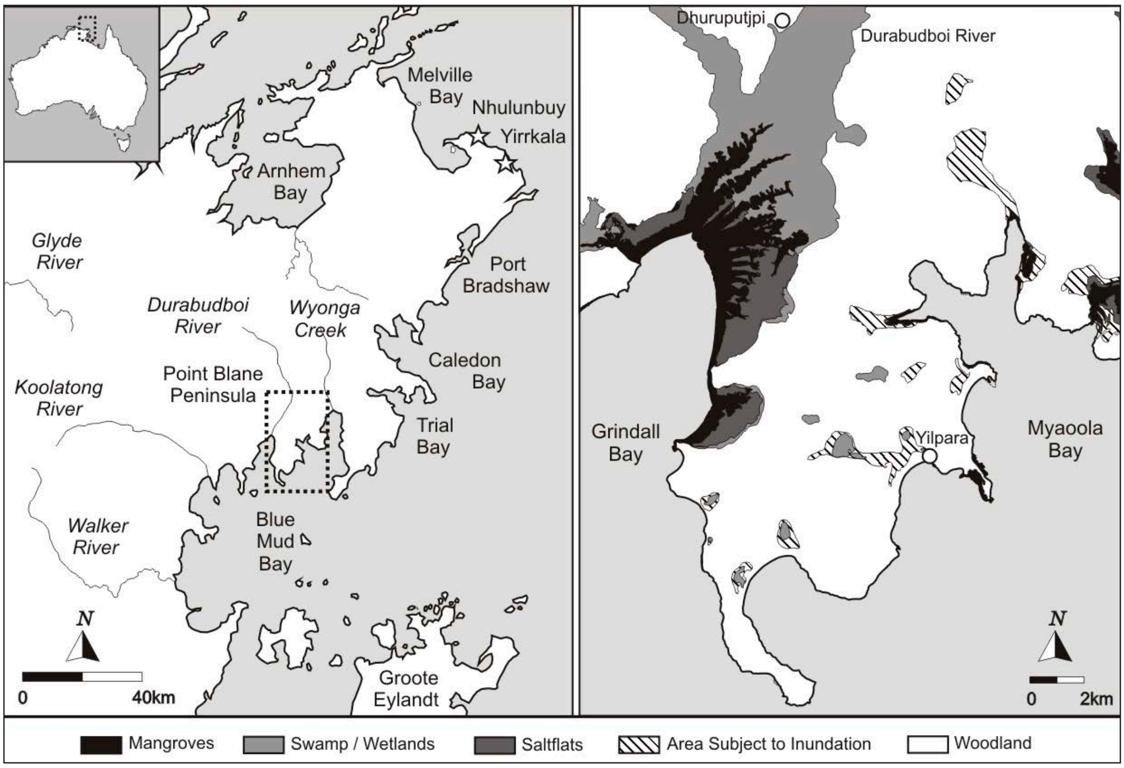

Figure 2.1: Northeast Arnhem Land region and the location of the Point Blane Peninsula study area.

Source: Based on Blue Mud Bay 1:250 000 Base Map and Baniyala 1:50 000 Topographic Map.

Structure of the physical landscape

Present physiography, geology and soils

The Blue Mud Bay region contains three main physiographic subdivisions: the Arafura Fall, the Gulf Fall and the Coastal Plain, the distributions of which are shown in Figure 2.2. The Parsons and Mitchell ranges lie along the major drainage divide separating the Arafura Fall (a region of dissected hilly country with drainage northwards towards the Arafura Sea) from the Gulf Fall (similar terrain with drainage south-eastwards towards the Gulf of Carpentaria). The Coastal Plain is comprised of low relief areas adjacent to the coast, extending up to 90km inland along the southern edge of Blue Mud Bay (Haines *et al.* 1999:1–2). The Point Blane Peninsula forms part of this Arnhem Land coastal plain, with mainly flat or undulating country (up to approximately 200m in elevation), often containing extensive wetlands or coastal swamps. These areas are generally bordered by upland plateaus and ranges along their inland margins. They are often characterised as depositional, low-energy shorelines that are still prograding via seaward and terrestrial sedimentary processes (Bureau of Meteorology 1998:1; Haines *et al.* 1999:91).

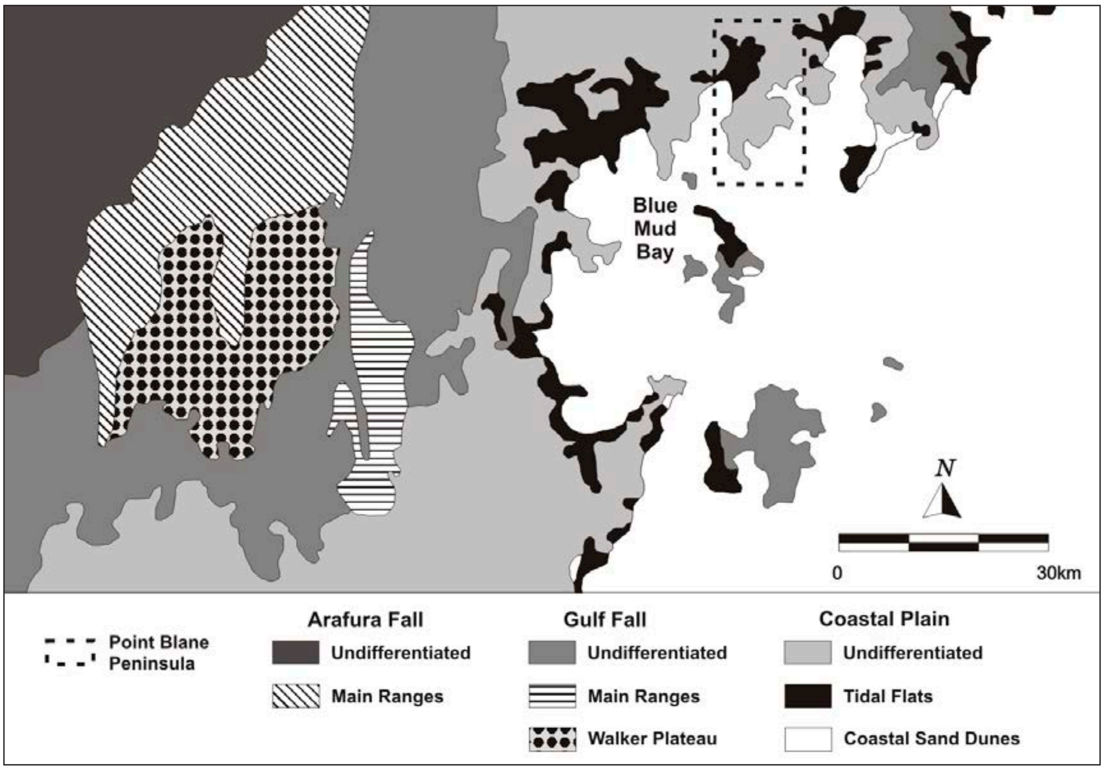

Figure 2.2: Blue Mud Bay physiographic divisions.

Source: After Haines *et al.* 1999:3.

The dominant land surfaces found across the study area are quite thin, as they have only been accumulating in their current configuration since the Holocene period of sea level rise and stabilisation (Haines *et al.* 1999:77). By extension, the archaeological record in this type of coastal landscape is tied spatially and chronologically to this mid-to-late Holocene pattern of landscape formation. The geological provinces located within the study area and neighbouring areas are summarised below in Table 2.1 and their distribution shown in Figure 2.3.

Table 2.1: Main geological/landscape units found within the study area and surrounding region.

Unit	Geological Grouping
*Cz	Shallow and gravelly soils, dominating plateau margins
*Czl	Earthy, gravelly sands, often difficult to differentiate from the above
*Qa	Alluvial gravel, sand, silt and clay, found in active channels, floodplains and outwash areas
*Qb	Grassy black soil and grey clay plains, old coastal deposits stranded by coastline regression
*Qc	Highly saline soils, unconsolidated grey clay, silt and sand with shell debris
*Qd	Aeolian dunefields on exposed coasts, calcareous and siliceous course sands on beach ridges
*Qr	Active/recently active cheniers and beach ridges, comprised of shelly sand
K	Fine- to coarse-grained quartzites with chert granules, part of the Yirrkala and Walker River formations
Pc, Pk, Px, Pew, Pv, Pgk	A composite of sedimentary and metamorphic rocks, shallow granites and undifferentiated volcanics, part of the Arnhem Inlier formation

Note: * indicates those geological units present in the study area.

Source: Haines *et al*. 1999.

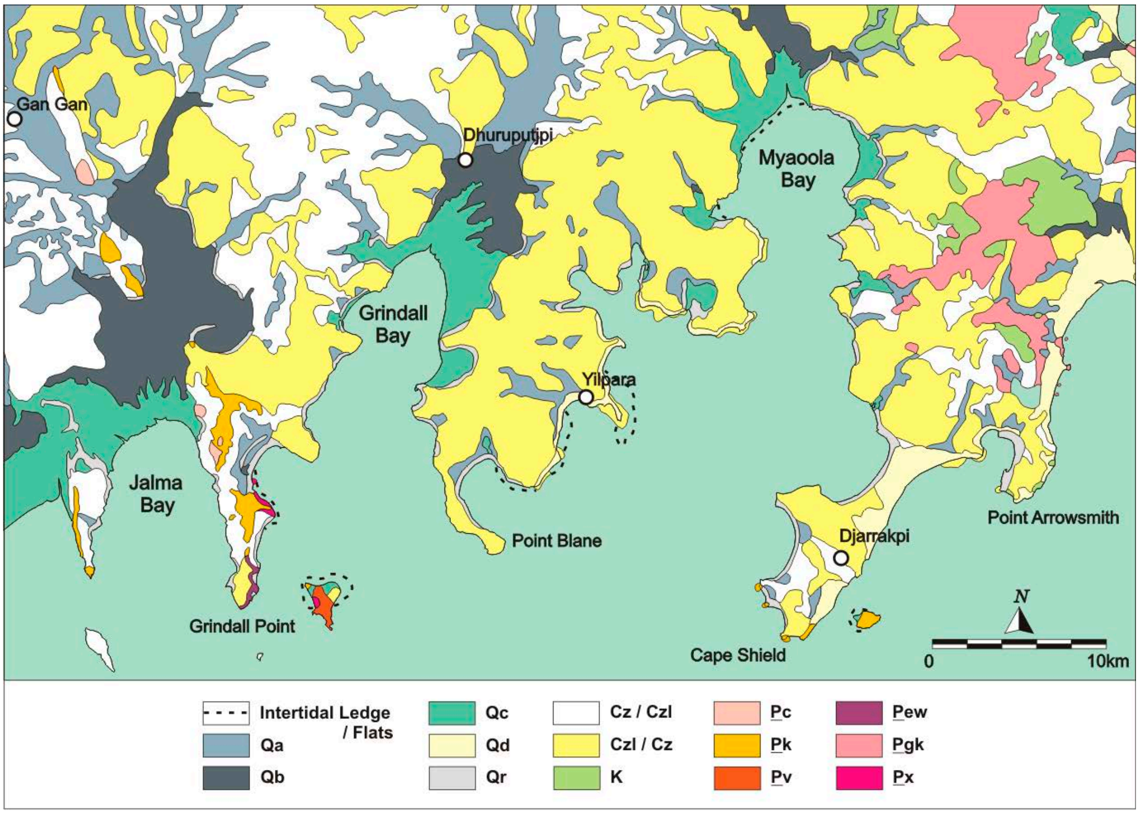

Figure 2.3: Geological divisions for the Point Blane Peninsula and neighbouring areas.

Source: Based on Blue Mud Bay 1:250 000 Geological Map SD 53–7.

Gravelly, earthy sands (Czl) are associated with all soils in the region (Specht 1958:343; Isbell 1983:195; Haines *et al.* 1999:77), with shallow and gravelly soils dominating the plateau margins and dissected areas (Cz). These two geological units are often difficult to differentiate, and have been mapped together in Figure 2.3. Importantly, long-term and intensive weathering and leaching during the formation of lateritic profiles across this region have also resulted in plant deficiencies and severe nutritional impoverishment of the soil profile (Paton and Williams 1972;

Hubble *et al.* 1983:26–7). Figure 2.4 illustrates the dominant geological formations across the study area, with exposed lateritic profiles on the coastal margin presented in Figure 2.5. Alluvial gravel, sand, silt and clay are found in active channels, flood plains and outwash sheets around ranges (Qa), fanning out towards the coastal zone where they merge with coastal sediments (Specht 1958:353–6; Haines *et al.* 1999:77). Highly saline soils are located adjacent to the coast (saltflats), forming on intertidal and supratidal flats and in tidal channels. These are largely unvegetated, apart from stands of mangroves, and consist of unconsolidated grey clay, silt and sand with entrained shell debris (Qc) (see Figure 2.6). The salt content of these soils is very high, with a salty crust present over much of the area (Specht 1958:350; Haines *et al.* 1999:77).

Figure 2.4: Dominant gravelly, earthy sands of the Point Blane Peninsula.

Source: Photo Patrick Faulkner.

Figure 2.5: Exposed lateritic profiles on the coastal margin of Myaoola Bay.

Source: Photo Annie Clarke.

Figure 2.6: Expansive saltflats in the Grindall Bay area.

Source: Photo Annie Clarke.

Figure 2.7: Estuarine meanders and dendritic tidal channels across elevated black soil plains.

Source: Photo Patrick Faulkner.

The saltflat areas are bordered by slightly elevated black soil and grey clay plains (Qb), which are often interpreted as slowly prograded coastline deposits and are traversed by well-developed estuarine meanders and dendritic tidal channels (Figure 2.7). These areas are often inundated by high tides and floodwaters, and some are slowly accreting by the addition of flood plain silts (Specht 1958:349; Isbell 1983:192; Walker and Butler 1983:83–5; Haines *et al.* 1999:77). Aeolian dunefields are located along the exposed coast (Qd), generally characterised as calcareous and siliceous coarse sands on beach ridges (Specht 1958:356; Isbell 1983:191; Haines *et al.* 1999:77). Active and recently active cheniers and sandy beach ridges (Qr) comprised of shelly sand occur as a narrow zone on the coastal fringes of many regions of the Gulf of Carpentaria, and are scattered along much of the coast as narrow ridges a few metres in height (Haines *et al.* 1999:77). Sources of knappable stone occurs in small, localised areas closer to the coast, pink to white quartzites form the bulk of the raw materials recorded in the study area's stone artefact assemblage, and are derived from the underlying Cretaceous and older quartzite, sandstone and granitic deposits. One example of a quartzitic outcropping is shown in Figure 2.8, an area located on the coast approximately 5km north of the Yilpara Community.

Figure 2.8: Example of a coastal quartzite outcropping, Point Blane Peninsula.

Source: Photo Patrick Faulkner.

The present landform characteristics detailed above have largely resulted from two main processes acting on the physical environment throughout the Holocene. The effects of changes in sea levels during the marine transgression, followed by ongoing patterns of progradation and sedimentary infilling initiated during the mid Holocene, strongly indicate that the current landscape is different from that seen in the past.

Changes in sea level

Sea levels have varied significantly from the Pleistocene into Holocene (see Figure 2.9A for sea level curve relating to the past 140,000 years), largely as a response to the cyclic expansion and contraction of the northern continental ice sheets. This process has dramatically altered the land area of Australia over time, affecting localised climatic patterns (Chappell 1983, 1993; Frakes *et al.* 1987).

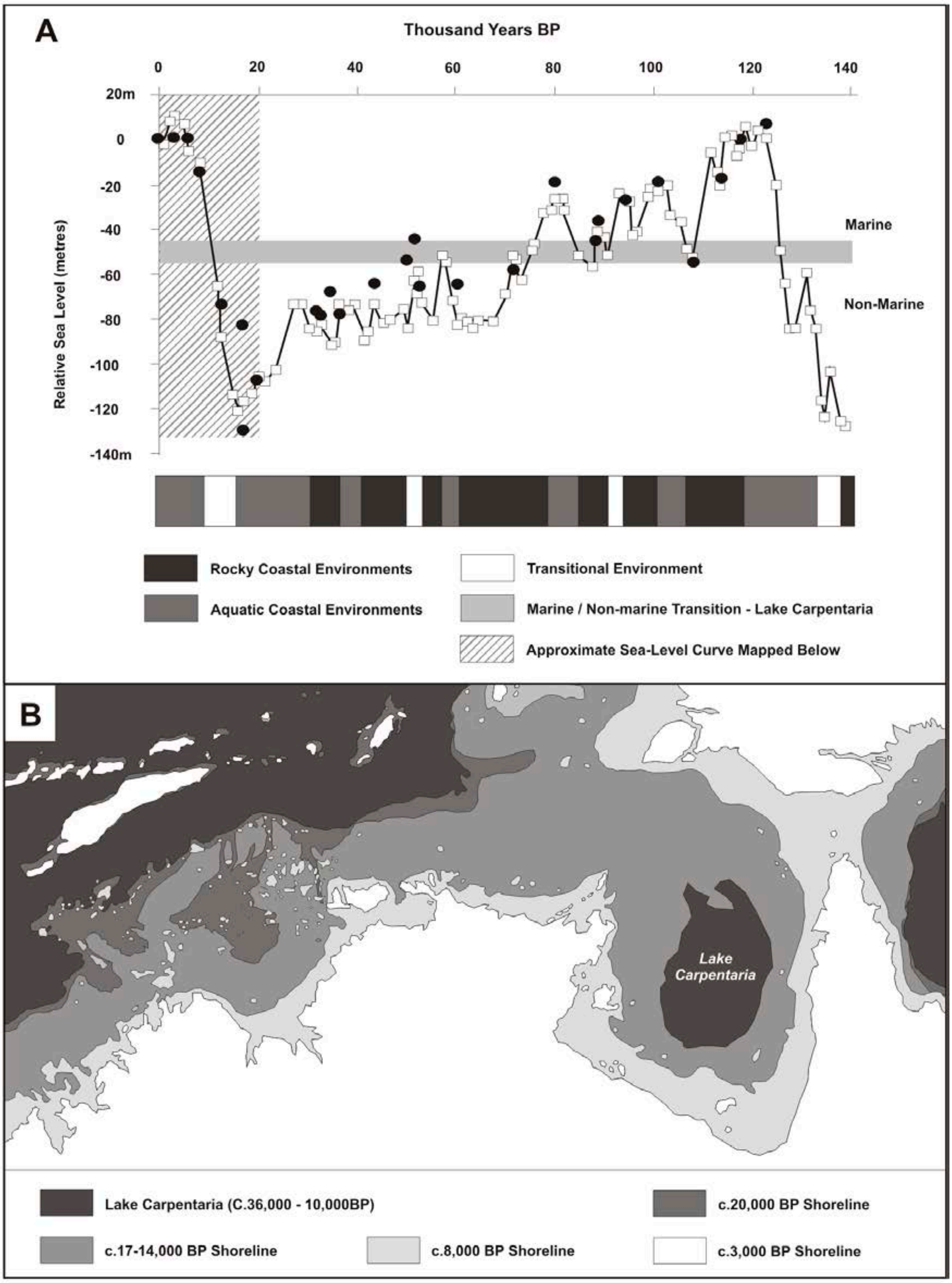

Figure 2.9: (A) Global sea level curve for the past 140 ka; (B) Stages of sea level rise for the past 20 ka for northern Australia and surrounding region.

Source: (A) Chappell *et al*. 1996; Chivas *et al*. 2001:39. (B) After Allen and Barton n.d. 5; Nix and Kalma 1972:88–9; Yokoyama *et al*. 2001:16.

Figure 2.9B illustrates sea level rise from approximately 20,000 BP when sea level was 120 to 130m below current levels (Chappell *et al.* 1996), through the breaching of the Arafura Sill and the marine transgression between 12,000 BP and 9700 BP, and establishment of fully marine conditions by 6000 BP (Chivas *et al.* 2001:24–9) through to the present (Hopley and Thom 1983:13–4; Lambeck and Chappell 2001; Lambeck *et al.* 2002:358–9). Chappell and Thom (1977:283), Torgersen *et al.* (1983) and Schrire (1982:9) have made the point that sea level rise at an approximate rate of 1-3mm per year would have had a dramatic effect on the distribution of fauna and flora in the Carpentaria drainage basin. The consequences of shoreline migration and coastal ecosystem response would have drastically affected human populations retreating from the rising sea levels.

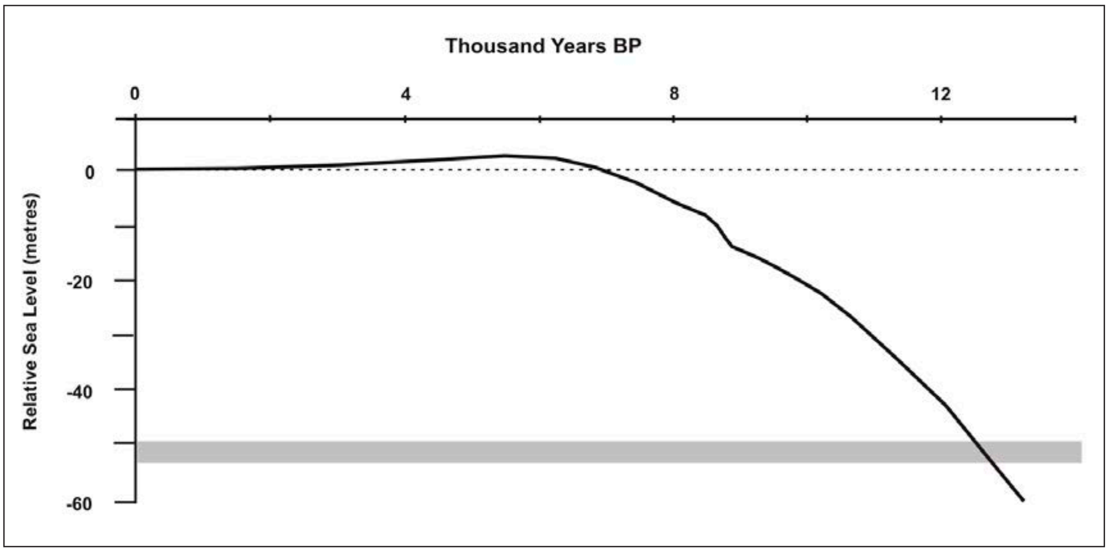

Figure 2.10: Smoothed sea level curve for the Gulf of Carpentaria. Grey band represents the marine/non-marine transition period for Lake Carpentaria.

Source: Nakiboglu *et al.* 1983:349; Yokoyama *et al.* 2001:14; Woodroffe and Horton 2004:3. Grey band following Clarkson, 2004.

Evidence across the north appears to suggest a general pattern, that sea levels stabilised following the last post-glacial marine transgression approximately 1-3m above present levels around 7000 to 6000 BP, with a decline in sea level in response to hydro-isostatic adjustment until approximately 600 BP (Chappell *et al.* 1982; Lambeck and Nakada 1990; Lees 1992b:6; Fleming *et al.* 1998:335; Nunn 1998; Woodroffe *et al.* 1998; Grindrod *et al.* 1999:465; Rowland 1999a:27). Rather than being a smooth decline from sea level highstand, around Australia there is growing evidence for a series of minor oscillations in relative sea level during the late Holocene superimposed over the general sea level trend (e.g. Lambeck 2002; Sloss *et al.* 2007; Woodroffe 2009). There is an absence of such research within the immediate Blue Mud Bay area, and geomorphological research from the Gulf of Carpentaria region as a whole must be evaluated. The smoothed Holocene sea level curve determined for the Gulf of Carpentaria is presented in Figure 2.10, based on data from Nakiboglu *et al.* (1983:349), Woodroffe and Horton (2004:3) and Yokoyama *et al.* (2001:14). This information is derived from slightly emerged beach and chenier ridges from the prograded southeast and east plains along the Gulf, and is indicative of the tidal zone position during the mid-to-late Holocene (Nakiboglu *et al.* 1983:356). In addition, chenier ridge development by 6000 BP along the southern shore of the Gulf of Carpentaria indicates highstands in excess of 2m (Rhodes 1980, 1982), and in the Sir Edward Pellew Island Group a probable highstand of 1.2m has also been reported for this time (Rhodes 1980). At Karumba, chenier ridges indicate a highstand 2.5m above present level, followed by a sea level fall at a uniform rate to its present

value (Lambeck and Nakada 1990:159–167). Therefore within the Gulf of Carpentaria, sea levels reached present levels (height at zero metres) at approximately 7000 BP, after a rapid rise from 10,000 BP of approximately 21m in 3000 years. The rate of sea level rise over this period equates to 7mm per year. With continued sea level rise, a maximum highstand of approximately 1.2 to 2.5m was reached between 6000 and 5000 BP, followed by a slow regression over the mid-to-late Holocene.

These changes in sea level are inter-woven with long-term climatic shifts linked to the El Niño/Southern Oscillation (ENSO) cycle, particularly relating to the intensity of the summer monsoon and cycling periods of aridity and increased precipitation. This is due to the fact that the Gulf of Carpentaria is located adjacently to the Western Pacific Warm Pool, which is responsible for the largest transfer of heat from the Pacific Ocean into the Indian Ocean and is implicated in the generation of El Niño/La Niña phases of the southern oscillation (Gagan and Chappell 2000:35; Chivas *et al.* 2001:20).

Landscape alteration: Patterns of coastal progradation and sedimentation

The effect of Holocene sea levels on riverine lowlands can be considered in two episodes, the first from 10,000 to 6500 BP when it was rising at 0.6 to 1.0m for every 100 years, and the second from 6500 to the present when it has been relatively stable. During the rising phase, the sea transgressed upon land and valleys were drowned, an effect offset to some extent by sedimentation (Chappell 1990:70). Following the marine transgression, many of the shallow bays in north Australia were gradually prograded to form freshwater wetlands and salt or mudflat areas. Although few geomorphological studies have been conducted in northeast Arnhem Land, a large amount of research has been carried out in the Alligator Rivers region of western Arnhem Land. The model of estuarine evolution during the Holocene for the Alligator Rivers region indicates that the process of sedimentation continued after the stabilisation of sea level leading to a transition from mangrove to freshwater environments. The diversity of mangrove species and the tidal swamp vegetation increased, creating a variety of environments influenced heavily by rainfall patterns. Channels formed as the surface built upwards and outwards on the tidally inundated flats, to a level where high tide flooding became rare, with brackish and freshwater swamps forming in residual depressions on the landward edge of the coastal plains (Woodroffe *et al.* 1985a, 1985b; Clark and Guppy 1988:679–81). The pattern and timing of the progradation phases for the South Alligator River are as follows:

1. Transgressive phase (8000 to 6000 BP) involving tidal incursion and landward extension of mangroves forests in a prior valley.
2. Big Swamp phase (6000 to 4000 BP) when mangrove forests were established throughout the estuarine plains.
3. Sinuous phase (4000 to 2000 BP) when mangrove forests were eliminated, tidal flows became confined to channels, and freshwater vegetation became established on the plains.
4. Cuspate phase (after 2000 BP) in which the river adopted a meandering form.

With regional variations, the model of estuarine evolution and Holocene deposition demonstrated for the Alligator Rivers region is said to apply broadly to other river systems across north Australia (Woodroffe 1995:80). This general model is shown in Figure 2.11, and it is suggested that the progradational model for the Dhuruputjpi wetlands system in the study area generally follows that of the South Alligator River, although the intensity of sedimentation and the timing of the phases will vary (Chappell 1990:73).

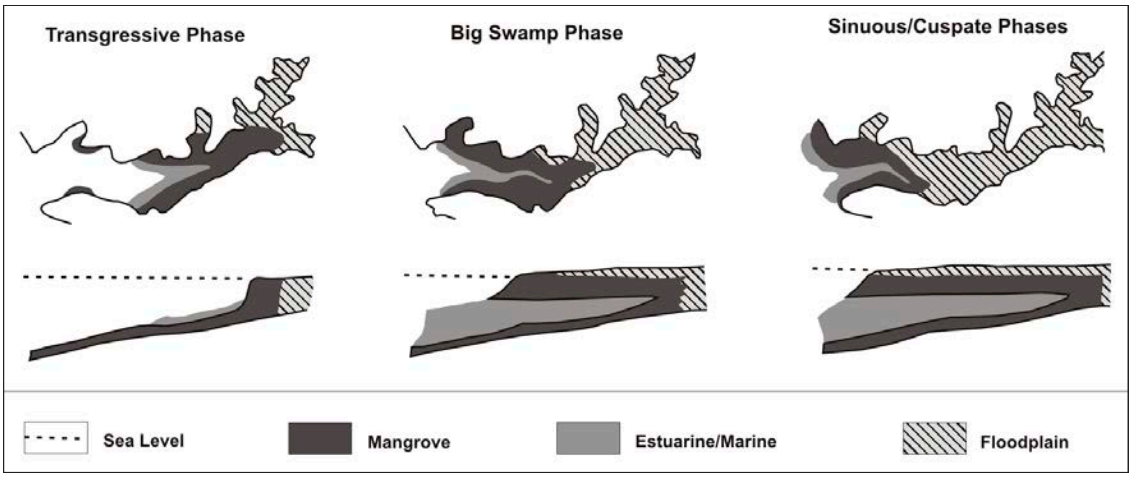

Figure 2.11: Holocene estuarine sedimentation/progradational model.

Source: After Woodroffe *et al.* 1985b:26.

When sea level rose rapidly (1.3 to 1.5m per 100 years) wave action consistently reworked the nearshore zone, producing a steeper slope, and as a result, little or no mangrove is envisaged on the seaward beach face (Chappell and Thom 1977:287). The rate of late Pleistocene and early Holocene sea level rise, although relatively rapid in the initial stages, had decreased by approximately 8000 BP. Therefore, the spread of mangrove swamps and sedimentation throughout prior valleys virtually kept pace with a rising sea level of 12m (at 0.6m per 100 years) between 8000 and 6000 BP (Woodroffe 1981; Chappell 1990:71; Ellison 1993). It is also thought that during a transgressive period, richer estuarine biota would be expected compared with a regressive phase on a seasonally dry tropical coast, as hypersaline conditions should be absent (Chappell and Thom 1977:287). Stratigraphically, the sequence of infill is composed of intertidal muds and sands, overlain by dark grey muds rich in mangrove fragments, and capped by grey-brown mottled muds. The upper mud is only vegetated adjacent to tidal creeks, estuarine shores and below high spring tide level, seaward of the outmost beach ridge. Vast bare high-tidal flats with hypersaline interstitial waters and localised evaporate deposits lie landward of the outer vegetated fringe (Chappell and Thom 1977:284). The elevation and absence of vegetation on the saline tidal flats are a function of both sediment supply and duration of sea level still-stand. Therefore, in areas of relatively slow input of fine-grained sediment, the transition from sub-tidal, to vegetated intertidal, to bare high-tidal mudflats requires a still-stand of up to several thousand years (Chappell and Thom 1977:284). Therefore, post-glacial processes associated with the marine transgression and sedimentary infill has formed the wetland and saltflat areas of the study area in a broadly similar way to that of the Alligator Rivers region, an example being that of the Dhuruputjpi wetlands area. In line with this pattern of substantial environmental change during the Holocene, there are quite dramatic changes in climatic conditions associated with these processes.

Holocene climatic variability

Current climate

Northeast Arnhem Land, located within Australia's humid zone, is characterised as a tropical monsoon summer rainfall area (see Figure 2.12A). The region experiences two distinct seasons: the wet (October to April) and the dry (May to September), with most rain falling between January and March. Two major atmospheric pressure systems affect the north Australian climate:

a subtropical ridge of high-pressure cells, and the monsoon trough. The subtropical highs move from west to east across southern Australia in winter, providing the driving force behind the southeast trade winds dominating the north Australian weather in the dry season from June to October or November. The monsoon trough runs east-west through the tropics in the summer months, lying for long periods over north Australia, and creating much of the rainfall during this time (Bureau of Meteorology 1998:1). The change between the seasons is usually gradual; the wet season begins during the transition months of October and November (build-up) and culminates during April (McDonald and McAlpine 1991:19–25; Bureau of Meteorology 1998:1).

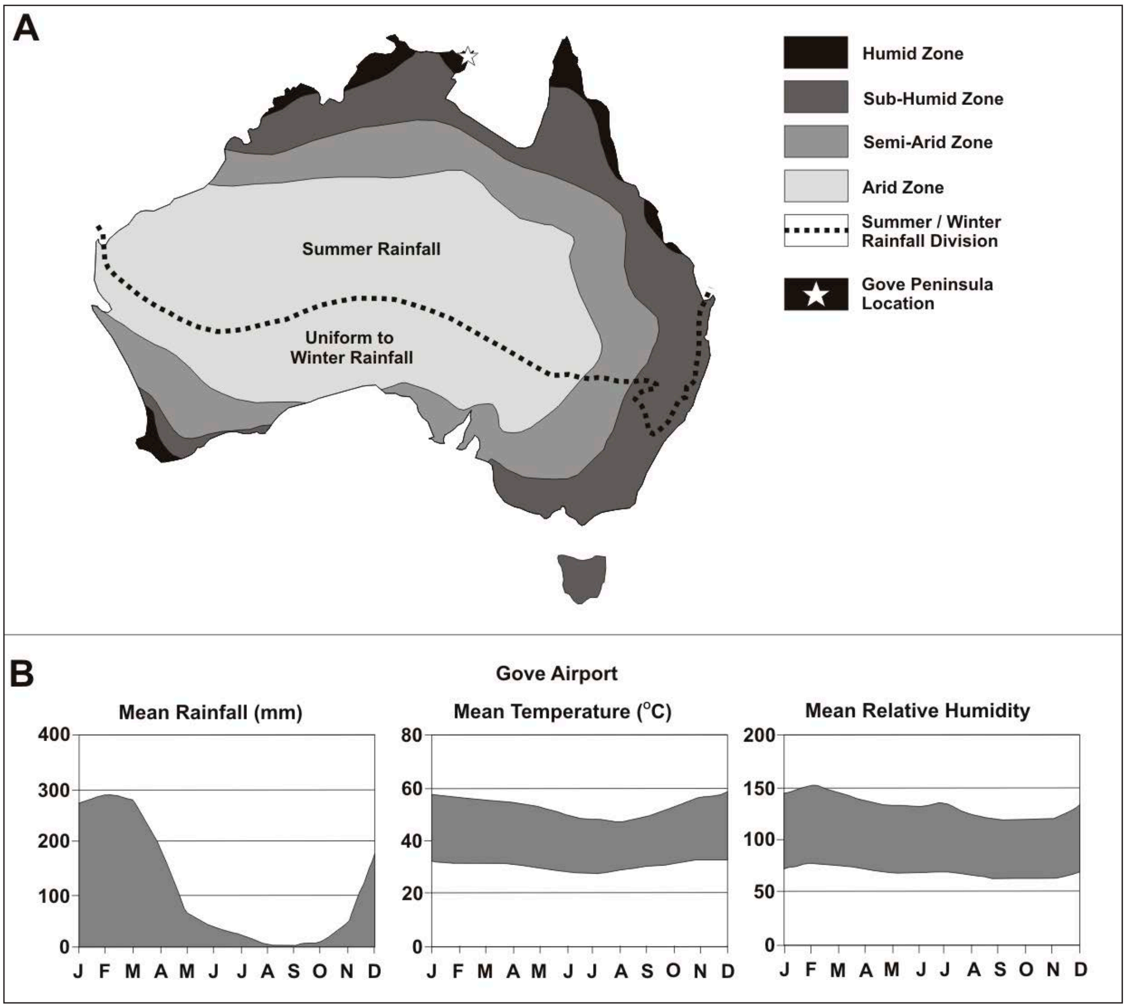

Figure 2.12: (A) Australian climatic regions; (B) Mean rainfall, mean temperature and mean relative humidity at Gove Airport, northern Arnhem Land.

Source: (A) After Pickering 1997 Vol. 2:4. (B) Bureau of Meteorology 1988:101–34; 1998:18–28.

Seasonal differences in rainfall, temperature and relative humidity (minimum and maximum) are shown in Figure 2.12B. These graphs are derived from data obtained at Gove Airport (Bureau of Meteorology 1988:101–34; 1998:18–28), 200km to the north of the study area. From May to September (dry season), the prevailing southwesterly winds bring predominantly fine conditions. In the study area, rainfall is generally low to non-existent with a lessening of humidity during this period (Bureau of Meteorology 1998:2). The periods of highest relative humidity and increases in temperature correspond with the build-up and wet season. During the wet, weather in the north is largely determined by the position of the active and inactive phases of the monsoonal trough. The active phase is usually associated with broad areas of cloud and rain, with sustained moderate

to fresh northwesterly winds. Inactive periods, which are characterised by light winds, isolated showers and thunderstorm activity, occur when the monsoon trough weakens or retreats north of Australia (Bureau of Meteorology 1986:4, 1989:45; Zaar *et al.* 1999:9). Tropical cyclones can develop off the coast in the wet season, usually forming within an active monsoon trough. Heavy rains and high winds can be experienced along the coast within several hundred kilometres of a cyclone's centre (Bureau of Meteorology 1998:2–3), causing widespread vegetation and landscape changes.

Climatic change during the Holocene

Many of the longer-term trends in climate change that have occurred during the period spanning the early Holocene to the present day are related to the ENSO cycle (Enfield 1989; Allan *et al.* 1996; Webster and Palmer 1997). During an El Niño episode, rainfall dramatically increases in certain areas of the world, whereas severe droughts occur in other regions (such as the Australian-Indonesian region). The ENSO phenomenon has strongly influenced climatic patterns in Australia for some time (McGlone *et al.* 1992; Shulmeister and Lees 1992; Jones *et al.* 1999), and at present, ENSO represents the principal source of inter-annual climatic variability within the Indo-Pacific region (Glantz 1991; Glantz *et al.* 1991; Diaz and Markgraf 1992; Allan *et al.* 1996; Rowland 1999a). During El Niño events, there is a weakening of sea level pressure in the southeastern tropical Pacific and a decrease in the strength of trade winds. This causes sea-surface temperatures to rise through a weakening of the cool oceanic upwelling along the western coast of South America. Warmer sea surface temperatures create increased heating and evaporation, resulting in intensified convection and rainfall over the western coast of continental America (Diaz and Markgraf 1992; Enfield 1992; Allan *et al.* 1996). Based on a review of long-term palaeoenvironmental climatic indicators, Bush (2001:25), McGlone *et al.* (1992) and Tudhope *et al.* (2001:1516) suggest that the ENSO cycle may have intensified in the last 5000 years. Shulmeister and Lees (1995) and Shulmeister (1999) have also argued that ENSO-scale variability became entrenched in the climatic system after approximately 4000 BP (see also Hughes and Brown 1992; Graumlich 1993; Knox 1993; Rodbell *et al.* 1999; Rowland 1999a, 1999b; Andrus *et al.* 2002; Koutavas *et al.* 2002).

El Niño events have strong ecological and economic consequences. The best-studied effects on ecosystems are in marine environments, where El Niño is correlated with dramatic changes in the abundance and distribution of many organisms (Bourke *et al.* 2007), and the collapse of fisheries (Holmgren *et al.* 2001:89). There are also documented impacts on terrestrial organisms as well, linked to impacts on the vegetation regime. For example, El Niño events have been linked to the almost complete defoliation of mangrove forests (Haberle 2000:66; Holmgren *et al.* 2001:90–1). Therefore, ENSO-related climatic oscillations must have had significant impacts on human populations, primarily affecting the resource base in terms of the long and short-term availability, stability and structuring of these resources (Clarkson 2004:163).

For the reasons outlined above, the Pleistocene to Holocene transition in northern Australia was a time of rapid climatic amelioration, characterised by an increase in lake water levels (Kershaw 1995), and the establishment of vegetation communities in their present position (Nix and Kalma 1972:88–9). This period was one of rapid environmental change, including climatic reversals with the onset of tropical conditions in some areas between 15,000 and 11,500 BP, followed by a swing back to full glacial conditions during the Younger Dryas, between approximately 10,800 and 10,200 years ago (Kershaw 1995). The timing and nature of Holocene climatic changes for northern Australia are presented in Figure 2.13, and the Holocene climatic record and the comparison of wet and arid phases for north Australia are summarised as follows, and expanded on below:

1. Effective precipitation and temperature gradually increase from the beginning of the Holocene until approximately 5000 BP.

2. A period of higher effective precipitation from 5000 BP to approximately 3700 BP.

3. Following this, a sharp falling off in effective precipitation after 3700 BP, with increase in climatic variability from approximately 1000 BP to the present (Shulmeister 1999:82).

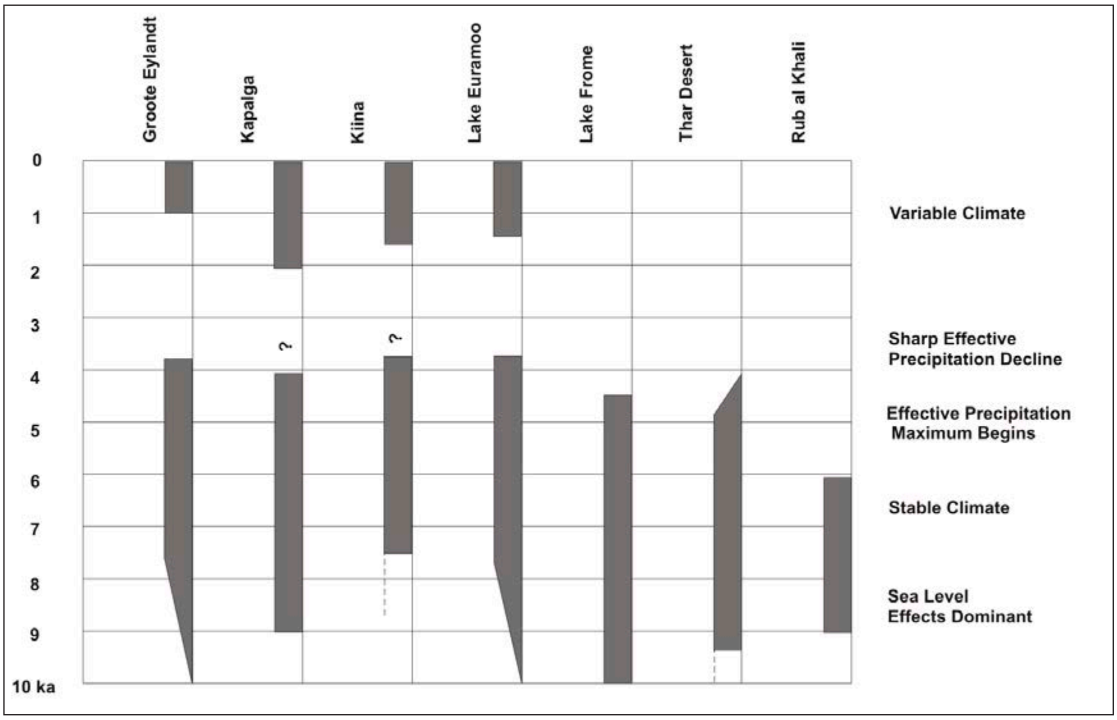

Figure 2.13: The timing and nature of Holocene climatic changes, wet phases indicated by grey shading.

Source: After Shulmeister and Lees 1995:12 and Shulmeister 1999:84.

For the period around 6500 BP, data suggest that the ENSO cycle may have weakened, an interpretation that is in agreement with data suggesting subdued ENSO in the early to mid Holocene from lake sediments in Ecuador, geoarchaeological evidence from Peru, and pollen data from Australia (Tudhope *et al.* 2001:1515). An interpretation of high effective precipitation between 5500 and 3700 BP, with precipitation values between 200 and 1000mm higher and temperatures 1^0 to 2^0C higher, is supported by evidence from Groote Eylandt, correlated with a phase of rapid organic sedimentation (Shulmeister 1992, 1999:82). It appears, therefore, that the north Australian Holocene environmental optimum (in regards to precipitation rather than a temperature maximum) occurred after 5000 BP, significantly at least 1000 years later than in southern Australia (Nix and Kalma 1972; Kershaw 1983, 1995; Kershaw and Nix 1989; McGlone *et al.* 1992; Gagan *et al.* 1994; Shulmeister 1999:83; Gagan and Chappell 2000:44;) alongside a reduction of interannual variability (Chappell 2001:177). Seasonality has continued to increase in the Southern Hemisphere since 5000 BP. It is widely observed that climates, at least in the Australasian region, have been much more variable in the last few thousand years (Wasson 1986; Shulmeister 1999:88), with this increased variability related to the onset of a Southern Oscillation dominated climate. The general trend appears to be a change from low seasonality in the early Holocene to increased seasonality in the late Holocene, a pattern that has been observed in recent reviews of the climate history of the south Pacific region (Markgraf *et al.* 1992; Shulmeister 1999:86). There also appears to be a trend toward increased aridity in the mid-to-late Holocene (after approximately 5000 to 3000 BP) based on coral, foraminifera, varve, lake and sea

bottom sediment data from sites in Australian and the circum-Pacific region (McPhail and Hope 1985; Brookfield and Allan 1989; Singh and Luly 1991; McGlone *et al.* 1992; Hope and Golson 1995; Kershaw 1995; Shulmeister and Lees 1995; Nott *et al.* 1999:233; Rodbell *et al.* 1999; McCarthy and Head 2001; Kim *et al.* 2002; Koutavas *et al.* 2002). Geomorphic evidence from cheniers and coastal dunefields (Lees *et al.* 1990, 1992; Lees 1992a, 1992b) indicates that some of the observed changes in these systems are synchronous across north Australia, and may represent coherent, broad-scale climatic signals (Shulmeister 1999:82; Prebble *et al.* 2005:367–9).

While the longer term evidence for climate change is important for contextualising the degree of variability in climate history throughout the Holocene, possibly the most significant period of climatic change for this study relates to the last 1500 years. There is evidence for a warm dry (relative to today) period about 1200 to 700 BP in low latitudes named the Little Climatic Optimum (or Medieval Warm Period). Likewise, there is evidence for the Little Ice Age, a cool dry period following the Little Climatic Optimum, about 600 to 100 BP (Nunn 2000:716). The Little Ice Age appears in most Northern Hemisphere palaeoclimate reconstructions as multiple, century-scale periods of anomalously cold, dry conditions between the 15^{th} and late 19^{th} centuries. Glacial advances in both hemispheres and enhanced polar atmospheric circulation suggest that the Little Ice Age was a global scale event (Hendy *et al.* 2002:1511). The transition between the Little Climatic Optimum and the Little Ice Age appears to be marked by rapid cooling and two stages of sea level fall throughout the Pacific Basin around 650 BP and 500 BP (Nunn 1998, 2000). Recent coral proxy records for sea-surface temperature and sea surface salinity anomalies in the tropical southwest Pacific indicate that a dramatic shift occurred in the tropical ocean-atmosphere system at the end of the Little Ice Age (Hendy *et al.* 2002; Gagan *et al.* 2004:132). Hendy *et al.* (2002) suggest that conditions in the tropical southwest Pacific during the Little Ice Age were also consistently more saline than present, largely between approximately 500 and 200 BP. Sea-surface temperature (SST) and rainfall are closely linked in tropical areas of strong convective rainfall, such as the western equatorial Pacific (Tudhope *et al.* 2001:1511). The lack of significant planktonic foraminiferal faunal change in the western Pacific results in estimated SST differences of only 1.5°C to 2.0°C or less between the present day and around 2000 to 3000 BP in low-latitude regions (Thunell *et al.* 1994:259–60; Shulmeister 1999:86; Tudhope *et al.* 2001:1515). Within the north Australian region, palaeotemperatures indicated by the fossil coral record from the Great Barrier Reef shows that the mean SST approximately 5350 years ago was 27.0°C, which is 1.2°C warmer than the mean SST for the early 1990s. Terrestrial pollen and tree-line elevation records in the tropical southwest Pacific indicate that the climate was generally warmer from 7000 to 4000 BP (Gagan *et al.* 1998:1016). Taken together with the 5°C cooling indicated by palaeotemperatures for late-glacial corals from the southwest Pacific, these results suggest that the full amplitude of the glacial-Holocene temperature change may have been about 6°C (Gagan *et al.* 1998:1017; Wasson and Claussen 2002:823).

While these studies show that there is a degree of regional variation in the timing and nature of cycles of aridity and precipitation, they also demonstrate a generally applicable climatic pattern across a wide area of northern Australia. The combination of substantial environmental and climatic changes throughout the Holocene suggests that the type of resources, their density and distribution, were thus quite different to that observed within the historic period. The current distribution and availability of resources such as water, vegetation and fauna are outlined below, with a brief discussion on the seasonal nature of these resources as they are now, followed by a consideration of the implications of changing environmental and climatic conditions for the availability of resources into the past.

Resource availability

Hydrology

The Point Blane Peninsula contains a number of reliable freshwater sources (Figure 2.14). Smaller creeks and rivers, such as the Durabudboi River and Wyonga Creek, drain the coastal plains (Haines *et al.* 1999:1–2), freshwater wetlands (Figure 2.15), small swamps and billabongs, and sub-surface aquifers make up the remaining components of the hydrological regime. Both the Durabudboi River and Wyonga Creek have large catchment areas, resulting in larger amounts of rainfall runoff and river flow in the wet season. The middle section of the Durabudboi River contains numerous pools and billabongs (Figure 2.16), which contain water even after the poorest wet season rainfall. In contrast, Wyonga Creek will often cease to flow entirely at the end of the dry season. Again, pools and water holes will contain a certain level of water, but are restricted in size and distribution along the course of the creek (Zaar *et al.* 1999:19–20). Both systems rely on groundwater discharge maintained by sandstone aquifers during the dry season. Many of the swamps and billabongs located along drainage lines feeding the main river and creek systems will retain water well into the dry season. In the case of the larger Dhuruputjpi wetlands system, fed by the Durabudboi River, freshwater may be available year round.

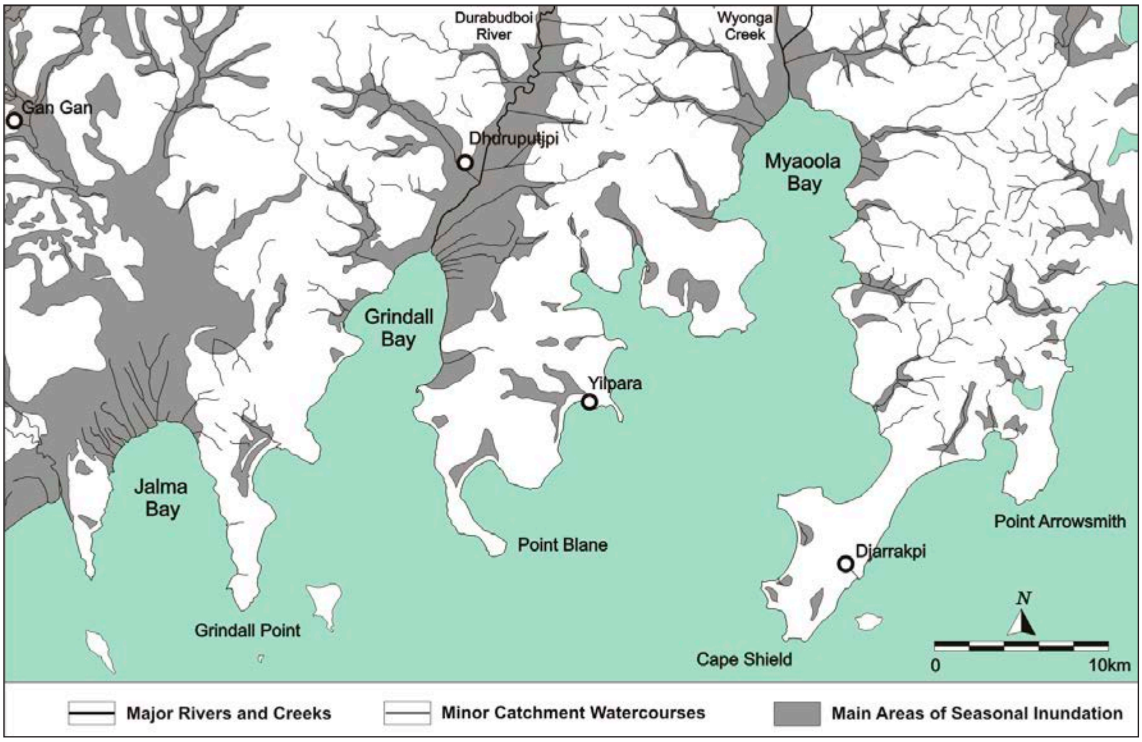

Figure 2.14: The hydrology of the Point Blane Peninsula and neighbouring areas.

Source: Water Resources of North Eastern Arnhem Land Mapsheet.

Figure 2.15: Section of freshwater wetland towards the mouth of the Durabudboi River.

Source: Photo Patrick Faulkner.

Figure 2.16: Durabudboi River billabong.

Source: Photo Annie Clarke.

The study area contains large regional aquifers consisting of poorly consolidated sandstone or limestone. They naturally discharge large volumes of water throughout the year and are responsible for the base flow of many of the large river systems (Zaar *et al.* 1999:9–10). Additionally, high annual wet season rainfall will result in increasing water recharge on the peninsula, resulting in higher water table levels and greater spring flows. In low rainfall years, discharge from the springs will be less and the water table levels will fall (Zaar *et al.* 1999:9–10). The availability of freshwater in the past would have been constrained by very similar factors as those seen at present, but it is likely that the influence of each factor would have fluctuated through time, creating a degree of variability in water availability. A decrease in annual precipitation would have substantially decreased the availability of both surface and sub-surface water, and as already noted, there were several periods of heightened aridity throughout the mid-to-late Holocene. Also, several major sources of surface water in the study area, highlighted as those larger areas of seasonal inundation in Figure 2.14 around the major rivers and creeks, were slowly developing throughout the late Holocene. Therefore, while many of the minor watercourses, seasonal floodplains and lower-lying swamps and billabongs have potentially changed very little throughout the mid-to-late Holocene, there are a number of environmental and climatic factors that may have affected the pattern of water availability through time.

Flora

The dispersal of plant communities is closely associated with the distribution of hydrological and geological zones within the landscape (Dunlop and Webb 1991:50). The distributions of the majority of the vegetation units described below are listed in Table 2.2 and shown in Figure 2.17.

Table 2.2: Main vegetation units found within the study area.

Unit	Vegetation Grouping
04	*Eucalyptus miniata* (Darwin Woolly Butt), *Eucalyptus tetrodonta* (Stringybark) Open-Forest with Sorghum Grassland Understorey
07	*Eucalyptus tetrodonta* (Stringybark), *Callitris intratropica* (Cypress) Woodland with Grassland Understorey
51*	*Melaleuca viridiflora* (Myrtle), *Eucalyptus* Low Open-Woodland with *Chrysopogonfallax* (Golden Beard Grass) Grassland Understorey
54	Mixed Closed-Grassland/Sedgeland (Seasonal Floodplain)
102	Coastal Dune Complex (*Casuarina equisetifolia* woodland, grasslands, Melaleuca swamps/mixed shrublands)
105	Mangal Low Closed-Forest (Mangroves)
106	Saline Tidal Flats with Scattered Chenopod Low Shrubland (Samphire)
01*	Mixed Species Closed-Forest (Monsoon Vine Thicket)
53*	*Melaleuca* Forest (Paperbark Swamp)

Note: * indicates those vegetation units not mapped in Figure 2.11 due to scale.

Source: Specht 1958; Wilson *et al*. 1990; Yunupingu *et al.* 1995; Brock 2001.

Based on changes in the structure of the environment and climatic conditions through time, the organisation and distribution of the majority of the vegetation communities in the area would have been quite different in the past compared with the present. It is possible that there may have been only minor variation in the distribution of the *Eucalypt* dominated woodland communities in the area (Units 4 and 7) through time. Those vegetation units that would have been most affected by processes of landscape alteration and climatic variability include the seasonal floodplain communities (Unit 54), paperbark swamps (Unit 53), the mangrove forests (Unit 105), coastal dune complex (Unit 102) and the samphire dominated saline tidal flats (Unit 106). These areas have been highlighted due to their susceptibility to environmental change, as

well as many of these vegetation units being a fairly recent occurrence based on patterns of late Holocene landscape change. The significance of changes in the availability and distribution of these vegetation units relates to their contemporary importance as key seasonal habitats for a number of resources. Changes in the structure of habitat areas through time directly affect the structure of the resource base, a point which is particularly important for a peninsula, where many resources are located within or bordering the margins.

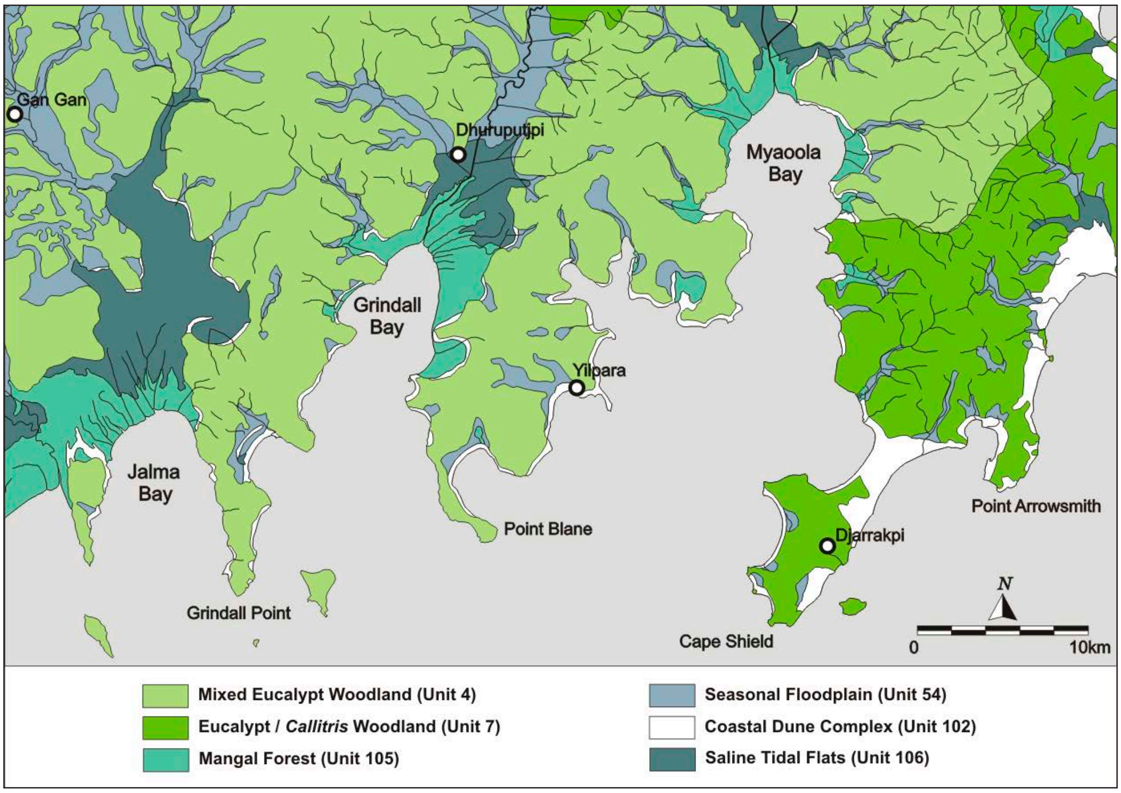

Figure 2.17: The distribution of the main vegetation regimes in the Point Blane Peninsula study area and neighbouring areas.

Source: Based on Wilson *et al.* 1990.

Fauna

A large number of faunal species were observed during the course of the fieldwork. Although little research has been conducted on the fauna in this area, detailed lists of molluscs, fish, reptiles and amphibians, birds, and mammals recorded in Arnhem Land during the 1948 American-Australian Scientific Expedition to Arnhem Land can be found in Specht (1964), with references to the mammals of the area recorded by Donald Thomson between 1935 and 1943 found in Dixon and Huxley (1985:18–174). Recent work by Barber (2002) and personal observation have also contributed to the faunal list. A large number of mammals can be found throughout the sub-coastal lowlands, floodplains and coastal woodlands, including the *Macropus robustus* (Common Wallaroo), *Macropus antilopinus* (Antilopine Wallaroo), *Macropus agilis* (Agile Wallaby), *Petrogale brachyotis* (Short-eared Rock Wallaby), *Petaurus breviceps ariel* (Northern Territory Sugar Glider), *Trichosurus arnhemensis* (Northern Brushtail Possum), *Isoodon macrourus* (Northern Brown Bandicoot) and *Rhinilophus megaphyllus* (the Eastern Horseshoe Bat). Other mammal species which may occur, albeit in low number, include the *Melomys burtoni* (Grassland Melomys), *Pseudomys delicatulus* (Delicate Mouse), *Conilurus penicillatus* (Brush-Tailed Tree-Rat), *Mesembriomys gouldii* (Black-Footed Tree-Rat), *Rattus colletti* (Dusky Rat), *Sminthopsis virginae* (Red-Cheeked Dunnart), *Dasyurus hallucatus* (Northern Quoll), *Antechinus bellus* (Fawn

Antechinus), and *Tachyglossus aculeatus* (Short-Beaked Echidna). Water Buffalo (*Bubalus bubalis*), *Sus scrofa* (Feral Pigs), *Felis catus* (Feral Cats) and *Canis lupus dingo* (Dingoes) are also widespread across the study area, with the two former species building in numbers nearer to permanent and ephemeral water sources, causing a high degree of environmental damage.

Marine and freshwater fauna are extensively exploited within the study area. *Dugong dugon* (Dugong) occurs in limited numbers, grazing on the sea-grass beds. *Scylla serrata* (Mud Crabs) and *Thalassina anomola* (Mud Lobsters) are frequently caught around mangrove stands. Varieties of mollusc species are harvested, including Oysters (*Saccostrea* sp.), mangrove gastropods (*Telescopium telescopium* and *Terebralia* spp.) and the larger near-shore marine bivalves (notably *Anadara antiquata*, *Polymesoda (Geloina) coaxans*, and *Isognomon* species). Fish are an important component of the present-day diet, and species present include *Lates calcarifer* (Barramundi), *Scleropages leichardti* (Saratoga), several *Epinephelius* species (Cod) and a variety of Wrasse spp. Freshwater mussels are also gathered from the billabongs of the major river systems. Reptiles occurring within the study area include the *Crocodylus porosus* (Saltwater Crocodile), *Crocodylus johnstoni* (Freshwater Crocodile), *Varanus* species (Goanna), *Scincidae* species (Skinks), *Varanus indicus* (Mangrove Monitor), and various Marine Turtle species, Freshwater Tortoises, *Acrochordus* species (File Snakes), *Demansia* species (Whip Snakes) and Brown Snakes. Bird species occurring on the coasts and wetlands include *Anseronas semipalmata* (Magpie Geese), *Grus rubicunda* (Brolga), *Ephippiorhychus asiaticus* (Jabiru) and *Dromaius novaehollandiae* (Emu).

The seasonal availability of resources and seasonal mobility

As previously noted, present-day seasonal variations in the climate and structure of the physical environment have an impact on the seasonal range and distribution of resources found within the region. The structure of the economy in the recent past was therefore organised around the current climate and configuration of particular habitats. Based on this, early ethnographers working in northeast Arnhem Land, and across northern Australia, have generally characterised the economic structure as being a yearly round based on the seasonal availability of resources (e.g. Thomson 1939, 1949:16; McCarthy and McArthur 1960; Warner 1969:4). Referred to by Warner (1969:127–8) as a fission/fusion type of social organisation, in addition to differences in the exploitation of resources, group movements and group sizes were also regulated by the seasonal cycle. The ethnographic and historical records indicate that there were significant differences in dry and wet season resource exploitation. For example, as the dry season advanced and the grass dried, systematic burning of the landscape occurred, during which kangaroo, wallaby, goanna and snakes were hunted (McArthur 1960:113). By the time the burning of the grass had been completed, another phase in the cycle was reached, where groups of people followed the drying watercourses, exploiting fish, tortoises and snakes (Thomson 1949:17–9). The main food supply, except at restricted seasons of the year, was vegetable rather than animal, particularly *Cycas media* (Cycad), the Tall Spike Rush corm (particularly in coastal areas), several species of yam, taro and water lilies (Thomson 1949:21, 1983:103–5). Inland groups utilised Cycads (after processing to remove the poison) during the dry season, while in coastal areas the corms of the Tall Spike Rush (*Heliocharis sphacelata*), or rakai, formed the staple food. The rakai was important during the dry season, particularly in those areas subjected to periodic flooding with brackish water (Thomson 1949:15, 19–20, 1983:103–5).

The dry season appears to have provided two distinct possibilities: people could spread out into small family groups to exploit seasonally available, diversely spread resources; alternatively, large groups could come together for ceremonies, or to exploit a particularly abundant resource. As water levels fell in rivers and billabongs during the early dry season, people may have moved inland. Later in the year, when the swamps and wetland dried out, water chestnuts and cycads provided an abundant staple vegetable resource (Thomson 1949:19–20; Warner 1969:128; H. Morphy 1983:103–5, 2004:142). Freshwater swamps proved to be focal points, as they are immensely rich in terms of the density of resources during the mid to late dry season, but for much of the rest of the year they are inaccessible and inhospitable (Warner 1969:18; H. Morphy 2004:63). While the ethnographic record indicates that the main food supply, except at restricted seasons of the year, was vegetable rather than animal (Thomson 1949:21, 1983:103–5), during the wet season the estuarine reaches, tidal arms and flood plains yield large quantities of food, mostly fish, with shellfish collected in quantity from the mangrove zone (Thomson 1949:15, 19–20, 1983:103–5). During most wet seasons, large areas of eastern Arnhem Land become inaccessible due to flooding, and as a result, the wet season exerts a major influence on the seasonal mobility. At that time of year, people traditionally had to base themselves at semi-permanent, well-resourced camping places, often on the coastal margins. In addition to this, group size tended to be small due to the dispersal of the population into geographically restricted areas (Thomson 1949:16; Warner 1969:127; H. Morphy 2004:141).

It has been noted by a number of researchers that shellfish were primarily a wet season resource, as the wet season was a time of limited mobility and limited resource availability, with populations concentrating on the high sand ridges in the coastal zone (Bailey 1977; Cribb 1996:155; Meehan 1983; Peterson 1973). Cribb (1996:169) has characterised coastal wet season occupation, stating that wet season settlement was not continuous in any one campsite but rather moved up and down the coastline from one campsite to the next, with most campsites being unoccupied at any one time. Seasonal movements were therefore made in response to resource depletion, as well as conflict situations and ceremonial obligations. This interpretation of strictly seasonal shellfish use depends on a number of variables, such as the structure of the environment relating to species availability and habitat distribution, and the degree of regional inter- and intra-seasonal population mobility. An example of this is the contemporary pattern of seasonal resource exploitation that has been highlighted by Barber (2002:24–5). The residents of the Yilpara community maintain a stable presence in the coastal areas surrounding their outstation throughout the year, with the main variation in seasonal resource exploitation being the increased use of freshwater fish from billabongs and a reduced use of birds on the floodplains during the dry season (Barber 2002:25). This data is detailed in Table 2.3 and presented graphically in Figure 2.18. Another example is Meehan's (1983:3–5) study on the Blyth River region, related specifically to shellfish exploitation. This research highlighted that there was significant day-to-day, and seasonal, variation in the number of shellfish species collected and in the utilisation of specific habitats. During the late dry season (August to October), the inland shell beds lying in the mangroves and the bivalve species *Batissa violacea* were exploited. During the wet season (January to April), the sandy intertidal zones and the bivalve species *Marcia hiantina* were targeted (Meehan 1983:5). Much of this variation related to issues of specific shellfish species biology and ecology.

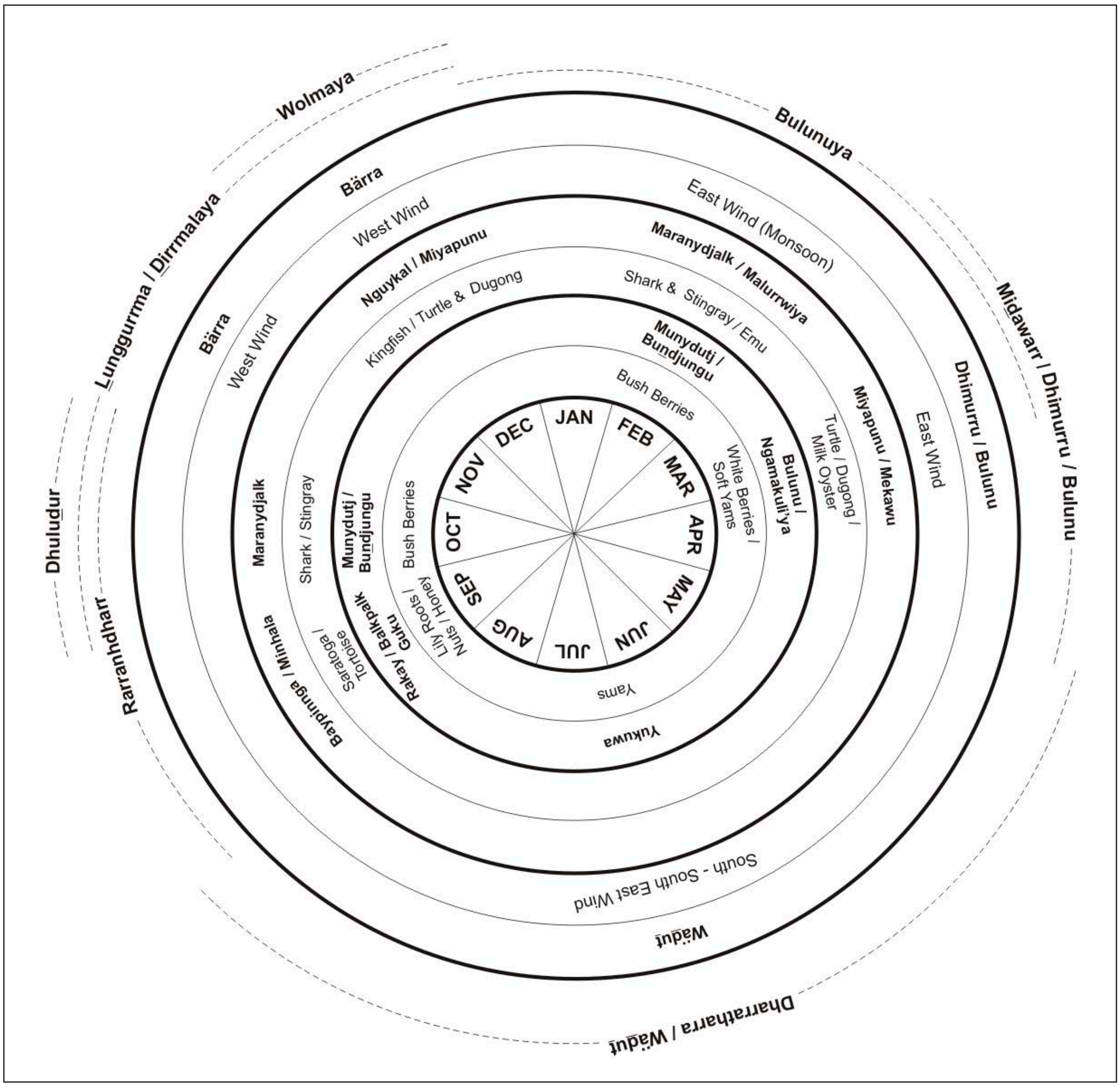

Figure 2.18: Diagrammatic representation of Yolngu seasonal calendar, northeast Arnhem Land from the data gathered by Marcus Barber contained in Table 2.3 (based on a similar diagram by Davis 1984 for a different area of Arnhem Land). The outermost ring represents the Yolngu name of the season, the next ring the name of the predominant wind of that season, and the inner rings are important resources available during that period. Yolngu words in bold are translated in the ring immediately below them.

Source: Barber 2005:90.

Table 2.3: Seasonal calendar from the Yolngu of Blue Mud Bay, northeast Arnhem Land. This table has been collated from information collected by Barber (2002) through direct observation and conversations with Djambawa Marawili and Ngulpurr Marawili.

Season	Wind	Description	Indicators	Food Available
Dhuludur (October)		The first rains come, and there is distant thunder and lightning	Bush berries (**munydutj** and *bundjungu*) are ready, indicating that the parrotfish is also becoming fat. Flowering plants signify that the livers of the shark and stingray (**maranydjalk**) are ready. These include the red flowering Kurrajong (**balwurr**), white sand lily (**wärrkarr**), and a creeper (wuluymung).	Bush berries (**munydutj** and **bundjungu**) Parrotfish Shark and stingray (**maranydjalk**)
Lunggurrma / Dirrmalaya (October – December)	**Bärra** – west wind (Dhuwa moiety)	The seas are calm and there is some new growth from the first rains, brought by **bärra**, the west wind.		
Wolmaya (December)	**Bärra** – west wind (Dhuwa moiety)	Lightning becomes much more prevalent, particularly in the evening after the afternoon clouds have built up. At first the lightning is silent, and the thunder is heard after a few weeks. This is kingfish (**nguykal**) season.	The weather is hot and the mosquitoes come out.	Kingfish (**nguykal**)
Bulunuya (January – March)	East wind (monsoon)	High wind season, and high tides during the full moon. There is lush growth from the rains, but the bush foods are not yet ready.	Yellow flowers show that the freshwater saratoga (**baypinnga**) are carrying eggs. Black berries appear on a palm tree at this time, signifying that the emus are fat. White flowers on the paperbark also signify this time. There are still some bush fruit of the early wet (**munydutj**) to be found, as well as other bush fruits such as **bundjungu**.	Saratoga - carrying eggs (**baypinnga**) Emu Bush fruit of the early wet (**munydutj**) Other bush fruits (**bundjungu**)
Midawarr / Dhimurru / Bulunu (March – April)	**Dhimurru/Bulunu** – east wind (Dhuwa moiety)	The season just after the wet when bush foods are ripe, animals are fat, seafood is plentiful, and the wind blows more softly from the east (**dhimurru**). It is a good time to hunt turtle and dugong.	The wattle tree flower that grows at this time tells Yolngu that it is the right time for milk oysters (**mekawu**), seagull eggs, and turtle eggs. The wind **dhimurru/bulunu** is associated with white berries called **bulunu** and sometimes the rains come when they are ripe.	Turtle, dugong milk oysters (**mekawu**) seagull eggs and turtle eggs. White berries (**bulunu**) soft yams (**ngamakuli'ya**)

Table 2.3 (continued): Seasonal calendar from the Yolngu of Blue Mud Bay, northeast Arnhem Land. This table has been collated from information collected by Barber (2002) through direct observation and conversations with Djambawa Marawili and Ngulpurr Marawili.

Season	Wind	Description	Indicators	Food Available
Dharratharra / Wädut (May – August)	**Wädut** - south south-east	Cold weather and rough seas with plenty of yams and bush food. **Wädut** is the name of the strong wind in this season, which flattens the grass, and the morning is sometimes foggy, caused by the bushfires lit in the dry grass. It is the time when all of the animals go into their holes, and Yolngu set bushfires (**worrk**) to burn off the undergrowth, making the holes easier to locate		Yams and bush food
Rarranhdharr (September – October)		The late dry season when it is hot, freshwater is becoming scarce, and some bush animals are getting thin. In the past, coastal Yolngu tended to head inland during this season, and built fish traps (**buyku'**) across the narrow creeks, taking advantage of the low water flow.	The stringybark blossoms signal wild honey, geese, **balkpalk** nuts, and an orange-red flowered bush with a nut inside (**dharranggulk**) are ready.	Freshwater fish and tortoises. Lily roots (**räkay**) and freshwater tortoises (**minhala**) can be found in the drying up mud. Magpie geese Wild honey, **balkpalk** nuts, and the orange-red flowered bush with a nut inside (**dharranggulk**) are ready.

Source: Barber 2002.

These patterns of seasonal resource availability and exploitation are a product of the contemporary climate, environmental structure and distribution of habitats. Based on the level of climatic and environmental variability noted within the region, there are a number of implications for the structure of the economy through time, particularly the structure of seasonal resource availability and exploitation. In fact, based on the data presented above, the patterns of resource availability and associated economic activity observed ethnographically may, at the most, relate only to the last 500 years. This hypothesis is particularly supported by the seasonal emphasis on those faunal and floral resources exploited from the freshwater wetlands. In effect, this knowledge system may only have emerged within the last 500 years with the disappearance of extensive sand and mud flats and the further development of the present extensive wetland systems via progradation. The implication of this is that the contemporary or historically recorded patterns of seasonal resource exploitation should not be automatically used to interpret the archaeological record from earlier time periods.

Implications of climatic/environmental change for human economic behaviour

Outlining the scale of environmental and climatic changes during the mid-to-late Holocene indicates that dramatic differences have occurred to the structure of the coastline itself, and in

the distribution of the faunal and floral communities that comprised the resource base relative to the pattern detailed for the present. The extent of these changes has a number of temporal and spatial implications for human foraging economies during this time. In particular, it can be seen that analogies for mid-to-late Holocene resource exploitation derived from early ethnographic observations of economic activity during the recent past in northern Australia are problematic. The availability and abundance of key resources in coastal areas were tied to changes in the climate and of shoreline characteristics throughout the Holocene. Although it is possible that the coastal zone could support a permanent population base, seasonal factors, such as the availability and distribution of resources and high water levels, were limiting factors during the recent past (Peterson 1973; Bailey 1977; Cribb 1996:155). The interpretation of strictly seasonal resource use depends on a number of variables, such as the structure of the environment relating to species availability and habitat distribution, and the degree of regional inter- and intra-seasonal population mobility. Within the type of economic structure emphasised via ethnographic research, movements and group sizes were regulated by seasonal variations in the current climate and structure of the physical environment, and in turn, the seasonal range and distribution of resources (McArthur 1960:113; Warner 1969:127–8; Meehan 1983:3–5). When the degree of landscape and climatic changes occurring throughout the Holocene, and, by extension, variability in the distribution and abundance of key resources, are also taken into account, it is clear that it is inappropriate to project the historically observed model of mobility and resource exploitation onto the mid-to-late Holocene. Instead, it suggests that the structure of the economy during the mid-to-late Holocene was probably quite unlike that recorded ethnographically. Potentially, it could have supported a range of different group sizes and exploitation strategies, particularly as the timing and nature of sea level rise and regression, progradation and climatic shifts would ultimately have created differences in foraging behaviour across the study area.

For instance, the differential spatial and temporal distribution of resources relative to these physical aspects could potentially have lead to differences in the exploitation of some areas. This in turn would have affected levels of mobility and the types of activities carried out in different locations. These patterns may be reflected archaeologically in a number of ways. The intensity of use and the differential distribution of activities across the study area may be measured in terms of the number, density and morphology of sites relative to a number of landscape features. These features include possible changes to the coastline itself, as well as faunal resources, freshwater and stone outcrops. Water is generally viewed as one of the most important variables in the use of tropical areas, and occupation could be expected to concentrate around water sources. Tracking changes in faunal and floral communities is more difficult, largely due to the scale of physical landscape changes over time, however, changes in the distribution and abundance of various faunal resources could be established by identifying trends in species richness throughout the sites themselves. The distribution and availability of suitable stone sources should leave distinguishable evidence in the form of stone procurement, artefact manufacture and transportation. There is also the possibility in an area of low stone availability, like the Point Blane Peninsula, that provisioning from other sources may also have occurred. Based on the data provided here, the nature and timing of the climatic and landscape changes of the mid-to-late Holocene may have had a direct impact on the pattern of occupation and resource utilisation within the study area (contra Barker 1996, 2004). The types of resources and their distribution and density within the landscape were all potentially affected by the palaeoenvironmental processes previously discussed. This in turn would have affected how people distributed themselves across the landscape, and the kind of activities carried out in different locations.