THE UNIVERSITY OF QUEENSLAND
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# Archaeological Expressions of Holocene Cultural and Environmental Change in Coastal Southeast Queensland

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# Abstract

This thesis is concerned with the relationship between Holocene environmental changes and human behaviour in coastal southeast Queensland. The study region covers an area stretching from Fraser Island in the north to the border of northern New South Wales in the south, and possesses the best documented and intensively scrutinised coastal archaeological record in Australia. The archaeology of the area was a major focus from the late 1970s when the Moreton Regional Archaeological Project, a long-term multi-stage regional project, was established to coordinate archaeological investigations in southeast Queensland. The Cooloola Region Archaeological Project was established in the mid-1980s to explore the archaeology north of the Noosa River. These initial studies provided the basis for a regional chronology, as well as models of settlement and subsistence based on the exploitation of the area's rich marine resources.

In the time since the original work was conducted the research foci for coastal archaeology, both in Australia and internationally, have moved toward more complex issues such as assessing the impact of humans on marine ecosystems, the identification of patterns in resource exploitation strategies, and the use of molluscs as proxy evidence in local and regional environmental reconstructions. Additionally, regionally-specific models of Holocene environmental change have been developed, in line with greater emphasis being placed on the ecology and biology of the constituent species in middens in addressing questions of spatial and chronological variations in site patterning.

In view of these developments, midden deposits from five sites from differing locations in southeast Queensland were re-analysed, and a literature review of two further sites was also undertaken, with the aim of assessing human behavioural variability during the mid to late Holocene through the identification of chronological and spatial trends in resource exploitation and site location, in the context of recent regional palaeoenvironmental reconstructions. While some constants have been identified, the findings indicate considerable variability in site characteristics across the region, strongly influenced by local environmental factors. Implications for previous models of long-term cultural change have been identified, and an historical ecology-based model of occupation presented. The chronology and nature of occupation in the region has been refined.

## Declaration by author

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## Publications during candidature

No publications

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No publications included.

## Contributions by others to the thesis

No contributions by others.

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None.

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archaeology, coastal archaeology, southeast Queensland, historical ecology, archaeomalacology, Aboriginal, subsistence, settlement

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# 1. Introduction

The coastal southeast Queensland archaeological region stretches from Fraser Island in the north to the border of northern New South Wales in the south (Mulvaney and Kamminga 1999; McNiven 2006; Morwood 1987; Ulm and Hall 1996). It possesses the best documented and intensively scrutinised coastal archaeological records in Australia (McNiven 2006:120; Ulm 2002:79; Figure 1-1), with approximately 2000 midden sites recorded. Estimates of dated sites vary: Robins *et al*. (2015) cited 43 dated sites, whereas Ulm and Hall (1996) indicated the number to be 58. The archaeology of the area, particularly the Moreton Region, became a major focus from the late 1970s when Dr H.J. 'Jay' Hall of the University of Queensland (UQ) established the Moreton Region Archaeological Project (MRAP), a long-term multi-stage regional project to coordinate archaeological investigations in southeast Queensland (Hall 1980a:79-83; see also Hall and Hiscock 1988a, 1988b, 1988c). Ian McNiven, one of Hall's students, later established the Cooloola Region Archaeological Project (CRAP) (McNiven 1984; 1985; 1990a) in the area north of the Noosa River. Hundreds of sites were recorded in that time, although relatively few have been excavated (even fewer have basal and termination dates), and a regional chronology as well as models of human occupation have been posited (e.g. Hall 1999; McNiven 1999; Morwood 1987; Walters 1989). However, with the exception of Ulm's (2006) work further to the north on the Curtis Coast, systematic research in the area has been stalled for almost 20 years. It is time to revisit the region's archaeology in the context of changing research foci, emerging theoretical frameworks, and recent research on palaeoenvironmental reconstructions and climate variability during the Holocene.

## *Changing perspectives in Australian coastal research*

Since the original research in coastal southeast Queensland was undertaken in the 1980s and early 1990s, there have been a number of developments, both in Australia and internationally, in methodological frameworks and research foci. Most particularly, there has been increasing interest in human behavioural-environmental relationships, the use of molluscs as proxies in environmental reconstructions, and the impacts of humans on marine ecosystems (e.g. Campbell 2008; Erlandson and Rick 2008; Faulkner 2009, 2013; Giovas *et al*. 2010; Giovas *et al*. 2013; Haberle and David 2004; Jerardino 1997; Jerardino *et al*. 2008; Mannino and Thomas 2002; Milner 2013). There is also a greater emphasis on the ecology and biology of the species found in archaeological contexts (Erlandson *et al*. 2008; Giovas *et al*. 2010; Giovas *et al*. 2013; Giovas *et al*. 2016; Thakar 2011; Thakar *et al*. 2015; Whitaker 2008). More refined and more regionally-specific palaeoclimatic data have become available. These changing perspectives are able to better inform ongoing debates on questions of the timing and nature of coastal occupation, the importance of molluscs in coastal foraging economies, and the uncritical application of ethnographic analogy to sites increasingly characterised by economic and social variability (Faulkner 2009, 2013; Hiscock 1999).

Current and recent coastal studies in Australia have a strong bias toward northern Australia. They include Faulkner's (2009, 2010, 2011, 2013) study of shell mounds in Blue Mud Bay (northeast Arnhem Land), where patterns of human behaviour and environmental variability were linked through, among other things, the detailed analysis of the mudflat bivalve *Tegillarca granosa* (formerly *Anadara granosa*). Research in the Torres Strait includes the nature and timing of the occupation of so-called non-viable reef islands spread out over some 700km of seascape (McNiven 2015), as well as considerations of marine specialisation (McNiven *et al*. 2015), and marine material culture (McNiven 2015). Palaeoenvironmental reconstructions and issues of late Holocene environmental change in the region are also a focus for interdisciplinary groups of researchers (e.g. Rowe 2014; Rowe *et al*. 2013), as well as in the Gulf of Carpentaria (Moss *et al*. 2015), and at Weipa (Stevenson *et al*. 2015). Earlier studies tended to more closely reflect individual research biases, with either little acknowledgement of environmental influences (e.g. Barker, 1996, 1999, 2004), or an over-reliance on them (e.g. Beaton 1985). The early coastal studies in southeast Queensland, with the exception of McNiven's systemic approach (e.g. 1990a, 1991b, 1991c, 1992a), were strongly influenced by processualism (e.g. Hall 1984), or by ethnohistorical observations in deriving models of social complexity (Morwood 1986, 1987).

## *Thesis Research Aims*

The regional chronology for coastal southeast Queensland as it currently stands is essentially a Holocene record. The Holocene is traditionally considered to have been climatically stable, with the marine transgression following the end of the Last Glacial Maximum its major defining feature. In recent years there has been a growing body of work (e.g. Allen *et al.* 1996; A. Anderson *et al.* 2007; D. Anderson *et al*. 2007: 5-7; Chappell and Grove 2000; Meggers 2007; Shulmeister 1992, 1999; Shulmeister and Lees 1999; Voorhies and Metcalfe 2007) indicating that the Holocene was (and is) a period of greater climatic variability than previously believed. For example, an increase in moderate to strong ENSO events over the past 5000 years (A. Anderson *et al.* 2007) roughly correlates with increased use and occupation of coastal sites worldwide. Certainly in some of the models outlined in Chapter 2 (McNiven 1999, 2006 being the exception) there is a tendency to principally, although not solely, relate changing patterns of occupation in coastal southeast

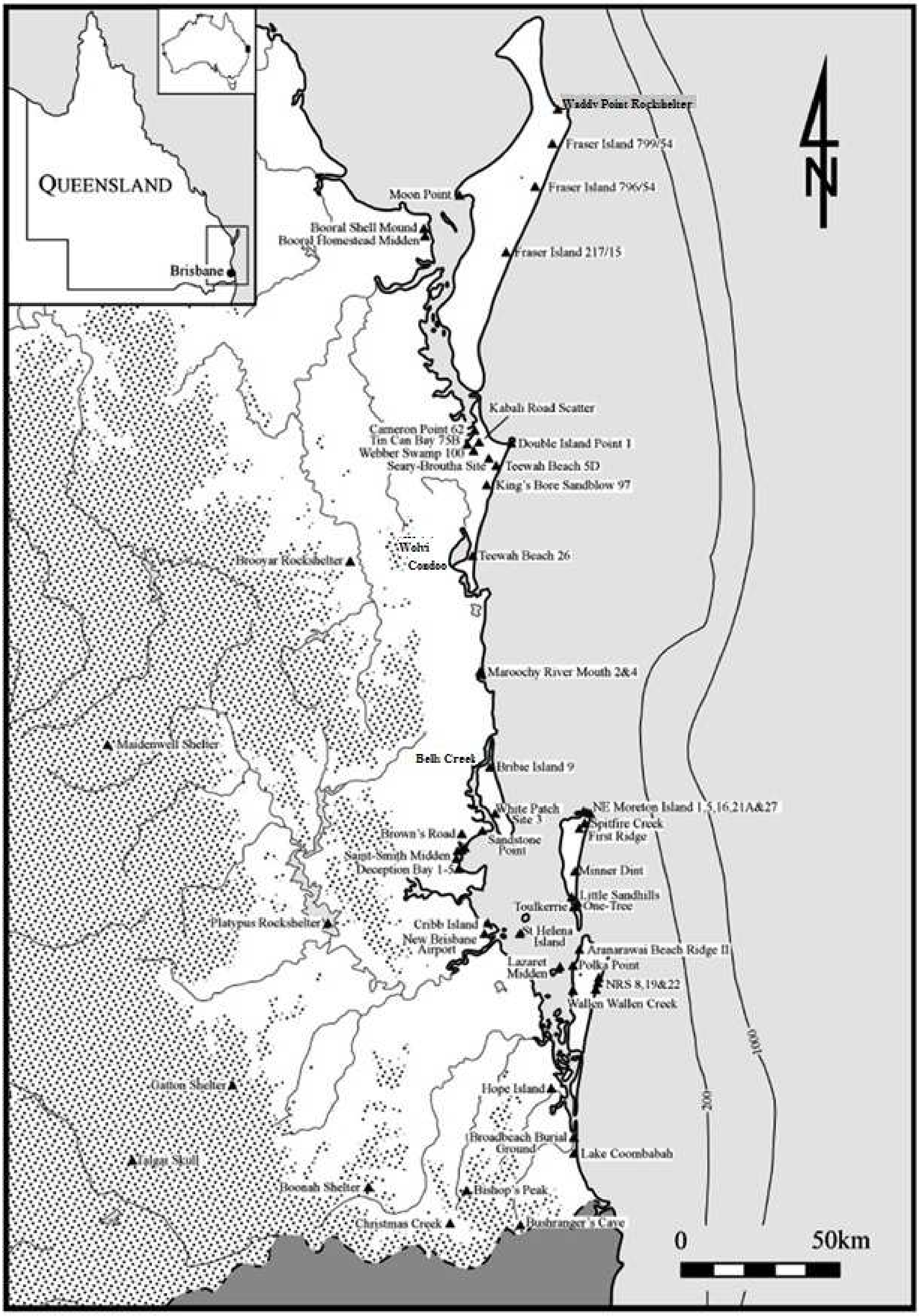

Figure 1-1 The coastal southeast Queensland region showing dated sites (after Ulm 2002).

Queensland to the progradation of mudflats and the development of rich littoral resource bases following sea level stabilisation. But is it really that simple?

The overarching question this thesis seeks to answer is whether there is evidence of a relationship between Aboriginal behaviour and mid to late Holocene environmental change in coastal southeast Queensland. From a general conceptual perspective:

- Is there archaeological evidence of Holocene environmental change?
- Can human behavioural change be identified?
- What factors influenced patterns of human behaviour?
- Is there evidence of over-exploitation or resource depression related to intensification of exploitation of marine resources?

In exploring the influences on patterns of occupation and resource use in coastal southeast Queensland, where a dramatic rise in the establishment of sites over the last 1000 years is well documented, the following sub-questions are posed:

- Is there evidence of marine resource intensification, with the inclusion of more marginal resources?
- Is there evidence of increased exploitation pressure on local molluscan populations, suggesting an increase in population size and shifting mobility?
- Are there changes from a curated to a more expedient stone technology?
- Are there increases in the use of local stone?

In order to address these questions, the assemblages from five sites, Booral Shell Mound, Tin Can Bay 75b, Cameron Point Site 62, White Patch 3, and Bribie Island 9 were re-analysed. The data from two other published sites, Hope Island and St. Helena Island, were subject to literature review. These seven sites were selected because of their multi-specific molluscan components, and covered the period from c5000 years ago until the recent past. Additionally the sites add a spatial component to the analysis as they are from different parts of the study area and reflect differing environments.

The theoretical approach taken in this thesis to address these issues is an environmental framework based on historical ecology (e.g. Braje *et al.* 2007; Crumley 1994; Erlandson and Colten 1991; Erlandson and Glassow 1997; Erlandson *et al.* 1998, 2004, 2005, 2008; Fitzpatrick and Erlandson 2009; Rick *et al.* 2001, 2005). Historical ecology is an approach that has implicitly been used in Australia by researchers such as Faulkner (2006, 2008, 2010, 2013), Rowland and Ulm (2010), and Ulm (2006). One of its major strengths lies in demonstrating the broader significance of archaeological research to studies of conservation ecology and biology, and cultural and environmental management, as it provides a particularly long-term, historical dataset for the evaluation of human-environmental interactions and the structure of past ecosystems and landscapes. Historically, coastal studies in Queensland have concentrated on behavioural responses to marine transgression and subsequent regression (Barker 1991, 2004; Hall 1982; 1999; Hall and Hiscock 1988a; Hall and Lilley 1987; Hall and Robins 1984; Nolan 1986; Walters *et al.* 1987), although Hall (1999:180) commented that such work "needs to be augmented ... In short a regionally specific environmental history is sorely needed". This research provides the vehicle to begin to develop that environmental history.

The utility of historical ecology in addressing global issues in coastal archaeology has been demonstrated by, for example, Jerardino (1997) and Jerardino *et al.* (2008) in explicating the deep archaeological record of the South African coast. Milner *et al.* (2007) and Milner (2013) also used a similar approach to identify human impacts on molluscan deposits in Orkney and Denmark, in the differing contexts of Viking-age Europe, and the Mesolithic-Neolithic transition. The Californian Channels Islands have been the focus of long-term studies (e.g. Braje 2007; Braje and Erlandson 2009; Braje *et al.* 2011; Erlandson *et al.* 1999, 2008; Rick *et al.* 2008; Rick *et al.* 2001) which encompass not only molluscan studies, but those of marine and terrestrial mammals, and human, faunal and environmental relationship to illustrate the changing nature of occupation over a period of 10000 years. As Thompson (2013:6-7) points out, historical ecology is an approach that lends itself to the study of small-scale economies (i.e. those who rely on hunting, gathering, fishing or low level agriculture). This makes it an ideal basis from which to approach the archaeological record of coastal Australia, and in this particular instance, a re-examination of the rich coastal archaeology of southeast Queensland. As such, it provides the vehicle for the current research to be relevant to global discussions of Holocene human behavioural and environmental relationships.

## *Thesis organisation*

Chapter Two provides the regionally-specific context of the research with an ethnohistorical overview of Aboriginal occupation and use of sites during the 19th century, and a review of key previous archaeological studies of southeast Queensland. A regional environmental history, including sea level changes, geomorphology, and in particular a comprehensive review of the palaeoenvironmental reconstructions based on pollen cores from Fraser Island, the Cooloola Sandmass, and North Stradbroke Island is presented in Chapter Three. Chapter Four details the methods employed in the re-analysis of the selected sites. Chapters Five to Eight present and discuss the results of the morphometric and statistical analyses. Chapter Nine draws together the palaeoenvironmental reconstructions, and the site-specific discussions. Explanations for the human behaviour/cultural change and environmental changes evidenced in the coastal southeast Queensland archaeological record are advanced, and the implications for previous models of occupation and use evaluated.

# 2. The Archaeology of Coastal Southeast Queensland

## Introduction

This chapter provides the regionally-specific context for the research questions and aims presented in Chapter One. The chapter is organised into three sections. The first section provides an ethnohistorical overview of the subsistence and settlement practices, as well as the socio-cultural networks, of the Aboriginal inhabitants of the southeast Queensland coastal region as recorded by 19th century European observers. These offer a point of comparison with the patterns of site location and cultural discard observed archaeologically developed in the final chapter. The second section reviews previous archaeological research in the study area, with a particular focus on studies from dated sites whose faunal assemblages have been reported. This review provides the chronological and spatial background to the thesis research. For consistency's sake the radiocarbon dates in the review are the median calibrated dates presented in Ulm and Reid (2000). The third section introduces models of long-term cultural change for the region, which are revisited in the final chapter.

## Ethnohistorical observations in the study region

### Subsistence and settlement

The mostly 19th century ethnohistorical observations of Aboriginal lifeways in the study region, particularly Moreton Bay, indicate that the subsistence economy had a strong marine focus, and that settlement was relatively sedentary (Hall 1982). The explorer Matthew Flinders visited Bribie Island on 16 July 1799 and noted 'natives with fishing nets over their shoulders' (in Steele 1972:23). In the vicinity of White Patch (Figure 1-1) he also observed:

> - five or six huts, from twelve to fifteen feet in length, ... standing near each other. They resembled a covered arch-way, rounded at the far end...the sides and roof were equally calculated to shelter the inhabitants from a storm. In one of them was found a small and very light shield, and in another an old net, which had a bag to it, and was knotted and made in the same way as it would have been if made by a European Seine maker. It appeared to be intended for a scoop-net (in Steele 1972:17-18).

Uniacke (1823, in Mackaness 1979:29) noted that the Bribie Islanders depended "principally on fish for their support", and had several huts three to four miles apart, moving between them as fish became scarce. He described the huts as spacious and commodious, and with room for ten to twelve people. Similar villages were described for North Stradbroke Island (Backhouse 1843 in Hall 1982). At Cooloola, Aboriginal camps were recorded at Lake Cooroibah, the northern end of Lake Cootharaba, Tin Can Bay, and Inskip Point (McNiven 1992c:13-14).

Uniacke commented that on journeys the women were required to carry heavy burdens, "including a large quantity of fern-root, which forms part of their daily food" (Uniacke 1823 in Mackaness 1979:29). Eipper (1841:10), after a visit to Toorbul on the mainland opposite Bribie Island, commented that "the women's time is also entirely taken up in digging roots and gathering oysters". Eipper also observed the women building a fire into which all the oysters were placed to both clean them and cook them. Bingle visited Bribie Island in 1822 in the *Sally*, anchoring in Pumicestone Passage, and noted that while there the local Aboriginal people "brought me fish in abundance, enough for myself and the ship's crew" (in Steele 1972:46).

Petrie (1904) offers a number of observations both on the resources used as food, as well as the methods of preparing them. He comments (1904:74-75) that although oysters could be eaten raw, the preference was for them to be roasted. The same cooking method was used for other shellfish, including periwinkles, mussels, freshwater mussels, 'yugari', and crabs. Fish were caught in large quantities using nets, traps, or spears, depending on the species. They were scaled using *Donax* spp. shell before being cooked whole over coals. Dugong were netted or speared, and were prepared at the place where they were brought ashore. A fire would be built, the dugong rolled onto it, and then more coals would be laid over the top. When the animal was half-cooked it was butchered, with the head and tail removed, and the back sliced down the middle to remove the flesh and fat in large flakes (Petrie 1904:68). Turtles were also processed where they brought to shore, cooked upside-down over a fire after the head and flippers were removed (Petrie 1904). Petrie (1904) also lists koalas, kangaroos and other macropods, possums, and reptiles as foods. Birds exploited included ducks, swans, emus, parrots, and scrub turkeys. Their eggs were also consumed. An extensive suite of plant foods is also recorded, including the root of *Blechnum* spp. ('bungwall') which was a staple, "roasted, then scraped and cut up finely with sharp stones on a log, when it was ready to eat ... one would hear the chop-chop continually all over the place, as this food was prepared" (Petrie 1904:92). In addition to wild yams, various fruits and blossoms, and palm shoots, there were a number of plants (e.g. *Alocasia* and *Macrozamia*) requiring extensive preparation to remove their toxicity. The subsistence strategies employed at Cooloola are not as well documented (McNiven 1992c), but it is assumed here that they would have been at least broadly similar for those recorded for the Moreton Region.

**Socio-cultural networks**

An extensive socio-cultural network was reported for southeast Queensland (Mathew 1910; Meston 1895; Petrie 1904). In November 1823 Uniacke recorded the stories of the castaway convicts Pamphlett and Finnegan who had been living with various Aboriginal groups on North Stradbroke Island, Bribie Island, and the adjacent mainland for six months. During that time they visited the area around Noosa, and also travelled up the Brisbane River, suggesting that clans and tribal groups exercised a degree of mobility. Pamphlett and Finnegan also reported the use of the beach on the east coast of Bribie Island as route for travellers, with a crossing point to the mainland at the northernmost tip of the island; this was used by groups from Moreton and North Stradbroke Islands who used calm water routes (Petrie [1904:97-98] described canoes made from the bark of bastard mahogany trees. Large canoes approximately 20 feet in length could accommodate nine or ten people). The accounts of Graham, an escaped convict who lived in the Cooloola region in the 1830s, suggest seasonal movements inland to join neighbouring groups (McNiven 1992c:14). The triennial bunya or bonyi festivals in the Bunya Mountains and Blackall Ranges attracted groups from as far away as northern New South Wales, southwest Queensland, and the Burnett River region north of Cooloola (Meston 1895); Petrie (1904) commented that inland groups would travel to the coast afterwards. Petrie (1904:160) also recorded the presence of the "Northern" coastal tribes in Brisbane during a gathering of groups to witness a new corroboree from Ipswich, followed by a "fearful fight". These accounts indicate that while Aboriginal people in the coastal area practised some degree of residential sedentism, they were also socially and culturally mobile.

## *Early archaeological research*

Early observers (e.g. Young 1926; Jackson 1939, 1940) commented on the extensive shell middens and artefact scatters, particularly on North Stradbroke Island, and at Point Cartwright and the Mooloola River areas on the mainland. However, the extent of Aboriginal use of the coastal Moreton Region became apparent following Ponosov's (1965) extensive survey of southern Moreton Bay. The survey concentrated on the string of three large barrier islands, Moreton, North Stradbroke, and South Stradbroke, and the smaller, inner islands in the southern region of the Bay. He identified 79 midden sites on Moreton Island, 121 on North Stradbroke Island, and 28 on South Stradbroke Island, and observed that numbers of sites were relative to the size of the island and availability of resources – the larger the island, the greater number of sites. Ponosov collected all the stone artefacts he found, but observed that artefact numbers were low in comparison to the volume of shell in the sites. The exception was a very large artefact scatter near Cape Moreton where there were many shells that were patchily distributed and low in number compared to the "great quantity of stone implements and waste flakes" (1965:34-35). Emergency surveys were undertaken in 1975 by Mike Morwood of the Archaeology Branch in the then Department of Aboriginal and Islanders Advancement, when Moreton Island was threatened by proposed sand mining activities. Morwood recorded a further 193 sites, over 90% of which were shell middens (Hall 1982).

In 1973, Stockton (1974, 1979) undertook an extensive survey of both sides of Pumicestone Passage to complement Ponosov's (1965) survey of southern Moreton Bay. Prior to the survey sites were known to exist in only two localities in the area, Bell's Creek and Sandstone Point (Stockton 1979:97). Stockton located and recorded 76 sites, 69 of which were middens. Thirty of these middens were along the mid to northern west coast of Bribie Island. Three types of archaeological sites were identified: living sites (middens/camp sites), ceremonial or sacred sites (e.g. bora rings), and 'other' sites (e.g. scarred trees) (1974:27). *Anadara trapezia* (cockles), *Saccostrea* spp. (oysters), and *Pyrazus ebeninus* (whelks) were the predominant molluscan remains in the middens.

### Establishing chronologies and site characteristics

Wallen Wallen Creek (Figure 1-1), an open site reported by Neal and Stock (1986), is the oldest known in the southeast Queensland region, with an extensive suite of $^{14}$C ages reported. These cover the period from 20789 cal BP to 635 cal BP (Neal and Stock 1986; Ulm and Reid 2000:35). It features at least five stratigraphic units with occupation since at least the Last Glacial Maximum when the site would have been on the western slopes of a dune overlooking a broad river valley (Hall 1999:172; Neal and Stock 1986). Although stone material recorded in Unit 4 between 225 and 305cm in depth was weathered and exhibited none of the usual surface morphology of artefacts, it was likely to be artefactual as the three (unspecified) raw materials do not occur naturally on the island (Neal and Stock 1986:619-620). In Unit 3 (c170-225cm) "a number" of steep-edged scrapers were recovered, while in Units 1 and 2 (c0-170cm) there was little evidence of use-wear or retouch. Raw materials in Unit 3 were "high quality chert, silcrete and siliceous petrified wood ... progressively replaced by quartz, quartzite and silcrete in Unit 2, with the further addition of basalt, rhyolite, quartz conglomerate and sandstone in Unit 1" (Neal and Stock 1986:620). Neal and Stock (1986:620-621) state that the high-quality raw materials in the Pleistocene levels are absent from the Holocene levels. They suggest that this pattern is due to significant changes in raw material availability following either inundation of sources during the post-glacial marine transgression or post-Pleistocene changes in cultural or social systems leading to a decrease in exchange or transportation networks (Neal and Stock 1986:620). Subsequent studies (e.g. Smith 2003) have identified a broad suite of raw materials in Holocene sites in the Moreton Region, and the definition of "high quality" is subjective; the putative changes from exotic to local raw materials (e.g. sourced from Point Lookout on the island), and changes in technology may be responses to reduced risk in the availability and exploitation of resources (Hiscock 1994). Although cited as the oldest continuous cultural sequence in southeast Queensland (e.g. Hall 1999; Neal and Stock 1986), Neal (1989) considered the possibility of abandonment of the island between 4000 and 2000 BP due to the scant depositional evidence during that period. There is evidence that occupants of Wallen Wallen Creek during the Holocene moved from low-level exploitation of marine (*Dugong dugon*) and terrestrial resources (pademelon, *Thylogale* sp., and carpet python, *Morelia spilota*) to an exclusively marine economy based around fish and molluscs. Neal and Stock (1986:621) concluded that the site must have been a "a marginal environment throughout the Pleistocene and Holocene, and the limited extent of the archaeological remains suggest that this location was a temporary transit camp located on an access route between major resource zones located on the coast to the east and the river valley and mountains to the west" (although see Chapter 9 discussion of long-term models of occupation). There are questions over the site's dating sequence as there are anomalies in some of the $^{14}$C ages relative to depth. Neal and Stock (1986:620) attributed these to ground-water contamination. However, Gowlett *et al*. (1987:144) who performed Accelerated Mass Spectrometry (AMS) dating on six separate samples considered that most of this potential ground water contamination would be removed by standard laboratory pre-treatment, and that the site presented an unusual dating problem requiring further investigation. As such, the dating of the lower levels remains ambiguous.

The New Brisbane Airport Site (LB: C69, Figure 1-1) shows evidence of occupation from 5494 cal BP on what was a small spit of land extending into Moreton Bay during the Holocene high stand (Hall and Lilley 1987; Ulm and Reid 2000:28). The lowest identified stratum (SUIV) was a layer of beach cobbles, which also formed the raw materials for artefact manufacture. All of the knapped stone from the site in SUIV and the overlying SUIII, a consolidated layer of jarosite cementing the cultural material in place, are made on immediately available sources (Hall and Lilley 1987). The artefacts (flakes, flaked pieces, retouched flakes, cores, and flaking debris) reflect on-site manufacture. In SUIII (4277 cal BP, Ulm and Reid 2000:28) the artefacts are associated with highly fragmentary fish bones, reverse casts of *Anadara* spp. shells, and charcoal, suggesting that the occupants were exploiting marine and terrestrial resources in addition to stone (Hall 1999; Hall and Lilley 1987). Occupation continued following the progradation of the shoreline (Hall and Lilley 1987) when the spit turned into a low ridge after the deposition of alluvial sediments (SUII). These and the uppermost stratum showed evidence of disturbance, probably by ploughing and construction work, both for the post-contact farm and dairy which later occupied the site as well as the construction of haul roads for the new Brisbane Airport. Hall (1999:174) posited that the site represents 5500 years of “Aboriginal accommodation to a transforming coastal landscape” during the mid to late Holocene.

McNiven’s (1985, 1988, 1990a, 1990b, 1991a, 1991b, 1991c, 1992a, 1992b, 1992c, 1993) CRAP in the Great Sandy Region north of the Noosa River recorded 124 middens and artefact scatters at Teewah Beach, the Cooloola sandmass and swamp zone, and Tin Can Bay; a burial at Double Island Point; and a specialised terrestrially-based hunting camp in the hinterland at Brooyar Rockshelter (Figure 1-1). Excavations of 17 sites including the rockshelter revealed a chronology of occupation over a period of 5500 years. A shell mound and midden were also excavated by McNiven and Frankland (Frankland 1990) at Booral on the western side of the Great Sandy Strait (Figure 1-1). Spatial and chronological variations were noted for the sites. For example, the midden deposits at Teewah Beach 26 dating from 962 cal BP were dominated by *Donax deltoides* and some fish bone, and overlay earlier deposits of artefacts dating from 5533 cal BP that were not associated with faunal material. The Tin Can Bay sites contained estuarine molluscan species including *Saccostrea* spp., *Pyrazus ebeninus*, and *Isognomon* spp. Sites on the sandmass demonstrated both estuarine and oceanic species, although the former decreased in abundance with increasing distance from Tin Can Bay. Additionally, spatial variations in the dominant lithic raw materials of arkose and andesite were noted along Teewah Beach. McNiven (1998) later re-surveyed the Corroboree Dune Field on Fraser Island and recorded 100 sites, four times the number observed in the area by Lauer (1979). As part of the Fraser Island Archaeological Project (FIAP), Waddy Point 1 rockshelter was also excavated (McNiven *et al*. 2002). The suite of molluscan fauna included *Thais orbita*, *Donax deltoides*, *Nerita* sp., *Polinices (Conuber) incei*, *Saccostrea* spp., and *Trichomya hirsuta*. Fish, bird, and mammal bones were also present. The site, which was occupied over a period of 1000 years, demonstrated two distinct pulses of shellfish discard. Further south, a series of middens on ridges on the northern bank of the Maroochy River mouth was investigated (McNiven 1989; Figure1-1), indicating exploitation of estuarine molluscan species despite the proximity of the surf coast in the period between 470 cal BP and the present day. A more detailed review of such a large dataset is not possible here; the assemblages from three of the sites (Booral Shell Mound, Tin Can Bay 75b, and Cameron Point Site 62) are the subjects of Chapters 5 and 6.

The Sandstone Point site is an extensive midden complex on a series of dune ridges 600m west of the Sandstone Point headland (Figure 1-1). The ridges represent prograded Holocene accretion dunes in front of a small wave-cut cliff (Hall 1999:174) formed by the Holocene high-stand in proto-Moreton Bay. The complex was estimated to cover 20,500m$^2$ (Crooks 1982:19-21; Haglund 1974:119) with later estimates extending this to 25,000m$^2$ (e.g. Hall 1999; Nolan 1986). Initial 1974 excavations by Haglund totalled 5m$^2$ (Crooks 1982:24; Ulm 2002:81 reports 6m$^2$) in two areas exhibiting active erosional faces and deflated artefacts. Most of the middens were diffuse scatters 15-20cm deep with molluscan species including cockles, whelks, oysters, and mussels as well as "many small shells typical of rock pools" (Crooks 1982:28). Fish bone was also found throughout most layers of the excavation, as well as some fragmented dugong and bandicoot bone. Overlaying large areas of the deposit was a powdery but compacted white layer containing whole and broken shells considered evidence of 19th century lime-burning practices, although this inference could not be confirmed (Haglund 1974: 123-124). The artefact assemblage analysed by Crooks (1982) was dominated by cores and bevelled artefacts made on locally available raw materials (e.g. silcrete, quartz, and chert), probably obtained from the creek beds in the region. Sandstone Point was re-excavated by Walters in 1984 and by Hall in 1985 (Hall 1999; Nolan 1986; Walters 1986, 1989, 1992). While Haglund (1974) focussed on the foreshore, the later excavations of eight pits totalling 10m$^2$ were placed on the foreshore, foredune, Holocene dune accretion ridges, and the mid-Holocene terrace above the wave-cut cliff forming the landward extremity of the site. Squares SSP-2-B, SSP-4-F, SSP-5-G, and SSP-7-K were analysed by Nolan (1986), while Walters (1986) reported on SSP-1-A. A series of 12 $^{14}$C dates (Nolan 1986) indicate that the site was used from 2328 cal BP (SSP-5) (Ulm and Reid 2000:31) until the modern period, although the sequence does not suggest continuous occupation. Stone artefacts included flakes, retouched flakes, cores, and one bevelled artefact made on locally available raw materials (Nolan 1986:72-73, 75-84), with no clear patterns indicating technological change through time. Molluscan remains were dominated by *Saccostrea* spp. and *Trichomya hirsuta* (hairy mussel), although the proportions varied spatially and temporally. Vertebrate remains were dominated by fish bone, with Walters (1986:209, 233) extrapolating a density of 46,000 NISP/m$^3$ from the upper four excavation units of SSP-1. Two fish bones were found in the basal layer of SSP-4 dating to 1349 cal BP (Ulm and Reid 2000:31), but the majority of the fish remains came from SSP-2 on the ridge closest to the shoreline and from SSP-1 on the shoreline. Fish bone discard corresponds with that of the molluscs, with both NISP and species diversity in SSP-2 increasing sometime after 1062 cal BP.

Twelve fish taxa were identified, accounting for 760 of the total NISP of 1854, with garfish (Hemiramphidae, NISP=602) the most abundant taxon throughout (Nolan 1986:68). Other vertebrate remains were low in abundance and highly fragmented, with only four taxa identified (red-legged pademelon [*Thylogale stigmatica*], bush rat [*Rattus fuscipes*], sugar glider [*Petaurus breviceps*], and grey-headed flying fox [*Pteropus poliocephalus*]) from five teeth found in SSP-2-B (Nolan 1986:72). These terrestrial vertebrates reflect the *Melaleuca quinquenervia* (broad-leaved paperbark) open forest and woodland around the site. Nolan (1986:99) suggested that Sandstone Point was a location for gatherings, perhaps reciprocally hosted visits from hinterland groups, as well as formal fights (such as that recorded by Nique and Hartenstein 1841), and ceremonies at the bora ground 5km from the site. The increased discard over the past 800-1000 years reflected this use, as well as the potential antiquity of the socio-cultural networks observed historically.

Brown's Road (Figure 1-1) was an extensive stone artefact scatter (Hall 1999:175 reported c4000m$^2$; Ulm 2002:80 reported 5000m$^2$) around a small dense shell midden, on a ridge 11m ASL immediately adjacent to a *M. quinquenervia* and *B. indicum* (bungwall) swamp. More than 400 stone artefacts were collected from the surface prior to a series of three excavations by Hall and Strong in 1982, with a further 1000 (Richter 1994:76) recovered from the excavations, including bevelled artefacts associate with bungwall processing. Although bone and shell were also recovered from the excavations (Richter 1994:76), there is no further information available regarding the midden deposit. A near-basal $^{14}$C sample returned an age of 1963 cal BP (Hall 1999:175; Richter 1994; Ulm and Reid 2000:19)

To redress the coastal bias of Stockton's (1974) survey, Hall and UQ Field Archaeology classes undertook extensive surveys of the inland sections of Bribie Island in 1981-1982, mostly within the 4400ha commercial pine plantation on the north-south trending Pleistocene dune ridges, where shell was exposed on the firebreaks. A total of 69 sites were located, principally shell middens and artefact scatters (MRAP files). Two major sites were identified: BI9 (c900000m$^2$; Smith 2003, 2006) in the northeast of the island, and BI67 (c300000m$^2$; Smith 2003, 2006) in the southwest near White Patch (Figure 1-1). Further work was undertaken by UQ Field Archaeology classes during Smith's (1992) Honours research, both being conducted under the Bribie Island Forest Archaeological Project (BIFAP), an extension of MRAP. Excavations at BI9 revealed a dense midden deposit to a depth of 20cm, dated to 149 cal BP (Smith 1992; Ulm and Reid 2000:18). Below this layer deposits containing degraded shell and stone artefacts continued for another 50cm, with a basal date of 3469 cal BP (Smith 1992; Ulm and Reid 2000:18). BI9, and White Patch 3 excavated by Haglund in 1974 and dated to 579 cal BP (Ulm and Reid 2000:37), are discussed in detail in Chapter 7. A predictive site location model developed by Smith (1992) was tested using multivariate analysis which demonstrated only one aberrant site out of the 71 in the study. Site location was dependent on proximity to the estuarine or oceanic coast; proximity to fresh water; proximity to bungwall fern (*Blechnum indicum*); elevation; and vegetation type, with 60% of sites located in open forest or woodland (Smith 1992, 2006). As part of ongoing BIFAP research, Smith recorded a further 21 sites by employing the predictive model, and raking possible target areas (Smith 1997, 2003, 2006). Locating sites away from the firebreaks had been previously been difficult due to the covering of pine needles. Analysis of the stone artefacts from surface deposits across the island (Smith 2003) indicated differential use of the western and eastern dune ridges and curation of both raw materials and tools. All raw materials for the assemblage were introduced as there is no naturally occurring stone on the island. Crooks (1982) analysed stone artefacts excavated by Haglund in 1974 from Bells Creek, Sandstone Point, and White Patch 3 in addition to a large number of artefacts collected over a period of some 20 years by a local resident, Ted Clayton, from deposits eroding onto the beach at White Patch. Crooks (1982:100) found that the differences between the mainland artefacts and those from the west coast of the island were no more or less marked than the differences between the two mainland sites.

Minner Dint was the first site excavated on Moreton Island (Figure 1-1), and with Toulkerrie remains one of the best reported. It was a discontinuous midden deposit in a truncated foredune behind the modern east coast beach (Hall 1980b:96) and was excavated in two 1m x 2m trenches, A and B, by UQ anthropology students in 1978. Dense midden deposits dominated by *D. deltoides* were located in both trenches, with a NISP of 6044 and a MNI of 3170 (incorrectly reported as 3134 in Hall 1980b:106) in Trench A, and a NISP of 7760 and MNI of 3911 in Trench B. The majority of whole valves were between 45mm and 65mm in length (Hall 1980b:108), suggesting that a mature and sustainable population was being harvested (Appendix A). One *A. trapezia* and 15 *Conuber* sp. (sand snail) were found in Trench B, and one *Conuber* sp. in Trench A. A small amount of fish bone unidentifiable to taxon was found in Trench A, while a NISP of 33 fish bones in Trench B were determined to belong to three Sparidae, three whiting (*Sillago* spp.), three mullet (*Mugil* sp.), and one stargazer (*Ichthyscopus lebeck*) (Hall 1980b:105-106). Stone artefacts included flakes, an anvil, and grindstone fragments. A significant component of *Pandanus* sp. charcoal was found in both trenches and was the basis for the $^{14}$C determination (Hall 1980b:100) with a median value of 523 cal BP (Ulm and Reid 2000:26) within the Trench B midden deposit. Hall (1980b:110) posited that Minner Dint represented a transit camp in an area previously in the lee of the dune system, and perhaps used in August to December when *Pandanus* fruit was most abundant.

Other dated sites on Moreton Island (Figure 1-1) include First Ridge (672 cal BP), Little Sandhills (modern), the adjacent sites of One Tree (1518 cal BP) and Toulkerrie (dates range from 2328 cal BP at the base of the deposit to 309 cal BP), Spitfire Creek (234 cal BP to modern), and NE Moreton Island 1, 5, 16, 21A, and 27 (all modern). The common feature of all of these sites is that *D. deltoides* is the dominant molluscan taxa. At Little Sandhills and Toulkerrie there are also estuarine species (e.g. *Saccostrea* spp., *A. trapezia, P. ebeninus, T. hirsuta, Conuber sordidum)* but in far less abundance (Robins 1983, 1984; Hall 1984; Hall and Bowen 1989).

The Toulkerrie complex was excavated on five occasions: by Hall and UQ Field Archaeology students in three short field trips in 1978-1980 (Hall 1984), by Walters in 1983 (Walters 1986), and by Hall in 1989 as part of a heritage assessment for the Department of Primary Industries Fisheries Division (Hall and Bowen 1989). The general characteristics of the complex were similar in all excavations, i.e. the dominance of the molluscan component by *D. deltoides* throughout the midden deposits, with a relatively greater abundance (and diversity) of estuarine species in the upper levels; the presence of fish bone from a total of ten taxa dominated by Sparidae and *Mugil* sp.; the presence of other vertebrate faunal remains in low abundance including dugong (*Dugong dugon*), varanids, marine and freshwater chelonidae, an unidentified cetacean, *Pteropus* sp. (flying fox), carpet python (*Morelia spilota*), an unidentified bird (*Aves*), and a dog (*Canis familiaris*); and a stone artefact assemblage comprising mostly flakes, flaked pieces, and some cores, made on six locally available (i.e. Cape Moreton, 30km to the north) raw materials (Hall 1984; Hall and Bowen 1989; Richardson 1979; Walters 1986). Hall (1984:68) considered the *D. deltoides* dominance noteworthy as the species derives from the east coast surf beach on the opposite side of the island. Hall (1984) and Hall and Bowen (1989) associated the increased diversity of molluscan species, dense midden deposit, and vertebral remains within the past 300-400 years with the development of a more estuarine environment and the extension of the tidal flats adjacent to the site complex. The earliest stone artefact discard, in association with more degraded *D. deltoides* remains, pre-dates this phase by some 1900 years, leading Hall and Bowen (1989:24-25) to infer that the locale was most likely used infrequently by small groups of people who fished and flaked stone, but did not occupy the area until the development of the littoral resources invited longer term residence.

In addition to the 121 sites recorded by Ponosov (1965), Quinnell (1975, in Durbridge 1984:10) listed 81 ocean beach sites and five middens on the eastern side of North Stradbroke Island. Both Ponosov and Quinnell noted destruction or damage to sites by ongoing sand mining which commenced on the island in 1949. A number of heritage assessments have been undertaken by a variety of consultants (e.g. the UQ Archaeological Services Unit) over the past 30 years, but the number of sites on the island, and the number destroyed by mining activities, is unclear. Radiocarbon age determinations are available for very few sites.

Richardson (1984:27-29) recorded 30 sites (24 shell middens, five midden/artefact scatters, and one isolated shell) designated NRS 1 to 30 on the east coast above Eighteen Mile Swamp during an archaeological survey of a sand mining lease on North Stradbroke Island (Figure 1-1). The sites varied in area from 16m$^2$ to 18050m$^2$, with the majority less than 5000m$^2$. Bulk samples were obtained from 11 of the sites by way of 15cm x 15cm x 10cm test pits, with the dominant molluscan component *D. deltoides* in varying densities (e.g. estimated at 14665 per m$^3$ at NRS 8A, 8444 per

$m^3$ at NRS 8B, 37330 per $m^3$ at NRS 8C, 27108 per $m^3$ at NRS 19, and 20442 per $m^3$ at NRS 22) with some *A. trapezia*, *P. ebeninus*, and *Saccostrea* spp., indicating that these resources were transported from the western or southern coasts. Six sites contained fragmented bone, but this could only be further identified to fish bone in two sites. Twenty-five stone artefacts consisting of flakes, retouched flakes, and a muller (grinding stone) fragment, made on andesite, chert, quartz, quartzite, sandstone, and silcrete were recovered from the midden/artefact scatters. Twenty-two (73.4%) of the sites were located within 100m of fresh water sources, with 21 (70%) located in open forest and open forest/shrubby understory vegetation zones. Richardson (1984:29) reported the dates for three sites, NRS 8, 19 and 22, as 470±60 BP, 450 ±60 BP, and 410±50 BP respectively. When calibrated, all ages were modern at the 2 σ range (Ulm and Reid 2000:29). While the dating samples were obtained from the bases of the shell deposits, the depths of these dated samples is unclear. Richardson (1984:31) observed that the locations of the sites roughly correlated with the major west-east access routes through the dune systems.

Alfredson (1983, 1984) excavated a section of a large midden on St. Helena Island (Figure 1-1) and recovered a faunal assemblage consisting of some 40 molluscan taxa, in addition to vertebrate faunal remains of fish, *Pteropus* (flying-fox), and dugong. The site returned a non-basal date of 1825 cal BP (Ulm and Reid 2000:33) and a non-terminal date of 912 cal BP (Ulm and Reid 2000:33). Alfredson (1984) considered that St. Helena was seasonally exploited, with increased use after c1300 BP when the extension of tidal mudflats rendered the crossing of Moreton Bay safer and easier. The archaeological record of St. Helena is discussed in greater detail in Chapter 8.

The most southerly area of the study region is also the most poorly represented in the dataset. The salvage excavation of two areas of an extensive midden at Hope Island (Walters *et al*. 1987; Figure 1-1) provided evidence of exploitation of an apparently narrow range of marine molluscs over a period of 3000 years from 4863 cal BP (Ulm and Reid 2000:23), although there is little information regarding so-called ‘non-economic’ species. Hope Island is reviewed in greater detail in Chapter 8. Alfredson and the Kombumerri Aboriginal Corporation for Culture (KACC) (1999) collected molluscan material for $^{14}C$ dating from a midden deposit bulldozed during the construction of a golf course on Lake Coombabah, approximately 7.5km southwest of Hope Island. The deposit contained *Anadara trapezia*, *Saccostrea* spp., and small numbers of the whelks *Pyrazus ebeninus* and *Batillaria australis*. Fourteen stone artefacts were also recovered and included flakes, retouched flakes, a blade, and a flaked piece; the two retouched flakes and two of the flakes exhibited use-wear. Raw materials included argillite, chert, “jasperoid quartzite” (Alfredson and KACC 1999:3), and quartzite. The $^{14}C$ determination was 2131 cal BP (Ulm and Reid 2000:24).

Five other rockshelters have been reported under the MRAP umbrella in addition to Brooyar: Bushrangers Cave, Christmas Creek, Gatton (also with art), Maidenwell (also with art), and Platypus, (Bonica 1992; Hall 1986; Hall and Hiscock 1988b; Hiscock and Hall 1988a, 1988b; Kearney 1999; Morwood 1986, 1987; Mowat 1989). Two further sites, Boonah and Bishop's Peak, were reported by researchers from the University of New England (Edmonds 1986) (Figure 1-1). Although the focus of the present study is the coastal zone, the sub-coastal sites cannot be excluded from broader interpretations of environmental and behavioural changes in the southeast Queensland region (e.g. Morwood 1986, 1987). The majority of the sub-coastal sites indicate increased discard from c3000-2500 BP (Hall 1986, 1999; Hall and Hiscock 1988b; Morwood 1986, 1987), while there may also be evidence of stone artefact technological change between c2500 and 1500 BP (Bonica 1992; Hiscock and Hall 1988a, 1988b). Bushrangers Cave is also the only site other than Wallen Wallen Creek that exhibits early-Holocene occupation, with a near basal date of 10459 cal BP (Ulm and Hall 1996; Ulm and Reid 2000:19).

### *Models of long-term cultural change*

Based on the Great Sandy Region and Brooyar Rockshelter site chronologies and cultural components, as well as linguistic evidence, McNiven (1989, 1990a, 1992a, 1999, 2006) hypothesised that the archaeological record of the region can be separated into Early Phase sites (5500 - 2500 BP), which contain relatively high amounts of silcrete from inland areas, and Recent Phase sites (roughly 1000 BP onwards) with artefact assemblages dominated by locally-available raw materials. These phases are said to represent group fissioning in the region based around Fraser Island, associated with broader-scale environmental and social changes, with the contraction of resource zones (e.g. rainforests) leading to economic stress and population pressure. There is a major increase in midden establishment in the past 1000 years, reflecting a local intensification in molluscan exploitation resulting from increased residency. Some aspects of the model are difficult to assess archaeologically, and it is discussed in greater detail in Chapter 9 in the context of regional palaeoenvironmental reconstructions, and the analyses presented in Chapters 5 and 6.

The Hall and Robins (1984) model of occupation for Moreton Island posits that people abandoned the area for a period of c4000 years when it became an island during the Holocene marine transgression, and gradually began to return c2000 years ago following the progradation of tidal mudflats and the development of a rich marine resource base. Hall (1984) and Hall and Bowen (1989) similarly associated increased species richness and more intense occupation at Toulkerrie with recent expansion of the tidal mud flats. Hall and Hiscock (1988a) considered fissioning of groups possibly accounts for temporal variations in the establishment of sites in the Moreton

Region, particularly the dramatic increase noted in the past 1000 years. Where groups had expanded westward with the rising sea levels, following the regression they began to expand eastwards, eventually establishing permanent populations on the islands in Moreton Bay. As they did so, and population increased, there would have been an increase in the number of discrete socio-political groups. These hypotheses are explored further in Chapter 9.

Proving that debates about southeast Queensland archaeology remain current, Robins *et al.* (2015:191) have criticised the southeast Queensland dataset, claiming the sample biases within the predominantly Holocene dataset, which has been used "somewhat uncritically as a representative sample", render interpretive arguments on cultural change "speculative scenarios". They offer critical issues, such as geomorphic research, employment of at least two dating techniques on sites in sandy deposits, consideration of taphonomic processes and/or environmental issues, and use-wear and residue analyses, for consideration in the development of models of cultural change (2015:205). The implication is that these issues have not been considered by previous researchers, although this is not the case (see e.g. Hall 1984, 1999; McNiven 1990a, 1992a). However, the article lacks the positive impact it may otherwise have had as it offers few new perspectives and demonstrates a lack of engagement with contemporary practices within zooarchaeological analyses, the increasing use (implicitly or explicitly) of historical ecology as a theoretical framework, and the integration of landscape and palaeoenvironmental studies into the interpretation of changes observed in archaeological assemblages.

Robins *et al.* (2015:191) stated that the Holocene-biased dataset has been employed in a number of constructive interpretations at a site or local level, "particularly for offshore islands" (e.g. Alfredson 1983; Bowen 1989; Hall 1980b, 1984; Hall and Bowen 1989; Hall and Lilley 1987; Hall and Robins 1984; Richardson 1984; Robins 1983), although they did not offer comment on these particular interpretations. Contrarily, they later (2015:193) complain that a consequence of the limited sample "is that the archaeological record of the islands of Moreton Bay has been largely subsumed within the regional picture", and that there have been few attempts to define their individual histories or discriminate "between island histories and those of the mainland coast ... a clear picture of the interconnection and differences between island, coastal and sub-coastal histories remains to be defined". This is a rather selective and somewhat disingenuous statement given the bodies of work relevant specifically to the archaeology of islands in southeast Queensland (e.g. Alfredson 1983, 1984; Bowen 1989; Hall 1980b, 1984, 2000; Hall and Bowen 1989; Hall and Robins 1984; McNiven 1998; McNiven *et al.* 2002; Richardson 1979, 1984; Robins 1983, 1984; Smith 1992, 2003, 2006), the coastal region (e.g. Cotter 1995, 1996; Crooks 1982; Frankland 1990; Hall and Lilley 1987; McNiven 1984, 1985, 1989, 1990a, 1991a, 1991b, 1991c, 1992a, 1992b, 1992c, 1992d, 1993, 1997, 2006; Nolan 1986; Walters 1986, 1992; Walters *et al*. 1987), and the sub-coastal region (e.g. Bonica 1992; Francis 2002; Kearney 1999; Lilley 1978, 1982; Hall 1986; Hall and Hiscock 1988; Hiscock and Hall 1988a, 1988b; Hall *et al*. 1991; McNiven 1988; Morwood 1986, 1987; Mowat 1989; Novello 1989; Skelton 1996). Robins *et al*. (2015:193) considered “the main reason for the late Holocene bias in the dated record lies in the fact that the sample of sites is unrepresentative of the potential universe of sites in space and time”, although they offer no explanation of what the potential universe might actually comprise. As Ulm (2002:90) pointed out, the fact that some 20,000km$^2$ of land in southeast Queensland has been submerged by transgressive seas over the last 18,000 years has obvious implications for the representation of sites dating to the period before the end of the transgression c7500 BP. That the record is truncated and biased toward the second half of the Holocene is to be expected. The reason for a Holocene bias is due to the fact that many Pleistocene sites will now be under Moreton Bay and the Coral Sea, or under aeolian deposits (Cotter 1995, 1996). McNiven (1990a, 1992a) intensively surveyed Pleistocene dune systems in the Cooloola region, with only recent midden sites (<900 BP) located. Robins *et al*. (2015:193) further attribute the perceived lack of representativeness in the dataset to its historical development under the umbrella of MRAP and proffer the extraordinary view that “the dataset of this region is essentially an exploratory, ad hoc collection of places and dates and hardly suited to form the basis for complex interpretations of cultural change”. This is despite the observation by Allen (2006:6) that MRAP has been a most significant contribution to Queensland archaeology. Robins *et al*. (2015:197-198) again emphasised the historical context of previous excavations when interpreting the data:

> Few sites in the study area have been excavated with the question of population increase or the advent of a particular technology in mind. Most were excavated as part of preliminary investigations in the 1970s and 1980s, attempting to answer basic questions such as How old are these sites? What are their characteristics? Is it possible to identify changes through time? Answers to more sophisticated questions require a more comprehensive approach than the current data permits.

That the original intention of excavations may not have been to explore specific issues such as population increase or technological innovation does not mean such questions, and others, cannot subsequently be addressed. Robins *et al*. (2015) do not offer further comment on, or definitions of, sophisticated questions or more comprehensive approaches, but certainly there is the implication that the current data are incapable of being used to address anything more than basic questions – which are fundamental to the explication of any archaeological assemblage, regardless of how many sophisticated questions may ultimately be asked of the data. The current study demonstrates that questions can still be asked of data derived from appropriately accessioned assemblages, and also of less than ideal published data, when coupled with contemporary approaches to analysis including palaeoenvironmental reconstructions, morphometric analyses of molluscs, and statistical analyses.

## *Conclusion*

This chapter provides the regionally-specific cultural context for the research aims and questions. The ethnohistorical overview has provided a basis against which to assess behavioural variations identified in the analyses in Chapters 5 to 8. The review of previous archaeological research in the region has flagged that there are spatial and chronological variations in the archaeological record. A number of models for long-term cultural change have been introduced, and recent criticism both of the existing dataset and its interpretations critiqued. The following chapter provides the environmental context for the present study.

# 3. Environmental Change in the Study Region

## *Introduction*

This thesis seeks to identify archaeological evidence of environmental change during the Holocene, and its influences on human behaviour. Therefore, this chapter reviews the evidence for the impacts of sea level change in eastern Australia, and offers some insight into the development of estuarine systems in south east Queensland. This is followed by a comprehensive review of palaeoenvironmental studies from Fraser Island and North Stradbroke Island. Finally, the potential applicability of these reconstructions to the present study is assessed.

## *Sea-level change and geomorphology*

The southeast Queensland region is characterised by a generally procumbent coastline punctuated by high transgressive dune systems at Cooloola and on Fraser Island, Moreton Island and North Stradbroke Island (Figure1-1). The dune systems demonstrate considerable antiquity, with the Kabali area of the Cooloola sandmass dated to approximately 730kya (Tejan-Kella *et al*. 1990), the central dune system of Fraser Island to ~600kya (Longmore 1997), and the dune systems of North Stradbroke Island to ~120kya (Neil 1998; Pickett *et al*. 1984, 1985). Bribie Island demonstrates low Pleistocene beach accretion ridges (Jones *et al*. 1978). Neil (1998:6) suggests that dune building occurred throughout the glacial - inter-glacial cycles, while Stock (1990) commented that dune sands observed today could have formed at any sea level. Moreton Bay, and by extension, Hervey Bay adjacent to Fraser Island, has been emptied and partially refilled at least four times over the last 150,000 years (Jones 1992; Lang *et al*. 1998; Lockhart *et al*. 1998; Figure 3-1).

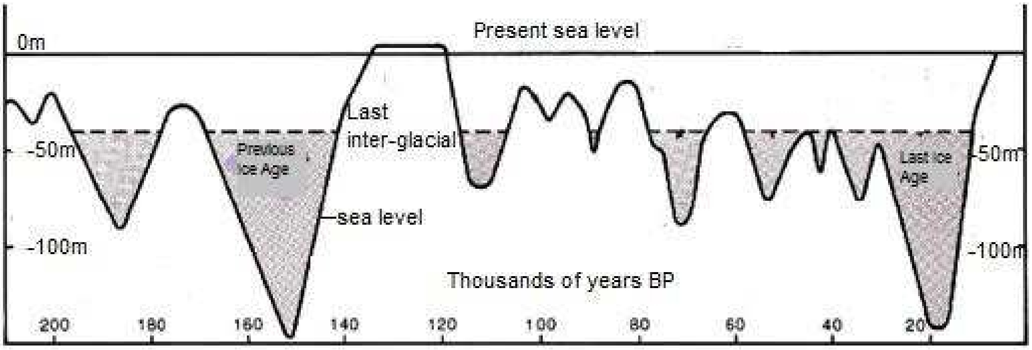

**Figure 3-1 Sea level variations in the Moreton Region over the past 200, 000 years demonstrating the periods when Moreton Bay was dry (after Jones 1992:27).**

During the last inter-glacial, c150,000-118,000 years ago, covering the period of the formation of the North Stradbroke Island dunes, the sea rose to approximately 6m above the present level. A series of oscillations then followed (Jones 1992; Lang *et al*. 1998; Lockhart *et al.* 1998) which defined the geomorphic character of the Bay (Neil 1998), including the early development of low coastal plains, before a rapid decline in sea level during the Last Glacial Maximum (LGM).

During the LGM the sea-level was approximately 130m (Jones [1992:27] posits 150m) lower than present day, with the southeast Queensland coastline up to 50km east of its present position. Much of Fraser, Moreton and North Stradbroke Islands, and the Cooloola region were high sub-coastal dunes overlooking an extensive coastal plain to the east; to the west of Moreton Island was a broad alluvial valley dominated by the Brisbane River (Hall 1999; Lang *et al*. 1998; Page and Hughes 2007; Willmott and Stevens 1992; Figure 3-2). After ~18,000 BP, the sea level rose again and flooded the coastal plain, although whether sea-level changes were episodic in nature or a rapid uninterrupted rise with the deposition of a continuous transgressive sand blanket is debated (e.g. Larcombe *et al*. 1995; Lewis *et al*. 2013). There is general consensus that, with regional variations, Holocene highstand sea-levels along the eastern Australian coast were ~1-1.5m higher than at present (e.g. Chappell *et al*. 1983; Flood 1981, 1984; Lambeck and Nakada 1990; Larcombe *et al*. 1995; Lewis *et al*. 2008; Lewis *et al*. 2013; Sloss *et al*. 2007; Switzer *et al*. 2010). There is less agreement, however, as to when the highstand occurred, the duration of the ensuing stillstand (or stillstands), and the establishment of present levels. Chappell *et al*. (1983) originally posited a model based on coral micro-atolls whereby the highstand was reached about 6000 years ago with a subsequent smooth fall to present levels. However more recent studies have suggested that the highstand occurred earlier, c7500 cal BP, and was followed by a stillstand for some 5000 years, before falling (pronounced, gradually, or in steps) to present levels after c2000 cal BP (Lewis *et al*. 2008; Lewis *et al*. 2013; Sloss *et al*. 2007; Switzer *et al*. 2010; Woodroffe 2009). Flood (1984:130) suggested a rapid seaward progradation in the mid-Holocene, but lamented the lack of detail concerning shoreline progradation in the last 3000 years. Similarly, Lewis *et al*. (2013:126-127) noted that there are few useful data available for southern Queensland, and that the conflicting estimates based on different indicators (beach rock, micro-atolls, foraminifera, and relict shell deposits) are evidence that each indicator reflects different tidal or supratidal levels, and local changes in these during coastal evolution (Figure 3-3).

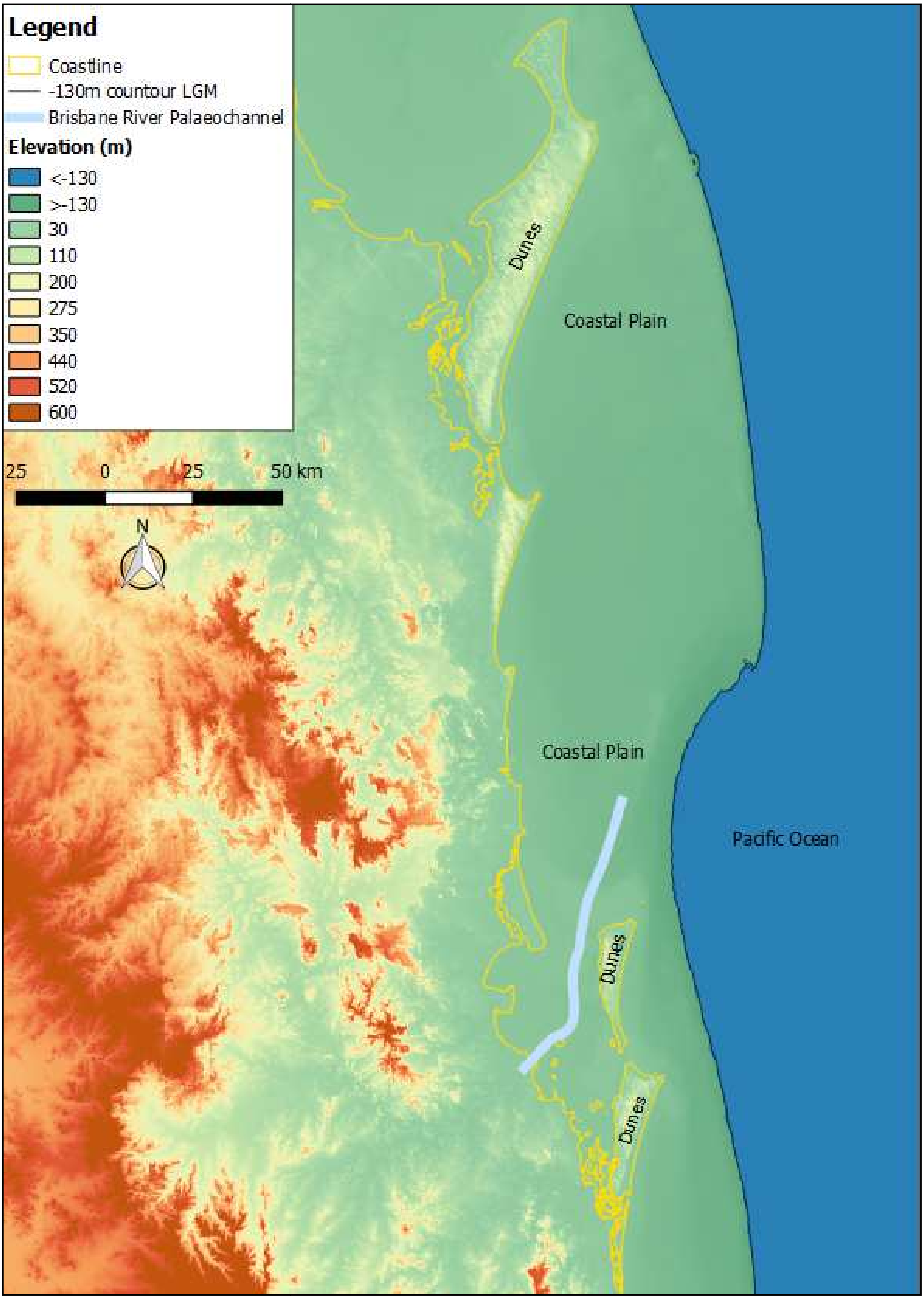

Figure 3-2 Coastline of southeast Queensland during the LGM (Figure courtesy of Jim Smith).

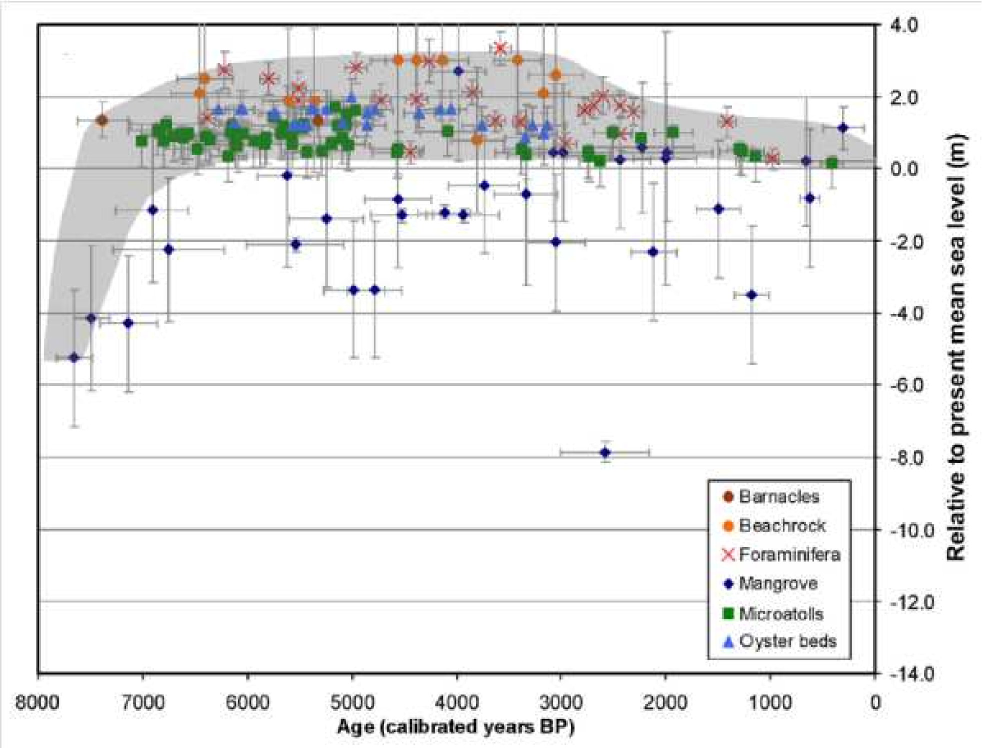

**Figure 3-3 Sea level data demonstrating conflicting evidence based on different indicators (Lewis *et al*. 2013:127 Figure A).**

### Estuarine development

The estuarine systems in the study region are examples of wave dominated (Moreton Bay), tide dominated (Great Sandy Strait and Pumicestone Passage) and river-dominated (with a tide-dominated delta, Coomera River) estuaries (OzCoast [Geoscience Australia] 2015). The estuaries would have formed during the period of relatively slower sea level rise after 7500 cal BP. Although individual characteristics vary depending on the rate of infilling by fluvial, terrigenous and aeolian sedimentation, all follow the same evolutionary process (Ryan *et al*. 2003; Figure 3-4). The estuaries are dynamic environments in a constant state of flux, as demonstrated in the analysis chapters which follow.

## *Palaeoenvironmental reconstructions*

The palaeoenvironment of sub-tropical southeast Queensland has been reconstructed from a number of palynological and sedimentary studies, principally from Fraser Island (e.g. Atahan *et al*. 2015; Donders *et al.* 2006; Donders *et al.* 2007; Gontz *et al*. 2014; Hembrow *et al*. 2014; Krull *et al.* 2004; Longmore 1997; Longmore and Heijnis 1999; Moss *et al*. 2015; Woltering *et al*. 2014) and North Stradbroke Island (e.g. Barr *et al*. 2013; Boyd 1993; McGowan *et al.* 2008; Mettam *et al.* 2011; Moss *et al.* 2011; Moss *et al.* 2013; Petherick *et al.* 2008a, 2008b, 2011; Petherick *et al.* 2013). Both Fraser and North Stradbroke are large sand islands with complex underlying geomorphology (Tejan-Kella *et al*. 1990; Ward 1977, 2006); in addition, Fraser Island shares

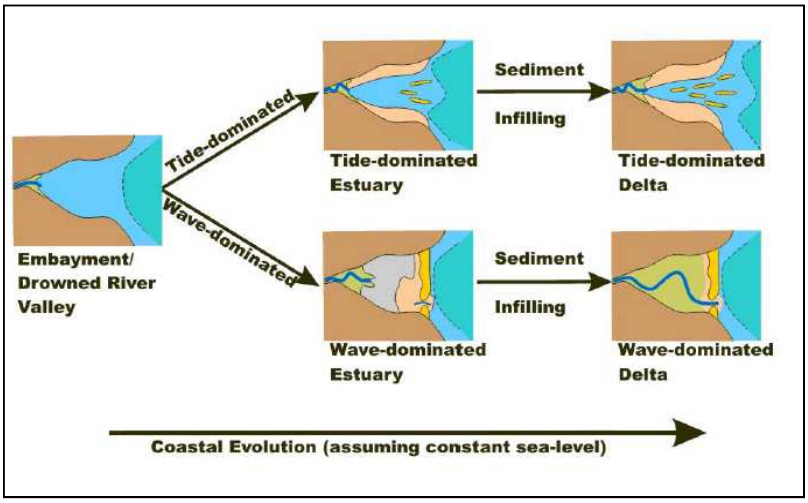

**Figure 3-4 Evolutionary model of estuarine development (Ryan *et al.* 2003:11).**

similar parent materials and dune systems with the Cooloola sandmass on the mainland coastline immediately to the south, as well as similar soil and floristic profiles (Longmore 1997:207-209; Tejan-Kella *et al*. 1990). There have been no similar palaeoenvironmental studies conducted on the mainland or in the southern areas of the Moreton Region, and therefore there remains a gap in the understanding of local palaeoenvironmental variability in greater southeast Queensland. However the available research can be seen to provide an initial baseline for palaeoenvironmental trends across the region, while acknowledging there will be some localised variability.

### Fraser Island

Fraser Island (K'gari) is the world's largest sand island, and is a UNESCO World Heritage Listed area. It is 1630km$^2$ in area, 122km long, with a varying width of 5-25km, and a maximum elevation of 235m. It is separated from the mainland by Hervey Bay and the Great Sandy Strait; the southernmost tip is located 2km from Cooloola on the mainland while the northernmost tip is 65km east of the mainland (McNiven *et al*. 2002) (Figure 1-1). The island has a maritime sub-tropical climate, with a mean annual rainfall of 1200mm, and an annual mean maximum temperature of 25.9$^o$C (Bureau of Meteorology).

The initial Fraser Island environmental reconstructions were based on cores taken from two perched lakes and basins, the Old Lake Comboo Depression (Longmore 1997; Longmore and Heijnis 1999), and Lake Allom (Donders *et al.* 2006; Donders *et al.* 2007). Perched lakes form above impermeable layers of sediment (aquitards) and thus are not influenced by groundwater levels, being instead fed by rainfall. In the case of the Fraser Island perched lakes the aquitard consists of coffee rock, a common feature in coastal southeast Queensland formed by the cementing of accumulated organic material such as leaf litter to an underlying sandy stratum resulting from impeded drainage (Donders *et al.* 2006; Longmore 1997). The accumulation of organic-rich sediments in the lake basins forms a natural archive for palaeoenvironmental studies, including the hydrological conditions prevailing for the local vegetation (Donders *et al.* 2006:419).

*Old Lake Comboo*

The ephemeral Old Lake Comboo Depression (OLCD) basin covers approximately 9ha and is located approximately 86m above sea level in an eroded area of one of the oldest dune systems on Fraser Island (Figure 3-5). At the time of the study the area was surrounded by low open woodland and tall shrubland, mostly *Eucalyptus signata* (scribbly gum), *E. gummifera* (red bloodwood) and *Banksia aemula* (wallum banksia). The younger dune systems bordering the lake basin support *E. pilularis* (blackbutt), *Syncarpia hillii* (satinay, or Fraser Island turpentine) and *Allocasuarina torulosa* (rose she-oak or forest oak), while notophyll vine forests including *Backhousia myrtifolia* (myrtle) occur in sheltered areas and gullies where the water table is close to the surface. Prior to Fraser Island's designation as a UNESCO World Heritage site in 1992 this area formed part of a State Forest logged for *Araucaria cunninghamii* (hoop pine), *Agathis robusta* (Queensland kauri pine), *S. hillii*, and *E. pilularis* (Longmore 1997:510). Sediment cores up to 6m in length were taken from the lowest point of the lake basin during a dry period, with the sediments subjected to palynological analysis, elemental analysis, radiocarbon dating and U-Th dating. The sediments were divided into 11 zones with Zone K being the basal unit and Zone A the terminal unit. A U-Th date of >350 ka was obtained from Zone G, and the basal date of the sequence was extrapolated to be c600kya, although the rate of sediment accumulation could not be assumed to be constant (Longmore 1997:513; Longmore and Heijnis 1999:41). The implication of the date was that the sequence spanned several glacial cycles and could therefore inform on long term floral response to and recovery from both glacial and inter-glacial periods. The results obtained from the upper two units, Zone B and Zone A, are presented here.

Zone B was a 30cm deep sandy deposit bracketed by radiocarbon dates of 21800±270 BP at its base at c1.3m and 12160±450 BP at its interface with Zone A at c1m. Longmore (1997) and Longmore and Heijnis (1999) considered it represents evidence of the LGM and late glacial period. The pollen values were dominated by Myrtaceae and Protaceae; while rainforest Araucariaceae pollen were initially present, they were replaced by the Myrtaceae types *E. intermedia* (pink bloodwood) and *Angophora costata* (Sydney red gum), and then *E. signata*. Poaceae and Juncaceae (grasses and rushes) also demonstrated an increase through the Zone, and groundwater elements were at

**Figure 3-5 Fraser Island showing the locations of the core extraction sites.**

maximum levels in the sequence. The picture proposed is one of dry conditions with swamps associated with sedges, reeds, and swamp grasses, high levels of groundwater seepage, cool conditions with reduced burning, and ultimately dominance by dry sclerophyll vegetation including *E. signata* and *Banksia* spp. (Longmore 1997:518; Longmore and Heijnis 1999:43-44). The sediment of Zone A was swamp peat; at its base were increased charcoal particles relative to Zone B but these decreased up to and post c4060±160 BP. There was a significant increase in

Casuarinaceae pollen to very high values, while dry sclerophyll values decreased markedly. Rainforest values increased slightly, but were at very low levels, while *E. pilularis* and *Melaleuca* frequencies increased. Pollen from littoral species such as *Haloragis* increased markedly, and groundwater elements remained at high levels. Longmore (1997:519) interpreted the results as indicating that the Holocene was much drier at OLCD than during any previous inter-glacial periods at the site, and that the lake became ephemeral with high groundwater seepage, a moderate to severe fire regime, with the development of a sedge swamp with fringing Restionaceae and *Melaleuca* spp. while *Haloragis* sp. formed a ground cover.

Longmore (1997:521) used the information obtained by Kershaw (1986) from Lynch's Crater on the Atherton Tableland in northern Queensland as a basis for comparison for Fraser Island. Wet rainforest species begin to disappear at OLCD in the period 70-22 kya, and at Lynch's Crater c26 kya; Araucariaceae pollen frequencies decline markedly at both sites before and during the LGM. Both sites demonstrate almost complete replacement of dry rainforest species by sclerophyll vegetation during the LGM, a phenomenon not witnessed in earlier glacial periods. Longmore (1997) claimed that the sites differed in that wet rainforest species pollen re-appear at Lynch's Crater in substantial amounts from c7000 years ago; but there is no such recovery at OLCD where small amounts of rainforest pollen occur in the Holocene sediments, but at far lower values than in earlier inter-glacial periods. Longmore (1997:521) suggested that this was due to coastal Fraser Island being more marginal than Lynch's Crater in terms of rainfall, and more sensitive to climatic change. These factors contributed to the present restricted distribution of rainforest on the Island, which represents a contraction of the range of rainforest re-establishment. The overall picture is one of the Holocene inter-glacial being more arid than previous inter-glacials, with a mid-Holocene arid phase seemingly at odds with mid-Holocene moist conditions reported elsewhere, but the picture is rather general in nature, and the descriptions and interpretations lack fine-grained detail.

### *Lake Allom*

The focus of the study by Donders *et al.* (2006) was another perched lake basin, Lake Allom. In order to resolve the timing and duration of short-term environmental changes, particularly during the Holocene, a more detailed record of palaeoenvironmental conditions was required. The Lake Allom basin lies at an elevation of 100m ASL in the central rainforest belt of Fraser Island at the boundary between Pleistocene and Holocene parabolic dune systems and covers an area of approximately 24ha with a 50m wide fringe of littoral vegetation. It is characteristic of many perched lakes in that it is an oligotrophic acidic lake rich in dissolved tannins (locally known as black water), in a nutrient-poor catchment (Donders *et al.* 2006:419). Unlike the ephemeral Old

Lake Comboo, Lake Allom is a permanent body of water. The surrounding vegetation comprises remnant araucarian and notophyll vine forests and wet-sclerophyll tall forest on the Pleistocene dune formations, and wet-sclerophyll to dry-sclerophyll blackbutt (*E. pilularis*) forests with a grassy understorey on the more easterly Holocene dune formations.

The Lake Allom core was extracted during a relatively dry winter season when the central lake area had a water depth of 3.7m. Three core sections to a depth of 3.2m were extracted, all consisting of dark organic-rich sediments with some mixed sand intervals and coarse charcoal particles in the lower halves (Donders *et al.* 2006: 421). Sediments at a depth of 180cm were drier and more compacted compared to the rest of the core, and interpreted as evidence of an erosional surface. In addition to palynological and charcoal analysis, 16 AMS $^{14}$C dates were obtained (Table 3-1). Two unconformities or hiatuses were noted, the first between the radiocarbon dates at 207cm and 177cm at the Pleistocene-Holocene transition roughly analogous with the inferred erosional surface at 180cm, and the second, smaller, between the $^{14}$C dates at 161cm and 149cm (Donders *et al.* 2006:422, 433-435).

**Table 3-1 Radiocarbon dates from Lake Allom (from Donders *et al*. 2006:422).**

| Depth (cm) | $^{14}$C years BP | Cal BP |
|---|---|---|
| 18 | 623±32 | 585±45 |
| 37.5 | 849±31 | 707±28 |
| 59 | 1469±34 | 1320±25 |
| 79.5 | 1770±60 | 1625±75 |
| 98 | 2177±40 | 2080±80 |
| 107.5 | 2477±31 | 2510±160 |
| 127.5 | 3420±35 | 3620±70 |
| 142.5 | 4213±42 | 4725±105 |
| 149 | 4640±50 | 5260±190 |
| 161 | 7620±60 | 8375±55 |
| 177 | 9860±60 | 11220±45 |
| 201 | 32500±400 | ~36-40 kya* |
| 221 | 35900± 800 | ~39-43 kya* |
| 264 | 45200±1500 | ~45-50 kya* |
| 304 | 44600±2400 | Not available |
| 323 | 45900±1900 | Not available |

*Estimate only (Donders *et al.* 2006:422).

Donders *et al.* (2006:422, 427-428) grouped the pollen samples into pollen assemblage zones (PAZ) based on vegetation type (trees/herbs/aquatics/ferns). In all seven PAZ were identified (including two depositional hiatuses), two in the Pleistocene levels of the site and five in the Holocene levels. Only the Holocene levels are discussed here.

**Table 3-2 Lake Allom pollen zones, depths, and ages (adapted from Donders *et al*. 2006:433).**

| Zone | Depth (cm) | Calibrated dates |
|---|---|---|
| Hiatus I | ~182 | ~35000-12000 cal BP |
| PAZ Ho I | 185-151.5 | 12000-6500 cal BP |
| Hiatus II | ~151.5 | 6500-5400 cal BP |
| PAZ Ho II | 151.5-112 | 5400-2700 cal BP |
| PAZ Ho III | 112-86.5 | 2700-1770 cal BP |
| PAZ Ho IV | 86.5-16 | 1770-450 cal BP |
| PAZ Ho V | 16-0 | 450 cal BP - AD 2003 |

The authors stated (2006:434-435) that the time-span of Hiatus 1, ~35000-12000 cal BP (28000-10000 $^{14}$C BP), is concurrent with the maximum aridity phase of ~ 26000 to 9000 BP reported by Kershaw (1986:48) for Lynch's Crater. The vegetation of Ho I (12000-6500 cal BP) reflect relatively dry conditions maintained by lower sea levels and relatively higher continentality than present, while the development of fire-resistant blackbutt forests in addition to the more frequent occurrence of *Banksia, Angophora* and charcoal indicates an increase in temperatures. The presence of mobile dunes in the vicinity of Lake Allom is evidenced by the high sand content of the sediments; dune mobility lessened following the stabilisation of sea levels in the mid-Holocene (Donders *et al.* 2006:435). Hiatus II heralds different climatic and vegetation regimes in Ho II after c5500 years ago. There is a sharp increase in sclerophyllous Casuarinaceae pollen, which the authors considered to be the result of the ability of *Casuarina* spp. to act as nitrogen-fixers in sandy low-nutrient soils and is evidence of colonisation of the early Holocene dunes. In association with increased tree pollen in Ho II are minimum levels of aquatic pollens, found today only at the lake margins, implying that the lake was relatively larger in the period 5400-2700 BP. Relatively more moist conditions are suggested by a fall in dry-indicator taxa and charcoal deposition, with a gradual increase in the occurrence of blackbutt and heathland pollen. In the lower levels of Ho III a return to slightly drier conditions is indicated by small increases in dry-indicator taxa, aquatic taxa (suggesting the lake-shore margins were closer to the central coring location) and charcoal particles. Donders *et al.* (2006:435) considered a small increase in charcoal after 3000BP to be significant; although associated with a significant expansion in rainforest species such as Araucariaceae and angiosperms, the microscopic windblown charcoal fraction (<120 µm) was interpreted as evidence of regional-scale fire events. As Ho III progressed, vegetation types became more heterogeneous and their distribution more mosaic-like, resembling the present-day vegetation cover, which the authors concluded to be the result of increased climatic variability and/or seasonality with more frequent exceptionally wet or dry conditions. The 1300 year period covered by Ho IV is not discussed beyond an initial vegetation description (Donders *et al.* 2006:433). In Ho V araucarian rainforest pollen drops markedly c450 BP, the reasons for which are unclear, although the majority of the other taxa remain stable (Donders *et al.* 2006:436). *Pinus elliottii* is evidence of European modification of the landscape, and although 20th century logging adversely affected Fraser Island rainforests it is obviously not the cause of the pre-European rainforest decline. Donders *et al.* (2007:1630) suggest the decline may be due to sub-optimal growth conditions, perhaps as the result of a decrease in temperature.

In comparing the Lake Allom and Old Lake Comboo records, the differences in modern vegetation in and around the lake basins, as well as the nature of the lakes themselves are highlighted. Old Lake Comboo is ephemeral and in a drier area outside the present rainforest zone, accounting for the low levels of gymnosperm pollen during the Holocene compared to Lake Allom. The comparison of relative changes between records rather than correlation of specific elements is therefore important, given that small lakes' pollen records reflect restricted forest areas. Donders *et al.* (2006:436-437) conclude that the early Holocene was a relatively dry period with low sediment accumulation rates, and high fire intensity, and that this dry phase was related to the lower sea-levels rather than regional climatic impacts. Following c5500 BP the climate becomes moister, with higher lake levels and reduced fire regimes, and the appearance of dune-stabilising vegetation. After c3000 BP conditions become more variable and slightly drier. These dry-wet-dry cycles are in accord with the variations observed by Longmore (1997) and Longmore and Heijnis (1999), as well as those observed for tropical north Queensland (e.g. Haberle 2005), although Donders *et al.* (2006:436) consider the development of "Holocene conditions" to be more pronounced at Lake Allom than northern Queensland, especially after 3000 BP. It is suggested that the subtropical zone is more climatically sensitive to small changes than the tropics, being less subject to monsoon-related rainfall variability. It is also suggested that Fraser Island is sensitive to ENSO-related climate variability because of its location, and that the heterogeneous nature of the modern-day vegetation is reflective of the greater climatic variability in Australia resulting from intensification of ENSO activity (e.g. Shulmeister and Lees 1995).

### *Lake McKenzie*

Lake McKenzie, also a perched lake, was the focus of studies on diatoms and stable isotope ratios (Hembrow *et al.* 2014), pollens (Atahan *et al.* 2015), and calculations of mean average air temperature (MAAT) based on branched glycerol dialkyl glycerol tetraether (GDGT) lipids from allocthonous soil-borne bacteria (Woltering *et al.* 2014) based on cores from the lake bed. The lake sits at c90m ASL within a dune system reaching 150m in elevation, covers an area of approximately 130ha, and has a maximum depth of 8.5m (Atahan *et al.* 2015; Hembrow *et al.* 2014; Woltering *et al.* 2014). The lake is a closed system and is therefore dependent on, and reflective of, levels of effective precipitation. Two adjacent cores, LM1 (430mm) and LM2 (450mm), were taken from the deepest basin of the lake at a water depth of 8.3m. LM1 was sampled at 2.5mm intervals for high resolution analysis and LM2 was sampled at 10mm intervals for chronological analysis (Hembrow *et al*. 2014; Woltering *et al*. 2014). Five $^{210}$Pb age estimations were obtained from the top 35mm of LM1, with two AMS $^{14}$C dates also obtained from LM1, and ten AMS $^{14}$C dates obtained from LM2 (Atahan *et al*. 2015:145; Hembrow *et al*. 2014:777; Tables 3-3 and 3-4), allowing for palaeoenvironmental reconstruction over a period of some 36,000 years.

**Table 3-3 $^{210}$Pb age estimations for Lake McKenzie surface sediments (Atahan *et al.* 2015:145).**

| **ANSTO ID** | **Depth (mm)** | **Calculated age** |
|---|---|---|
| M897 | 0 – 2.5 | AD 2005 |
| M898 | 2.5 – 5 | AD 1995 |
| M899 | 15 – 17.5 | AD 1945 |
| M900 | 17.5 – 20 | AD 1935 |
| M901 | 30 – 32.5 | AD 1879 |

**Table 3-4 $^{14}$C dates from Lake McKenzie (Atahan *et al.* 2015:145). Anomalous dates are highlighted in grey.**

| **Laboratory Code** | **Depth (cm)** | **Core** | **Composition** | **$^{14}$C age** | **2σ calibrated age range** |
|---|---|---|---|---|---|
| OZN683 | 10 – 11 | LM2 | Pollen | 2395±35 | 2183 – 2654 |
| OZN684 | 15 – 16 | LM2 | Pollen | 3785±35 | 3931 – 4230 |
| OZN685 | 20 – 21 | LM2 | Pollen | 6485±50 | 7260 – 7431 |
| OZO411 | 23 – 24 | LM2 | Pollen | 4515±40 | 5044 – 5309 |
| OZN686 | 25 – 26 | LM2 | Pollen | 12110±70 | 13786 – 14148 |
| OZO412 | 26 – 27 | LM2 | Pollen | 15100±70 | 18026 – 18859 |
| OZN687 | 30 – 31 | LM2 | Pollen | 18670±100 | 21872 – 22545 |
| OZN688 | 35 – 36 | LM2 | Pollen | 23270±120 | 27785 – 28499 |
| OZN689 | 40 – 41 | LM2 | Pollen | 30940±190 | 34924 – 36280 |
| OZN690 | 45 – 46 | LM2 | Pollen | 31870±180 | 35575 – 36783 |
| OZN680 | 21.3 – 21.5 | LM1 | Pollen | 19150±210 | 22330 – 23428 |
| OZN681 | 21.2 – 21.5 | LM1 | Wood | 11470±60 | 13188 – 13457 |

### *Mean annual air temperature*

The lowest estimated MAAT for Lake McKenzie (~4.1°C lower than the present day) occurs during the period of the LGM at ~19kya (Woltering *et al*. 2014:140). It is followed almost immediately by the hiatus in the deposition of sediment, suggesting that the drier and cooler conditions persisted for some 4000 years. Upon resumption of sedimentation during the Pleistocene - Holocene transition (13300-12000 cal BP), the estimated MAAT reached a peak of up to 1.1°C higher than the present day which are speculated to reflect the Antarctic Cold Reversal or the early Younger Dryas. However, high temperatures at around 13kya are not observed in the $\delta^{18}$O records from the marine cores GC-12 at Capricorn Channel (Bostock *et al*. 2006) and GC-25 at Noosa (Troedson and Davies 2001), or from other Australian records (Woltering *et al*. 2014:141). The peak in temperatures may result from a different source location or season for the GDGTs produced during and immediately after the hiatus in sedimentation, as it is unlikely that the higher temperatures are a Lake McKenzie (or Fraser Island) specific phenomenon (Woltering *et al*. 2014:141; see also McGowan *et al*. 2008:177).

**Table 3-5 Reconstructed mean annual air temperature (MAAT) as reflected in the GDGT distributions at Lake McKenzie (based on Woltering *et al*. 2014:137-142).**

| Date | Reconstructed MAAT | Relation to present day MAAT (20.4°C) |
|---|---|---|
| 13.3kya-12kya | ~21.5°C – ~20.6°C | ~+1.1°C – ~+0.2°C |
| 12kya-8kya | ~20.6°C at 12kya | Near present day MAAT. |
| | ~20°C at c11kya | |
| | ~20.3°C at c9kya | |
| | ~20.5°C at 8kya | |
| 8kya-5kya | ~20.7°C at c7kya | ~+0.4°C |
| | ~21.1°C at c6.5kya | ~+0.7°C |
| | ~21.3°C at c5.8kya | ~+0.9°C |
| | ~20.3°C at c5.2kya | ~-0.1°C |
| 5kya-c0.4kya | ~19.5°C at 4kya | ~-0.9°C |
| | ~20.3°C at c3.6kya | ~-0.1°C |
| | ~20.7°C at c3.4kya | ~+0.3°C |
| | ~20°C at c3kya | ~-0.4°C |
| | ~20.1°C at c1kya | ~-0.3°C |
| | ~19.8°C at c0.5kya | ~-0.6°C |
| | ~19.7°C at c0.4kya | ~-0.7°C |
| <c0.4kya | ~19.4°C–~20.4°C | ~-1°C – ~current MAAT |

For the period 12000 to 8000 cal BP the reconstructed MAAT closely approximated present day temperatures. A similar trend was noted for Sea Surface Temperature (SST) in the central Indo Pacific Warm Pool (IPWP) at around the same period (Gagan *et al*. 2004; Woltering *et al*. 2014:141). SST reached modern levels in tropical and temperate Australian waters by ~11000-9000 years ago (Petherick *et al*. 2013; Reeves *et al*. 2013), and in the southern Great Barrier Reef and at Noosa c9000 years ago (Bostock *et al*. 2006; Troedson and Davies 2001). Woltering *et al*. (2014:141; see also Donders *et al*. 2006; Moss and Kershaw 2007:19) attribute the onset of “modern day temperatures” on Fraser Island in the early Holocene to “the higher sensitivity of terrestrial environments to changes in insolation compared to the delayed response of the oceans due to the higher heat content of the oceans relative to the atmosphere”. In contrast, the mid-Holocene (c8000-5000 cal BP) data demonstrate higher temperatures than the early Holocene, up to 0.9°C above the present day MAAT. Mid-Holocene high temperatures are also recorded elsewhere in Australasia although the timing varies between regions (Reeves *et al*. 2013), with Woltering *et al*. (2014:142) noting the peak of +0.9°C at c5800 cal BP to be coincident with the thermal optimum recorded by Abram *et al*. (2009) for the IPWP. The peak does correspond with the hiatus recorded by Donders *et al*. (2006) between 6500 and 5400 years ago at Lake Allom, reflecting a period of reduced effective precipitation on Fraser Island. Finally, the period from c5000 years ago to the present shows numerous fluctuations at fairly short time scales, although the low resolution of both the data and chronology prevented identification of any cycles in the variations, and the GC-12 and GC-25 data reflected increasing temperatures during this period. Coupled with the record of higher water levels and reduced fire activity at Lake Allom during this time, Woltering *et al*. (2014:142) concluded that the late Holocene was a period of cooler temperatures and higher levels of effective precipitation than the mid-Holocene.

*Pollen analyses*

The discussion by Atahan *et al*. (2015) of the floral species observed in the Lake McKenzie cores lacks the level of detail provided by Donders *et al*. (2006) for Lake Allom, and does not offer any comment on the implications of the variations between species at the sites for palaeoenvironmental reconstructions on Fraser Island on a broader level. An arid period is considered to be the reason for a hiatus in sedimentation from c18300 -14000 cal BP and it is speculated (Atahan *et al*. 2015:152) that the lake became perennially or intermittently dry. This period falls within the extended hiatus (35000 – 12000 cal BP) observed at Lake Allom (Donders *et al*. 2006:433) and within the period of the dry conditions inferred from the sandy layer bracketed by the $^{14}$C dates 21800 ± 270 BP and 12169±450 BP (Longmore 1997:513, Longmore and Heijnis 1999:43) (26000-14500 cal BP, Atahan *et al*. 2015:152) at Old Lake Comboo. The arid periods observed on Fraser Island occur earlier than those identified from vegetation reconstructions for North Stradbroke Island (e.g. Moss *et al*. 2013; see also below). Atahan *et al*. (2015:152) suggested that this time lag may be due to the 1.5$^{o}$ difference in latitude between the islands, and the changes recorded in the East Australian Current (EAC) after the LGM, indicating the zone of separation of the EAC which transports warm tropical waters southwards was forced south of 26$^{o}$S between 12000-11000 BP (Bostock *et al*. 2006:654). Warmer waters would pass Fraser Island before reaching North Stradbroke Island, and therefore there would be a difference in the timing of the arid phases on the islands. However, Bostock *et al*. (2006:654) do not suggest that the EAC separation is associated with periods of increasing aridity. Atahan *et al*. (2015:152) also suggested the possibility that the differing topography of the islands and the effects of sea level changes may influence their moisture regimes.

Zone LM2-3 (c14000 – 6100 cal BP) represents a period of relatively wet conditions, denoted by a reduction in littoral/aquatic species, grasses and daisies, reduced fire activity, and an increase in *Monotoca* (myrtles) and *Lophostemon* (box); the appearance of the latter two genera may indicate the establishment of modern types of eucalypt forest in the lake basin and on the surrounding dune systems. There is a small increase in littoral/aquatic pollens in Zone LM2-4 suggesting that after c6000 cal BP slightly drier conditions returned, and remained until c2500 cal BP, corroborated by an associated slight increase in grass pollens. Woltering *et al*. (2014) noted the highest Holocene temperatures in the MAAT at c6500 cal BP and c5800 cal BP and Atahan *et al*. (2015:152-153) equated these drier conditions at Lake McKenzie with the arid phase noted by Donders *et al*.

(2006:433) in Hiatus II at Lake Allom, and the conditions reported for Hidden Lake (Longmore 1998 in Atahan *et al*. 2015:153). At Hidden Lake an extended dry period from c9500 cal BP to c2600 cal BP was reported, associated with falling groundwater levels from c9500cal BP – c6300 cal BP, stable and low groundwater levels c6300 – c5100 cal BP, followed by increasing groundwater levels to c2600 cal BP. Lees (2006:85) considered this observation to be a mismatch with dune transgression evidence from the region as an extended dry period with reduced vegetation cover would lead to a period of dune instability, but the Cooloola dune field on the mainland was stable at this time. Similarly, beyond an initial description (Atahan *et al*. 2015:150,) there is no discussion of the last zone, LM2-5, which covers a period of 2500 years to the present, although presumably it is of some value to the interpretation of environmental change, as well as having implications for late Holocene occupation in the region. Atahan *et al*. (2015:151-152) commented that human influence on fire regimes during the glacial period is difficult to discern, and must remain speculative in the absence of archaeological evidence of pre-Holocene human habitation on Fraser Island and the contiguous mainland. Although high frequencies of charcoal have elsewhere been associated with Aboriginal burning of vegetation (e.g. Kershaw 1986), Krull *et al.* (2004:421) argue that fire frequency is largely dependent upon vegetation profiles, with sclerophyll forest being fire-prone and rainforest being fire-tolerant.

### *Wathumba and Moon Point wetlands*

Augmenting the evidence from the lake cores is the analysis by Moss *et al.* (2015) of sediment cores extracted from fen complexes within Ramsar-listed wetlands at Wathumba and Moon Point on the west coast of Fraser Island. The regional micro-charcoal and local macro-charcoal records reflect significant fire regime alterations during the late-Holocene: more frequent fires occurred before European settlement, with less frequent fires in the post-settlement period. While the dominant taxon in the wetlands remained *Empodisma minus*, following the post-European reduction in fire frequency there was an increase at Moon Point in myrtaceous shrubs such as *Leptospermum* and *Melaleuca*, suggesting the pre-European fire regimes kept the wetlands more open. Although direct evidence that the fire regimes were part of Aboriginal fire management of the wetlands is presently lacking, Moss *et al*. (2015) noted the Aboriginal use of the region over a period of 5500 years.

### *Tin Can Bay/Rainbow Beach*

The results of the analysis of a peat core from the Tin Can Bay/Rainbow Beach area is included with the Fraser Island discussion as the Cooloola strandplain is essentially a mainland extension of the island (McNiven 1992a:1-2; Tejan-Kella *et al*. 1990). Krull *et al.* (2004) used a combination of organic chemical analysis and $^{14}C$ data to characterise a peat core taken from the Carlo Creek catchment area of Tin Can Bay, approximately 2km southwest of Rainbow Beach (Figure 3-6), by J. E. Coaldrake of the CSIRO Plant Division in 1955. The catchment area is a low coastal plain (<10m ASL) with shallow valleys providing drainage through swampy areas. The soil profile is dominated by humus podzols with peaty podzols and acid peats in the wetter areas (Coaldrake 1961; Krull *et al.* 2004:412). The maximum depth of the core sample was 305cm, returning a basal radiocarbon date of 18,580±120 BP. Based on the radiocarbon dates and chemical composition, the sample was divided into four zones: Zone 1 representing the Pleistocene glacial zone; Zone 2 the Late Pleistocene – Early Holocene; Zone 3 the Late Holocene; and Zone 4 designated as Modern (Krull *et al.* 2004:414; Table 3-6). Zones 2, 3 and 4 are presented in detail here.

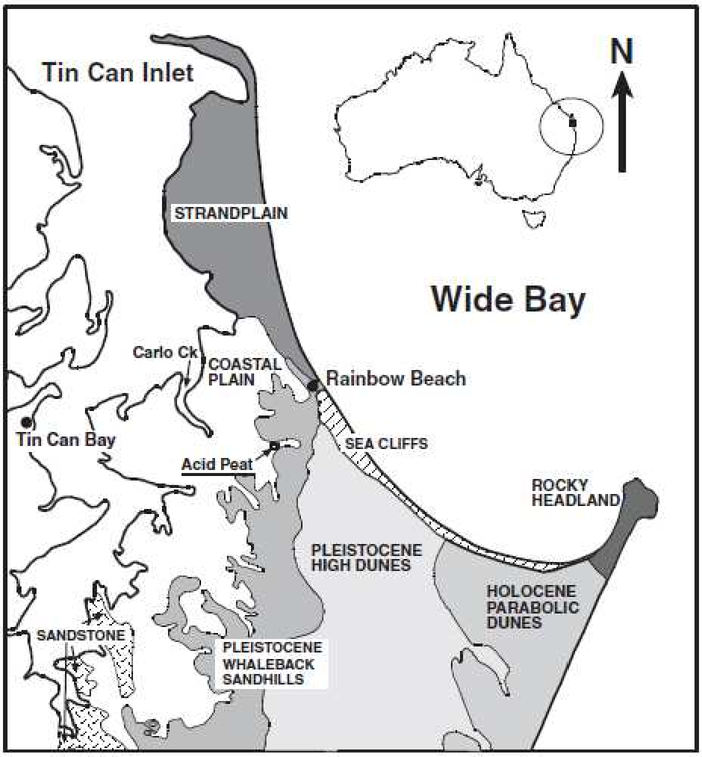

**Figure 3-6 Location of Tin Can Bay acid peat (after Krull *et al.* 2004).**

**Table 3-6 Carlo Creek catchment sample depths, radiocarbon dates, and zones (after Krull *et al.* 2004:414).**

| **Depth in cm** | **$^{14}C$ years BP** | **Zone** |
|---|---|---|
| 2-23 | 220±60 | Zone 4 Modern |
| 23-68 | 270±70 | Zone 4 Modern |
| 68-150 | 2850±60 | Zone 3 Late Holocene |
| 150-250 | 9190±70 | Zone 2 Late Pleistocene-Early Holocene |
| 250-275 | 17980±190 | Zone 1 Pleistocene last glacial |
| 275-305 | 18580±120 | Zone 1 Pleistocene last glacial |

Zone 2 indicates that peat accumulation began during the Pleistocene-Holocene transition when rising sea levels led to the development of the current drainage system and the development of peat swamps in the lowest-lying levels of the coastal plains. The accumulation of the Carlo Creek catchment peats most likely commenced as the result of increased rainfall levels and warmer temperatures, leading to higher groundwater levels, increased soil moisture and a change in vegetation cover. The $^{14}C$ and carbon accumulation data alone do not support a hypothesis of altered climatic conditions, but there is also no evidence of a change to drier conditions such as those proposed for Fraser Island by Longmore (1997) and Longmore and Heijnis (1999). Krull *et al.* (2004:419) consider "this enigmatic dry period" to be a local event, particularly in light of the Holocene sea level high-stand which occurred at the same time.

The chemical composition of Zone 3 indicates that there was a continuously high water table, possibly related to higher sea levels, promoting the retention of lipid materials from plants adapted to comparatively warmer and wetter conditions (Krull *et al.* 2004:419-420, 422). In particular the alkyl carbon levels, linked to low pH, decreased microbial activity and waterlogged conditions, indicate a period of increased rainfall, high ground water levels and anaerobic conditions. The dating of Zone 3 suggests that it coincides with the return to wetter conditions and a rise in the groundwater levels described by Longmore (1997) for Old Lake Comboo on Fraser Island. Zone 4 consisted of humified peat 86cm deep with "a moderate amount of fibrous roots", (Krull *et al.* 2004:419) with peat accumulation estimated to be 1.5mm per year based on the $^{14}C$ age of 270±70 at a depth of 45cm.

### North Stradbroke Island

At c285km$^2$ North Stradbroke Island is the world's second largest sand island. It is approximately 38kms long and up to 11km wide, with a maximum elevation of 239m. The climate is sub-tropical with warm summers and mild winters; the mean annual rainfall is 1580mm, and the mean annual maximum temperature is 25$^{o}$C (Barr *et al*. 2013:13).

The palaeoenvironment of North Stradbroke Island is one of the best documented for southeast Queensland. Initially centred on Native Companion Lagoon in the southwest of the Island (McGowan *et al.* 2008; Petherick *et al.* 2008a, 2008b, 2009, 2011), the more recent deep-time studies also include data from Tortoise Lagoon close to the east coast, and Welsby Lagoon in the northwest (Moss *et al.* 2013; Figure 3-7). In 2011 Moss *et al.* also reported on the palaeoecology of Myora Springs over the past 800 years. Other palaeoecological studies include those by Barr *et al*. (2013) at Blue Lake, Boyd (1993) on the pollen record of the 600 year old Eighteen Mile Swamp, and Pickett *et al.* (1984) and Pickett *et al.* (1985) on fossil corals buried beneath the dunes at Amity

Point. This section discusses the analyses from Native Companion, Tortoise and Welsby Lagoons, and Blue Lake.

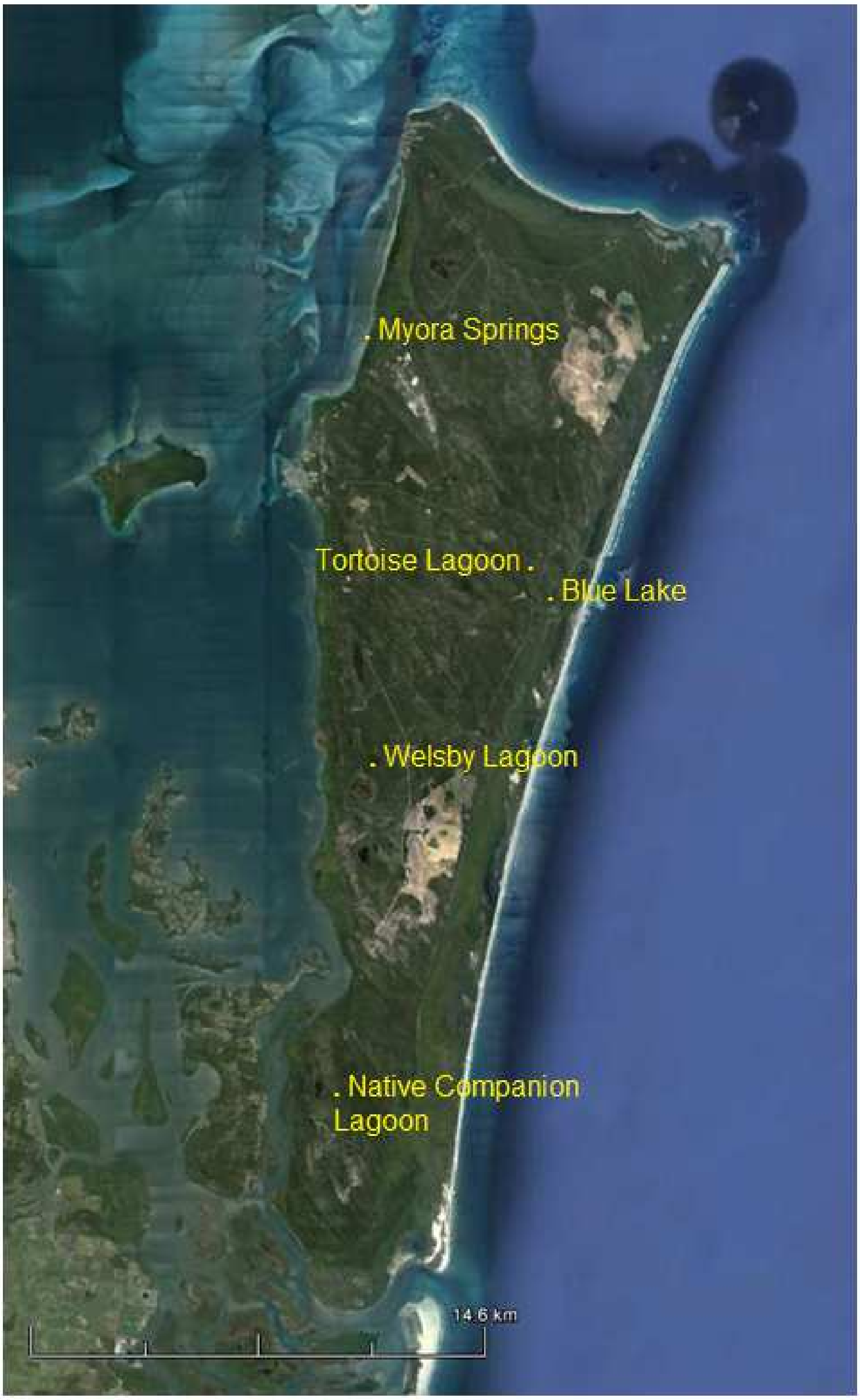

**Figure 3-7 North Stradbroke Island showing the locations of the core extraction sites.**

*Native Companion Lagoon*

A 3.8m long sediment core was extracted from the northwest corner of Native Companion Lagoon (NCL) in February 2004. The lagoon is one of the perched water-bodies on North Stradbroke

Island, and is a closed, ephemeral system. It is approximately 1km long and 300m wide, and c20m ASL in a depression within a large parabolic dune vegetated with remnant mixed *Eucalyptus* forest, *Casuarina* and *Banksia* trees. While the lagoon can reach a depth of c1.5m, it was dry at the time of the core extraction due to a prolonged drought and was colonised by reeds, grasses and small woody shrubs, with a mat of decaying plant matter (McGowan *et al*. 2008:172; Petherick *et al*. 2008:789). Both the living and decaying vegetation protect the lake bed from deflation by wind, and the surrounding dunes shelter it from strong winds; aeolian transport of sand is also restricted by the dune vegetation. The porous nature of the podzols which form the surrounding dune systems render overland flows into the lagoon rare and although there may be small fluvial flows from the dunes during heavy storm events (Petherick *et al*. 2008a:788, 789), at the time of the core extraction there was no evidence of such on either the lake bed or shoreline (McGowan *et al*. 2008: 172).

The core consisted of dark organically-rich peats which became increasingly sandy in the lower 38cm (350cm to basal depth of 388cm), and was sampled at 5mm intervals (Moss *et al*. 2013:262; Petherick *et al*. 2008a:789; Petherick *et al*. 2009:68). Nineteen AMS $^{14}$C dates are presented by Petherick *et al*. (2008a:789) (Table 3-7), 16 by McGowan *et al*. (2008:173) and Petherick *et al*. (2009:72), and 17 by Moss *et al*. (2013:264) and Petherick *et al*. (2008b:4). The $^{14}$C dates for four of the samples were considered questionable (NC-1-069, NC-1-081, NC-P-009 and NC-1-312); these samples were possibly contaminated by younger carbon introduced through rootlets (McGowan *et al*. 2008:173; Petherick *et al*. 2008a:789; Petherick *et al*. 2009:74). There are some differences in the calibrated ages presented by the four groups of authors, but these are occasioned by the use of different methods or programs to calibrate the radiocarbon dates (Table 3-7).

**Table 3-7 Radiocarbon dates from Native Companion Lagoon Core (adapted from Petherick *et al*. 2008:789). Anomalous dates are highlighted in grey.**

| **Sample ID** | **Average depth in mm** | **$^{14}$C age** | **McGowan *et al*. 2008; Petherick *et al*. 2009 IntCal04 (Reimer *et al*. 2004).** | **Petherick *et al*. 2008a, 2008b Cariaco Basin (Hughen *et al*. 2006).** | **Moss *et al*. 2013 IntCal09 (Reimer *et al*. 2009).** |
|---|---|---|---|---|---|
| NC-1-001 | 5.0 | 540±36 | 537.5±17.5 | 624±7 | 640 |
| NC-1-028 | 197.5 | 1745±37 | 1655±55 | 2016±21 | 2016 |
| NC-1-069 | 395.0 | 6353±50 | 7285±45 | 7341±76 | 7341 |
| NC-1-081 | 455.0 | 6176±47 | 7045±55 | 7136±74 | 7136 |
| NC-P-009* | 543.0 | 5818±45 | 6615±65 | 6723±70 | Not mentioned |
| NC-1-149 | 792.5 | 9222±65 | 10335±95 | 10656±111 | 10656 |
| NC-1-177 | 935.0 | 10130±73 | 11650±300 | 11705±121 | 11705 |
| NC-1-207 | 1090.5 | 11478±79 | 13350±200 | 13623±152 | 13623 |
| NC-1-224 | 1172.5 | 12714±90 | 14600±250 | 14691±152 | 14691 |
| NC-1-256 | 1334.5 | 13467±98 | 16175±275 | 15561±161 | 15561 |
| NC-1-270 | 1403.0 | 13570±100 | 16300±300 | 15680±163 | 15680 |
| NC-1-279 | 1450.0 | 13586±100 | 16325±275 | 15699±163 | 15699 |
| NC-1-301 | 1567.0 | 14762±116 | 17675±325 | 17058±176 | 17058 |
| NC-1-312 | 1623.0 | 13534±99 | 16250±300 | 15639±162 | Not mentioned |
| NC-1-335 | 1737.5 | 15999±132 | 19100±350 | 18487±192 | 18487 |
| NC-1-394 | 1982.0** | 19311±157 | 22900±450 | 22314±231 | 22314 |

**Table 3-7 (continued) Radiocarbon dates from Native Companion Lagoon Core (adapted from Petherick *et al*. 2008:79**.

| | | | | | |
|---|---|---|---|---|---|
| NC-1-528 | 2667.5 | 28684±456 | Not included | 33144±344 | 33144 |
| NC-1-567 | 2862.5 | 33187±816 | Not included | 41317±429 | 41317 |
| NC-1-677 | 3482.5 | 35757±1147 | Not included | 43614±452 | 43614 |

*Sample ID NC-1-100 in McGowan *et al*. (2008:173, Table 1).

**Depth 2038mm in McGowan *et al*. (2008:173, Table 1) and 2048mm in Petherick *et al*. (2009:72, Table 2).

### *Sediment analyses*

The Native Companion Lagoon sediment record generally reflects evidence of most major late Pleistocene and Holocene global climatic events known to have affected the Southern Hemisphere and Australia (McGowan *et al*. 2008:175-176). Aeolian sedimentation was at its highest during the LGM at more than twice all other rates of sedimentation, temperatures were low, effective precipitation was reduced, and increased aridity was widespread. Similar patterns of aeolian sediment transport and deposition have been noted elsewhere in eastern Australia in dated contexts such as cores from beneath the Tasman Sea, and on the mainland at Belarabon and Lake Mungo (Hesse and McTainsh 2003: 2012, 2018, 2021; McGowan *et al*. 2008:175). Hesse and McTainsh (2003:2030) suggest that for southeast Australia LGM increased dust activity and deposition were the result of relatively weaker hydrological cycles rather than increased wind strength. Other periods of increased sedimentation noted in the NCL core for the period following the LGM, and not previously identified at other Australian sites, occurred at c18900, 18100, 16400, 13800, 10700, 7100 and 6100 years ago (McGowan *et al*. 2008:175). There were notable peaks in the deposition of local sediments during these periods, as well as during and immediately after the LGM, and from 7500-2000 cal BP, including a peak in deposition between 4500 and 3500 cal BP. Far-travelled sediments were a substantial component of the LGM flux, and during the period 15000-8000 cal BP (Figure 3-8).

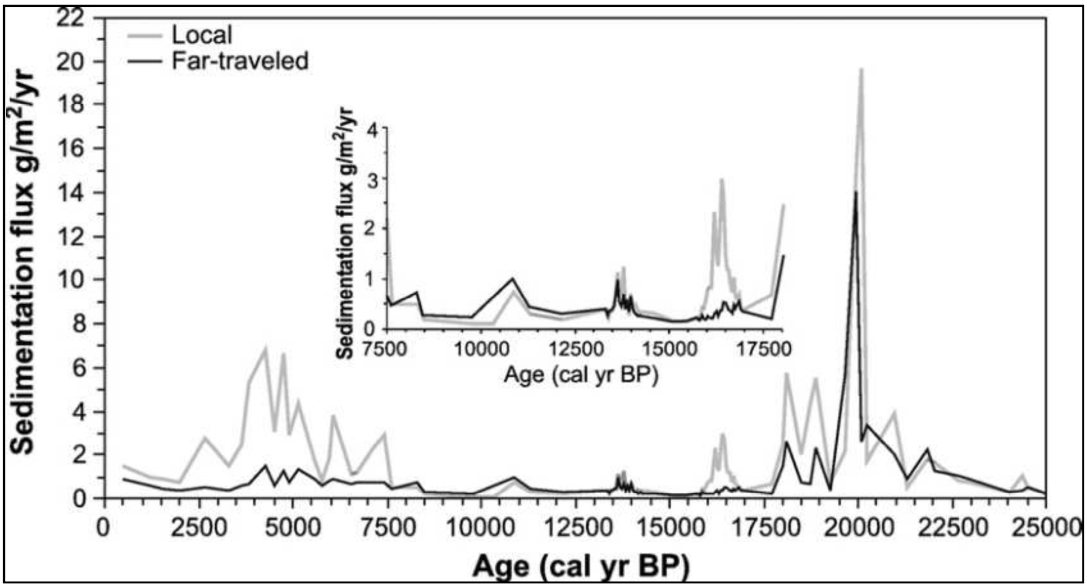

**Figure 3-8 Deposition rates of local and far travelled sediments at NCL (McGowan *et al*. 2008:176)**

There is an increase in aeolian sedimentation in the NCL record during the period c12000 cal BP to c9900 cal BP, with a peak at c10,757 cal BP, which coincides with the Antarctic Climatic Optimum reported by Masson *et al*. (2000) for the period c11500 – 9000 years ago when February SST rose. McGowan *et al*. (2008:177) comment that this evidence is otherwise only reported in palaeoenvironmental records from Australia by Haberle (2005), noting “that in northeastern Australia a number of rainforest taxa disappeared during this period, suggesting a reversal to drier climatic conditions, although a mechanism for this change was not given”, but the authors may have slightly misrepresented Haberle’s position. While Haberle (2005:354) did comment that the disappearance of wet sclerophyll taxa such as *Agathis* and *Podocarpus*, associated with a return to peak representation of *Casuarina* could represent a return to drier climatic conditions, he continued “... however, rainforest taxa continue to make initial appearances in the record suggesting that taxa disappearances may represent shifts in canopy dominance through competitive advantage rather than a reversal in climatic conditions necessarily restricting rainforest advancement into the area”. Significant peaks in sedimentation rates, particularly of local sediments, were noted for the mid-Holocene at c7200 cal BP and c6200 cal BP, and for the late Holocene at c4700 cal BP and c3890 cal BP (McGowan *et al*. 2008:178). Although the causes of the mid-Holocene peaks could not be identified with any certainty, they were suggested to be reflections of a secondary Antarctic Climatic Optimum, and of changes in oceanic circulation which affected the local climate to a degree that sands were mobilised and periods of dune formation occurred (see also Petherick *et al*. 2009). McGowan *et al*. (2008:178) note that the late-Holocene sedimentation peaks are second only to those during the LGM, but with a much-reduced contribution from far-travelled sediments. The LGM climate of North Stradbroke Island was influenced by dry south-westerly winds, and it is postulated that these conditions returned to central and eastern Australia bringing increases in aridity at previously unreported levels, creating extended local severe coastal droughts and widespread wind erosion. Similar conditions were reported by Longmore (1997) and Donders *et al*. (2006) for Fraser Island, and Woltering *et al*. (2014; Table 3-5) reported fluctuating MAAT for the late-Holocene arid periods at Lake McKenzie. It is also possible that the increased aeolian sedimentation may be influenced by increased ENSO activity (Gagan *et al*. 2004; McGowan *et al*. 2008:178). McGowan *et al*. (2008:178) offered no comment on the last 1500 years of the sedimentation record other than to note that aeolian sedimentation rates remained fairly constant.

The sources of the far-travelled sediments noted in the Native Companion Lagoon cores were identified by Petherick *et al*. (2008a, 2008b) and Petherick *et al*. (2009) using trace element analysis and comparative samples from 149 locations. Four pathway models were developed (Petherick *et* *al*. 2009:75-77), however only the two covering the Pleistocene-Holocene transition and the Holocene are presented here (Table 3-8).

**Table 3-8 Summary of the major dust pathways (from Petherick et al. 2009:75 Table 3)**

| Pathway model | Age range | Possible dominant sources | Climate conditions |
|---|---|---|---|
| III | 17400 – 5100 cal BP | Lake Frome<br>Strzelecki Desert<br>Central South Australia | Late Last Termination to mid-Holocene: generally decreased aridity, including the onset of a mid-Holocene arid phase. |
| IV | 5100 – 0 cal BP | Darling River floodplains | Mid- to Late-Holocene: generally decreased aridity, although this period encompasses the termination of a mid-Holocene arid phase. |

Unlike McGowan *et al*. (2008:178), Petherick *et al*. (2009:77) do not address peaks of aeolian sedimentation during the period 7500 cal BP and 6000 cal BP, and also offer a slightly different explanation of the dominance of local sediments during this period. They hypothesise that the increased local activity may be linked to the Holocene high-stand, and increased dune activity on North Stradbroke Island, when shoreline erosion by transgressive seas provided loose sands for deflation by onshore winds and contributed to dune development (see also Ward 2006). This may not be the only explanation, however, as local sands and dusts continue to dominate the sediments throughout the late Holocene, indicating that the dunes remained active after the sea levels had stabilised. It is posited that Aboriginal fire regimes may have contributed to increased dune activity and sedimentation around NCL (Petherick *et al*. 2009:77). Deposition increased between c5100 cal BP and 4500 cal BP and sedimentation decreased from c4000 cal BP onward (Petherick *et al*. 2009:76-77); the increase is most likely associated with the widely-recorded mid-Holocene arid phase of decreased effective precipitation, “increased windiness” and increased fire frequency in eastern Australia. In common with most other observers, Petherick *et al*. (2009) offer no further detail on the more recent Holocene climatic conditions and sedimentation patterns.

### *Pollen analyses*

#### *Native Companion Lagoon*

Six pollen zones were identified in the NCL core (Moss *et al*. 2013:262, 264). The time period covered is deeper than in earlier studies derived from this core (e.g. McGowan *et al*. 2008; Petherick *et al*. 2008a, 2008b; Petherick *et al*. 2009; Petherick *et al*. 2011), and while there is some overlap there is little direct correlation between the pollen zones and sediment analyses due to the use of differing levels of resolution. Generally speaking, sclerophyll arboreal taxa, particularly

Casuarinaceae and *Eucalyptus*, dominate the pollen record; relatively high values of rainforest pollen, mostly *Araucaria*, are recorded for the period ~47000 – 19600 cal BP, followed by a sharp decline. Sclerophyll herbs, dominated by Poaceae, occur throughout with their highest values between ~42500 – 13700 cal BP. While present through most of the record, only relatively minor contributions are recorded for aquatic (*Melaleuca*, Cyperaceae, Restionaceae and *Myriophyllum*) and fern (pteridophytes or monolete ferns) taxa, with the latter more abundant when rainforest pollen values are high. Mangroves (*Avicennia marina*, *Rhizophora stylosa*, *Ceriops tagal* and *Bruguiera gymnorrhiza*) appear at ~9600 cal BP. There is a relatively low representation of rainforest species and sclerophyll herbs from ~9600 cal BP, with the rainforest component almost non-existent after ~1250 cal BP. Charcoal values increased after ~5600 cal BP and remained high until the modern period.

### *Tortoise Lagoon*

Tortoise Lagoon is a small ephemeral perched lake at an elevation of 39m ASL, within a swale between two dunes over 130m in height. The surrounding vegetation is eucalypt forest with an understorey of heath and grass, while the lagoon is fringed on its northern margin by a large Casuarinaceae forest. At the time of extraction of the 5.01m core the vegetation on the lagoon surface consisted of sedges and reeds (Moss *et al*. 2013:260). The core consisted of alternating peat and lacustrine muds (Moss *et al*. 2013:264), and was sampled at 10cm increments for pollen and charcoal analysis. Twelve samples consisting of seven bulk organic sediments and five pollen concentrates were also obtained for $^{14}$C dating (Table 3-9). All of the pollen samples returned erroneously young ages considered to be evidence of contamination, with anomalous dates were excluded from the age-depth profile. Tortoise Lagoon differed from NCL in a greater abundance of sclerophyll herbs (Moss *et al*. 2013:264), lesser abundance of rainforest species, predominantly *Araucaria*, an absence of mangroves, and a greater abundance of aquatic taxa such as *Melaleuca* and Restionaceae.

**Table 3-9 Radiocarbon ages for Tortoise Lagoon (after Moss *et al.* 2013:264). Anomalous dates are highlighted in grey.**

| **Sample ID** | **Depth in cm** | **Description** | **Age $^{14}$C yr** | **Age cal BP*** |
|---|---|---|---|---|
| TOR-D-001 | 63 | Peat | 4160±60 | 4654 |
| TOR-D-002 | 122 | Organic muds | 6350±70 | 7333 |
| TOR-D-003 | 176 | Peat | 10410±80 | 12193 |
| TOR-D-004 | 267 | Peat | 13360±100 | 16669 |
| TOR-D-005 | 311 | Peat | 18630±140 | 22019 |
| TOR-D-006 | 395 | Peat | 23860±140 | 28717 |
| TOR-D-007 | 470 | Sandy peat | 16870±140 | N/A |
| TOR-D-008 | 282 | Pollen | 16090±80 | N/A |
| TOR-D-009 | 297 | Pollen | 14420±80 | N/A |
| TOR-D-010 | 332 | Pollen | 15640±280 | N/A |
| TOR-D-011 | 359 | Pollen | 15060±100 | N/A |
| TOR-D-012 | 380 | Pollen | 16710±80 | N/A |

*As presented in the original

*Welsby Lagoon*

Welsby Lagoon is a perched wetland near the northwest coast of North Stradbroke Island with an elevation of 29m ASL. At the time of the extraction of a 4.5m core (2012) the water depth was between 0.5 and 1m and the lagoon vegetation was dominated by sedges and reeds, with large patches of *Melaleuca* both within the lagoon and on its fringes (Moss *et al*. 2013:260). The surrounding vegetation was eucalypt forest/woodlands and Casuarinaceae woodlands, with a mainly heath understorey. The uppermost 50cm of the core was composed of roots from the overlying sedges and was not analysed. The remainder of the core was composed of highly organic peat which generally became more compacted with increasing depth. Eleven AMS $^{14}$C dates were obtained (Table 3-10). While the Holocene dates demonstrated increasing age with increasing depth, there were some age reversals in the Pleistocene-age sediments below 342cm; this was considered to be due to the charcoal component which, being resistant to degradation, can return old ages. On this basis, the older series of dates were excluded from the analysis and age profiles were estimated following exclusion of the outlying dates (Moss *et al*. 2013:260).

**Table 3-10 Radiocarbon dates for Welsby Lagoon (after Moss et al. 2013:264). Anomalous dates are highlighted in grey.**

| **Sample ID/Depth in cm** | **Description** | **Age $^{14}$C yr** | **Age cal BP*** |
|---|---|---|---|
| WEL 80cm | Charcoal | 1803±30 | 1760 |
| WEL 125cm | Charcoal | 4070±30 | 4545 |
| WEL 165cm | Charcoal | 5556±26 | 6347 |
| WEL 251 | Charcoal | 8043±30 | 8940 |
| WEL 287 | Charcoal | 9903±38 | 11310 |
| WEL p304 | Pollen | 14250±50 | 17010 |
| WEL 342cm | Peat | 18696±88 | 22285 |
| WEL p398 | Pollen | 16350±70 | 19490 |
| WEL 414 | Charcoal | 29096±250 | 33827 |
| WEL 435 | Peat | 18320±90 | 21800 |
| WEL p438 | Pollen | 18980±80 | 22480 |

*As presented in original.

In common with Native Companion Lagoon and Tortoise Lagoon, the pollen record at Welsby Lagoon is dominated by sclerophyll arboreal taxa. Casuarinaceae is again the dominant family, with *Eucalyptus* and *Callitris* comprising the other key taxa; eucalypts were most common in the period ~26000 – 20000 cal BP, and there is a peak in *Callitris* at ~14500 cal BP. There is a greater rainforest representation, mainly *Araucaria* and palms, as well as sclerophyll herbs, principally Asteraceae (Tubuliflorae) from ~26000 – 20000 cal BP. Pteridophytes represent only a minor component of the pollen sum. *Melaleuca*, Restionaceae and *Myriophyllum* are the most abundant aquatic taxa, while sedges have a much lower representation. Mangrove pollen is absent from the record, with *Pinus* pollen appearing after ~190 cal BP.

*Blue Lake*

Blue Lake differs from Native Companion, Tortoise and Welsby Lagoons in that it is a window rather than a perched lake. It is located on the eastern side of the island, south of Tortoise Lagoon, in an inter-dunal depression intersecting the regional water table. It has an area of approximately 10.3ha, an approximate volume of 500 000m$^3$, and a maximum depth of 11m (Barr *et al*. 2013:1616). It was the subject of a multi-disciplinary study (Barr *et al*. 2013:1614) designed to assess the lake's response to environmental change by investigating hydrological and water quality variation at different temporal scales and, most importantly for this study, a palaeoenvironmental reconstruction of the last 7500 years based on pollen, stable isotope, macrofossil and diatom evidence. The pollen evidence is presented in this section.

Unlike the ephemeral perched lakes on North Stradbroke Island and Fraser Island, Blue Lake is permanent and recharged by groundwater from an extensive aquifer. At the time of the Barr *et al*. (2013) study it received no surface inflow and the maintenance of water levels depended on groundwater input and the elevation of the swampy outflow barrage, circumstances which have operated for at least the last 7500 years (Barr *et al*. 2013:1627). The sediment cores from which the pollen and other data were obtained were extracted from the lake bed at a water depth of 7.2m in 2007. Core 1 consisted of the upper 92cm of sediment and Core 2 consisted of a further 202 cm of sediment below Core 1. Five $^{14}$C ages were obtained for the sediments below 50cm in depth (Table 3-11) (Barr *et al*. 2013:1618, 1622).

**Table 3-11 Radiocarbon and calibrated ages for the composite Blue Lake core (after Barr et al. 2013:1618).**

| **Sample depth in cm** | **Dating method** | **$^{14}$C age** | **Median calibrated age** |
|---|---|---|---|
| 50 - 51 | AMS | 2397±30 | 2380 BP |
| 110 - 111 | AMS | 3807±30 | 4129 BP |
| 160 - 163 | AMS | 5111±37 | 5816 BP |
| 185 - 195 | Conventional | 5781±108 | 6541 BP |
| 235 - 138 | AMS | 7367 | 7400 BP |

Overall the pollen record shows vegetation around Blue Lake to be dominated by sclerophyll arboreal taxa, in particular Casuarinaceae, *Eucalyptus* and *Melaleuca*, with some traces of sclerophyll herbs, in the main part Poaceae, and rainforest taxa (Barr *et al*. 2013:1624-1626). These remain fairly constant, with more variation demonstrated in the understorey taxa; there is an increase in *Leptospermum* and *Callitris* from c3880 cal BP, and a sharp decline in charcoal from c4170 cal BP. For the period c7500 – 6500 cal BP there were high rates of deposition of carbon-rich leaf litter, demonstrated by peaks in total organic carbon and carbon/nitrogen ratios. Casuarinaceae and fire-tolerant *Eucalyptus* and *Melaleuca* dominated the vegetation, and there were substantial amounts of regionally-sourced micro-charcoal in the deposits. In contrast there were only small amounts of locally-sourced macro-charcoal, which does not travel any appreciable distance, and therefore biomass burning was probably regional rather than local (Barr *et al.* 2013:1625). There was an increased sand component and increased macro-charcoal deposition during the period 6000 – 5000 cal BP, indicating that in the local catchment fires exposed top soil, allowing erosion by surface run-off or deflation. There were also regional increases in fire frequency, reflected in high levels of micro-charcoal deposition. Peaks in carbon/nitrogen ratios and total organic carbons reflect high levels of deposition of leaves or wood material into the lake. Taken together, these observations indicate environmental change on a regional scale, perhaps with increased wind strength leading to the transport and deposition of larger amounts of sand, organic matter and micro-charcoal. Barr *et al.* (2013:1625) note that similar conditions were identified by McGowan *et al.* (2008) for Native Companion Lagoon and by Donders *et al.* (2006) for Lake Allom on Fraser Island.

In the period following c5000 cal BP there were reductions in the amount of far-travelled plant material and increased contributions from aquatic algae and macrophytes. There were also decreases in sand and charcoal deposition, implying reduced wind strengths and fire frequency. Barr *et al.* (2013:1626) note that these observations are divergent from those of McGowan *et al.* (2008) who recorded continued sand deposition at Native Companion Lagoon during this period, and Neal and Stock (1986) who noted increased charcoal deposition at Wallen Wallen Creek and suggested that it was due to intensified human occupation of the locale. The reasons for the discrepancies remain unclear, but Barr *et al.* (2013:1626) acknowledge human use of fires may account for some of the differences between the western and eastern sides of the Island. The most significant environmental changes reflected in the Blue Lake record occur at c4000 cal BP when there is a shift towards a drier climate demonstrated by an increase in more drought-tolerant dryland taxa such as *Eucalyptus*, *Leptospermum* and *Callitris* and dry sclerophyll herbs, with a proportional decline in Casuarinaceae. Lake levels appear to be largely unaffected by the shift, as the proportion of aquatic taxa increased after 3500 cal BP. There is little variation in the pollen and isotope data for the remainder of the record, except for a brief increase in Casuarinaceae values at c2000 cal BP. At the top of the core there is a further decline in Casuarinaceae values and an increase in Myrtaceae values which may reflect European use of the island (Barr *et al.* 2013:1626).

*Myora Springs*

Moss *et al.* (2011) presented a ~800 year palaeoecological record for Myora Springs, adjacent to the north-west coast of North Stradbroke Island, based on the analysis of a 32cm peat core taken from an area lying between the edge of the present remnant rainforest and the intertidal mangrove forest.

Samples were taken at 4cm increments to test for pollen and charcoal, and loss on ignition analysis. Three AMS radiocarbon dates were also obtained from the bulk sediments. The pollen analysis indicated dominant sclerophyll arboreal taxa (principally *Melaleuca*, *Eucalyptus* and Casuarinaceae), a significant rainforest component (podocarps, palms, and *Syzygium*), and ferns. Three vegetation zones (Moss *et al.* 2011:135) were identified and categorised by depth in centimetres and age values (calendar years BP).

Zone M1 (32 to 24cm, ~ 800 – 500 cal BP) reflected warm and dry El Niño conditions, possibly associated with the Northern Hemisphere Little Ice Age. Dry conditions were demonstrated by the dominance of fire-tolerant eucalypt forest/woodland and paperbark swamps, as well as high charcoal values and inorganic sediment content. Increased representation of fire-sensitive Casuarinaceae, rainforest taxa and pteridophytes combined with decreased charcoal and inorganic sediment abundances in zones M2 (20 to 8cm, ~ 550 to 120 cal BP) and M3 (4 to 0cm, ~ 120 cal BP to 0) suggested wetter, more La Niña-type conditions from about 500 years ago. Changes observed in the topmost layers of M3 included sharp declines in Casuarinaceae, *Baeckia/Tristania*, *Leptospermum,* and rainforest representation, while *Melaleuca*, *Eucalyptus* and pteridophytes markedly increased at 4cm but sharply declined above that depth. *Callitris*, *Banksia* and grasses were consistently represented, with a significant increase in Asteraceae abundances and charcoal values. These changes are considered to be evidence of post-European landscape modifications such as drainage works, road building, and changes in fire regimes rather than episodes of significant climate variability. Although the sediment record from Myora Springs does not demonstrate obvious or significant environmental impacts by the Aboriginal occupants of North Stradbroke Island, the climatic variability it reflects may have influenced resource availability and exploitation, and therefore subsistence and settlement patterns. Moss *et al.* (2011:137) suggest that the El Niño conditions obtaining 800-500 years ago may have made the permanent water source at Myora Springs an area at which people congregated, and that this may be reflected by the levels of burning demonstrated in M1, possibly as the result of more intense fire regimes. Moss *et al.* (2011:136-137) considered the significant changes observed in both vegetation and fire regimes to be associated with ENSO-linked natural climate variability and the effects of European landscape modification from the 1820s onward. The decreased evidence of burning M2 and M3 may suggest that the wetter conditions in the last 500 years allowed people to disperse more widely across the island, with Myora Springs and other permanent water sources havens in times of drought. The authors (2011:138) acknowledge, however, that more archaeological and palaeoecological data from North Stradbroke Island are required to clarify the relationship between climatic variability and Aboriginal resource use.

## Fraser Island Summary

The reconstruction of palaeoenvironmental changes for Fraser Island and Cooloola on the basis of the available literature is frustrated by the differing temporal resolutions of the data presented, conflicting data, and the general tendency of researchers (with the exceptions of Donders *et al*. 2006; Moss *et al*. 2015; and Woltering *et al*. 2014) to ignore the late Holocene or provide scant details of climatic change over the more recent past. Despite this, it is clear that palaeoenvironmental reconstructions for the region are complex, and may differ between locations that geographically appear quite similar. Records from Old Lake Comboo, Lake Allom and Lake McKenzie all indicate hiatuses in sedimentation although these differ in age of onset and duration. The extended arid period posited by Longmore (1997, 1998) and Longmore and Heijnis (1999), although covering part of the time frame for the mid-late Holocene arid period more widely recognised (e.g. Shulmeister and Lees 1995), is not expressed in such intensity at Lake Allom or Lake McKenzie and is absent from the Carlo Creek record. The fenland records also suggest open water environments in the mid-Holocene. The Moon Point record which suggests high fire frequency covers 9000 years and thus cannot be considered irrefutable evidence for a mid-Holocene arid phase. While the highest MAAT are recorded at c6500 cal BP and c5800 cal BP at Lake McKenzie, and temperatures between 8000 years ago and 5000 years ago are generally higher than the earlier in the Holocene, the associated pollen records suggest that conditions were only slightly drier than previously. The Lake McKenzie diatom record is stable throughout the sequence, but with higher water levels indicated between 14000 BP and 5000 BP, which seems to run contrary to the pollen evidence. Late Holocene increased climate variability is indicated by Donders *et al*. (2006), Atahan *et al*. (2015), and Krull *et al*. (2004), while the evidence presented by Moss *et al*. 2015 for the topmost levels of the Wathumba A may indicate European arrival and changes in wetlands management.

## North Stradbroke Island summary

The sediment deposition/flux records and dust pathway models for NCL indicate that during the Pleistocene – Holocene transition, periods covered by the ARC, ACO, and Younger Dryas, eastern Australia was drier than during the Pleistocene. This is followed by a period of climate amelioration, with decreased sedimentation levels, the lowest in the record, until c8400 cal BP. Sediment levels then increase, with two peaks at c7200 – 6200 cal BP and c4700 – 3890 cal BP; these reflect the mid-late Holocene arid phase associated with reduced effective precipitation, increased windiness (Petherick *et al*. 2009), and increased fire frequency in eastern Australia. Sedimentation rates remained fairly constant over the past 1500 years.

The pollen record from NCL suggests a slightly different picture, with period 19600 cal BP – 9600 cal BP initially warmer and wetter. There are drier environments at 13700 cal BP and 10,500 cal BP. Sea level rise is reflected in the appearance of mangrove pollens at c9600 cal BP. The late Holocene is drier, with a significant increase in burning. Moss *et al*. (2013) commented that the three perched lagoons have different signatures of increased climate variability during the late deglacial and early Holocene which may be due to their elevations and locations. At Welsby Lagoon there is increased Casuarinaceae representation ~14000 – 12000 cal BP and a peak in charcoal values – the highest in the record at 11,500 cal BP. The Tortoise Lagoon record demonstrates a number of changes including a sharp decline in *Melaleuca* between 14,000 and 12000 cal BP, a peak in the wetland herb *Hydrocotyle* at 11800 cal BP and a peak in *Monotoca* at 11,000 cal BP. These changes may indicate drier conditions with lower water levels leading to the replacement of a paperbark swamp by a shallow swamp and ultimately a wet heath. All three records demonstrate similarities for most of the Holocene with the development of Casuarinaceae-dominated sclerophyll open forest/woodland. Donders *et al.* (2006:427, 434) note that Casuarinaceae mostly indicate the presence of sandy soils, and are not suitable for identifying very specific environmental factors as they grow in both dry and wet conditions. All three cores also have lower representations of rainforest taxa after 4350 cal BP, which Moss *et al*. (2013:269) suggested represents the development of Moreton Bay, with rainforest communities moving to the mainland in the face of rising sea levels although this date is rather later than the Holocene highstand. They also (2013:269) contrasted the decline with the situation on Fraser Island "where there is an expansion of rainforest taxa (in particular the gymnosperms *Araucaria* and *Agathis*) from 2700 cal yr BP to present (Donders *et al*. 2006)". While Donders *et al*. (2006) do note an increase in rainforest taxa, they also note a sharp decline in abundance c450 years ago, perhaps due to climatic conditions. All sites exhibit evidence of wetter conditions from 10000 cal BP – 5000 cal BP with generally lower charcoal values reflecting less burning than during the late Holocene. There is increased burning in the late Holocene reflective of drier conditions, as well as lowered abundance of myrtaceous shrubs and ferns although this is less marked at Tortoise Lagoon. Moss *et al*. (2013:270) suggest that the sustained increase in burning noted at Native Companion Lagoon over the last 5000 years was significantly influenced by human activity, and relate this to increased occupation intensity as demonstrated at Wallen Wallen Creek (Neal and Stock 1986). This is a largely archaeologically-unsupported premise, however, as Wallen Wallen Creek is currently the only site on North Stradbroke dated to the mid-Holocene, and is described by Neal and Stock (1986:621) as a temporary transit camp on an access route between major resource locations. A major environmental change indicative of drier conditions after c4000 cal BP was noted at Blue Lake, although the lake levels remained unchanged and the diatom record stable. The Myora

Springs record indicates changes from drier El Niño-type conditions to wetter, more La Niña-type conditions at about 500 cal BP.

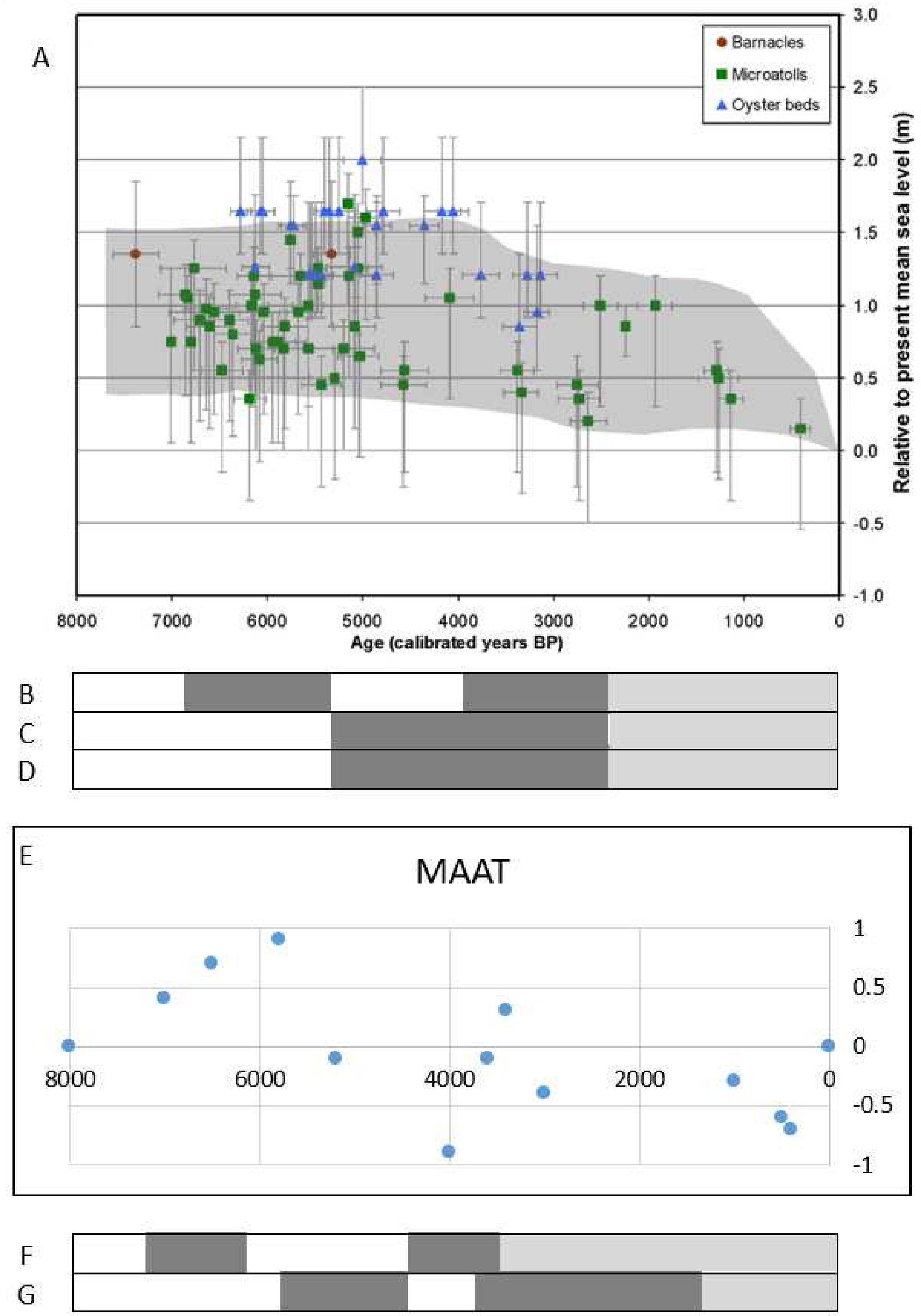

**Figure 3-9 A: Sea level curve from Lewis *et al*. 2013:127, Figure B; B: Old Lake Comboo (Dark shading indicates relatively dry conditions; white shading indicates increased precipitation; light shading indicates increasing climatic variability) C: Lake Allom D: Lake McKenzie E: MAAT reconstruction F: Native Companion Lagoon G: Blue Lake.**

### *Comparison of trends*

Figure 3-9 demonstrates the trends in sea level change, MAAT, periods of relatively wetter and drier conditions, and the onset of greater climatic variability in the southeast Queensland region during the Holocene. As can be seen, there is some variability between the models, but there is some commonality in that all demonstrate wetter conditions in the early Holocene, a mid-Holocene arid phase, and increasing climatic variability in the late Holocene.

### *Summary*

The data derived from the palaeoenvironmental constructions forms the context for assessing human behavioural variation during the Holocene. It also informs the observations made on the molluscan assemblages, the analyses of which are presented in the following chapters.

# 4. Analytical Methods

## Introduction

This chapter describes the methods employed in the analysis of the major faunal, most particularly molluscan, remains and stone artefactual components from Booral Shell Mound, Tin Can Bay 75b, Cameron Point Site 62, White Patch 3, and Bribie Island Site 9, in order to address the thesis aims outlined in Chapter One. The methods are contextualised in a discussion of the use of archaeological molluscan remains as indicators both of human behaviour and environmental variability.

## Invertebrate remains

### Marine molluscs

The marine molluscan taxa were identified with the assistance of Dr. Patrick Faulkner of the University of Sydney, formerly of the University of Queensland School of Social Science; Dr. Brit Asmussen, Senior Curator of Archaeology, Queensland Museum; and Dr. John Healy, Senior Curator – Marine Molluscs, Queensland Museum, and by comparisons with specimens in the shell reference collection held at the University of Queensland Archaeological Science Laboratories (UQASL). Identifications were also assisted by photographs from Abbott and Dance (1982), Lamprell and Healy (1998), Lamprell and Whitehead (1992), and Wilson (1993).

As this study is concerned with questions of environmental reconstruction and change, no distinction was made between potentially economic and non-economic taxa, with all molluscs included in the analysis (see Szabó 2009). A conservative approach to taxonomic identification was taken. Care was taken to avoid the over-identification of specimens. If a fragment only retained diagnostic features or characteristics to family or genus level it was not assumed that that it was part of a dominant group already identified to species level (Driver 1992; Szabó 2009; Wolverton 2013). That is, while the majority of the marine molluscs could be identified to genus and species, some specimens lacked sufficient diagnostic criteria to identify them beyond the level of family. This included Potamididae and Batillariidae gastropod juveniles which are extremely difficult to differentiate, particularly in individuals less than 10-15mm in height (Ewers 1967; Ewers and Rose 1966; Vohra 1965); these specimens were placed together in a juvenile pot/bat category. Shell fragments whose taxa were indeterminate due to a lack of diagnostic features preserving were bagged together and weighed. Each taxon was weighed and the numbers of identifiable specimens (NISP) and minimum number of individuals (MNI) counted. While there are ongoing debates about the most appropriate method for quantifying molluscan remains (e.g. Claassen 1998, 2000;

Giovas 2009; Glassow 2000; Lyman 2008; Mannino and Thomas 2001; Mason *et al*. 1998; Mowat 1994; Nunn *et al*. 2007; Poteate and Fitzpatrick 2013; Reitz and Wing 2008), this combination is frequently used in faunal studies both in Australia and internationally, as it is able to more accurately describe the proportions of taxa, the degree of inter-site and intra-site fragmentation, and also provides comparisons with non-molluscan components (see e.g. Faulkner 2013:73; Szabó 2009; Ulm 2006). For molluscs, a good argument can be made that MNI more accurately reflects abundance given the number of features used in calculation and the differential effects of fragmentation and weathering on NISP and MNI counts (e.g. Thomas and Mannino in press).

For three of the re-analysed sites (Booral Shell Mound, Tin Can Bay 75b, and Cameron Point Site 62), MNI was the sole quantitative method employed in the original analyses (Frankland 1990; McNiven 1990a, 1994) and points of comparison were required. The use of NISP and MNI also allows for calculation of the fragmentation ratio (NISP: MNI) for individual taxa, which may reflect the level of intensity of site use, while acknowledging morphological differences between taxa that may affect fragmentation rates, e.g. thin vs. thick, obese vs. flat valves, as well as micro-structural differences that can assist particular taxa to resist crushing or treadage. Sites at which deposition or accumulation rates are low and where cultural material such as shell is exposed for longer periods before being buried, generally exhibit greater levels of fragmentation than those sites where deposition is more rapid and cultural material is buried before prolonged exposure to weathering and treadage (Claassen 1998; Faulkner 2010, 2013; Hiscock 1985).

The method of calculating MNI for bivalves was straightforward and involved sorting the bivalves into left and right valves using the non-repetitive elements (NRE) of umbones and hinges with >50% of features preserved. Counts were taken for each excavation unit (XU), tallied, and the higher number of left or right valves for the stratigraphic unit (SU) was used as the MNI (Grayson 1984; Grayson *et al*. 2001). This method avoids the aggregation effects associated with using counts from XUs (which may be arbitrary units) when the SU is the main analytical unit (Grayson 1984). Gastropod MNI is frequently calculated by adding the number of spires to the number of whole individuals or apertures (e.g. Claassen 1998; Faulkner 2006, 2013; Giovas 2009; Mannino and Thomas 2001; Mason *et al*. 1998; Nunn *et al*. 2007; Poteate and Fitzpatrick 2013; Szabó 2009; Ulm 2004, 2006). However, gastropods possess a greater number of NRE than bivalves (Figure 4-1), and so for this study, depending on individual taxa, an additional range of NRE was used to calculate MNI, including apertural lips >50% complete, decks which included columellar folds (nerites), umbilici, and opercula >50% complete (Figure 4-1) (modified from Harris *et al*. 2015).

In addition to NISP, MNI, and weight, a number of measurements were taken depending on taxa, including valve height, length and depth, hinge length, and umbo height and length for bivalves (with no distinction between right and left valves for equivalve species) (Figure 4-2); and shell height, width, spire height, aperture width and aperture height for gastropods (Figure 4-3). The morphometric data are important in determining the composition of samples in terms of population structure, determining ratios of juveniles to adults, levels of exploitation and potential evidence of resource depletion, and biological, ecological, and environmental conditions. Breakage patterns were also noted, as was the condition of the shell (e.g. chalky, weathered, degraded, burned, or damaged by worms or borers) (e.g. Zuschin and Stanton 2001). The basis for this suite of analyses for the molluscan component is contextualised in the discussion below of the role of molluscs as indicators of human behaviour and environmental variability.

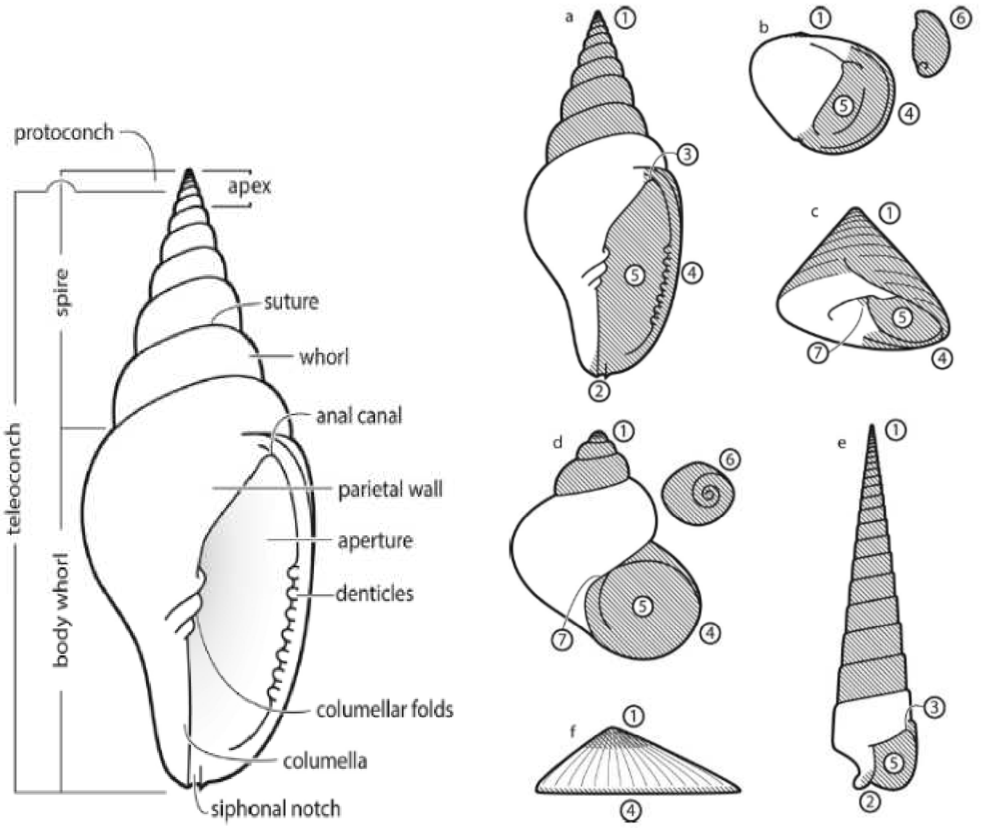

**Figure 4-1 Gastropod terminology and gastropod NRE 1= spire; 2= anterior canal; 3=posterior canal; 4= outer lip; 5= aperture; 6= operculum; 7= umbilicus. The hatched areas are the areas of the shell included in the MNI quantification; not all shell forms share the same NRE (after Harris *et al*. 2015:170,171).**

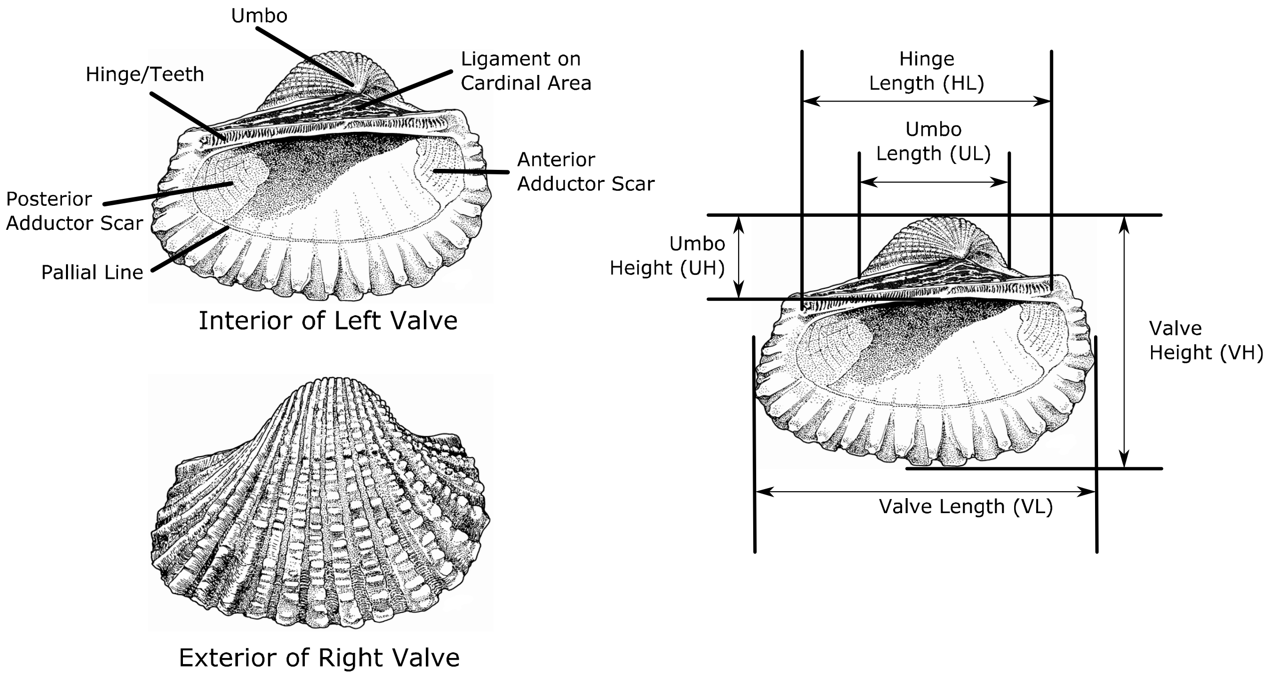

**Figure 4-2 Bivalve terminology and attributes for measurement; the species illustrated is *Tegillarca (Anadara) granosa* (after Faulkner 2010:1944).**

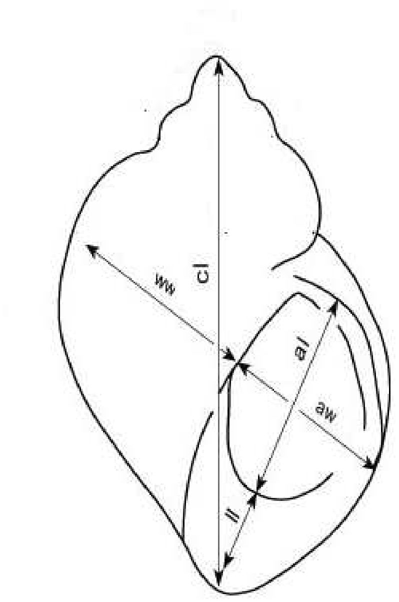

**Figure 4-3 Gastropod measurements. Cl= columellar length (height); ww=whorl width; al=aperture length (height); aw=aperture width; ll= lip length (after Palaeo-electronica).**

The degree of species diversity, richness and evenness in the assemblages was measured. Taxonomic units were grouped in the highest common level so that, while the level of taxonomic identification varies, none of the taxa overlapped within the analyses of richness and diversity (Driver 1992: Szabó 2009; Wolverton 2013). The characteristics and performance of these diversity statistics vary in terms of their discriminant ability, sensitivity to sample size, and focus on richness or evenness/dominance. The diversity measures employed were NTAXA, Shannon's Index of Diversity, Shannon's Evenness, and Simpson's Index of Diversity (Lyman 2008; Magurran 2004). All diversity indices were calculated using Palaeontological Statistics (PAST) version 3.04. The estimated density of molluscan remains per $m^3$ was calculated for each site to provide for additional robust inter-site comparisons in the final chapter.

### Terrestrial molluscs

The marine gastropod methods for identification, counting, and measuring were also applied to the land snail component of the assemblages. Specimens were compared with photographs in Stanisic *et al*. (2010).

### Crustaceans

Crab (Portunidae) exoskeleton and barnacles (Cirripedia) were recovered from the assemblages. The fragmented nature of most of the crab exoskeleton rendered identification to genus and species level difficult. Where possible the elements present (e.g. cheliped, dactyl) were identified and compared with specimens in UQASL reference collection. The barnacle plates retained no diagnostic criteria to identify them beyond the infraclass level.

## *Vertebrate remains*

Bone was sorted into fish bone (including otoliths) and terrestrial vertebrate classes, counted (NISP values only) and weighed. The otoliths were identified to the lowest taxonomic level possible with the assistance of Professor Marshall Weisler of the University of Queensland's School of Social Science, Mr. Jason McGilvray, Fisheries Officer, Queensland Department of Agriculture, Fisheries and Forestry, and by comparison with specimens in the UQASL reference collection, as well as photographs in Furlani *et al*. (2007). The terrestrial bone was identified to the lowest taxonomic level possible with the assistance of Dr. Tiina Manne of the University of Queensland School's of Social Science, Dr. Brit Asmussen, and by comparison with specimens held in the UQASL reference collection.

## *Stone artefacts*

The methods used in the identification and recording were those used by Smith (2003) in the analysis of stone artefacts from Bribie Island, and based on those of Hiscock (1984, 1986, 1988) and McNiven (1992, 1993). Artefact categories included whole flakes, broken flakes, retouched flakes, cores, and flaked pieces (i.e. an artefact unable to be classified as a flake, retouched flake, core or other implement). The artefact attributes are detailed in the data analysis chapters (5 to 8) and are not repeated here. However, some comment on the choice of attributes and their potential contribution to the analysis is appropriate.

Raw material has the potential to inform on access to and availability of resources (e.g. local vs. exotic raw materials, and also socio-cultural or socio-political networks [e.g. McNiven 1991a, 1999; Ross *et al*. 2003]), distribution of raw materials across the landscape, and preferred material for manufacture. Levels of reduction are indicated by the percentage and type of cortex on artefacts. The number of dorsal scars on flakes and the number of negative scars on cores, in addition to the number of platforms, inform on core rotation and core use, and by extension access to raw material sources. Platform modification by techniques such as faceting or overhang removal indicates intent to strengthen platforms and maximise flake size (see Clarkson 2004:109-110). Taken together, the artefact attributes can assist in determining if the people using both the stone and marine resources were relatively mobile or relatively sedentary, or on the continuum between; were expedient tool makers and users, or curated resources; as well as indicating what activities were undertaken at the sites.

As with the molluscan remains, the estimated density of stone artefacts per m$^3$ was calculated for each site to provide for additional robust inter-site comparisons in the final chapter.

## *Calculation of the accumulation rates of deposits*

Accumulation rates are frequently employed in behavioural interpretations of sites, particularly in assessing the intensity of occupation. Stein *et al*. (2003:298) presented a quantitative method of calculating the rate of accumulation of deposits within archaeological sites to measure changing landscape use over time and to assist in the interpretation of stratigraphically complex sites. The method relies on the determination of $^{14}$C age and depth below surface for at least two points in a deposit, with accumulation rates calculated by dividing the thickness of the accumulation in centimetres by the duration of the accumulation in years:

$$\frac{depth\ of\ lower\ point - depth\ of\ upper\ point}{age\ of\ lower\ point - age\ of\ upper\ point} = xcm/yr$$

Stein *et al*. (2003:313) defined three categories of accumulation: slow, intermediate, and rapid. Slow accumulation rates are less than 2cm/100 years, with material being mixed in the process of deposition due to factors such as treadage. Intermediate rates of accumulation are greater than 2cm/100 years and less than 50cm/100 years, with material being buried before mixing. Rapid accumulation rates are greater than 50cm/100 years, with rapid burial preserving the contextual relationships between sediments and cultural material. Accumulation rates can be calculated for stratigraphic units, and also for the excavation units within them to provide a finer-grained profile. This method of calculating accumulation rates does not allow for extrapolation of basal dates but it is a reasonably accurate reflection of occupation intensity, and is the method employed in the present study.

### *Statistical analyses*

A number of statistical analyses were performed on the data, with the test varying according to the assumptions being tested. The appropriate tests were determined by reference to Field (2014) and Pallant (2013). Statistical analyses were undertaken using IBM$^{©}$ SPSS$^{©}$ Statistics Version 22.

### *Molluscs as indicators of human behaviour and environmental variability*

Discussions on the role of molluscs in archaeological assemblages are undertaken at a global scale: in Australia (e.g. Bourke *et al.* 2007; Faulkner 2006, 2008; Williams *et al.* 2010); the middle/western Pacific, and Papua New Guinea (e.g. Allen 2006, 2012; Anderson 2001; A. Anderson *et al*. 2005; A. Anderson *et al.* 2007; Giovas *et al.* 2010; Szabó 2009), southern Africa (e.g. Jerardino 1997, 2003, 2010; Jerardino and Yates 1997; Kusimba 2005); Europe (e.g. Bailey and Craighead 2003; Karlén and Larsson 2007); the Americas (e.g. Braje *et al*. 2007; Erlandson 2001; Erlandson and Rick 2008; Giovas *et al*. 2013; Meggers 2007; Moss *et al.* 2007), the Middle East (e.g. Kennett and Kennett 2007), and China (Lu 2007). Many of these studies employ shell deposits not only as evidence of human behaviour, but also as proxy records for localised environmental shifts, habitat restructuring, and human-resource impacts in marine ecosystems.

A common theme in these studies is that all humans affect their environment and the larger the population, the larger the ecological impacts (Rick and Erlandson 2008:6). Over extended periods (up to thousands of years) there is the expectation of a wide range of resource harvesting strategies that will differently impact the environment and ecosystems, requiring "deft integration of both environmental and cultural information at a variety of temporal and spatial scales" (Crumley 1994:9). This integration requires the differentiation of 'natural' (non-human) ecosystem variations from those caused by humans (Rick and Erlandson 2008:8) - thus introducing ecological and biological information on regional species (faunal and floral) and their responses to natural events (e.g. nonhuman predation, climate phenomena, and associated impacts such as sea temperature change, disease etc.), as well changes to the physical environment (e.g. progradation or degradation of landforms). Archaeologists frequently measure human foraging impacts on their environments in terms of resource depletion or depression (moving from preferred or high-ranked resources to lower ranked resources, with evidence of reduction of productivity in preferred resources).

Claassen (1998:45) observed that "Overexploitation by humans is commonly thought to account for species ratios or in the mean or modal size of a species" and outlined four test implications or criteria based on the literature:

1. Mean shell length will decrease from the bottom of deposit sample to the top.
2. The modal size of the archaeologically derived populations of a species, when examined against figures for an unexploited population of the same species, will be significantly smaller.
3. Less easily procured individuals or species will increase in number from bottom to top of the deposit.
4. Less easily processed individuals or species will increase in number from bottom to top of the deposit.

Faulkner (2013:150) includes a further criterion based on the literature post-Claassen: the decrease in relative abundance of preferred species through the deposit. Claassen (1998:45) considered the test implications inadequate for identifying a shellfish population subjected to human overharvesting and that, separately and collectively, could result from environmental change. The first two implications could also represent intensive molluscan exploitation by other predators; the third and fourth could be representative of technological innovation. Recruitment success, failure and juvenile mortality are not addressed by the criteria. Her cautionary comments equally apply to the fifth criterion concerning relative abundance. Despite Claassen's (1998:45) obvious lack of confidence in the applicability of the criteria in demonstrating human impact on population sizes and the alteration of demographics, some or all of them have nevertheless been generally accepted within the archaeological community more or less as benchmarks against which data can be evaluated (e.g. Allen 2012; Braje *et al*. 2007; Erlandson *et al*. 2008; Faulkner 2006, 2009, 2013; Giovas *et al*. 2010; Giovas *et al*. 2013; Grayson *et al*. 2001; Jerardino 1997; Jerardino *et al*. 1992; Mannino and Thomas 2002; Mason *et al*. 1998; Mason *et al*. 2000; Nagaoka 2002; Whitaker 2008). Most if not all of the studies apply the criteria cautiously and address the potential of factors external to human influence.

Faulkner (2006, 2008, 2011, 2013) highlighted the requirement of understanding the individual biology and ecology of prey species in order to determine archaeological correlates of resource depletion and/or over-exploitation. His work on Blue Mud Bay identified overlapping phases of change that potentially reflected changes in land use, demography, and mobility as well as resource use tied to near shore environmental restructuring, including patterns of sediment progradation and dynamic dune development. It also included a detail consideration of the biological and ecological characteristics of *Tegillarca* (*Anadara*) *granosa*, the dominant molluscan species for much of the known period of occupation in the region, as well as extensive morphometric analyses, and informs much of the present study. Other researchers (e.g. Campbell 2008; Giovas *et al*. 2010; Giovas *et al*. 2013; Thakar 2011; Thakar *et al*. 2015; Whitaker 2008) have also focussed on species ecology and biology, with some studies suggesting that, rather than depressing resources, some intensive gathering practices may increase the size of prey species, as well as maintain populations at healthy levels. Previous studies in southeast Queensland often associate ‘estuarine species’ with mudflats with little consideration of individual habitat preferences or requirements. This can be seen as a product of the time the original research was undertaken, and a circumstance this thesis seeks to at least partially redress.

### *Summary*

This chapter has described the methods used in the analysis of the archaeological assemblages from the five sites selected for re-analysis. It has also provided the context for the factors considered in the interpretation and discussion of the results of the analyses presented in detail in the following four chapters.

# 5. Booral Shell Mound

## Introduction

This chapter presents the results and discussion of the analysis of cultural remains from site KD: A11, Booral Shell Mound (BSM). It places the site in its broader geographical context, and outlines the findings of the initial analysis (Frankland 1990). The results of the current analysis are presented in detail, with a discussion of the findings offered at the end of the chapter.

## The Great Sandy Strait

BSM lies on the Great Sandy Strait (GSS) opposite the southern end of Fraser Island (K'gari) (Figure 5-1) in the Great Sandy Region (GSR), an area comprising Fraser Island, southern Hervey Bay, the Cooloola sandmass, and the GSS. The GSS was Ramsar-listed as a wetland area of international significance in 1999. It is a double-ended estuary, with Fraser Island acting as a barrier blocking the outflow of the Mary River which is diverted north through the estuary. The Mary River is the largest source of freshwater in the GSS with an average discharge of 2300GL, with large inputs of sediment and freshwater occurring during flood episodes contributing to siltation and turbidity, and seagrass mortality (Campbell and McKenzie 2004; McKenzie and Campbell 2003; McKenzie *et al*. 2014). Other major freshwater sources are creek and drainage basin runoffs from Fraser Island and the Cooloola sandmass. The area has a sub-tropical climate, with warm, wet summers and dry, cool winters. Mean daily temperatures range from 15°C to 27°C while the mean annual rainfall is 1166mm, with the wettest months being December through to March (Department of Environment n.d.; McKenzie and Campbell 2003).

The GSS comprises the largest tidal swamp within the South East Queensland bioregion, and is made up of intertidal sand/mud flats, extended seagrass beds, mangrove forests, salt flats and salt marshes, freshwater *Melaleuca* wetlands and coastal wallum swamps (Department of Environment n.d.). Coaldrake (1961:5) characterised wallum country as low undulating areas below the 30m contour, all of which have an assured rainfall, similar soil morphology, low soil fertility and similarly constructed floristic communities. There is a deep main channel which facilitates rapid water exchange with the open ocean (although the same does not apply to Tin Can Inlet - see Dredge *et al*. 1977) and tidal variations to 2.5m. The substrate consists of fine- to medium-grained sands with a mud content of up to 6%, with very little coarse material in the way of shells or stones (Department of Environment n.d.). Fisheries Research Consultants (FRC) (1994) observed an increase in the deposition of fine mobile sands from the Mary River in the years between their 1993 survey and that of Dredge *et al*. in 1977. Frankland (1990:26) noted the Booral shoreline also had a rocky intertidal substrate which underlies beaches between the Mary River Heads and Urangan, and rocky shores also occur at Big Woody, Little Woody, Duck and Picnic Islands. Coral reefs and sponge beds also occur around Big Woody Island. Faunal studies for the area have concentrated on the marine and avian species and there is little or no information available concerning terrestrial fauna, which presumably reflect the depauperate range of species associated with wallum country (Coaldrake 1961). Studies from Fraser Island and Cooloola suggest the potential terrestrial mammalian resource base in the region is poor (McNiven 1991c:86). The GSS currently supports active commercial and recreational fisheries, with species such as *Pagrus* spp. (snapper), *Rhabdosargus sarba* (tarwhine), Scombridae (mackerel spp.), *Pomatomus saltatrix* (tailor), *Carangoides* spp. (trevally), *Platycephalus* spp. (flathead), *Sillago* spp. (whiting), *Lutjanus argentimaculatus* (mangrove jack), and Sparidae spp. (bream) commonly targeted (Department of Environment n.d.; Frankland 1990; McKenzie and Campbell 2003; McKenzie *et al*. 2014). Sand crabs (*Portunus pelagicus*) and mud crabs (*Scylla serrata*) are also taken commercially and recreationally. Frankland (1990:27) observed that “Along the shoreline at Booral thousands of oysters can be found attached to the mudstone which lies all over the beach. Hairy mussels and whelks are also present on the shoreline in great numbers. Further out on the mudflats hundreds of *Pinctada fucata* or what the locals call "Booral shells" can also be found.” FRC (1994:25) noted that at the commencement of their 1993 survey the habitats and distribution of the molluscs of the area were poorly understood; the findings of their survey are incorporated in the discussion below.

## *The Site*

BSM is part of a complex of sites on the historic property ‘Booral’ (Figure 5-2) originally recorded by the Queensland State Archaeology Branch between 1979 and 1982, and subsequently re-surveyed by McNiven in 1984 for National Estate listing, and by McNiven and Frankland in 1989 to identify appropriate areas for excavation (Frankland 1990; McNiven 1994). McNiven also mapped five fish traps on the rocky foreshore adjacent to the property. The shell mound and homestead midden were selected for excavation, but only BSM is reported in detail here. McNiven later re-surveyed the area in September and November 1993 during the preparation of a report for the management of the site complex as the property was to be subdivided (McNiven 1994). In the course of a short absence between surveys parts of the shell mound, the Booral Dam Midden in the southeast, and B93/11, a low (0.5m) shell mound, were bulldozed during the clearance of vegetation to improve the views to the Great Sandy Strait and Fraser Island (McNiven 1994:94).

In 1989 BSM comprised a discrete undisturbed U-shaped mound approximately 14 m long and 1.4m high near the top of a steep embankment approximately 10m asl fronting the shore in an area of dense grass, shrubs and trees (Frankland 1990; McNiven 1994). The excavation was placed over the highest area of the mound and consisted of a 1m x .5m trench divided into two 50cm x 50cm squares designated A and B. The Johnson (1980) bucket method was employed, with BSM excavated in spits equivalent to 2.5 buckets (c.25 litres), with an average of 15kg of sediment removed from each spit. The total volume of the excavation was 0.4m$^3$ per square. All excavated material was wet sieved through 5mm and 2mm mesh. There were 28 spits (excavation units, XUs) to a depth of 160cm, although no cultural material was found below c.137cm. Five stratigraphic units (SU) were identified and described (Figure 5-3).SUs1-3 contained dense shell deposits and lay directly on top of each other with no sterile sediments in between, while SUs 4 and 5 represent the original ground surface (Frankland 1990; McNiven 1994). SU1 comprised XUs 1-7; SU2 XUs 8-16; SU3 XUs 17-25, and SU4 and SU5 the final three XUs 26-28. A series of six radiocarbon age determinations was obtained from charcoal in Square A. Calibrations were revised by Ulm and Reid (2000:16) (Table 5-1), and their median $^{14}$C ages are used in the present discussion.

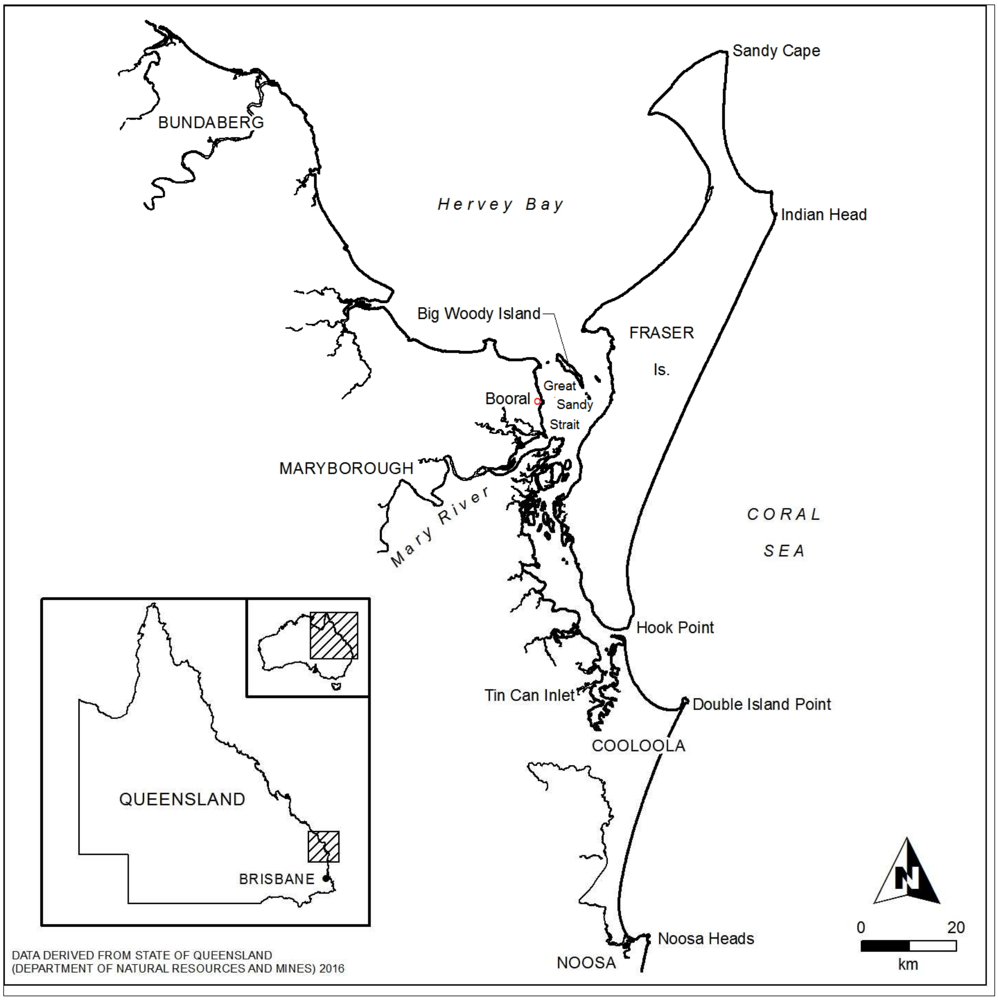

**Figure 5-1 The Great Sandy Region showing the location of the Booral Shell Midden (after Frankland 1990; McNiven 1994).**

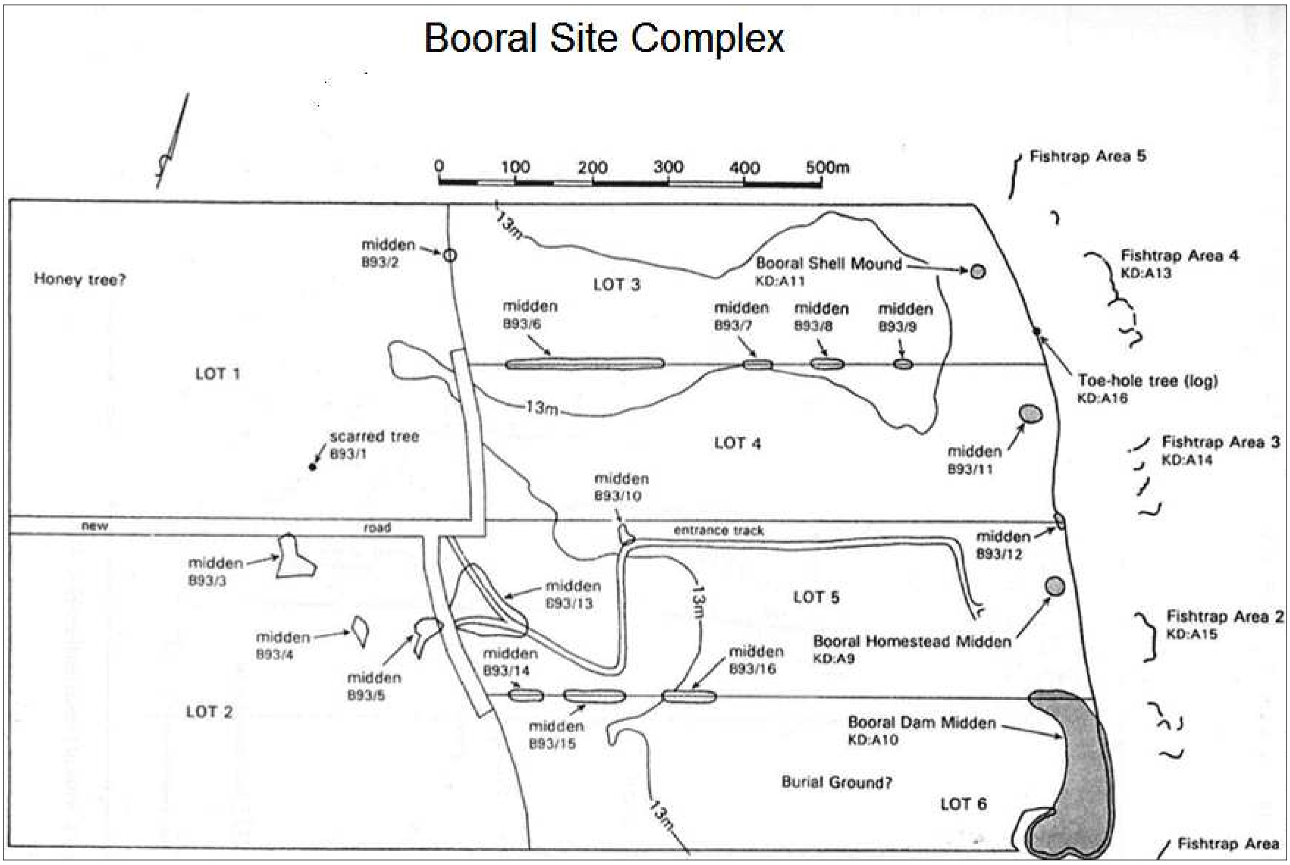

**Figure 5-2 The Booral site complex (after McNiven 1994:21).**

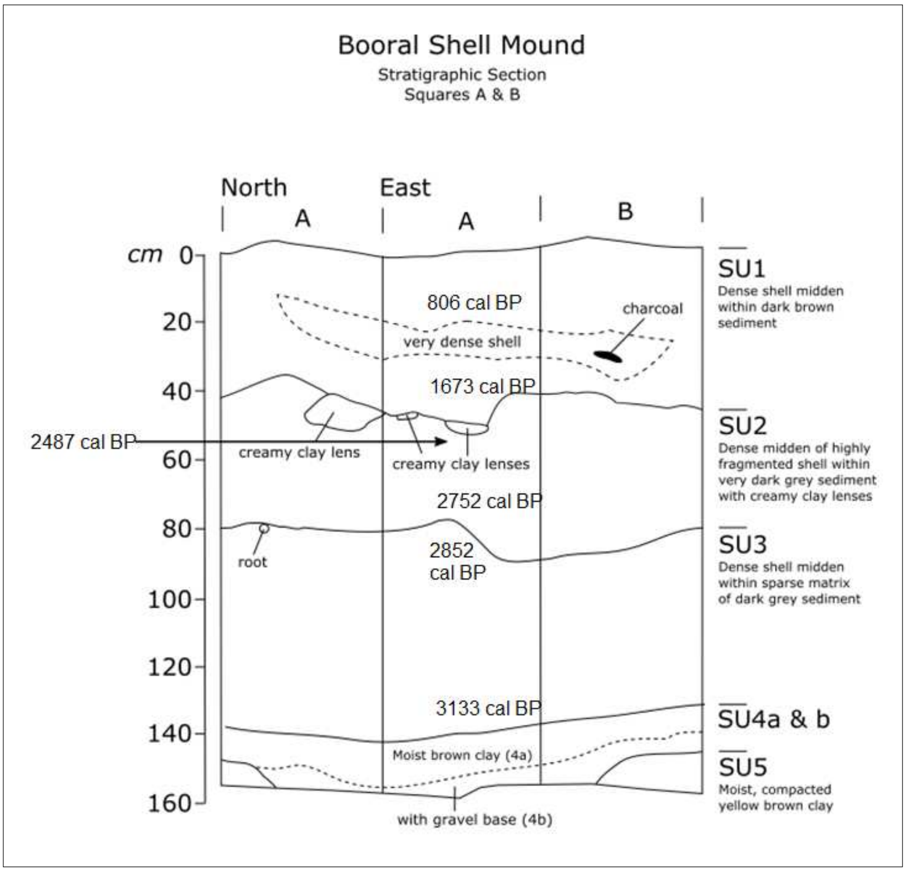

**Figure 5-3 Booral Shell Mound stratigraphic profile and locations of 14C dates (after McNiven 1994:84).**

**Table 5-1 Radiocarbon age determinations for Booral Shell Mound (after Frankland 1990; Ulm and Reid 2000:18).**

| SU | XU | Depth cm | Sample | Laboratory code | Conventional $^{14}$ Cage | 2σ calibrated age range |
|---|---|---|---|---|---|---|
| 1 | 2 | 9.5 | Charcoal | Beta-37394 | 980±60 BP | 968(915,806,804)732 |
| 1 | 7 | 39.5 | Charcoal | Beta-36303 | 1750±60 BP | 1817(1688,1673,1613)1520 |
| 2 | 11 | 59.0 | Charcoal | Beta-36304 | 2480±60 BP | 2744(2704,2671,2487,2479,2471)2347 |
| 2 | 14 | 75.0 | Charcoal | Beta- 38415 | 2660±60 BP | 2852(2752)2621 |
| 3 | 17 | 91.2 | Charcoal | Beta-38242 | 2790±80 BP | 3136(2852)2748 |
| 3 | 25 | 137.1 | Charcoal | Beta-32046 | 2950±60 BP | 3319(3135,3133,3076)2875 |

### Accumulation of sediments

The formula developed by Stein *et al.* (2003:300) outlined in Chapter 4 to measure the rate of accumulation of deposits was employed to determine potential variations in site use. For SU3 (3133–2852 cal BP), the rate of accumulation was 0.163cm/yr or 16.3cm per 100 years. Excavation units 16 -14 (2852-2752 cal BP) at the base of SU2 returned a similar rate of accumulation of 0.162cm/yr or 16.2cm per 100 years, while the middle XUs 13-11 (2752- 2487 cal BP) demonstrate a slowing of accumulation at 0.06cm/yr, 6cm per 100 years. The upper parts of SU2, 10-8 (2487-1673 cal BP), demonstrated a further slowing to 0.02cm/yr or 2cm per 100 years. SU1 (1673-806 cal BP) demonstrated a slight increase at 0.03cm/yr, 3cm per 100 years (Figure 5-4). The upper levels of SU2 fall into the category described by Stein *et al.* (2003:313) as slow, while the remainder fall into the intermediate category (between 2cm and 50cm per 100 years). The authors consider that material deposited at this rate would be buried before being mixed. Although the majority of the site falls into the intermediate category, differences in the rates of accumulation are demonstrated throughout, reflecting potentially differing levels of site use. No rapid depositional events occur, instead suggesting continuous but perhaps not necessarily intensive use of the site.

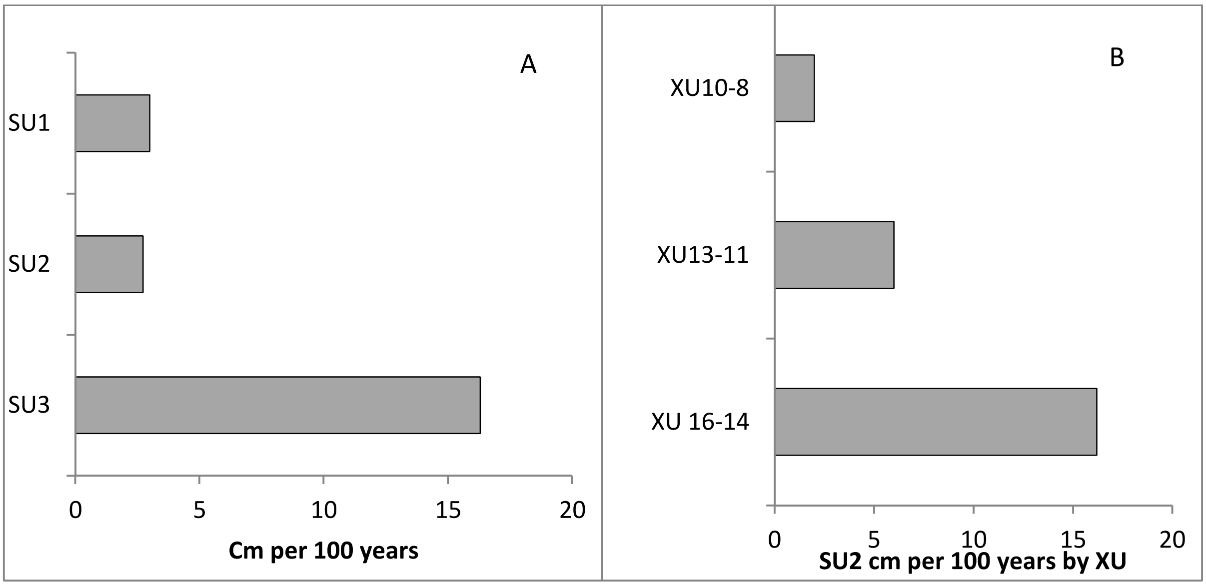

**Figure 5-4 Sediment accumulation rates for BSM. (A) Accumulation rates per 100 years with average values for SU2; (B) SU2 accumulation rates by XU.**

### *Molluscs*

**Square A**

Frankland (1990:42-43) identified nine ‘economic’ molluscan taxa and 20 ‘non-economic’ molluscan taxa (Tables 5-2, 5-3, and 5-4), although the distinction between economic and non-economic molluscs is not made clear, and three taxa (*Chama reflexa* [jewel box, referred to by Frankland as spiny oyster], *Nerita lineata* (= *balteata*) [lined nerite], and *Trichomya hirsuta* [hairy mussel]) occur in both lists. McNiven (1994) indicates that size was a distinguishing factor. *Velacumantus (Batillaria) australis* (mud whelk) and *Bembicium auratum* (gold-mouthed periwinkle) are stated to have been deemed non-economic because of their small size (45mm and 20mm respectively) and low numbers, although the latter could be disputed (see Table 5-3). A single specimen of *Phalium glaucum* (grey or glaucus bonnet) was included in the economic list, and *Donax deltoides* (pipi) is included in the non-economic list although no reason is given. Four non-economic Chitonidae specimens were recovered from XUs 2, 3, 4, and 8. MNI was calculated for all taxa (economic and non-economic) using common diagnostic elements which are not further described. Non-diagnostic elements were classified as unidentifiable shell fragments and bagged and weighed separately, although no shell weights were included in Frankland’s data.

The MNI of 11966 for economic taxa (Frankland 1990:54) was dominated by *Saccostrea* spp. (MNI=9316, 77.85%), with a lesser *Trichomya hirsuta* component (MNI=2155, 18%). The other taxa have very minor representations (Table 5-2). *Batillaria australis* (MNI=676, 35.95%), *Patelloida heteromorpha* (MNI=595, 31.64%), and *Bembicium auratum* (MNI=335, 17.81%) were the dominant non-economic gastropod taxa. The four non-economic bivalve taxa were evenly distributed with the exception of *Donax deltoides* (Table 5-4).

**Square B**

The previously unsorted contents of Square B were analysed for the present study. Due to the volume of material the decision was taken to sort and analyse every second excavation unit in addition to those units from which the radiocarbon age determinations were obtained, totalling 17 XUs, five from each SU containing cultural material, and one each from SU4 and SU5. The unsorted material was mechanically sieved through nested 8mm, 4mm, and 2mm Endicott sieves, with the <2mm fraction excluded from the analysis. NISP and MNI were calculated for all taxa as outlined in Chapter 4. The total NISP for 62 taxa of molluscs variably identified to family, genus and species from Square B was 184435 (Table 5-5). At 9425 the total MNI for Square B (Table 5-6) was fewer than that recorded for Square A, reflecting the sampling strategy. However, volume-corrected MNI estimates indicate that molluscan density for Square A is 39729 per $m^3$and 52580 per $m^3$ for Square B. The volume-corrected MNI density estimates for all shell, as well as individual estimated for the dominant species, for both squares are presented in Table 5-7; the estimates for Square B are based on the volumes of the 15 XUs sampled in SUs1-3. SUs 4 and 5 were excluded from the calculations as they did not contain molluscan remains. While the data from Square A are presented below as originally reported, the material from Square B is presented and discussed here by SU, rather than XU. As noted in Chapter 4, using SUs rather than XUs as the main analytical units avoids potential aggregation effects.

**Table 5-2 MNI for economic molluscan taxa from BSM Square A (after Frankland 1990:54).**

| **XU** | **Naticidae** | ***P. ebeninus*** | ***Ph. glaucum*** | ***N. balteata*** | ***Saccostrea spp.*** | ***T hirsuta*** | ***A. trapezia*** | ***C. pacifica*** | ***P. fucata*** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 5 | 0 | 10 | 350 | 49 | 2 | 1 | 1 | 418 |
| 2 | 1 | 3 | 0 | 18 | 402 | 67 | 7 | 4 | 0 | 502 |
| 3 | 5 | 6 | 0 | 16 | 690 | 48 | 2 | 3 | 2 | 772 |
| 4 | 1 | 16 | 0 | 32 | 523 | 46 | 2 | 3 | 2 | 625 |
| 5 | 4 | 12 | 0 | 18 | 366 | 62 | 13 | 3 | 1 | 479 |
| 6 | 0 | 10 | 0 | 11 | 303 | 91 | 12 | 9 | 0 | 436 |
| 7 | 2 | 9 | 0 | 2 | 210 | 150 | 1 | 2 | 2 | 378 |
| 8 | 1 | 3 | 0 | 4 | 161 | 125 | 0 | 12 | 2 | 308 |
| 9 | 0 | 1 | 0 | 0 | 110 | 73 | 0 | 4 | 0 | 188 |
| 10 | 1 | 3 | 0 | 0 | 169 | 47 | 1 | 4 | 0 | 225 |
| 11 | 1 | 2 | 0 | 0 | 102 | 42 | 0 | 11 | 0 | 158 |
| 12 | 1 | 4 | 0 | 1 | 172 | 117 | 0 | 12 | 0 | 307 |
| 13 | 1 | 15 | 0 | 0 | 189 | 78 | 2 | 5 | 1 | 291 |
| 14 | 1 | 6 | 0 | 0 | 170 | 43 | 0 | 2 | 0 | 222 |
| 15 | 0 | 2 | 0 | 0 | 138 | 34 | 0 | 3 | 0 | 177 |
| 16 | 0 | 2 | 0 | 0 | 204 | 106 | 0 | 10 | 0 | 322 |
| 17 | 0 | 0 | 0 | 0 | 327 | 178 | 0 | 8 | 0 | 513 |
| 18 | 0 | 3 | 0 | 0 | 569 | 278 | 0 | 16 | 0 | 866 |
| 19 | 0 | 11 | 0 | 1 | 685 | 179 | 0 | 19 | 0 | 895 |
| 20 | 0 | 5 | 0 | 1 | 723 | 120 | 0 | 7 | 0 | 856 |
| 21 | 2 | 1 | 0 | 0 | 593 | 37 | 0 | 6 | 0 | 639 |
| 22 | 0 | 1 | 0 | 1 | 575 | 26 | 0 | 2 | 0 | 605 |
| 23 | 0 | 2 | 0 | 2 | 608 | 38 | 0 | 7 | 0 | 657 |
| 24 | 0 | 11 | 1 | 2 | 594 | 42 | 0 | 5 | 0 | 655 |
| 25 | 0 | 4 | 0 | 0 | 383 | 79 | 0 | 6 | 0 | 472 |
| 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total** | **21** | **137** | **1** | **119** | **9316** | **2155** | **42** | **164** | **11** | **11966** |
| **% MNI** | **0.17%** | **1.14%** | **0.008%** | **0.99%** | **77.85%** | **18%** | **0.35%** | **1.37%** | **0.09%** | **100%** |

Note: *N. balteata* originally reported as *N. lineata*; *Saccostrea* spp. as *S. cucullata*; and *C. pacifica as C. reflexa*.

**Table 5-3 MNI for non-economic gastropod molluscs from BSM Square A (after Frankland 1990:55-56).**

| XU | *B. auratum* | *No. pyramidalis* | *No. australis* | *L. scabra* | *S. sipho*[1] | *S. antipodes* | *D. mus* | *P. heteromorpha*[2] | *B. australis*[3] | *B. paivae* | *Dr. cornus* | Troch. | *C. atropureus* | *N. balteata* | *Na. pauperatus* | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6 | 0 | 0 | 0 | 0 | 0 | 1 | 27 | 29 | 0 | 0 | 1 | 1 | 1 | 0 | 66 |
| 2 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 26 | 28 | 2 | 0 | 5 | 2 | 0 | 1 | 87 |
| 3 | 37 | 0 | 1 | 0 | 0 | 0 | 0 | 75 | 59 | 1 | 0 | 3 | 3 | 0 | 2 | 181 |
| 4 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 51 | 34 | 0 | 0 | 4 | 2 | 1 | 0 | 110 |
| 5 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 40 | 18 | 0 | 0 | 0 | 1 | 1 | 0 | 70 |
| 6 | 23 | 1 | 0 | 0 | 1 | 1 | 0 | 35 | 40 | 2 | 0 | 2 | 7 | 0 | 0 | 112 |
| 7 | 14 | 0 | 3 | 0 | 0 | 1 | 0 | 28 | 31 | 2 | 0 | 3 | 7 | 0 | 7 | 96 |
| 8 | 10 | 0 | 1 | 0 | 0 | 0 | 0 | 15 | 32 | 2 | 0 | 1 | 4 | 0 | 2 | 67 |
| 9 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 43 | 1 | 0 | 5 | 4 | 0 | 0 | 80 |
| 10 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 29 | 33 | 1 | 0 | 4 | 3 | 0 | 0 | 82 |
| 11 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 43 | 25 | 0 | 0 | 2 | 6 | 0 | 0 | 92 |
| 12 | 18 | 0 | 4 | 0 | 0 | 0 | 0 | 17 | 38 | 2 | 0 | 4 | 6 | 0 | 0 | 89 |
| 13 | 22 | 3 | 0 | 0 | 0 | 0 | 0 | 16 | 26 | 2 | 0 | 1 | 4 | 0 | 0 | 74 |
| 14 | 15 | 0 | 2 | 0 | 0 | 0 | 0 | 27 | 23 | 3 | 0 | 7 | 4 | 0 | 2 | 83 |
| 15 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 12 | 2 | 0 | 6 | 5 | 2 | 0 | 61 |
| 16 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 17 | 1 | 0 | 2 | 10 | 0 | 0 | 71 |
| 17 | 19 | 0 | 0 | 1 | 0 | 0 | 0 | 16 | 15 | 1 | 0 | 3 | 4 | 0 | 0 | 59 |
| 18 | 13 | 0 | 0 | 1 | 0 | 0 | 1 | 7 | 26 | 1 | 1 | 6 | 5 | 0 | 0 | 61 |
| 19 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 20 | 1 | 0 | 7 | 7 | 0 | 1 | 48 |
| 20 | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 11 | 32 | 2 | 0 | 6 | 1 | 1 | 0 | 58 |
| 21 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 23 | 0 | 0 | 5 | 3 | 0 | 0 | 49 |
| 22 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 14 | 0 | 0 | 3 | 4 | 0 | 0 | 37 |
| 23 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 22 | 1 | 0 | 3 | 5 | 0 | 0 | 57 |
| 24 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 13 | 2 | 0 | 2 | 6 | 0 | 0 | 49 |
| 25 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 8 | 23 | 0 | 0 | 1 | 7 | 0 | 1 | 41 |
| 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total** | **335** | **4** | **14** | **2** | **1** | **2** | **2** | **595** | **676** | **29** | **1** | **86** | **111** | **6** | **16** | **1880** |

[1] *Serpulorbis sipho*, originally reported as *Vermicularia sipho*; [2] *Patelloida heteromorpha*, reported as *Chiazacmea heteromorpha*; [3] *Batillaria australis*, reported as *Velacumantus australis*.

**Table 5-4 MNI for non-economic bivalve molluscs from BSM Square A (after Frankland 1990: 56).**

| XU | *T. hirsuta* | *D. deltoides* | *C. pacifica* | *S. sulcatus* | Total |
|---|---|---|---|---|---|
| 1 | 0 | 1 | 2 | 0 | 3 |
| 2 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 5 | 2 | 0 | 7 |
| 4 | 4 | 2 | 0 | 0 | 6 |
| 5 | 0 | 1 | 0 | 0 | 1 |
| 6 | 0 | 1 | 3 | 0 | 4 |
| 7 | 0 | 3 | 0 | 0 | 3 |
| 8 | 0 | 2 | 0 | 2 | 4 |
| 9 | 1 | 0 | 0 | 0 | 1 |
| 10 | 0 | 2 | 2 | 0 | 4 |
| 11 | 1 | 2 | 0 | 0 | 3 |
| 12 | 0 | 1 | 0 | 2 | 3 |
| 13 | 1 | 0 | 2 | 0 | 3 |
| 14 | 0 | 1 | 0 | 0 | 1 |
| 15 | 1 | 0 | 0 | 4 | 5 |
| 16 | 0 | 0 | 0 | 0 | 0 |
| 17 | 0 | 0 | 0 | 0 | 0 |
| 18 | 1 | 0 | 0 | 0 | 1 |
| 19 | 1 | 0 | 0 | 0 | 1 |
| 20 | 2 | 0 | 0 | 3 | 5 |
| 21 | 1 | 0 | 1 | 0 | 2 |
| 22 | 0 | 0 | 0 | 0 | 0 |
| 23 | 0 | 0 | 0 | 4 | 4 |
| 24 | 8 | 0 | 0 | 4 | 12 |
| 25 | 0 | 0 | 0 | 2 | 2 |
| 26 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0 | 0 | 0 | 0 | 0 |
| 28 | 0 | 0 | 0 | 0 | 0 |
| Total | 21 | 21 | 12 | 21 | 75 |
| **%Total MNI** | **28%** | **28%** | **16%** | **28%** | **100%** |

**Table 5-5 Molluscan NISP by SU for BSM Square B.**

| Species | SUI | SUII | SUIII | Total NISP | % Total NISP |
|---|---|---|---|---|---|
| *Anadara trapezia* | 290 | 0 | 3 | 293 | 0.16% |
| Arcidae | 46 | 29 | 4 | 79 | 0.04% |
| *Astele* sp. | 47 | 59 | 68 | 174 | 0.09% |
| *Austrocochlea porcata* | 0 | 0 | 1 | 1 | 0.00% |
| *Austrocochlea* sp. | 6 | 10 | 1 | 17 | 0.01% |
| *Barbatia* sp. | 4 | 1 | 1 | 6 | 0.00% |
| *Batillaria australis* | 16 | 8 | 1 | 25 | 0.01% |
| *Bedeva hanleyi* | 12 | 19 | 9 | 40 | 0.02% |
| *Bembicium auratum* | 112 | 158 | 24 | 294 | 0.16% |
| *Bembicium nanum* | 8 | 0 | 0 | 8 | 0.00% |
| Cardiidae | 0 | 0 | 2 | 2 | 0.00% |
| Carditidae | 1 | 0 | 0 | 1 | 0.00% |
| *Chama* sp. | 251 | 257 | 226 | 734 | 0.40% |
| *Circe* sp. | 2 | 0 | 0 | 2 | 0.00% |
| *Clanculus* sp. | 0 | 2 | 3 | 5 | 0.00% |
| *Clypeomorus petrosa* | 0 | 0 | 9 | 9 | 0.00% |
| *Clypeomorus* sp. | 22 | 1 | 15 | 38 | 0.02% |
| *Corbula* sp. | 7 | 1 | 0 | 8 | 0.00% |
| *Fusinus* sp. fasciolariidae | 0 | 2 | 0 | 2 | 0.00% |
| *Gafrarium* sp. | 0 | 0 | 1 | 1 | 0.00% |
| *Herpetopoma atrata* | 43 | 62 | 33 | 138 | 0.07% |
| *Hiatella australis* | 9 | 0 | 0 | 9 | 0.00% |
| *Irus* sp. | 15 | 11 | 9 | 35 | 0.02% |

**Table 5-5 (continued) Molluscan NISP by SU for BSM Square B**

| **Species** | **SUI** | **SUII** | **SUIII** | **Total NISP** | **% Total NISP** |
|---|---|---|---|---|---|
| Land snail | 450 | 221 | 64 | 735 | 0.40% |
| *Littorina* sp. | 0 | 1 | 0 | 1 | 0.00% |
| *Mactra* sp. | 1 | 2 | 1 | 4 | 0.00% |
| *Melo* sp. | 4 | 1 | 0 | 5 | 0.00% |
| *Modiolus* sp. | 3 | 0 | 0 | 3 | 0.00% |
| Muricidae | 2 | 0 | 0 | 2 | 0.00% |
| *Nassarius* sp. | 26 | 14 | 9 | 49 | 0.03% |
| Naticidae | 75 | 11 | 5 | 91 | 0.05% |
| *Nerita balteata* | 3389 | 234 | 87 | 3710 | 2.01% |
| *Notoacmea petterdi* | 216 | 165 | 55 | 436 | 0.24% |
| *Patella chapmani* | 1 | 0 | 0 | 1 | 0.00% |
| Pectinidae | 10 | 2 | 0 | 12 | 0.01% |
| *Phenacolepas* sp. | 0 | 0 | 1 | 1 | 0.00% |
| *Pinctada fucata* | 54 | 17 | 65 | 136 | 0.07% |
| *Planaxis* sp. | 0 | 1 | 0 | 1 | 0.00% |
| *Polinices sordidus* | 14 | 0 | 0 | 14 | 0.01% |
| Polyplacophora | 4 | 0 | 2 | 6 | 0.00% |
| Pot/bat juveniles | 586 | 521 | 131 | 1238 | 0.67% |
| *Pyrazus ebeninus* | 422 | 769 | 70 | 1261 | 0.68% |
| *Pyrene* sp. | 0 | 1 | 0 | 1 | 0.00% |
| *Saccostrea* sp. | 47785 | 27999 | 41544 | 117328 | 63.62% |
| *Scutus unguis* | 1 | 1 | 0 | 2 | 0.00% |
| *Serpulorbis sipho* | 54 | 2 | 12 | 68 | 0.04% |
| *Siliquaria* sp. | 0 | 0 | 4 | 4 | 0.00% |
| *Siphonaria denticulata* | 0 | 2 | 3 | 5 | 0.00% |
| *Solecurtus sulcatus* | 1 | 2 | 0 | 3 | 0.00% |
| *Tellina* sp. | 11 | 0 | 0 | 11 | 0.01% |
| Tellinidae | 3 | 0 | 0 | 3 | 0.00% |
| *Terebra* sp. | 3 | 0 | 0 | 3 | 0.00% |
| Trapeziidae | 0 | 2 | 0 | 2 | 0.00% |
| *Trapezium* sp. | 0 | 0 | 6 | 6 | 0.00% |
| *Trichomya hirsuta* | 19469 | 19036 | 18810 | 57315 | 31.08% |
| Triphoridae | 0 | 0 | 5 | 5 | 0.00% |
| Trochidae | 0 | 1 | 2 | 3 | 0.00% |
| Turbinidae | 0 | 2 | 2 | 4 | 0.00% |
| Turritellidae | 1 | 0 | 0 | 1 | 0.00% |
| Veneridae | 29 | 6 | 3 | 38 | 0.02% |
| Vermetidae | 0 | 0 | 4 | 4 | 0.00% |
| Volutidae | 0 | 2 | 0 | 2 | 0.00% |
| **Total** | | | | **184435** | **100.00%** |

**Table 5-6 Molluscan MNI by SU for BSM Square B**

| **Species** | **SUI** | **SUII** | **SUIII** | **Total MNI** | **% Total MNI** |
|---|---|---|---|---|---|
| *Anadara trapezia* | 15 | 0 | 2 | 17 | 0.18% |
| Arcidae | 1 | 2 | 1 | 4 | 0.04% |
| *Astele* sp. | 23 | 25 | 29 | 77 | 0.82% |
| *Austrocochlea porcata* | 0 | 0 | 1 | 1 | 0.01% |
| *Austrocochlea* sp. | 6 | 7 | 1 | 14 | 0.15% |
| *Barbatia* sp. | 2 | 1 | 1 | 4 | 0.04% |
| *Batillaria australis* | 15 | 7 | 1 | 23 | 0.24% |
| *Bedeva hanleyi* | 12 | 19 | 9 | 40 | 0.42% |
| *Bembicium auratum* | 109 | 155 | 24 | 288 | 3.06% |
| *Bembicium nanum* | 8 | 0 | 0 | 8 | 0.08% |
| Cardiidae | 0 | 0 | 1 | 1 | 0.01% |

**Table 5-6 (continued) Molluscan MNI by SU for BSM Square B.**

| **Species** | **SUI** | **SUII** | **SUIII** | **Total MNI** | **% Total MNI** |
|---|---|---|---|---|---|
| Carditidae | 0 | 0 | 0 | 0 | 0.00% |
| *Chama* sp. | 45 | 46 | 54 | 145 | 1.54% |
| *Circe* sp. | 2 | 0 | 0 | 2 | 0.02% |
| *Clanculus* sp. | 0 | 1 | 3 | 4 | 0.04% |
| *Clypeomorus petrosa* | 0 | 0 | 9 | 9 | 0.10% |
| *Clypeomorus* sp. | 22 | 1 | 15 | 38 | 0.40% |
| *Corbula* sp. | 6 | 1 | 0 | 7 | 0.07% |
| *Fusinus* sp. fasciolariidae | 0 | 2 | 0 | 2 | 0.02% |
| *Gafrarium* sp. | 0 | 0 | 1 | 1 | 0.01% |
| *Herpetopoma atrata* | 30 | 45 | 24 | 99 | 1.05% |
| *Hiatella australis* | 4 | 0 | 0 | 4 | 0.04% |
| *Irus* sp. | 10 | 9 | 4 | 23 | 0.24% |
| Land snail | 48 | 37 | 12 | 97 | 1.03% |
| *Littorina* sp. | 0 | 1 | 0 | 1 | 0.01% |
| *Mactra* sp. | 1 | 2 | 0 | 3 | 0.03% |
| *Melo* sp. | 3 | 1 | 0 | 4 | 0.04% |
| *Modiolus* sp. | 3 | 0 | 0 | 3 | 0.03% |
| Muricidae | 1 | 0 | 0 | 1 | 0.01% |
| *Nassarius* sp. | 22 | 14 | 9 | 45 | 0.48% |
| Naticidae | 8 | 3 | 1 | 12 | 0.13% |
| *Nerita balteata* | 152 | 19 | 12 | 183 | 1.94% |
| *Notoacmea petterdi* | 216 | 156 | 53 | 425 | 4.51% |
| *Patella chapmani* | 1 | 0 | 0 | 1 | 0.01% |
| Pectinidae | 0 | 0 | 0 | 0 | 0.00% |
| *Phenacolepas* sp. | 0 | 0 | 1 | 1 | 0.01% |
| *Pinctada fucata* | 6 | 5 | 8 | 19 | 0.20% |
| *Planaxis* sp. | 0 | 1 | 0 | 1 | 0.01% |
| *Polinices sordidus* | 1 | 0 | 0 | 1 | 0.01% |
| Polyplacophora | 0 | 0 | 1 | 1 | 0.01% |
| Pot/bat juveniles | 304 | 301 | 99 | 704 | 7.47% |
| *Pyrazus ebeninus* | 49 | 64 | 24 | 137 | 1.45% |
| *Pyrene* sp. | 0 | 1 | 0 | 1 | 0.01% |
| *Saccostrea* sp. | 1530 | 1329 | 2464 | 5323 | 56.48% |
| *Scutus unguis* | 1 | 1 | 0 | 2 | 0.02% |
| *Serpulorbis sipho* | 17 | 2 | 3 | 22 | 0.23% |
| *Siliquaria* sp. | 0 | 0 | 2 | 2 | 0.02% |
| *Siphonaria denticulata* | 0 | 2 | 3 | 5 | 0.05% |
| *Solecurtus sulcatus* | 0 | 1 | 0 | 1 | 0.01% |
| *Tellina* sp. | 3 | 0 | 0 | 3 | 0.03% |
| Tellinidae | 0 | 0 | 0 | 0 | 0.00% |
| *Terebra* sp. | 3 | 0 | 0 | 3 | 0.03% |
| Trapeziidae | 0 | 2 | 0 | 2 | 0.02% |
| *Trapezium* sp. | 0 | 0 | 2 | 2 | 0.02% |
| *Trichomya hirsuta* | 406 | 707 | 477 | 1590 | 16.87% |
| Triphoridae | 0 | 0 | 5 | 5 | 0.05% |
| Trochidae | 0 | 1 | 0 | 1 | 0.01% |
| Turbinidae | 0 | 2 | 1 | 3 | 0.03% |
| Turritellidae | 1 | 0 | 0 | 1 | 0.01% |
| Veneridae | 4 | 4 | 0 | 8 | 0.08% |
| Vermetidae | 0 | 0 | 0 | 0 | 0.00% |
| Volutidae | 0 | 1 | 0 | 1 | 0.01% |
| **Total** | **3090** | **2978** | **3357** | **9425** | **100%** |

**Table 5-7 Volume-corrected MNI density estimates for all shell, and dominant species, for BSM Squares A and B. Estimates for Square B are based on the volumes of the 15 XUs sampled in the current study; SUs 4 and 5 are excluded for both squares as they did not contain molluscan remains.**

| **BSM Sq A** | | **SU1 volume** | **SU2 volume** | **SU3 volume** | **Totals** |
|---|---|---|---|---|---|
| | | 0.09875 | 0.12925 | 0.1225 | 0.3505 |
| All shell | MNI | 4359 | 2922 | 6644 | 13925 |
| | MNI/m$^3$ | 44142 | 22607 | 54237 | 39729 |
| *Chama* sp. | MNI | 25 | 63 | 76 | 164 |
| | MNI/m$^3$ | 253 | 487 | 620 | 468 |
| *Nerita balteata* | MNI | 107 | 5 | 7 | 119 |
| | MNI/m$^3$ | 1084 | 39 | 57 | 340 |
| *Pyrazus ebeninus* | MNI | 61 | 38 | 38 | 137 |
| | MNI/m$^3$ | 618 | 294 | 310 | 391 |
| *Saccostrea* sp. | MNI | 2844 | 1415 | 5051 | 9310 |
| | MNI/m$^3$ | 28800 | 10948 | 41233 | 26562 |
| *Trichomya hirsuta* | MNI | 513 | 665 | 977 | 2155 |
| | MNI/m$^3$ | 5195 | 5145 | 7976 | 6148 |
| **BSM Sq B** | | **SU1 volume** | **SU2 volume** | **SU3 volume** | **Total** |
| | | 0.0675 | 0.055 | 0.057 | 0.179 |
| All shell | MNI | 3090 | 2978 | 3357 | 9425 |
| | MNI/m3 | 45778 | 54145 | 59154 | 52580 |
| *Chama* sp. | MNI | 45 | 46 | 54 | 145 |
| | MNI/m3 | 667 | 836 | 952 | 809 |
| *Nerita balteata* | MNI | 152 | 19 | 12 | 183 |
| | MNI/m3 | 2252 | 345 | 211 | 1021 |
| *Pyrazus ebeninus* | MNI | 49 | 64 | 24 | 137 |
| | MNI/m3 | 726 | 1164 | 423 | 764 |
| *Saccostrea* sp. | MNI | 1530 | 1329 | 2464 | 5323 |
| | MNI/m3 | 22667 | 24164 | 43419 | 29696 |
| *Trichomya hirsuta* | MNI | 406 | 707 | 477 | 1590 |
| | MNI/m3 | 6015 | 12855 | 8405 | 8870 |

## Molluscan Richness, Diversity, and Density

The results of the application of the diversity measures of taxonomic richness, diversity and evenness (Chapter 4) for both squares by MNI are detailed in Table 5-8. Taxonomic richness and abundance varies in both squares, but otherwise the results demonstrate moderate levels of diversity due to the overwhelming dominance of *Saccostrea* spp. for both squares.

**Table 5-8 Diversity measures for BSM Square and Square B by MNI.**

| Measure of diversity | Square A | Square B |
|---|---|---|
| NTAXA | 20 | 42 |
| Individuals | 13925 | 9425 |
| Simpson's Index 1-D | 0.5226 | 0.643 |
| Shannon Index of Diversity (′H) | 1.217 | 1.624 |
| Shannon Index of Evenness (E) | 0.4062 | 0.4344 |

## Square B taxon-specific analyses

### *Saccostrea spp*.

Frankland (1990) and McNiven (1994) describe the oysters found at BSM as *Saccostrea cucullata* (hooded rock oyster). There is some debate as to whether the oysters found in middens in southeast Queensland are *Saccostrea glomerata* (Sydney rock oyster) or *Saccostrea cucullata* (hooded rock oyster) (e.g. Buroker *et al.* 1979; Healy 2011; Lam and Morton 2005; Thomson 1954). Oysters live attached to hard objects and are usually gregarious and often densely packed, leading to frequent morphological variability among individuals - what are described as separate species may in fact simply be ecophenotypical variations (Carpenter and Niem 1998:224). A conservative approach is taken here and the taxon of oyster present at BSM (and in the other sites analysed) is referred to simply as *Saccostrea* spp.

*Saccostrea* spp. dominated both the NISP (117328, 63.62%) and MNI (5323, 56.48%) determinations. As described in Chapter 4, heights were measured for a total of 1,412 complete lower valves from the three SUs (for the descriptive statistics see Table 5-9).

**Table 5-9 Descriptive statistics for *Saccostrea* valve heights in mm by SU for BSM Square B.**

| SU | N | Minimum | Maximum | Mean | Range | Std. Deviation |
|---|---|---|---|---|---|---|
| 1 | 419 | 6.14 | 84.47 | 42.86 | 78.33 | 9.99455 |
| 2 | 352 | 5.06 | 77.04 | 35.736 | 71.98 | 10.21567 |
| 3 | 641 | 5.25 | 88.24 | 43.72 | 82.99 | 11.5654 |

The results of a Shapiro-Wilk test of normality (SU1 $W$=0.992, $df$=419, $p$=0.033; SU2 $W$=0.987, $df$=352, $p$=0.004; SU3 $W$=0.975, $df$=641, $p$=0.000) indicated that valve heights did not follow a normal distribution. A one-way analysis of variance (ANOVA) was used to compare mean valve height by SU, with the results ($F$=67.121, $df$=2, $p$=0.000) indicating a significant difference across the SUs. Levene's test of homogeneity of variance indicated that the variances for each group were significantly different ($L$=5.082, $df1$=2, $df2$=1409, $p$=0.006). As the assumption of homogeneity of variance was violated, additional robust nonparametric tests of equality of means were conducted, with both Welch ($W$=71.259, $df1$=2, $df2$=850.331, $p$=0.000) and Brown-Forsythe ($B$=70.496, *df1*=2, *df2*=1305.420, *p*=0.000) test results also being significant. Post hoc testing using Tukey HSD indicated a significant difference at the 0.05 level for valve heights between SU2 and SUs 1 and 3 (Table 5-10). Although not dramatically different to SU1, SU2 has the smallest sample size and this may have influenced the result.

**Table 5-10 Post hoc results for *Saccostrea* valve height by SU in BSM Square B.**

| | **(I) SU** | **(J) SU** | **Mean Difference (I-J)** | **Std. Error** | **Sig.** | **95% Confidence Interval** | |
|---|---|---|---|---|---|---|---|
| | | | | | | **Lower Bound** | **Upper Bound** |
| Tukey HSD | 1 | 2 | $7.12403^{*}$ | .78001 | .000 | 5.2940 | 8.9541 |
| | | 3 | -.85861 | .67775 | .414 | -2.4487 | .7315 |
| | 2 | 1 | $-7.12403^{*}$ | .78001 | .000 | -8.9541 | -5.2940 |
| | | 3 | $-7.98265^{*}$ | .71569 | .000 | -9.6618 | -6.3035 |
| | 3 | 1 | .85861 | .67775 | .414 | -.7315 | 2.4487 |
| | | 2 | $7.98265^{*}$ | .71569 | .000 | 6.3035 | 9.6618 |
| *. The mean difference is significant at the 0.05 level. | | | | | | | |

*Saccostrea* individuals are sexually mature as males at a height of 20mm and as females at 50-60mm, and can grow to heights of 60-80mm (Catterall and Poiner 1987; Appendix A). All SUs contained juvenile oysters, although these were relatively few in number (2.13%), as well as mature oysters at the upper ends of the height range (Figure 5-5). During the laboratory work a number of oysters were observed to have distinctively curved morphologies. Galtsoff (1964:16) noted that the beaks or ligamental areas of the umbo of lower valves represent the oldest part of the shell and can reach considerable sizes in old oysters (although he does not specify exactly what ‘old’ means in this context), curving usually, but not always, to the posterior (Figure 5-6). Beak shape 1 is associated with oysters growing on soft muddy bottoms, but its extreme development can indicate growth on crowded, narrow reefs. The other beak shapes cannot be associated with any particular environment and these formed the majority of the beak morphologies from BSM. In SU1 131 of the lower valves (11.81%) exhibited beaks between 11.03mm and 28.07 mm in height. In SU2, 70 lower valves (7.7%) exhibited beaks between 9.07mm and 24.22mm, whilst in SU3 66 lower valves (2.89%) exhibited beaks between 11.6mm and 24.87mm in height.

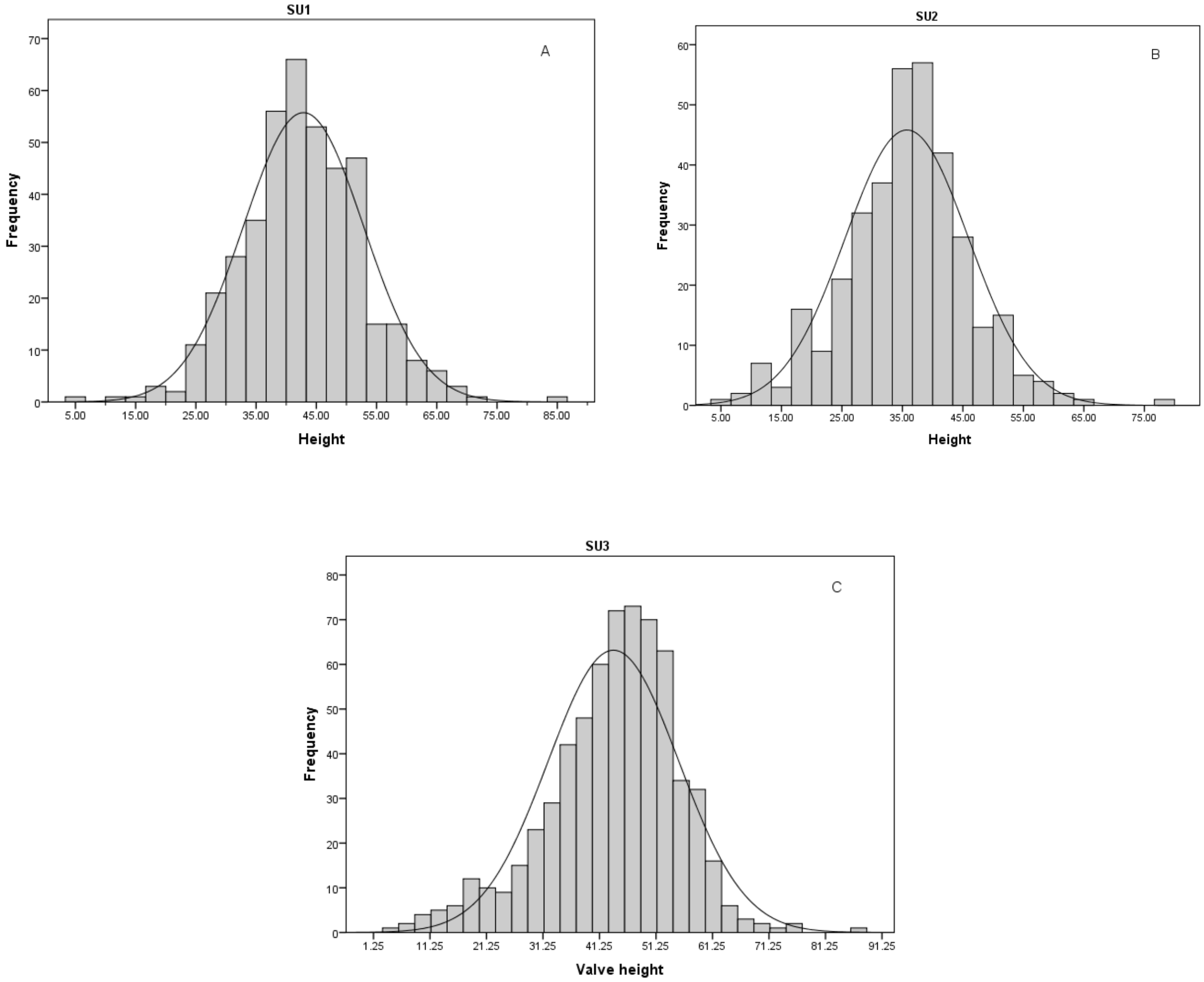

**Figure 5-5 *Saccostrea* valve height distributions for BSM Square B by (A) SU1 (B) SU2 and (C) SU3**

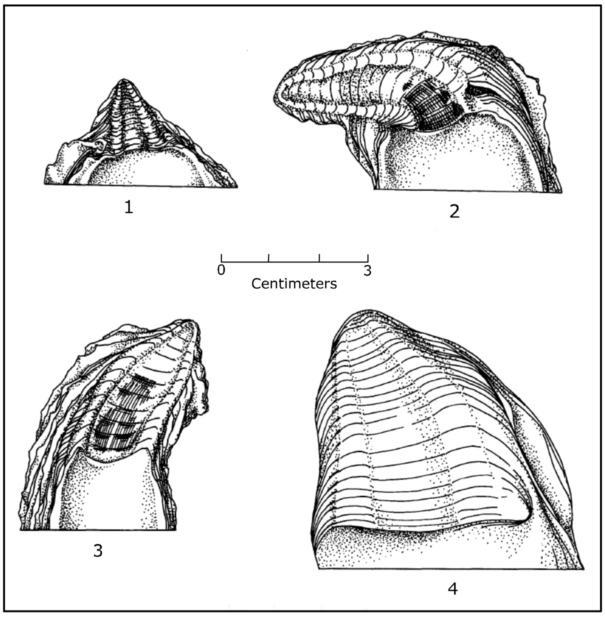

**Figure 5-6 Beak shapes of 'old' oysters (after Galtsoff 1964:16).**

Valve depth and morphology are environmentally influenced and there was little evidence of growth in tightly-packed clusters or reefs. In SU1, 43 lower valves (3.7%) were cemented to other *Saccostrea* whole or partial valves (with one cemented to a *Bembicium* sp. shell); in SU2 45 lower valves (4.95%) were cemented to other whole or partial valves, and in SU3 only 31 valves (1.35%) were cemented to other whole or partial valves. All SUs contained lower valves with flat bases (SU1 n=25, 2.25%; SU2 n=204, 22.44%; SU3 n=242, 10.6%) implying that they grew directly either on rock or a firmly packed surface. Kent (1992:4; see also Appendix A) noted that "sand oysters" from bars of coarse firmly packed sand in the intertidal zone or in very shallow water have well-developed radial ribs and strongly coloured valves caused by exposure to sunlight. In SU3, 223 lower valves (9.77%) exhibited fluted edges with well developed radial ribs, and both upper and lower valves were observed to be relatively more deeply coloured, being quite purple, than the upper SUs. The colouration may of course also be due to taphonomic factors, reflecting the relatively more rapid accumulation of sediments in the lowest section of the midden, which implies that material would be buried before extended surface exposure, abrasion or treadage. Depth measurements were obtained from a total of 1884 complete and partial lower valves, and the descriptive statistics are detailed in Table 5-11.

**Table 5-11 Descriptive statistics for *Saccostrea* valve depth in mm by SU from BSM Square B**

| SU | N | Minimum | Maximum | Mean | Range | Std. Deviation |
|---|---|---|---|---|---|---|
| 1 | 418 | 2.4 | 27.86 | 14.6376 | 25.02 | 3.95964 |
| 2 | 350 | 1.74 | 24.92 | 12.3257 | 23.18 | 3.92169 |
| 3 | 1116 | 1.59 | 27.02 | 13.4734 | 25.43 | 4.19546 |

The results of a Shapiro-Wilk test of normality (SU1 $W$=0.998, $df$=418, $p$=0.850; SU2 $W$=0.997, $df$=350, $p$=0.859; SU3 $W$=0.997, $df$=1116, $p$=0.017) indicated that valve depths followed a normal distribution in the upper two SUs, but not for SU3, although this was not demonstrated in the associated histograms (Figure 5-7); Field (2014:184) warns that the Shapiro-Wilk test results on large samples can be significant even for small and unimportant effects, which is particularly important for SU3. The Levene result ($L$=1.239, $df1$=2, $p$=0.29) demonstrated that the assumption of homogeneity of variances was not violated, while the ANOVA result indicated that there was a difference in the group means ($F$=30.534, $df$=2, $p$=0.000). The robust Welch ($W$=32.918, $df1$=2, $df2$=785.086, $p$=0.000) and Brown-Forsythe ($B$=32.092, $df1$=2, $df2$=1193.615, $p$=0.000) results confirmed the significant differences in valve depths across the SUs.

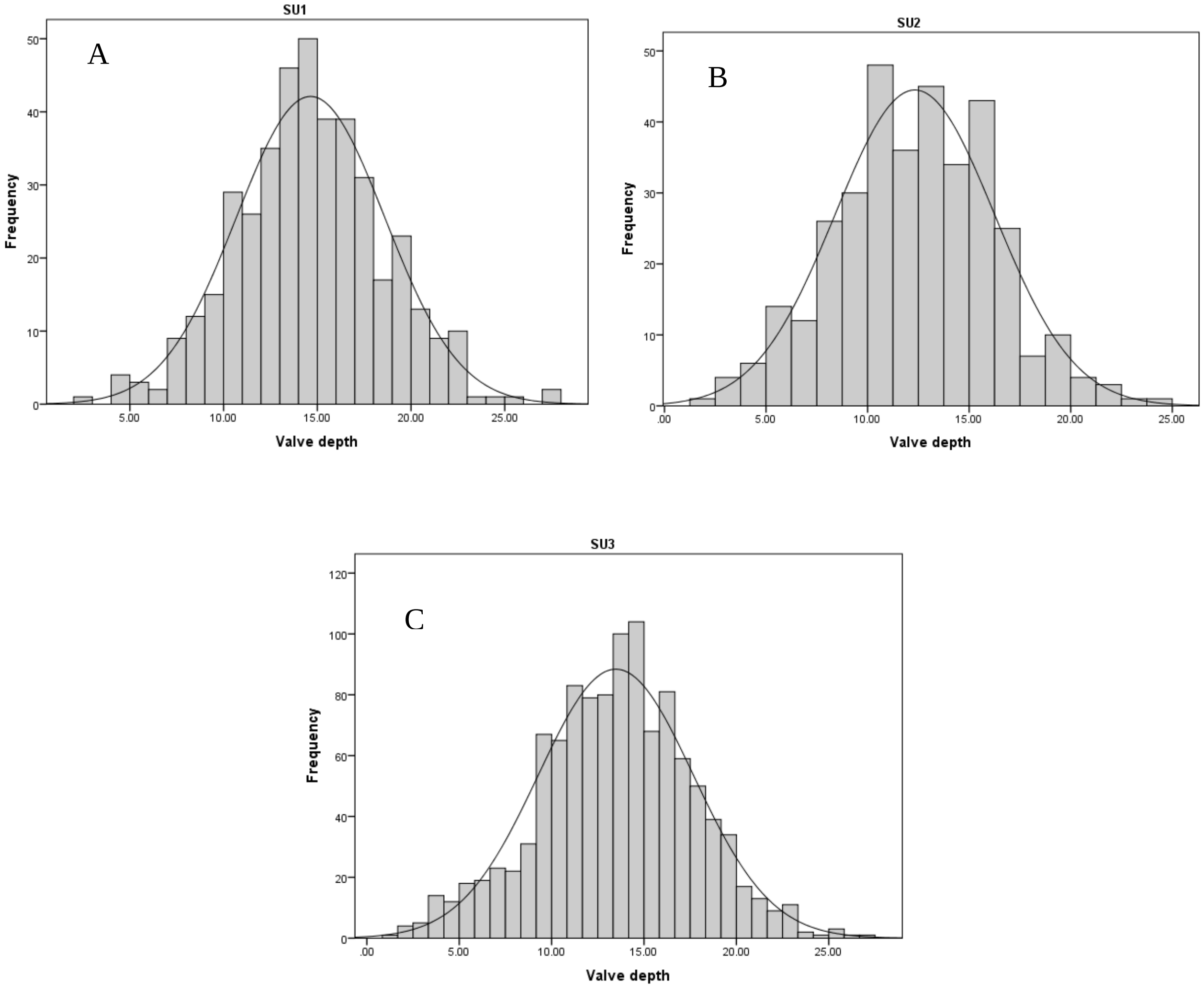

**Figure 5-7 Plot of *Saccostrea* valve depths in mm for SU1 (A); SU2 (B) and SU3 (C).**

The *Saccostrea* fragmentation ratios (NISP: MNI) varied across the SUs (SU1 31.23, SU2 21.06, and SU3 16.86), and overall are the highest for *Saccostrea* from the five sites for which material was re-analysed. The ratios do not correspond with the estimated rates of accumulation of the deposit, although the high fragmentation rate in SU1 may indicate post-depositional and post-abandonment trampling. There was little worm or drill/borer damage noted on the complete and partial upper and lower valves in all SUs (1.24% of individuals), although drill and borer damage has been observed to be a contributory factor to shell breakage (Zuschin and Stanton 2001) and may be more prevalent in the fragmented specimens. None of the remains exhibited signs of burning or exposure to high temperatures.

### *Trichomya hirsuta*

*T. hirsuta* (hairy mussel) was the second most abundant taxon both in terms of NISP (57315, 31.08%) and MNI (1590, 16.87%). Hairy mussels are sessile suspension feeders, clumping together on rocks, artificial structures, or simply other mussel shells (Goggin 1997; Gosling 2003) by byssal threads, and may play a role in the stabilisation of muddy sediments. The clumps are home to a variety of organisms including barnacles and other crustaceans, as well as small fish and worms (Morton 2008; Morton and Lutzen 2008).

Height measurements were obtained from 283 whole valves and the descriptive statistics are detailed in Table 5-12.

**Table 5-12 Descriptive statistics for *T. hirsuta* valve height in mm by SU from BSM Square B.**

| SU | N | Minimum | Maximum | Mean | Range | Std. Deviation |
|---|---|---|---|---|---|---|
| 1 | 61 | 7.55 | 60.74 | 17.399 | 53.19 | 10.06397 |
| 2 | 140 | 6.53 | 57.78 | 20.3321 | 51.25 | 10.82389 |
| 3 | 82 | 6.97 | 57.52 | 20.9054 | 50.55 | 10.94451 |

The results of a Shapiro-Wilk test of normality (SU1 *W=0.820, df=61, p=0.000*; SU2 *W=0.895, df=140, p=0.000*; SU3 *W=0.863, df=82, p=0.000*) indicated that for each SU the distribution of valve heights is not normal and this is clearly demonstrated in the associated histograms (Figure 5-8). As the sample sizes are quite variable, a Kruskal-Wallis test was used as the non-parametric alternative to ANOVA, with the results $x^2$=6.498, *df*=2, *p*=0.039. Application of the non-parametric Mann-Whitney U Test indicated a difference between SU 1 and SU 2 (*U*=3454.5, *z*=-2.151, *p*=0.031), and SU 1 and SU 3 (*U*=1915.0, *z*=-2.392, *p*=0.017), but not between SU 2 and SU 3 (*U*=5450.5, *z*=-0627, *p*=0.531).

Mussels are sexually mature within their first year of growth (Gosling 2003). There are no data available on the growth rates of *T. hirsuta* from spat to adult, although Goggin (1997) noted that individuals grew more quickly in Brisbane and Lake Macquarie than in other areas of distribution. He estimated heights of 50mm between four and 14 years with 95% of asymptotic heights reached between ten and 25 years of age based on a van Bertalanffy plot; the highest growth rates resembled those of European exploited populations of *M. edulis* which reach 50mm in two to four years (Goggin 1997:65). The adult mussels exhibit variable maximum heights; Goggin (1997) reports heights between 60mm and 100mm while Lamprell and Healy (1998), and Healy *et al*. (2011) suggest maximum heights of 65mm. The mean heights across the BSM SUs suggest that the mussels, if conforming to Goggin's observations (1997:64), were between 2-4 years of age at the time of harvest and hence sexually mature but not fully grown (although see Discussion section below for an alternative explanation).

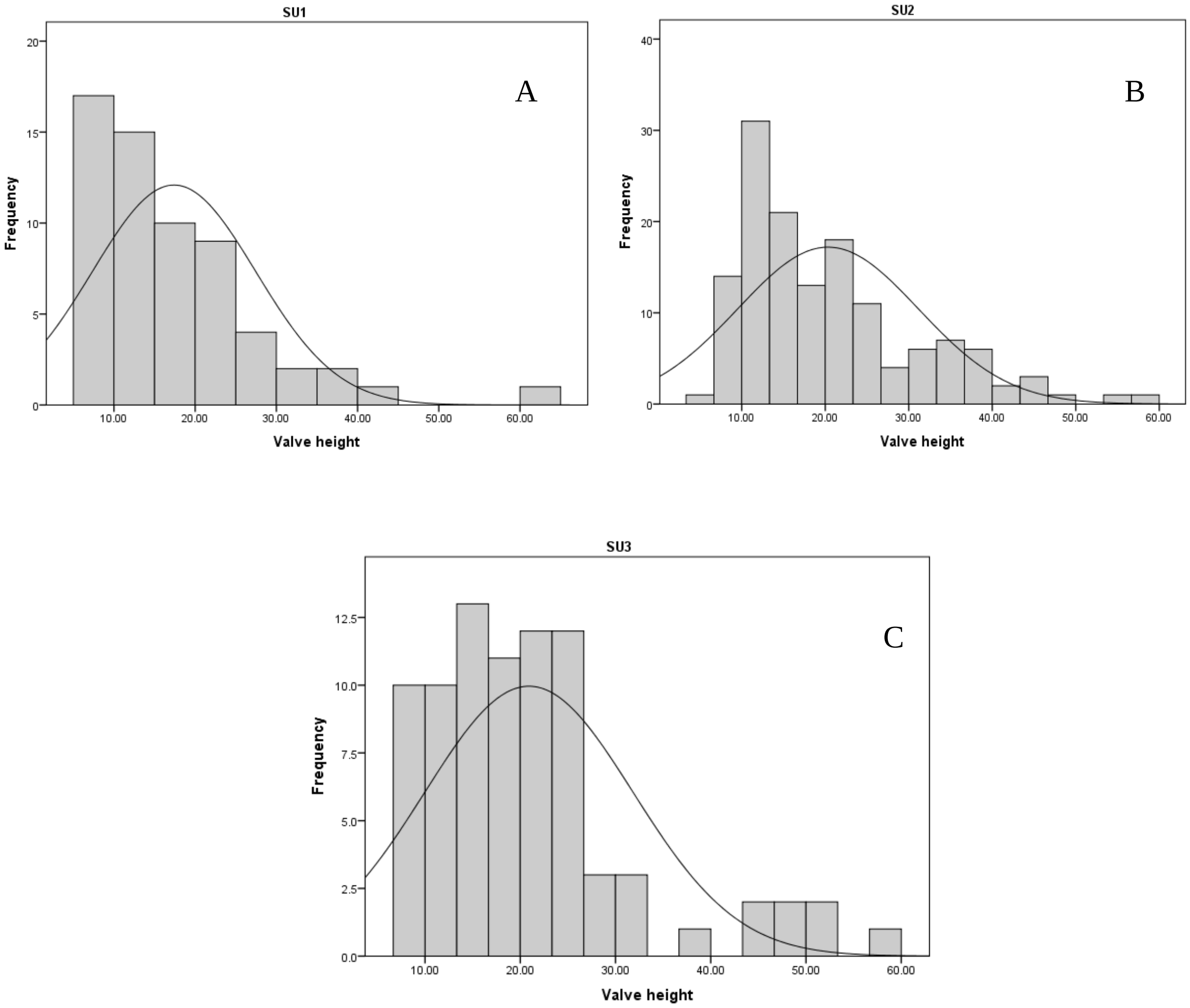

**Figure 5-8 Plot of *Trichomya hirsuta* valve heights in mm for SU1 (A); SU2 (B) and SU3 (C).**

As might be expected, the fragmentation ratios for *T. hirsuta*, a thin-walled mollusc, were high across all three SUs (SU1 48.01, SU2 26.92, and SU3 39.43; see also e.g. Claassen 1998; Campbell 2012:6) (Figure 5-9). The relatively high proportion of complete valves (63.93%) from juveniles and sub-adults ≤10mm in height, as well as from 'young adults' ≥11mm and ≤20mm (Figures 8-11 to 8-13), suggests that smaller valves are more resistant than larger valves to post-depositional breakage (e.g. by trampling), perhaps due to their smaller surface area. Their small size also suggests that, although they may have been exposed to low temperature fires while clumped with larger valves, they were not subsequently subjected to further processing to remove the meat. None of the mature valves exhibited evidence of thermal alteration.

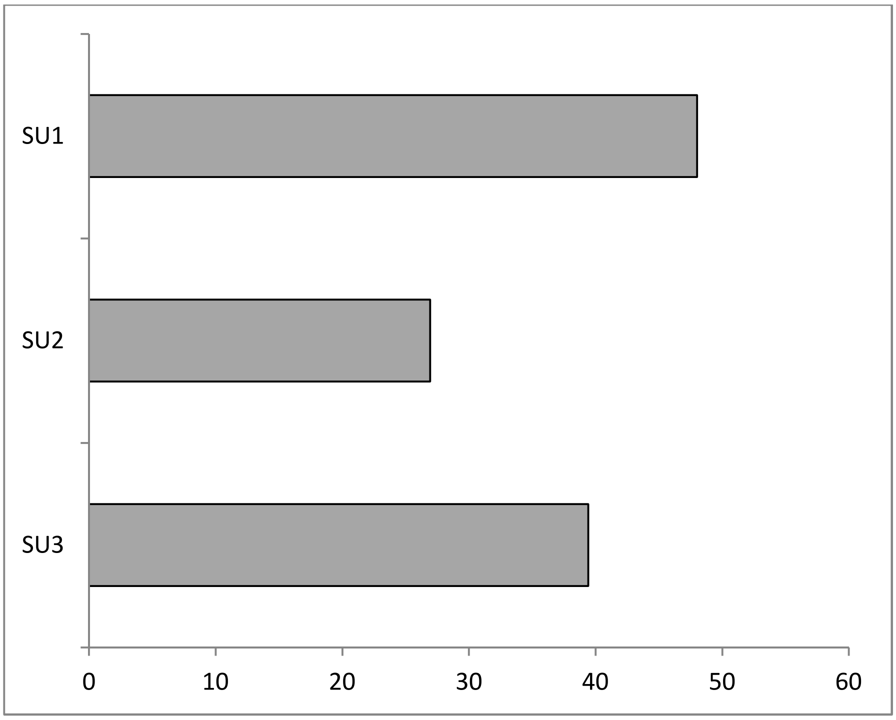

**Figure 5-9 BSM Square B *T. hirsuta* fragmentation ratios by SU.**

*Nerita balteata*

Unusually for middens in southeast Queensland, *N. balteata* (lined nerite) was the third most abundant taxon by NISP (3710, 2.01%) although not by MNI (183, 1.94%) (Table 5-5 and Table 5-6). The nerite MNI for Square A was 119 (Table 5-2; Frankland 1990:54). Nerites are algal grazers (Carpenter and Niem 1998:420), with species often living quite high in the intertidal zone, where they are exposed to the air and sun for long periods. The tightly fitting operculum prevents desiccation surface of the mantle cavity which acts as a primitive lung. They are herbivorous, grazing nocturnally at low tide on fine algae and detritus, and sometimes forming very large colonies. *N. balteata* lives on the trunks and branches of mangrove trees where they feed on the algae and detritus (Wilson 1993:40). The species grows to a height of approximately 40mm. The vast majority (NISP 3389, 91.34%) of the *N. balteata* specimens occurred in SU1 (Figure 5-10), with a similar trend also noted in Square A.

Although the numbers of complete specimens from each SU (SU1 n=17, SU2 n=5, and SU3 n=4) were too small for meaningful statistical analysis of shell height, some general observations may be made. The height of the SU1 specimens ranged from 4.11mm to 21.6mm with a mean value of 16.53mm, the SU2 specimens ranged from 6.81mm to 38.6mm with a mean value of 19.8mm, and the SU3 specimens ranged from 16.43mm to 27mm with a mean value of 20.83mm.

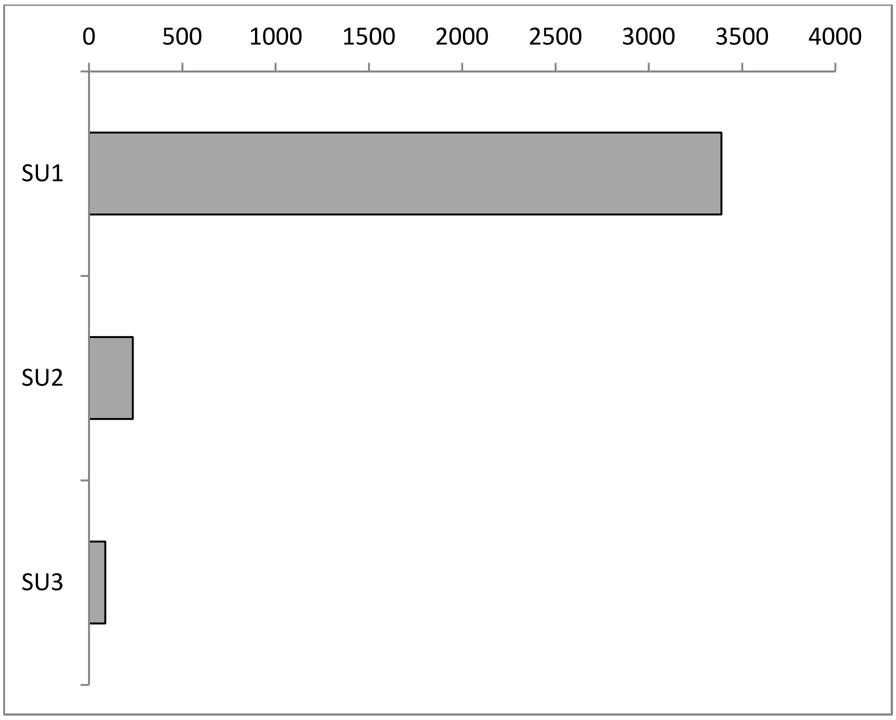

**Figure 5-10 BSM Square B *Nerita balteata* NISP by SU.**

There are no comprehensive ecological studies available regarding *N. balteata* and growth rates (see Appendix A) but based on the maximum adult height it would appear that with one exception the complete specimens were juveniles or sub-adults. None of the complete or partial specimens exhibited evidence of burning or exposure to high temperatures. The fragmentation ratios were variable (SU1 22.29, SU2 12.31, and SU3 7.25), conforming to the pattern noted for the *Saccostrea* spp.

*Pyrazus ebeninus*

Although considered one of the major economic species in southeast Queensland (Appendix A), the seagrass and mudflat-dwelling gastropod *P. ebeninus* (Hercules Club whelk) accounted for only 0.68% of the total NISP (1261) (Table 5-5) and 1.45% of the total MNI (137) (Table 5-6) from Square B. The Square A MNI for *P. ebeninus* was also 137 (Table 5-2).

Only 21 complete specimens were recovered rendering meaningful statistical analysis of shell heights impossible, although it was noted that the ten complete shells from SU1 had a mean height of 33.09mm, while the 11 complete specimens from SU3 had a mean height of 60.24mm. The majority of partial specimens demonstrated pre-depositional breakage at or above the level of the second or third whorl to extract the snail. Hercules Club whelks are a robust species (Appendix A) and the fragmentation ratios from SU1 (8.61) and SU3 (2.91) reflect this robustness. The fragmentation ratio for SU2 was highest at 12.01, which may reflect the slower rates of accumulation of the deposit and greater potential for post- depositional breakage. None of the specimens exhibited evidence of burning or exposure to high temperatures.

As outlined in Chapter 4, the juvenile Hercules Club (*P. ebeninus*) and mud whelks (*Batillaria australis*) were included in a single category due to the difficulty in differentiating the two, especially in individuals less than 10mm high (Ewers 1967; Ewers and Rose 1966; Vohra 1965). Juvenile whelks comprised 0.67% (n=1238) of the total NISP and 7.47% (n=704) of the total MNI due to their very good preservation, and their numbers compared to mature *P. ebeninus* and *B. australis* were very high (Table 5-4 and Table 5-5). Frankland (1990) also noted high numbers of small whelks for Square A. Vohra (1965:62) reported freshly settled *P. ebeninus* juveniles (<4mm) on a wet silty area near *Zostera* seagrass margins in numbers in excess of 1000 in an area 15cm x 15cm. Although the recruitment rate is very high, so is the rate of juvenile mortality. There is no reason to believe that all of the juvenile whelks were collected live, as many are small enough for the dead shells to be washed around in the intertidal zone, and it may be that the shells were collected from, or originated from, more than one environmental zone. Their relative abundance is puzzling. The elevation of BSM would seem to preclude frequent storms surges as a possible source, even during the Holocene highstand. It may be that they are by-catch linked to gathering practices on mudflats (see e.g. Meehan 1982).

### *Chama spp.*

*Chama* is not a taxon commonly recorded in the middens of southeast Queensland (although small numbers were found on St. Helena Island and at Sandstone Point - see Alfredson 1984; Nolan 1986; Chapter 8), and hence there is little local ecological or biological literature available (Appendix A). *Chama* spp. can grow up to 90mm and live on rock or coral platforms in the intertidal zone, but can occur to depths of 100m. They are fully cemented to the substrate. Studies conducted by Zurel *et al.* (2011) on invasive *C. pacifica* in the eastern Mediterranean showed that the species could develop dense clumps on rocky substrate. They are dioecious, with spawning occurring during spring and summer when the water temperature exceeds 21°C. Healy and Potter (2010:240) note that chamids, like oysters, settle and grow on the shells of other molluscs (alive and dead), rocks and dead coral. Further, during the 2005 Moreton Bay Benthic Survey (Healy and Potter 2010:240) it was observed that most shallow subtidal mussel and oyster clump samples contained one or more species of *Chama* cemented on, and that they also occurred on the clumps in small clusters. Chamids were more common subtidally in the bay, as intertidally they were in intense competition with oysters and barnacles for appropriate settlement sites. The *Chama* spp. (insufficient landmarks remained to further identify the genus to species level) in Square B comprised 0.4% of the total

NISP (n=734) and 1.54% of the total MNI (n=145). The Square A MNI was 164. Shapiro-Wilk testing indicated no significant difference between the Square B SUs in lower valve height (SU1 *W*= 0.980, *df*=17, *p*=0.953; SU2 *W*=0.965, *df*=32, *p*=0.373; SU3 *W*=0.977, *df*=49, *p*=0.447; *F*=1.130, *df*=2, *p*=0.327), although the mean values for each SU (SU1 17.71mm; SU2 19.59mm, and SU3 19.89mm) suggests that the whole specimens were juveniles or sub-adults. Despite the consistent numbers of *Chama* spp. across the SUs, in view of Healy and Potter's comments (2010: 240) it is considered here that they were not a targeted species *per se* but by-catch (albeit perhaps part of a collection strategy; see Whitaker 2008) from the gathering of oysters and mussels. The fragmentation ratios were SU1 8.96, SU2 5.58, and SU3 4.18. None of the specimens exhibited evidence of burning or exposure to high temperatures.

### *Anadara trapezia*

Often considered a common component of coastal middens, *A. trapezia* (mud ark, blood cockle, cockle) comprised only 0.16% of the total NISP (n=293) and 0.18% of the total MNI (n=17). As noted above, A. *trapezia* occupy a similar environmental zone to *P. ebeninus*, and are frequently found in association with *Saccostrea* and *T. hirsuta* (Healy and Potter 2010:238). Individuals of the species were found only in SU1, and in XU23 of SU3 (in Square A the SU1 MNI was 40, and the SU2 MNI was two). The two individuals in Square B SU3 suitable for measurement - a pair of valves 6.6mm in length, and a valve 11.84mm long - were both well below reproductive age. In contrast, 13 valves suitable for measurement from SU1 averaged 35.68mm, well into the sexually mature range (Appendix A). This suggests that in the lower levels of the site, the *A. trapezia* population was low in density, and perhaps in an establishment phase. The fragmentation ratio of 19.33 for SU1 was also surprisingly high for a relatively robust valve. The fragmentation ratio of 1.5 in SU3 simply reflected the minimal occurrence of *A. trapezia* in that stratum. None of the specimens exhibited evidence of burning or exposure to high temperatures.

### ***'Other' molluscan species***

The key prey species indicate exploitation of rocky intertidal and subtidal zones, muddy sand and seagrass flats, and mangrove forests. Other marine molluscan species with MNI ≥10, ranked on their percentage contribution to the total NISP and MNI, and their preferred habitats are presented in Table 5-13 in order to round out the near shore palaeoenvironmental reconstruction and resource exploitation zones.

**Table 5-13 Other marine molluscan taxa with MNI ≥ 10 and habitats for BSM Square B.**

| Species | NISP | % Total NISP | MNI | % Total MNI | Habitat |
|---|---|---|---|---|---|
| *Notoacmea petterdi*<br>Petterd's limpet | 436 | 0.24 | 425 | 4.51 | Vertical rock faces in high intertidal zone. Algal and detrital grazers. |
| *Bembicium auratum*<br>Gold-mouthed periwinkle | 294 | 0.16 | 288 | 3.06 | Sheltered estuarine on mangroves/rocky shores. Algal grazer. |
| *Astele* sp.<br>Top snail | 174 | 0.09 | 77 | 0.82 | Subtidal seagrass beds in association with food sources coelenterates, sponges and tunicates. |
| *Herpetopoma atrata*<br>Beaded top snail | 138 | 0.07 | 99 | 1.05 | Rocky intertidal and shallow sublittoral zones. Algal grazer. |
| *Pinctada fucata*<br>Southern pearl oyster | 136 | 0.07 | 19 | 0.2 | Suspension feeder attached by byssus to intertidal and especially subtidal rocks, or to gorgonians and hydroids. |
| Naticidae<br>Sand snails | 91 | 0.05 | 12 | 0.13 | Sandy substrates, intertidal to subtidal. Predates on bivalves, marine snails, and soldier crabs. |
| Arcidae<br>Arks | 79 | 0.04 | 4 | 0.04 | Depending on species, intertidal sand/mud/seagrass flats or attached by byssus subtidally to rock or shells. |
| *Serpulorbis sipho*<br>Common worm shell | 68 | 0.04 | 22 | 0.23 | Sessile suspension feeders, rocky shores. |
| *Nassarius* spp.<br>Dog whelks | 49 | 0.03 | 45 | 0.48 | Sand/sandy mud substrates, intertidal to shallow subtidal. Scavengers/predators on molluscs and other animals. |
| *Bedeva hanleyi*<br>Oyster drill | 40 | 0.02 | 40 | 0.42 | Intertidal and shallow subtidal, rocks or coral reefs. Predates on other molluscs and worms. |
| *Clypeomorus* spp.<br>Creeper | 38 | 0.02 | 38 | 0.40 | Intertidal, usually coarse rocky substrates or mangroves. |
| *Irus* spp. | 35 | 0.02 | 23 | 0.24 | Mussel clumps or littoral debris. |
| *Batillaria australis*<br>Mud whelk | 25 | 0.01 | 23 | 0.24 | Intertidal sandy substrates, seagrass beds. |
| *Austrocochlea* spp.<br>Top shell | 17 | 0.01 | 14 | 0.15 | Depending on species, intertidal and shallow subtidal rocky reefs or seagrass beds. |

Of the above, *P. fucata* (southern pearl oyster or Booral shell) is also exploited as a prey species. These 'other' species, by-catch of foraging strategies or perhaps, in the case of *N. petterdi*, introduced to the site on mudstone collected as raw material for artefact manufacture, indicate a general preference for the rock platforms close to the site.

## Non-molluscan invertebrate remains

Crustaceans are represented in the site by Cirripedia and two species of crab, most likely the mud crab *Scylla serrata* and the sand crab *Portunus pelagicus*. The Cirripedia (barnacles) were unable to be identified beyond infraclass level due to a lack of distinguishing characteristics. Cirripedia (total NISP =272) were identified in all SUs, but were most common in XU23 of SU3 (NISP =131). They are again indicative of exploitation of the rocky shore environmental zone. *S. serrata* (total NISP =110) was most abundant in SU2 (NISP=84), with only one fragment found in XU1 of SU1, and 24 fragments scattered through the five sampled XUs of SU3. Mud crabs inhabit estuarine and mangrove areas in the intertidal and subtidal zones (Davie 1998:44). *P. pelagicus*, as its common name of sand crab implies, inhabits shallow, sandy-muddy inshore waters and seagrass beds (Davie 1998:100). The relatively low abundance of both crabs in the site may be due to the fact that they require longer processing, probably at higher temperatures than the molluscs, and need to be broken up to extract the meat. Only dactyl and cheliped fragments were identified, with the body shell (exoskeleton) fragments likely disposed of close to the point of consumption.

### Coral

Small amounts of coral were found in SU1 (1.17g), SU2 (1.77g), and SU3 (5.32g). The genera and species could not be identified.

### Marine vertebrates

Part of Frankland's research question was to test Walters' (1987; 1989) fishery model, and therefore both NISP and MNI were calculated for the fish bone, as NISP was the only measurement employed by Walters. Frankland (1990) reported a total of 1470 fish bones from Square A (1423 of which could not be identified to species), with the majority discarded in the early period of occupation 3133-2852 cal BP (SU3). In all, nine species of fish were identified (Table 5-14). There was a slight rise in discard in SU1, with an associated increase in species richness from that seen in the lower units e.g. *Mugil* sp. (mullet), *Sillago* spp. (whiting), *Pomadasys kaakan* (grunter), *Atherinomorus vaigiensis* (hardyhead), and *Psammoperca waigensis* (sand bass), were recovered only from SU1 (Frankland 1990:59-60; McNiven 1994:86). In comparison, only 57 fish bones (28 from SU1, one from SU2, and 28 from SU3) were identified in Square B, with the disparity perhaps due to the decision not to sort the <2mm sieve fraction (see Ross and Duffy 2000; Ross and Tomkins 2011). However, in addition to the bones, 24 complete and 16 fragmentary otoliths were recovered, with the majority found in SU1 (12 complete and nine partial; SU2 10 complete and seven partial, and SU3 two complete). Although not all could be identified to species, those that could be identified reflect the species represented in Square A with *Pomadasys kaakan* (grunter), *Sillago* sp. (whiting), and *Arius* sp. (catfish) found in SU1, and grunter in SU2. Bowen (1998) suggested that the increased species richness reflected in SU1 (i.e. from 1673 cal BP onward) may be related to the construction of the fish traps associated with the shell mound and surrounding midden and artefact scatters, and which remain undated (Bowen 1998: Frankland 1990; McNiven 1994). However, Jason McGilvray, Fisheries Officer, Queensland Department of Agriculture, and Fisheries, considered that the overall species diversity is low given the taxa which occur in the GSS (pers. comm., 25 March 2015), with the absence of flathead (*Platycephalus* spp.) particularly surprising.

**Table 5-14 Fish species identified in Square A BSM (after Frankland 1990:60; McNiven 1994:86).**

| **Scientific name** | **Common name** | **MNI** |
|---|---|---|
| *Arius* sp. | Catfish | 9 |
| *Rhabdosargus sarba* | Tarwhine | 7 |
| *Mugil* sp. | Mullet | 5 |
| *Acanthropagus australis* | Yellowfin (silver, sea) bream | 5 |
| *Sillago ciliata* | Sand whiting | 4 |
| *Pomadasys kaakan* | Grunter | 2 |
| *Argyrosomus holoepiclotus* | Jewfish | 1 |
| *Psammoperca waigensis* | Sand bass | 1 |
| *Atherinomorus vaigiensis* * | Hardyhead | 1 |

*Formerly *Praneus ogilbyi*

## Terrestrial Invertebrates

Land snails (NISP=735, MNI=37) accounted for 0.4% of the total molluscan NISP and 1.03% of the total MNI. They were very broadly classified into three taxa, one large and two small, with the two smaller taxa distinguished by their spire characteristics. Further identification to species was not possible due to the lack of preservation of key features. The large species was tentatively identified as *Sphaerospira fraseri* (Fraser's Banded Snail), based on its size and remnant colouration on one specimen. The snails were most abundant in SU1 (NISP=450) and SU2 (NISP=221), with SU3 having a NISP of 64. Whilst there is no ethnographic evidence to suggest the larger species may have been eaten, this does not necessarily argue against potential dietary use. However in this instance the snails are taken as proxy environmental indicators. Their increased abundance in SU1 and SU2 may indicate a shift towards a locally more forested environment in the period after 2852 cal BP; the preferred habitat for Fraser's Banded Snail is rainforest and closed woodland.

## Terrestrial vertebrates

The remains of terrestrial vertebrates are poorly represented in comparison to the molluscan remains in Square B (total NISP=293, weight 34.38g), although they occur throughout the site (SU1 NISP=154, SU2 NISP=102, SU3 NISP=37). This poor representation is not due to poor preservation conditions – the pH of Square B is mostly 8.0 throughout. As is often typical of Australian sites, the remains are highly fragmented and identification of the majority was not possible, although some small humeri and femora were attributed to small rodents and lizards.

However, one medial distal fragment of a humerus from an adult *Macropus*, as well as two lower incisors and five molars, one attached to a mandibular fragment, were identified in SU2, as was a partial lower premolar from a *Trichosurus vulpecus* (brushtail possum) in SU3.

McNiven (1994) considered the paucity of terrestrial vertebrate remains not due to taphonomic factors, but because they were never there in the first place. This is not to say that terrestrial vertebrates were not part of the subsistence of the BSM inhabitants – clearly they were as evidenced by the macropod remains and the brushtail possum tooth, but that terrestrial hunting activities and their results took place elsewhere and the remains were not deposited at BSM. It may also be a reflection of the depauperate terrestrial species in wallum country.

### Charcoal

A total of 72.47g of charcoal was found in SUs1-3. SU1 had the highest charcoal values at 40.82g which is reflected in the discrete charcoal patch in the stratigraphic profile (Figure 5-3). SU2 had the lowest value of 9.38g, while there was a small peak in SU3 at 22.27g.

### Stone artefacts

Frankland (1990:66-67) reported 654 stone artefacts from BSM Square A, with the overwhelming majority (n=648, 99%) made on the indurated mudstone which forms the rocky platforms adjacent to the site. The other raw materials were chert, chalcedony and quartz, and Frankland (1990:65) suggested the Mary River 9km south of the site as a source. Artefact categories in this earlier analysis included flakes (n=37), broken flakes (n=49), flaked pieces (n=558), retouched flakes (n=4), and cores (n=6). Many of the flaked pieces were noted to be heavily pot-lidded and discoloured by exposure to heat.

In the present study a total of 552 pieces of artefactual stone were recovered from Square B, including seven from SU4 which underlies the midden deposit. Artefact categories represented include flakes, broken flakes (BF), flaked pieces (FP), retouched flakes (RF), cores, and manuports. There was also a high incidence of heat-shattered stone, reflecting thermal modification to improve its knapping qualities, and perhaps also the use of mudstone for hearthstones (Table 5-15). The majority of artefacts (n=341, 61.66%) (Table 5-16) were made on the locally available raw material, mudstone. The other raw materials – chert, sandstone, quartz, quartzite, and silcrete – are available within 40km of the site. The pumice stone forming part of the manuport count can be found floating in the strait or outcropping in dune formations; the latter circumstance also applies to the ochreous mudstone or ferruginous sandstone which formed a significant component of the manuport count.

**Table 5-15 Summary of artefact categories by SU for BSM Square B.**

| Category | SU1 | SU2 | SU3 | SU4 | Total | % Total |
|---|---|---|---|---|---|---|
| Flake | 22 | 9 | 1 | 1 | 33 | 6% |
| BF | 24 | 6 | 3 | 0 | 33 | 5.98% |
| RF | 0 | 1 | 0 | 0 | 1 | 0.18% |
| FP | 203 | 41 | 31 | 6 | 281 | 50.91% |
| Core | 4 | 2 | 0 | 0 | 6 | 1.09% |
| Manuport | 61 | 17 | 8 | 0 | 86 | 15.58% |
| Heat shatter | 50 | 29 | 33 | 0 | 112 | 20.29% |
| Total | 364 | 105 | 76 | 7 | 552 | 100.00% |

**Table 5-16 Summary of artefact categories by raw material for BSM Square B.**

| Raw material | Flake | BF | FP | RF | Core | Manuports | Heat shatter | Total | % Total |
|---|---|---|---|---|---|---|---|---|---|
| Chert | 9 | 13 | 45 | 1 | 1 | 0 | 28 | 97 | 17.57% |
| Mudstone | 10 | 16 | 224 | 0 | 4 | 3 | 84 | 341 | 61.78% |
| Ochreous | 0 | 0 | 0 | 0 | 0 | 78 | 0 | 78 | 14.13% |
| Pumice | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 5 | 0.91% |
| Quartz | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0.91% |
| Quartzite | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0.18% |
| Sandstone | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.36% |
| Silcrete | 7 | 4 | 11 | 0 | 1 | 0 | 0 | 23 | 4.17% |
| Total | 33 | 33 | 281 | 1 | 6 | 86 | 112 | 552 | 100.00% |

### *Whole flakes*

The attributes and distribution of the whole flakes from Square B are presented in Table 5-17. The majority of the flakes (64.7%) were recovered from SU1; mudstone, chert, and silcrete occurred throughout the sequence, but quartz was recorded only in SU1. With the exception of one chert flake from SU1 and one silcrete flake from SU2 (both with overhang removal), there was no evidence of platform preparation. All termination types were feather, and the majority of flakes exhibited one or more dorsal scar. A poorly executed blade was identified in SU3, approximately 10cm above the basal date of 3133 cal BP. It was made on thermally-modified but still poor quality chert. There were insufficient numbers of each raw material type to attempt statistical analyses of variations in length, width, and thickness between the SUs.

*Broken flakes*

The attributes and distribution of the broken flakes from Square B are presented in Table 5-18. The majority of the broken flakes (70.6%) were recovered from SU1; mudstone and chert occurred throughout the sequence, but silcrete was recorded only in SU2. With the exception of one chert flake from SU2 which had overhang removal, there was no evidence of platform preparation. The majority of flakes exhibited one or more dorsal scars. There were insufficient numbers of each raw material type to attempt statistical analyses of variations in length, width, and thickness between the SUs.

*Retouched flake*

The attributes of the retouched flake or backed artefact from the SU2 layer dating to 2752 cal BP are presented in Table 5-19. The backed artefact is important in supporting McNiven's (1990a) assertion that backed blades observed on the surface of some sites in the Great Sandy Strait and Cooloola Regions pre-date 2300BP. It also provides potential evidence of the exploitation of terrestrial and perhaps avian resources, as backed artefacts have not been associated with the procurement or processing of marine resources (see Robertson 2002; Robertson *et al*. 2009 for discussions of backed artefact use).

*Flaked pieces*

This was the most populated artefact category. A total of 281 flaked pieces were recovered from SUs1-4 (Table 5-14), with the majority (n=203, 72.24%) coming from SU1. Mudstone dominated the raw material types for each SU (SU1 n=171, 84.24%; SU2 n=36, 87.8%; SU3 n=16, 51.61%) except for SU4, which contained four chert flaked pieces and one each of silcrete and mudstone. In SU1, 90 (44.33%) of the flaked pieces exhibited evidence of heating which dropped to only four (9.75%) in SU2 and only one (3.22%) in SU3 (Appendix B). Similar patterns of high proportions of heat damage in the absence of associated thermally altered shells have been noted at Caution Bay in Papua New Guinea (Professor Ian McNiven, Monash University, pers. comm., 5 April 2016), the reasons for which are not yet clear.

*Cores*

The attributes and distribution of the cores from Square B are presented in Table 5-20. The mudstone cores are evidence of expedient use of local raw material, particularly given the lack of significant core rotation and the high percentage of cortex. The three mudstone cores in SU1 were essentially large pebbles demonstrating thermal modification, presumably to increase their flaking qualities.

### *Manuports*

Of the 61 manuports in SU1, 58 were of ochreous material varying in colour between red, dusky red, yellow, yellow-brown, and white. The remaining three were reddish-brown and dark red mudstone, including one tabular piece 91.95mm long. In SU2 there were 12 pieces of red and yellow ochreous material, and five pieces of pumice stone. Eight pieces of red and yellow ochreous material comprised the manuports for SU3. Two of the mudstone manuports in SU2 appeared polished.

### *Heat shatter*

The heat-shattered fragments were differentiated from heat-shattered flaked pieces on the basis that they bore no evidence of flaking or knapping. Mudstone made up all of the 50 pieces of heat-shattered fragments in SU1. Of these, 47 pieces were dark reddish-brown in colour, with another two red in colour, and one yellow in colour. Similarly, 28 of the 29 heat-shattered fragments from SU2 were dark reddish brown mudstone and the other was white mudstone. By comparison, 28 of the 33 heat-shattered fragments in SU3 were dark reddish-brown chert, with four dark reddish-brown and one yellowish-red mudstone fragments. There is no direct correspondence with the proportion of these colours of raw materials in the flake, broken flake, and flaked piece categories. Corkill (1978) has demonstrated that fine-grained raw materials will change colour depending upon the length of time they are exposed to heat, with the longest exposure turning the raw materials dark red.

### *Volume-corrected estimates of stone artefact discard*

The volume-corrected estimates of the density of stone artefact discard for Square B are presented in Table 5-21.

**Table 5-17 Attributes of whole flakes by SU from BSM Square B.**

| SU | Category | Raw Material | Colour | Wt g | Width mm | Length mm | Thickness mm | Plat. Thick. mm | Plat. Width mm | Plat. Type | Cortex % | Ret/Damage | Dorsal scar number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Flake | Chert | Lt olive brown | 0.18 | 10.34 | 9.53 | 1.96 | 1.4 | 4.47 | Flaked | 0 | Dam dist margin | 1 |
| 1 | Flake | Chert | Dusky red | 4.75 | 21.55 | 32.67 | 6.19 | 4.83 | 18.3 | Flaked | 50 | Nil | 2 |
| 1 | Flake | Chert | Dusky red | 0.48 | 16.1 | 14.61 | 2.44 | 2.19 | 9.08 | Flaked | 0 | Nil | 1 |
| 1 | Flake | Chert | Dark reddish brown | 3.21 | 26.59 | 27.36 | 4.12 | 3.04 | 9.06 | Flaked | 50 | Nil | 2 |
| 1 | Flake | Chert | Yellowish brown | 1.06 | 16 | 17.73 | 2.9 | 2.95 | 9.77 | Flaked | 0 | Nil | 4 |
| 1 | Flake | Mudstone | Brown | 0.79 | 17.77 | 11.94 | 4.35 | 3.79 | 10.54 | Flaked | 0 | Dam dist margin | 0 |
| 1 | Flake | Mudstone | Dusky red | 7.73 | 19.53 | 28.33 | 8.2 | 3.87 | 8.19 | Flaked | 0 | Dam left margin | 1 |
| 1 | Flake | Mudstone | Red | 4.64 | 15.24 | 34.25 | 8.67 | 2.09 | 7.95 | Cortical | Entire dorsal | Nil | 0 |
| 1 | Flake | Mudstone | Reddish grey | 0.2 | 8.53 | 8.56 | 1.91 | 2.22 | 5.39 | Flaked | 0 | Dam distal margin | 0 |
| 1 | Flake | Mudstone | Reddish grey | 0.31 | 7.98 | 13.44 | 2.96 | 2.07 | 5.02 | Flaked | 0 | Nil | 1 |
| 1 | Flake | Mudstone | Yellowish brown | 3.26 | 20.12 | 30.09 | 6.72 | 1.38 | 12.71 | Cortical | 20 | Nil | 2 |
| 1 | Flake | Mudstone | Yellowish brown | 0.43 | 16.08 | 12.54 | 1.88 | 2.09 | 12.59 | Flaked | 0 | Dam all margins | 1 |
| 1 | Flake | Quartz | White/clear | 0.09 | 7.11 | 8.43 | 1.76 | 1.74 | 6.47 | Flaked | 0 | Nil | 1 |
| 1 | Flake | Quartz | White/clear | 0.06 | 5.9 | 6.06 | 1.41 | 1.15 | 3.76 | Flaked | 0 | Nil | 1 |
| 1 | Flake | Quartz | White, stained pink | 0.43 | 9.95 | 9.55 | 3.78 | 3.46 | 7.7 | Flaked | 0 | Dam distal margin | 0 |
| 1 | Flake | Quartz | White, stained pink | 0.46 | 13.11 | 10.81 | 3.63 | 1.83 | 12.55 | Flaked | 0 | Nil | 0 |
| 1 | Flake | Quartz | White, stained pink | 0.19 | 6.98 | 9.21 | 3.12 | 1.69 | 3.99 | Flaked | 0 | Nil | 0 |
| 1 | Flake | Sandstone | Greyish yellow | 10.03 | 37.91 | 31.26 | 8.28 | 5.72 | 18.69 | Flaked | 0 | Dam distal margin | 1 |
| 1 | Flake | Sandstone | Reddish grey | 10.85 | 27.95 | 35.1 | 8.94 | 6.95 | 27.09 | Flaked | Entire dorsal | Nil | |
| 1 | Flake | Silcrete | Light yellowish brown | 0.06 | 6.9 | 7.29 | 1.63 | 1.74 | 3.9 | Flaked | 0 | Nil | 1 |
| 1 | Flake | Silcrete | Dusky red | 0.84 | 14.38 | 15.48 | 3.34 | 3 | 11.25 | Flaked | 0 | Dam all margins | 1 |
| 1 | Flake | Silcrete | Reddish brown | 2.24 | 23.81 | 14.67 | 5.34 | 5.54 | 26.31 | Flaked | 0 | Dam rt margin | 3 |
| 2 | Flake | Chert | Black | 1.85 | 16.32 | 18.79 | 6.35 | 3.19 | 6.39 | Flaked | 5 | Nil | 2 |
| 2 | Flake | Chert | Dark reddish brown | 1.87 | 13.08 | 29.48 | 5.57 | 5.06 | 7.2 | Flaked | 0 | Nil | 2 |

**Table 5-17 (continued) Attributes of whole flakes by SU from BSM Square B.**

| SU | Category | Raw Material | Colour | Wt g | Width mm | Length mm | Thickness mm | Plat. Thick. mm | Plat. Width mm | Plat. Type | Cortex % | Ret/Damage | Dorsal scar number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Flake | Mudstone | Mudstone | 1.64 | 19.73 | 18.45 | 4.86 | 5.57 | 19.74 | Flaked | 0 | Nil | 1 |
| 2 | Flake | Mudstone | Red | 3.98 | 15.14 | 33.64 | 5.44 | 3.07 | 11.16 | Cortical | Entire dorsal | Nil | |
| 2 | Flake | Mudstone | Reddish brown | 1.9 | 15.35 | 20.95 | 5.57 | 3.55 | 10.86 | Flaked | 0 | Nil | 0 |
| 2 | Flake | Silcrete | Red | 16.39 | 27.47 | 48.16 | 12.68 | 4.34 | 16.91 | Flaked | 25 | Nil | 5 |
| 2 | Flake | Silcrete | Red | 1.02 | 19.33 | 15.39 | 3.26 | 1.56 | 11.59 | Flaked | 0 | Nil | 2 |
| 2 | Flake | Silcrete | Red | 1 | 16.55 | 12.5 | 4.34 | 3.1 | 8.66 | Flaked | 0 | Nil | 2 |
| 2 | Flake | Silcrete | Red | 1.44 | 17.35 | 23.26 | 4.51 | 2.4 | 6.91 | Flaked | 0 | Nil | 2 |
| 3 | Flake* | Chert | Yellowish brown | 3.5 | 11.11 | 56.92 | 5.89 | 2.92 | 9.04 | Flaked | 0 | Nil | 3 |
| 4 | Flake | Chert | Yellowish brown | 0.21 | 11.62 | 8.26 | 2.72 | 2.75 | 10.92 | Flaked | 0 | Nil | 2 |

**Table 5-18 Attributes of broken flakes by SU from BSM Square B.**

| SU | Category | Raw material | Colour | Wt g | Length mm | Width mm | Thickness mm | Plat. thickness mm | Plat. Width mm | Plat. Type | Cortex % | Dorsal scar number | Ret/damage | Breakage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | BF | Chert | Pale yellowish orange | 1.33 | 12.02 | 17.09 | 5.25 | 6.27 | 16.25 | Flaked | 0 | 2 | Nil | Transverse |
| 1 | BF | Chert | Light olive brown | 10.68 | 29.18 | 38.11 | 9.5 | 12.88 | 12.1 | Flaked | 0 | 4 | Nil | Longitudinal |
| 1 | BF | Chert | Grey | 0.26 | 8.78 | 10.35 | 1.79 | Nil | Nil | Nil | 0 | 3 | Nil | Transverse |
| 1 | BF | Chert | Dark reddish brown | 0.97 | 13.73 | 8.79 | 5.64 | Nil | Nil | Nil | 50 | 0 | Nil | Oblique |
| 1 | BF | Chert | Dark reddish brown | 0.27 | 13.12 | 6.4 | 2.73 | 1.47 | 4.99 | Flaked | 0 | 2 | Nil | Transverse |
| 1 | BF | Chert | Dark reddish brown | 0.12 | 15.08 | 7.65 | 1.41 | 1.66 | 4 | Flaked | 0 | 1 | Dam r margin | Right margin |
| 1 | BF | Chert | Red | 1.87 | 26.25 | 13.58 | 5.24 | 5.76 | 0 | Flaked | 0 | 0 | Nil | RSC |
| 1 | BF | Chert | Yellowish brown | 0.21 | 12.05 | 7.29 | 2.99 | 2.66 | 6.14 | Flaked | 0 | 3 | Nil | Distal |
| 1 | BF | Mudstone | Dark red | 0.15 | 11.61 | 8.82 | 1.35 | 1.74 | 6.44 | Flaked | 0 | 2 | Nil | Transverse |
| 1 | BF | Mudstone | Dark red | 0.39 | 11.63 | 11.48 | 2.76 | 1.37 | 10.22 | Flaked | 0 | 1 | Nil | R margin |
| 1 | BF | Mudstone | Dark red | 0.26 | 5.2 | 18.17 | 2.57 | 2.29 | 5.01 | Flaked | 0 | 0 | Dam r margin | Longitudinal |
| 1 | BF | Mudstone | Brown | 3.89 | 30.18 | 20.12 | 4.93 | 3.91 | 21.63 | Cortical | Plat | 1 | Nil | Left margin |
| 1 | BF | Mudstone | Dark reddish brown | 0.08 | 6.35 | 7.04 | 1.92 | 2.69 | 6.03 | Flaked | 0 | 2 | Nil | Transverse |

**Table 5-18 (continued) Attributes of broken flakes by SU from BSM Square B.**

| SU | Category | Raw material | Colour | Wt g | Length mm | Width mm | Thickness mm | Plat. thickness mm | Plat. Width mm | Plat. Type | Cortex % | Dorsal scar number | Ret/damage | Breakage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | BF | Mudstone | Dark reddish brown | 0.38 | 16.5 | 7.1 | 3.98 | 1.36 | 5.77 | Flaked | 0 | 2 | Nil | R margin |
| 1 | BF | Mudstone | Yellowish brown | 0.53 | 15.8 | 12.81 | 3.52 | 0 | 3.95 | Nil | 0 | 2 | Nil | Trans |
| 1 | BF | Mudstone | Reddish brown | 0.14 | 18.63 | 5.95 | 1.25 | 1.12 | 0 | Flaked | 0 | 0 | Nil | LSC |
| 1 | BF | Mudstone | Reddish brown | 1.53 | 27.94 | 15.93 | 5.05 | 1.5 | 7.8 | Flaked | 0 | 0 | Nil | Right margin |
| 1 | BF | Mudstone | Reddish grey | 0.17 | 11.2 | 6.27 | 2.77 | 0 | 0 | Nil | 0 | 0 | Nil | Long/trans |
| 1 | BF | Mudstone | Reddish grey | 1.33 | 19.69 | 13.71 | 7.55 | 0 | 0 | Nil | 0 | 1 | Nil | Transverse |
| 1 | BF | Mudstone | Red | 0.24 | 11.47 | 10.79 | 1.76 | 1.11 | 7.28 | Flaked | 0 | 2 | Nil | Transverse |
| 1 | BF | Mudstone | Grey | 2.52 | 26.82 | 16.34 | 7 | 0 | 0 | Nil | 0 | 2 | Nil | Transverse |
| 1 | BF | Mudstone | Reddish grey | 0.17 | 12.25 | 5.28 | 1.98 | 1.55 | 5.86 | Flaked | 0 | 3 | Nil | Distal |
| 1 | BF | Silcrete | Red | 0.12 | 8.08 | 10.38 | 1.37 | 1.08 | 6.25 | Cortical | 0 | 0 | Nil | Transverse |
| 1 | BF | Silcrete | Red | 0.48 | 14.87 | 9.61 | 3.25 | 3.04 | 9.17 | Flaked | Dorsal | 0 | Nil | Right distal margin |
| 2 | BF | Chert | Yellowish brown | 1.43 | 16.02 | 20.96 | 3.93 | 2.73 | 15.83 | Flaked | 0 | 2 | Nil | Transverse |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 2 | BF | Chert | Dark reddish brown | 0.12 | 12.42 | 7.73 | 1.57 | 0 | 0 | 0 | 0 | 2 | Nil | Transverse |
| 2 | BF | Chert | Very pale brown | 0.4 | 17.23 | 8.51 | 2.29 | 1.6 | 8.15 | Flaked | 0 | 3 | Dam left margin | Transverse |
| 2 | BF | Mudstone | Yellowish brown | 0.31 | 11.22 | 7.53 | 4.54 | 0 | 0 | 0 | 0 | 2 | Nil | Transverse |
| 2 | BF | Mudstone | Grey | 1.46 | 22.69 | 12.67 | 5.14 | 4.74 | 15.78 | Flaked | 0 | 2 | Nil | Left distal margin |
| 2 | BF | Silcrete | Red | 0.81 | 11.9 | 12.25 | 5.64 | 5.41 | 11.08 | Flaked | 0 | 1 | Nil | Transverse |
| 3 | BF | Chert | Dark reddish grey | 0.27 | 15.42 | 9.39 | 2.01 | 1.56 | 4.92 | Flaked | 0 | 1 | Nil | Right margin |
| 3 | BF | Chert | Dark grey | 0.44 | 17.78 | 8.11 | 3.07 | 3.27 | 5.17 | Flaked | 0 | 2 | Nil | Distal margin |
| 3 | BF | Silcrete | Light brown | 1.67 | 25.57 | 13.53 | 6.17 | 0 | 0 | 0 | 0 | 1 | Nil | Proximal |

**Table 5-19 Attributes of retouched flake from BSM Square B.**

| SU | Category | Raw Material | Colour | Wt g | Width mm | Length mm | Thickness mm | Plat. thickness mm | Plat. Width mm | Plat. Type | Cortex % | Ret/damage | Max length ret. mm | Min length ret. mm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Retouched flake | Chert | Yellowish brown | 4.97 | 16.57 | 32.5 | 10.9 | 4.95 | 0 | Crushed |  | Right margin | 10 | 4.6 |

**Table 5-20 Attributes of cores by SU from BSM Square B.**

| SU | Category | Raw Material | Colour | Wt g | Length mm | Width mm | Max Dim. mm | Plat. Number | Scar no. | Max scar mm | Min scar mm | Cortex % | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Core | Mudstone | Dark reddish brown | 2.79 | 14.46 | 19.29 | 19.74 | 1 | 1 | 11.65 | 11.65 | 50 | Big pebble, heated. |
| 1 | Core | Mudstone | Dark reddish brown | 1.38 | 16.87 | 11.72 | 16.89 | 1 | 2 | 15.04 | 14.65 | 50 | Big pebble, heated. |
| 1 | Core | Mudstone | Red | 26.48 | 35.67 | 29.74 | 40.61 | 1 | 1 | 20.74 | 20.74 | All cortex except scar | Big pebble, heated. |
| 1 | Core | Silcrete | Yellowish brown | 4.65 | 24.36 | 26.37 | 30.41 | 2 | 2 | 23.28 | 21.18 | 0 | Exhausted. |
| 2 | Core | Chert | Yellowish brown | 19.15 | 34.45 | 29.78 | 38.82 | 2 | 6 | 14.47 | 8.72 | 0 | Exhausted. |
| 2 | Core | Mudstone | Red | 19.3 | 23.39 | 31.26 | 35.75 | 2 | 2 | 22.8 | 18.78 | 0 | Angular. |

**Table 5-21 Volume-corrected density estimates for stone artefact discard for BSM Square B.**

| BSM Sq B | SU1 | SU2 | SU3 | SU4 | Total |
|---|---|---|---|---|---|
| **SU Volume** | 0.0675 | 0.055 | 0.05675 | 0.011 | 0.19025 |
| **N** | 364 | 105 | 76 | 7 | 552 |
| **N/m$^3$** | 5393 | 1909 | 1339 | 636 | 2901 |

### Shell artefact

In addition to the stone artefacts, a piece of worked *Melo* sp. (baler) shell (Figure 5-11) was identified from XU15 in SU2, immediately below the XU dated to 2752 cal BP. It appears to be a pendant or other item of adornment, probably broken during manufacture as there is evidence of drilling at one end, and flaking along one margin. McNiven (1997: 6-7, 10; figures 5 and 6) illustrated and described a broken baler shell pendant from a midden at Middle Rocks north of Corroboree Beach on Fraser Island, the first archaeological example of such an artefact from the Great Sandy Region. The artefact from BSM does not resemble the pendant illustrated by McNiven, being more elongated and narrow; there may also be some post-depositional damage along the flaked margin. Nevertheless it represents the first example of securely-dated worked shell from the Great Sandy Region.

**Figure 5-11 Worked piece of *Melo* sp. shell from SU2 in BSM Square B. Evidence of drilling circled.**

## *Discussion*

Booral Shell Mound demonstrates long-term and repeated occupation over a period of some 2300 years before the site was abandoned around 806 cal BP, one of the longest sequences in coastal southeast Queensland. From its inception, the site reflects a well-developed, specialist marine-based economy. Differences in the rates of accumulation are demonstrated throughout, reflecting differing intensities of site use. No rapid depositional events occur, instead suggesting continuous but perhaps not necessarily intensive use of the site. The most rapid accumulation of the deposit, and by extension relatively more frequent use of the site, occurred immediately after its establishment during 3133 cal BP up to 2752 cal BP (above the base of SU2). Accumulation (and occupation) slowed further during the period 2752 cal BP – 1673 cal BP (SU2 – the base of SU1). The accumulation of sediments over the last 800 years or so of site occupation then increased slightly. The site use may also have changed during the last phase of occupation, when the majority of stone artefacts were discarded. This may reflect differences in mobility, and changes in economic structure, e.g. a transition to a more broadly based and generalised subsistence strategy with less focus on marine resources (Kelly 1992; Mannino and Thomas 2002; McNiven 1999).

### Environmental context

#### *Terrestrial*

The elevation of the wave-cut embankment on which the site is situated (c10m ASL) means that the area of the site would have been above the Holocene highstand, although there is currently no evidence of early Holocene use of the area. Palaeoenvironmental reconstructions from Fraser Island indicate that from c3000 years ago there developed a relatively heterogeneous, mosaic-like vegetation perhaps due to increased climatic variability or altered seasonality resulting in more frequent exceptionally wet or dry conditions (increased ENSO activity) (Donders *et al*. 2006). During the period 2700-1770 cal BP the occurrence of *Agathis robusta* (kauri pine) gradually increased, and there was a significant expansion in rainforest species such as Araucariaceae and angiosperms. An increase in the microscopic (i.e. non-local) windblown charcoal fraction (<120 µm) was interpreted by Donders *et al.* (2006:435) as evidence of regional-scale fire events. Krull *et al*. (2004) note from the peat record at Carlo Creek that the period around 2850 ± 60 BP is one of increased rainfall, with a continuously high water table possibly associated with higher sea levels. In peat cores from the Wathumba and Moon Point fenlands on Fraser Island, Moss *et al*. (2015) observed that from 1586 cal BP onwards there were increases in *Leptospermum* and *Melaleuca*, and significant increases in grasses, *Callitris*, and mangroves. Araucariaceae disappeared from record between 893 and 648 cal BP, during the period for which there is evidence of a warm and dry El

Niño phase from 800-500ya at Myora Springs on North Stradbroke Island (Moss *et al*. 2011). However, Donders *et al*. (2006) note that Araucariaceae disappear from the Lake Allom record at c450 BP, perhaps as the result of sub-optimal conditions (although they do not specify what these may be). From these reconstructions it is inferred that at the time of its establishment, the people at BSM had access to not only a rich marine resource base, but also diverse and productive terrestrial resources. With some variations, these circumstances obtained throughout the period of mound accumulation.

*Marine*

Fisheries Research Consultants (1994) noted changes in the location, density and composition of seagrass meadows between surveys conducted by Dredge *et al*. in 1977 and their survey in late 1993, and local fishermen advised that the meadows were always in a state of flux. Long term monitoring of the seagrass in the GSS (Campbell and McKenzie 2004; McKenzie and Campbell 2003; McKenzie *et al*. 2014) confirms these observations. For example, the February 1999 Mary River flood significantly increased the sediment load and turbidity in the GSS, reduced light levels and lowered salinity; monitoring in April 1999 revealed that 90% of all intertidal seagrass meadows in the GSS had disappeared. Recovery of the seagrass beds took three years, but the locations of some beds had changed as had the component species (Campbell and McKenzie 2004). FRC (1994) found a high correspondence between molluscan species diversity and abundance, and the presence of seagrass beds. *A. trapezia* were observed to occur more commonly in bare substrates or beds of *Cymodocea serrulata* than in beds of the dominant *Zostera capricorni*, the density of which may prevent spatfall larvae from penetrating the sediments and settling. Detrital-feeding whelks and carnivorous gastropods were present in all seagrass beds (FRC1994:27). FRC (1994) found that mangrove communities were often also in flux.

### Molluscan remains

These reflect a foraging preference for the rocky substrates close to BSM over most of the period of occupation. Statistically significant differences in the heights of the dominant molluscan taxa, *Saccostrea* spp. and *T. hirsuta*, were demonstrated, as were differences in *Saccostrea* spp. valve depth. There are significant differences in the relative abundance of *N. balteata*, while the estuarine ‘staples’ of *P. ebeninus* and *A. trapezia* are in relatively low abundance. The question is, do the data fit a scenario of over-exploitation and resource depression, or are other factors also at play?

*Saccostrea spp.*

The significant reduction in *Saccostrea* spp. valve heights is in SU2, with the lowest values of minima, maxima, and means. MNI values for both Squares A (=1415) and B (=1329) are lower in SU2, although not significantly, as is the Square B NISP (=27999). Accumulation rates in SU2 are variable, but overall rather slower than for the underlying SU3. Diminished productivity may have contributed to less intensive site use, reflected in the deposition rates, as people moved elsewhere to find their food. However, such relocation is not reflected across the other key species. Chamids, which often live attached to oyster clumps and which are considered here to be oyster by-catch, demonstrated no significant differences in NISP across the three SUs, suggesting continued exploitation of the oyster beds. There is no associated change in levels of mussel exploitation. The NISP of *P. ebeninus* increased in SU2, but this cannot be considered evidence of the increase in a less preferred, less easily procured (even given the whelk's top speed of 1.25cm/minute [Vohra 1965]) or less easily processed species at a time of depressed oyster numbers. The differences in valve height may reflect continued harvesting of a relatively depleted resource, albeit at lower levels than was previously the case. The return to larger *Saccostrea* valve heights in SU1 may be evidence of recovery of the population (but see below). It is a moot point whether the environmental changes noted by Donders *et al*. (2006) and Krull *et al*. (2004) for roughly the same time period as the perceived depression affected the *Saccostrea* population in the GSS.

The differences in valve depths across all SUs are interesting, as only the valves in SU3 exhibited different morphological characteristics from those in the upper units. The SU3 valves were more fluted, indicating increased resistance to disturbance by currents; the GSS has tidal currents with $180^{o}$ reversal at ebb and flood tides, and speeds that can exceed 0.8m $s^{-1}$ (FRC 1994:1). The valves exhibited some evidence of increased clustering in SU2 and SU1, although there is little indication of tightly-packed reefs, and all SUs contained valves with flat bases. The valve depths may indicate retention of characteristics for resistance to tidal influences.

Excavated samples from the Booral Homestead Midden returned median $^{14}C$ age determinations of 2353 cal BP and 2356 cal BP (Ulm and Reid 2000:16) at the top and bottom of a layer 50cm deep, suggesting a rapid and intensive depositional event coincidental with the slower accumulation identified in the upper layers of BSM SU2 (Frankland 1990; McNiven 1994). The dominant midden constituent was oyster shell, as at BSM. This suggests some differential use of the site complex, but no further conclusions can be drawn on the material available.

*T. hirsuta*

Mussel heights in SU1 are statistically significantly different from those in SU2 and SU3 and *may* be evidence of some resource depression after 'carrying the load' for the oysters in SU2, although the differences are at a small scale. The levels of exploitation exhibit little variation across the SUs. The maximum valve heights across all SUs suggest a mature population, while the mean heights indicate a preference for harvesting smaller individuals. An important consideration is the relationship between rejection size during gathering, and size at sexual maturity, as if the latter is smaller than the former then the population will always contain reproducing individuals (Catterall and Poiner 1987:120). Whitaker (2008) discusses the impact of two different foraging strategies, plucking and stripping, on populations of the mussel *Mytilus californianus* and this discussion can to some extent be extrapolated to all clustered bivalves. In stripping, the forager collects all shellfish regardless of size from sections of a mussel bed; this technique is aided by the tendency of mussels to cluster together on intertidal rocks. The area stripped would then be left to fallow for varying lengths of time to allow the population to recover. In plucking, a more selective strategy is applied and the forager theoretically takes only larger individuals from the beds. However due to the clustered nature of mussel beds where large individuals crowd out smaller individuals, those smaller individuals often attach to other mussels rather than the rocky substrate and become by-catch (Whitaker 2008:1116, 1117, 1120). Whitaker suggests that with regular collection the risk of losing large mussels to catastrophe or other predators is reduced, and that for long term productivity of a mussel bed, small shells are preferable. He also cites the Yamada and Peters study (1988) of mussel beds which indicates that frequent harvesting increases the overall productivity and health of mussel populations (Whitaker 2008:1120). Whitaker concludes that reduced shell size is not necessarily evidence of declining foraging returns if long term productivity rather than immediate returns is the focus, while acknowledging that these are almost mutually exclusive for foragers. Whitaker's study (2008:1121) highlights that knowledge of prey-specific characteristics is necessary to understand human predator-prey relationships and the population structure of their prey (see also Faulkner 2013).

Thakar *et al*. (2015) explored the effects of tidal regimes on both gathering practices and the overall size of *Mytilus californianus* valves at Santa Cruz Island in the Californian Northern Channel Islands. The island has a similar tidal regime to the GSS (i.e. semi-diurnal) in which two unequal high tides alternate with two unequal low tides each lunar day (Thakar *et al*. 2015:6). For the GSS this is 0.6m at high tide and 0.2m at low tide. There is a spring-neap tide cycle about every 15 days; spring and neap tide ranges are 2.8m and 1.2m respectively, although spring tides of 3m occasionally occur (FRC 1994:1; Meehan [1982] noted that modern mussel-gathering practices in northern Arnhem Land were tidally-influenced). Mussels growing high in the intertidal zone may grow more slowly than those lower in the intertidal zone or in the subtidal zone due to the relatively greater aerial exposure and potential expenditure of energy in stress responses. Smaller mussels tend to occur in the upper intertidal zones, with sizes increasing in the lower intertidal zones. Thakar *et al*. (2015:6) demonstrated quantitatively that this resulted in zonation based on size not necessarily related to ontogenetic age. Daily exploitation of clustered bivalves (including oysters) in areas dominated by semi-diurnal tidal regimes will lead to a greater representation of individuals from the higher intertidal zone (i.e. smaller individuals), potentially mimicking anthropogenic effects such as over-exploitation and resource depression.

*P. ebeninus and A. trapezia*

The NISP of *P. ebeninus* increased in SU2, and the occurrence of *A. trapezia* increased in SU1. It is contended here that both are reflections of local environmental or micro-habitat changes, particularly the availability of appropriate seagrass beds.

*N. balteata*

*N. balteata* is present in relatively low numbers throughout SU3 and most of SU2. There is a marked increase from the uppermost sampled excavation unit, 9, of SU2 (NISP=126), peaking in the upper three sampled excavation units of SU1 (XU1 NISP = 818, MNI=25; XU2 NISP=1198, MNI=47; XU4 NISP=796, MNI=43).

There are a number of scenarios that may explain the variability in *N. balteata* numbers. Firstly, that the lower numbers recorded for SU2 and SU3 reflect the actual distribution/ density of the shellfish in the proximity of BSM, which implies that the preferred habitat of *N. balteata* (i.e. mangrove forests in the intertidal area), was locally restricted or patchy in nature. As such, any shellfish collected in these localities may have been consumed on site and not returned to the area around BSM for processing and consumption (e.g. Meehan 1988). Secondly, *N. balteata* was not a preferred prey species, and that its increased presence is a reflection of resource depression and over-exploitation of preferred prey species. However, as outlined above, there is no clear evidence for resource depression or over-exploitation of either of the dominant prey species, *Saccostrea* and *T. hirsuta*. Although motile, *N. balteata* cannot be considered fast-moving and procurement would be fairly easy as would be processing (see Meehan 1982:109 for an ethnographic example). Also, the peak in *N. balteata* does not correspond with the perceived depression of oysters in SU2. Thirdly, cultural preferences may have changed over the period of the occupation of the mound, and what was once a food largely ignored or consumed only by some, became a more preferred food item. Finally, that the increased numbers of *N. balteata* reflect a genuine, local environmental shift characterised by a greater proliferation of mangrove forest within the foraging range of the site over the period from around 1673 cal BP (see Moss *et al*. 2015) until the abandonment around 806 cal BP. This is the explanation favoured here.

### Stone artefacts

The artefact assemblage has the hallmarks of a technology used in low-risk environments (Hiscock 1994; see also Smith 2003), suggesting that the resource base serving BSM was reliable and assured. The backed artefact dating to 2752 cal BP is evidence of exploitation of terrestrial resources in an otherwise potentially marine–dominated economy. Interestingly, there is no artefactual evidence for plant processing, although these activities may have taken place away from the site itself.

A similar suite of raw materials is present throughout the BSM, suggesting that the sources exploited remained accessible through the sequence, with the only exception being the occurrence of quartz only in SU1. The assemblage is dominated by the mudstone available immediately adjacent to the site and at other locations between River Heads and Urangan, as well as on Big Woody Island. The latter may also be the closest source of chert (Lauer 1979:68; McNiven 1998:13). Silcrete occurs in low numbers throughout the sequence, but its occurrence increases in SU1, accounting for over half (n=12, 52.17%) of its representation in the site; six of the silcrete artefacts come from the XU dated to 806 cal BP. This increase post 1673 cal BP has implications for the fissioning model for the GSR proposed by McNiven (1999), which was partially based on the absence or reduction in the occurrence of exotic inland silcrete (most probably sourced from Wolvi Mountain and Mt Condoo approximately 40km to the southwest) in the estuarine and coastal sites in the period between 3000-2000 years ago. These implications are discussed further in the regional synthesis in the final chapter.

The increase in silcrete occurrence, and the inclusion of quartz, reflects a pattern of increased artefact discard in SU1 (n=365, 65.76% of the total), and to a lesser extent in SU2 (n=106, 19.09% of the total) (Table 5-15). These observations are not the result of the Square B sampling strategy, as the same trends are apparent in Square A, where the majority (n=459, 70.18%) of artefacts occur in SU1 (XUs 1-7), with a further 136 (20.79%) of the artefacts occurring in SU2 (XUs 8-16). The increased artefact discard suggests a change in site use, which may be associated with a change in vegetation patterning around the same time as suggested by the increased occurrence of land snails, the observations of Donders *et al*. (2006:435) regarding increased regional fire-regimes after 2700 cal BP, and the increase in rainforest taxa noted for Fraser Island. The environmental changes would have flow-on effects in terms of nutrient input and near-shore sedimentation etc., which may also have affected local habitat structure. Whilst there is no observable change in the discard of terrestrial fauna, there may have been a shift towards a greater inclusion of terrestrial resources in subsistence practices, although these are not evidenced elsewhere in the southeast Queensland coastal region.

## *Conclusion*

There are a number of conclusions that may be drawn from the above discussion of the molluscan and other evidence from BSM. The first is that at c.3133 cal BP, a group or groups of people pre-adapted to a coastal economy and the exploitation of marine resources, established themselves on an area of high ground adjacent to their resource base. Having established themselves, the group or groups continued to exploit the area's marine, and presumably terrestrial, resources for a period of some 2300 years before discard ceased, at least on the mound itself. During that period there were several phases of differing occupational intensity, but no evidence of large, rapid depositional events (at least for BSM). Instead, there appears to have been long-term, low-level occupation and discard, although the evidence suggests that the most intensive use of the site was in the period following its initial occupation. The levels of exploitation of the molluscan resources were not sufficient to result in definitive archaeological indicators of intensive or over-exploitation of the available resources, although resource patterning did change over time. There is evidence of a change in site use in the upper SU dating from 1673 cal BP to 806 cal BP, which may be associated with a change in vegetation patterns indicated by the increased representation of land snails and changes in the pollen record from Fraser Island. Evidence of environmental change is also reflected in the significant increase in the *Nerita balteata* discard in SU1, a circumstance not observed elsewhere in the region. The GSS is a rich marine environment, but the excavated area of BSM exhibits low taxonomic diversity in fish remains. There is no evidence of exploitation of dugong or turtle, and minimal evidence of the exploitation of terrestrial resources. The available evidence, however, suggests not only a specialised marine-based economy, but one specifically focussed on the exploitation of molluscs.

# 6. Tin Can Bay Sites

## *Introduction*

This chapter presents the results and discussion of the analysis of two Tin Can Bay inlet sites, Tin Can Bay Site 75b (TCB 75B) and Cameron Point Site 62 (CP 62). It outlines the findings of the initial analysis (McNiven 1990a), with some additional observations including measurements of richness and diversity, before turning to a more detailed presentation of the material analysed during the present study.

## *Tin Can Bay*

The Tin Can Bay inlet forms the southern part of the Great Sandy Strait, and has a 60km eastern coastline from Carland Creek in the south to the western tip of Inskip Point in the north (Figure 6.1). This eastern margin is bounded by low coastal sand plains, the formation of which was influenced by water draining from the sandmass behind Teewah Beach and marine processes within the inlet. Degraded old dune margins and remnant stream fans form low sandy banks in the southern and inland sections of the plains. Peaty swamps and fens occur in the low central section of the sand plain (<1m), fed by groundwater seepage from the coastal dunes to the east. The elevation of the coastal fringe of the bay, <1km inland, is generally below 5m asl and is composed of Pleistocene and Holocene aeolian deposits. Aeolian deposits also form sporadic slightly higher sand sheets and low sandy banks, and sandy and muddy sediments are trapped by mangrove stands in the intertidal zone (Dredge *et al*. 1977; McNiven 1990a:184, 1991c:85; Thompson and Moore 1984:14; see also Krull *et al*. 2004).

The coastal fringe vegetation is influenced by local drainage regimes, varying from tall open forests on areas of higher elevation to swamp communities in the lower elevations. McNiven (1991c:85-86) describes four vegetation zones: forest red gum (*Eucalyptus tereticornis*) and cypress (*Callitris columellaris*) forest complexes, and casuarina (*Casuarina littoralis*) and Queensland brush box (*Lophostemon confertus*, syn. *Tristania conferta*) forests; wallum banksia (*Banksia aemula*) woodland and scribbly gum (*Eucalyptus signata*) woodland; heathland (*Banksia* spp.) ranging to paperbark (*Melaleuca quinquenervia*) swamps, mixed paperbark woodland, and paperbark and forest red gum woodland; and large mangrove forests (e.g. orange mangrove, *Bruguiera gymnorrhiza;* grey mangrove, *Avicennia marina;* and spotted mangrove, *Rhizophora stylosa*) in the intertidal zones of most of the bay. Major plant food sources include bungwall or swamp fern (*Blechnum indicum*), cabbage-tree palm (*Livistonia decipiens*), bracken fern (*Pteridium esculentum*), and orange mangrove (McNiven 1991c:87).

The rich marine resources available within Tin Can Bay include 39 species of fish of modern commercial or recreational importance (Queensland Department of Environment and Heritage, n.d:8), with bream (*Acanthopragus* spp.), whiting (*Sillago* spp.), and flathead (*Platycephalus* spp.) constituting major elements of the shallow water fishery. The sand banks, mud flats, seagrass and mangrove communities, support a wide variety of molluscan species such as oyster (*Saccostrea* spp.), Hercules Club whelk (*Pyrazus ebeninus*), cockle (*Anadara trapezia*), and nerites (*Nerita* spp.), crustaceans such as mud crab (*Scylla serrata*) and sand crab (*Portunus pelagicus*), and a nursery environment for juvenile prawns. By comparison, terrestrial fauna are far less numerous in terms of both species diversity and abundance. Barry and Campbell (1979:173) remarked on the "high diversity" of mammals and amphibians on the Cooloola Peninsula, but other sources (Dwyer, Hockings and Willmer 1979, Dwyer, Kikkawa and Ingram 1979 cited in McNiven 1991c:86) suggest that the potential terrestrial mammal resource base in the coastal and strand plains is poor. Although Barry and Campbell (1979) recorded a number of amphibian species for the Cooloola peninsula, reptile records for the general area are poor to non-existent.

Seventy-one sites were recorded on the eastern side of Tin Can Bay during the initial Cooloola Regional Archaeological Project (CRAP) surveys (McNiven 1984:85, 1985:14, 1990a:188, 1991c:87), including shell middens, artefact scatters, and a scarred tree. There was a strong positive bias (91.3% of sites) for midden location in forest red gum and cypress forest, *Casuarina* and Queensland brush box forest, and scribbly gum woodland (McNiven 1985:15, 1991c:87, 101; see also Smith 1992; Stockton 1974). The majority of the sites (n=56) were located in the southern portion of the inlet (Figure 6-1) and this was where McNiven (1990a:191, 1991c:90) excavated two sites, Tin Can Bay 75b and Cameron Point Site 62, to determine their content and chronology.

### Tin Can Bay Site 75b

Tin Can Bay Site 75b is the more southerly of the two sites, part of a large complex of middens along a 'small baylet' (McNiven 1990a:191, 1991c:90) adjacent to extensive tidal mudflats. The site area is not reported as visibility in the survey area was limited (McNiven 1991c:88), but the midden was exposed intermittently over at least 10m within a mixed *Melaleuca*, *Eucalyptus*, *Banksia* and Cypress forest on the top of a 1-1.2m erosional face approximately 20m from a freshwater spring (McNiven 1990a:191-192, 1991c:90). Two contiguous 50cm x 50cm excavation squares, A and B, were placed in an area of relatively densely concentrated surface shellfish remains; each consisted of 21 XUs to depths of 92cm and 89cm respectively (McNiven 1990a:192,403-404; 1991c:90). The excavated volume for Square A was 0.23m$^3$, and 0.22m$^3$ for Square B.

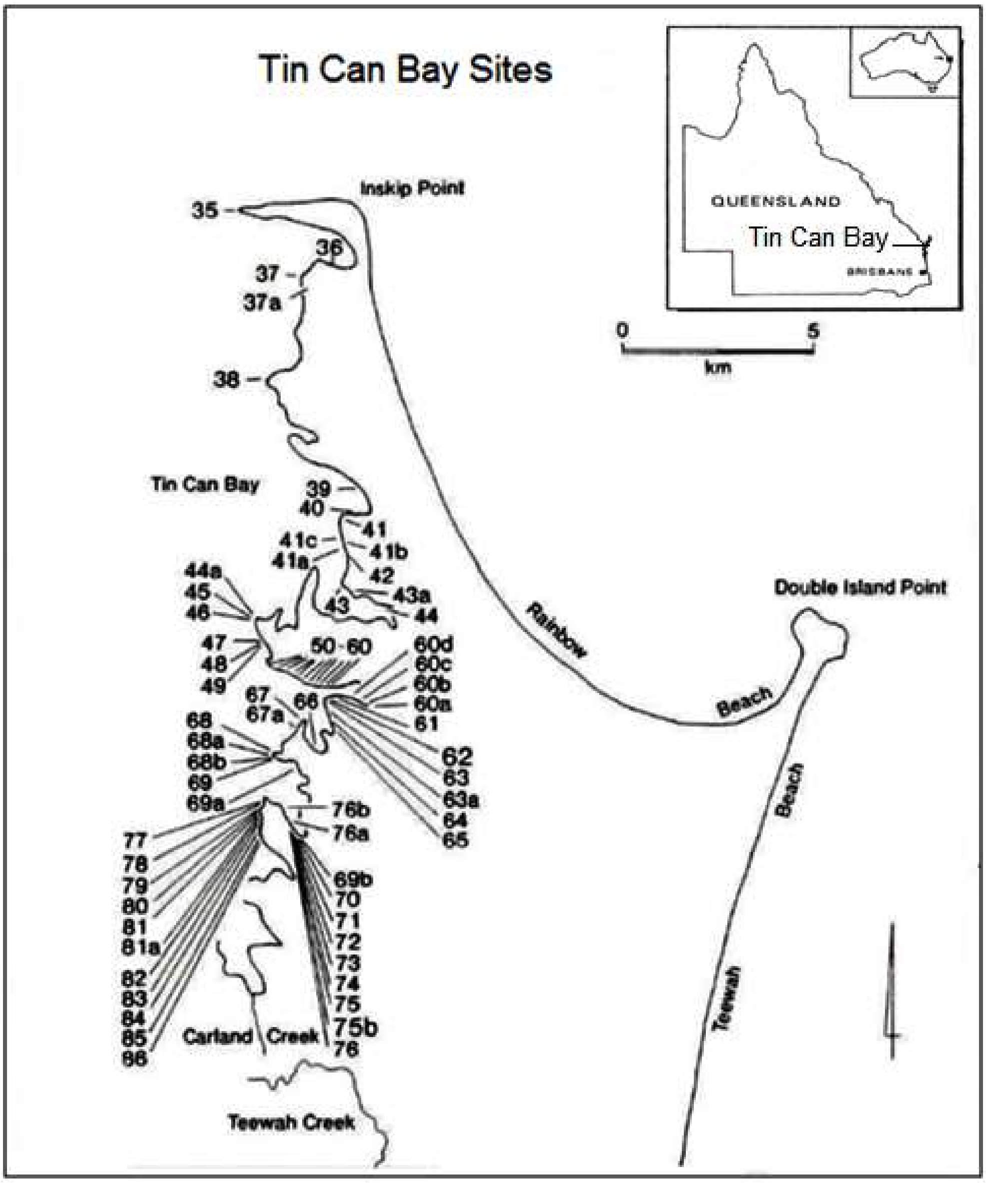

Figure 6-1  Location of sites on the eastern periphery of Tin Can Bay (after McNiven 1991c).

The excavation employed the Johnson (1979, 1980) bucket method, with sediments wet sieved through 3mm mesh. Two major stratigraphic units, SU1 and SU2, were identified. SU1 was further divided into units 1a and 1b: SU1a consisted of relatively loose dark grey sandy sediment that was slightly acidic (pH value 4.5), while SU1b consisted of light brownish grey sandy sediment of a more neutral pH value (7.5) and contained a concentration of shell, as well as the majority of the other cultural material recovered. SU1 varied in thickness from c.9cm to c.23cm across the excavation squares, with the greatest volume of SU1b appearing to have been deposited in a shallow depression in the underlying SU2 (Figure 6-2). SU2, loose sand grading from light grey to white and very light grey with variable pH values of 8.0 in the upper levels to 6.5 at the base, contained a small number of shell fragments and stone artefacts associated with intrusive large tree roots (McNiven 1990a:192-194, 1991c:90).

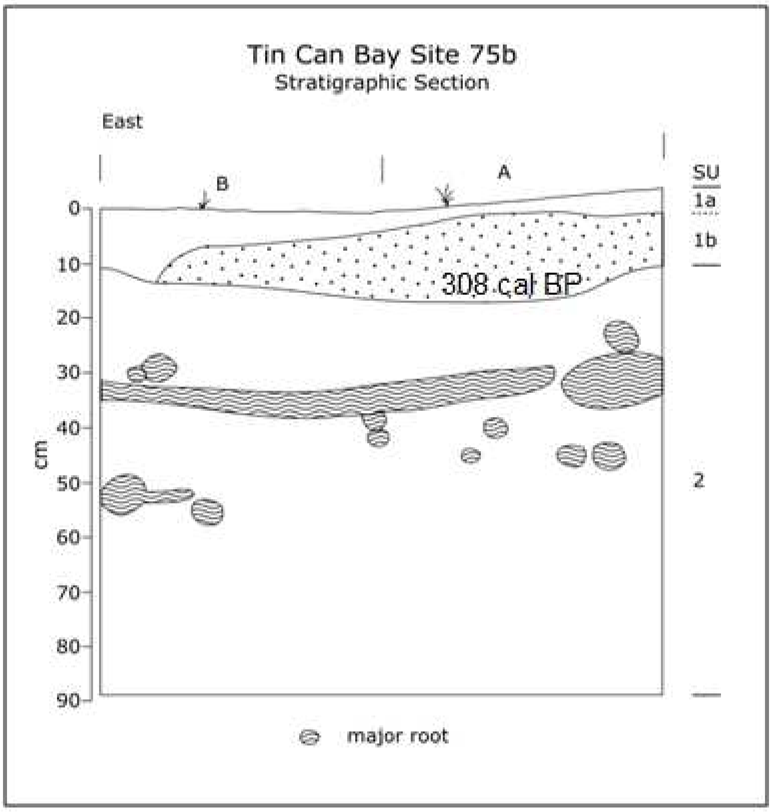

**Figure 6-2 Stratigraphic profile of TCB 75b Squares A and B. Stippling indicates main midden deposit (after McNiven 1991c:91).**

Due to time restrictions, only the faunal material (molluscan and vertebrate remains) from Square A was fully analysed, although stone artefacts from both squares were sorted and classified. The data presented for the molluscan remains consist of MNI only for each species, and total shell weights per XU. McNiven (1990a, 1991) does not provide a rationale or methodological basis for such an approach, however variations on it were commonly employed in the region during the 1980s (see e.g. Alfredson 1984; Hall 1984; Nolan 1986; Walters *et al*. 1987), and it was sufficient to address his research aims. Radiocarbon dating of the site was based on a mixed sample of oyster (*Saccostrea*) and Hercules Club whelk (*Pyrazus ebeninus*) from a depth of 18-21cm in Square A XU7 at the base of SU1b. McNiven (1990a:194, 1991c:90, 92) reported a conventional age of 700±70 BP, with a calibrated age (corrected for marine reservoir effect) of modern, i.e. 19th century. Ulm and Reid (2000:33) revised the calibration (Table 6-1). The median calibrated age of 308 years BP is the age determination used in the present discussion.

**Table 6-1 Radiocarbon age determination for TCB 75b (after McNiven 1990a; 1991c; Ulm and Reid 2000:33).**

| SU | XU | Depth cm | Sample | Laboratory code | Conventional 14 C date | 2σ calibrated age range |
|---|---|---|---|---|---|---|
| 1b | 7 | 9.5 | Marine shell | Beta-19421 | 700±70 BP | 471(308)233 |

## *Molluscs*

### Square A

A total of 6656.2g comprising 14 taxonomic categories of molluscs with an MNI of 909 was recovered from Square A, which contained the bulk of the midden material recovered (Table 6-2). The shell was most numerous in the upper eight XUs, after which numbers declined significantly with only a few specimens identified and quantified by MNI below that level, although shell weights are recorded for all but one XU (Table 6-3). McNiven (1990a:196-197, 1991c:92) noted that all the taxa with the exception of the *Donax deltoides* (pipi), could be obtained from the intertidal zone adjacent to the site. The pipi could have been obtained from Rainbow Beach or Teewah Beach, a distance from the site of 9km and 13km respectively. He also noted vertical changes in the distribution of the mollusc species: while *Saccostrea* spp. (oyster) and *Pyrazus ebeninus* (Hercules Club whelk) occurred throughout most of the midden, *Isognomon* spp. (toothed or tree oysters) occurred only in the top four XUs, and sand snails occurred only in XUs 4 to 7, but could not speculate whether the difference in shell discard related to temporal variations in resource availability and/or selection criteria. Possible reasons for the variations are discussed below.

**Table 6-2 Molluscan taxa and MNI by XU for Square A, TCB 75b (after after McNiven 1990a:197, 1991c:93).**

| **Taxon** | **XU 1** | **XU 2** | **XU 3** | **XU 4** | **XU 5** | **XU 6** | **XU 7** | **XU 8** | **XU 9** | **XU 11** | **XU 12** | **XU 17** | **Total MNI** | **% MNI** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Anadara trapezia* | 0 | 0 | 0 | 5 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 1.43% |
| *Bedeva paivae* | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.22% |
| *Bembicium nanum* | 0 | 1 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0.66% |
| *Cerithidea largillierti* | 0 | 0 | 2 | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 1.54% |
| *Conuber sordidum*[1] | 0 | 0 | 0 | 3 | 27 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 36 | 3.96% |
| *Ergalatax contracta*[2] | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.11% |
| *Donax deltoides* | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0.44% |
| *Isognomon* sp.[3] | 3 | 21 | 38 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 67 | 7.37% |
| Mactridae | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.11% |
| *Nerita balteata*[4] | 0 | 0 | 0 | 0 | 2 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 1.54% |
| *Patelloida mimula* | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 6 | 0.66% |
| *Pyrazus ebeninus* | 0 | 0 | 16 | 40 | 35 | 29 | 12 | 1 | 1 | 1 | 1 | 1 | 137 | 15.07% |
| *Saccostrea* spp.[5] | 4 | 41 | 90 | 249 | 168 | 38 | 11 | 3 | 0 | 0 | 0 | 0 | 604 | 66.45% |
| *Trichomya hirsuta* | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0.44% |
| **Total** | | | | | | | | | | | | | **909** | **100.00%** |

[1]syn. *Polinices sordidus* [2] Formerly *Cronia contracta* [3]*Ephippium ephippium* in original text [4] Formerly *Nerita lineata*
[5]*Saccostrea commercialis* in original text

**Table 6-3 TCB 75b Square A data recordings (McNiven 1990a:403 Table A.25, 1991c:104).**

| SU | XU | Mean depth cm | XU wt kg | Charcoal wt g | Shell wt g | Artefact wt g | pH |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 5.5 | 19.34 | 21.4 | 0.05 | 4.5 |
| 1 | 2 | 5 | 7.7 | 12.52 | 344.9 | 0.2 | - |
| 1 | 3 | 8 | 11.1 | 11 | 1679.9 | 0.33 | 5.0 |
| 1 | 4 | 12 | 12.7 | 31.11 | 2361.5 | 0.1 | - |
| 1 | 5 | 16 | 12.7 | 17.9 | 1568.5 | 131.36 | 7.0 |
| 1 | 6 | 18 | 9.1 | 8.17 | 491.6 | 0.89 | - |
| 1 | 7 | 21 | 8.9 | 6.61 | 151 | 0.09 | 7.5 |
| 2 | 8 | 23 | 8.6 | 3.77 | 28.9 | 0.14 | - |
| 2 | 9 | 28 | 10.5 | 4.25 | 3.9 | 4.05 | 7.0 |
| 2 | 10 | 31 | 9.6 | 3.4 | 1.2 | 1.1 | - |
| 2 | 11 | 34 | 9 | 1.59 | 0.4 | 0.34 | 8.0 |
| 2 | 12 | 37 | 10.5 | 1.2 | 0.3 | 0.07 | - |
| 2 | 13 | 40 | 9.9 | 2.15 | 0.6 | 0.19 | 7.5 |
| 2 | 14 | 42 | 7.9 | 0.79 | 0.1 | 0.08 | - |
| 2 | 15 | 47 | 16.7 | 0.5 | 0.8 | 0.19 | 7.0 |
| 2 | 16 | 52 | 19.2 | 0.29 | 0.1 | 0.19 | - |
| 2 | 17 | 58 | 20.6 | 0.39 | 0.8 | 0.19 | 7.5 |
| 2 | 18 | 62 | 18.6 | 0.14 | 0.1 | 0.05 | - |
| 2 | 19 | 71 | 32.2 | 0.03 | 0.1 | 0.33 | 7.0 |
| 2 | 20 | 81 | 37.5 | 0.06 | 0 | 0.41 | - |
| 2 | 21 | 92 | 41.2 | 0.08 | 0.1 | 0.68 | 6.5 |
|  | **Totals** |  | **319.7** | **125.29** | **6656.2** | **141.03** |  |

## Square B

The present study employed an analysis of the previously unsorted (other than the stone artefact component) contents of Square B. The molluscan assemblage from this square was on the eastern periphery of the major midden deposit and exhibited only slight differences in composition compared to Square A. Unlike Square A, shell in Square B was recorded only for the upper seven units (Table 6-4). Species recorded for Square A but absent from Square B were *Bedeva paivae* (oyster drill), *Patelloida mimula* (limpet), *Ergalatax contracta* (murex), and *Cerithidea largillierti* (mud whelk). Likewise, two taxa recorded for Square B were absent from Square A, ceriths (creepers, *Cerithium* spp.) and false or yellow striped mussel (*Fluviolanatus subtorta*). The conservative approach to identifying specimens to genus and species level described in Chapter 4 was also applied to the Square B assemblage: for the *Isognomon* spp. and *Cerithium* spp. insufficient landmarks were preserved to confidently identify them beyond genera. The total NISP for molluscs from Square B was 4386 (Table 6-5). At 348 the total MNI for Square B was fewer than that recorded for Square A, reflecting the less dense concentration of midden deposit in the square (Tables 6-6 and 6-8, Figure 6-2). Estimates of MNI based on volume are 3952 per m$^3$ for Square A, and 1513 per m$^3$ for Square B (Table 6-9). Shell weights are similarly lower than those recorded for Square A (Table 6-4, Table 6-7), with a total shell weight of 2779.28g. While the data from Square B is initially presented here by XU to provide a comparison with those previously published, the subsequent discussion is framed within the context of SU1b as a whole, rather than arbitrary excavation units within it.

**Table 6-4 TCB 75b Square B data recordings (based on McNiven 1990a:404).**

| XU | Mean depth cm | XU wt kg | Charcoal wt g* | Bone wt g* | Shell wt g* | Artefact wt g |
|---|---|---|---|---|---|---|
| 1 | 2 | 6.0 | 0 | 0 | 6.73 | 0.00 |
| 2 | 4 | 7.5 | 0 | 0 | 48.79 | 0.00 |
| 3 | 8 | 10.5 | 9.33 | 0.09 | 926.34 | 0.00 |
| 4 | 10 | 10.3 | 13.7 | 0.24 | 579.95 | 1.64 |
| 5 | 15 | 13.3 | 16.11 | 0 | 831.73 | 4.74 |
| 6 | 17 | 9.7 | 10.29 | 0.01 | 316.59 | 0.12 |
| 7 | 20 | 9.6 | 6.33 | 0 | 69.15 | 0.04 |
| 8 | 23 | 9.5 | 4.92 | 0 | 0 | 0.27 |
| 9 | 25 | 8.8 | 5.45 | 0 | 0 | 1.02 |
| 10 | 28 | 8.9 | 0 | 0 | 0 | 0.06 |
| 11 | 31 | 9.3 | 0 | 0 | 0 | 0.12 |
| 12 | 33 | 8.5 | 0 | 0 | 0 | 0.00 |
| 13 | 37 | 9.5 | 0 | 0 | 0 | 0.00 |
| 14 | 39 | 8.8 | 0 | 0 | 0 | 0.03 |
| 15 | 45 | 19.7 | 0 | 0 | 0 | 0.26 |
| 16 | 50 | 18 | 0 | 0 | 0 | 0.16 |
| 17 | 56 | 17.4 | 0 | 0 | 0 | 0.03 |
| 18 | 60 | 21.7 | 0 | 0 | 0 | 0.15 |
| 19 | 69 | 28.4 | 0 | 0 | 0 | 0.11 |
| 20 | 78 | 37.1 | 0 | 0 | 0 | 0.33 |
| 21 | 89 | 38.1 | 0 | 0 | 0 | 1.01 |
| **Total** | | **310.6** | **66.13** | **0.34** | **2779.28** | **10.09** |

*Absent from the original data recordings and recorded during the present study.

**Table 6-5 TCB 75b Square B molluscan taxa NISP by XU.**

| **Taxon** | **XU1** | **XU2** | **XU3** | **XU4** | **XU5** | **XU6** | **XU7** | **Total NISP** | **%NISP** |
|---|---|---|---|---|---|---|---|---|---|
| *Anadara trapezia* | 1 | 0 | 0 | 13 | 19 | 0 | 0 | 33 | 0.76% |
| *Bembicium* sp. | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 4 | 0.09% |
| *Cerithium* sp. | 0 | 0 | 6 | 0 | 0 | 1 | 0 | 7 | 0.16% |
| *Conuber sordidum* | 0 | 0 | 0 | 1 | 22 | 5 | 1 | 29 | 0.66% |
| *Donax deltoides* | 1 | 9 | 0 | 0 | 0 | 0 | 0 | 10 | 0.23% |
| *Fluviolanatus subtorta* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.02% |
| *Isognomon* spp. | 0 | 215 | 854 | 60 | 0 | 0 | 0 | 1129 | 25.84% |
| *Nerita balteata* | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 4 | 0.09% |
| *Pyrazus ebeninus* | 0 | 0 | 20 | 60 | 196 | 101 | 33 | 410 | 9.38% |
| *Saccostrea* spp. | 17 | 4 | 529 | 1297 | 557 | 204 | 91 | 2699 | 61.78% |
| *Trichomya hirsuta* | 0 | 1 | 37 | 0 | 5 | 0 | 0 | 43 | 0.98% |
| **Total** | | | | | | | | **4369** | **100.00%** |

**Table 6-6 TCB 75b Square B molluscan taxa MNI by XU.**

| **Taxon** | **XU1** | **XU2** | **XU3** | **XU4** | **XU5** | **XU6** | **XU7** | **Total MNI** | **%MNI** |
|---|---|---|---|---|---|---|---|---|---|
| *Anadara trapezia* | 1 | 0 | 0 | 3 | 7 | 0 | 0 | 11 | 3.16% |
| *Bembicium auratum* | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 4 | 1.15% |
| *Cerithium sp.* | 0 | 0 | 6 | 0 | 0 | 1 | 0 | 7 | 2.01% |
| *Conuber sordidum* | 0 | 0 | 0 | 1 | 10 | 4 | 1 | 16 | 4.60% |
| *Donax deltoides* | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0.57% |
| *Fluviolanatus subtorta* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.29% |
| *Isognomon* spp. | 0 | 4 | 29 | 2 | 0 | 0 | 0 | 35 | 10.06% |
| *Nerita balteata* | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 4 | 1.15% |
| *Pyrazus ebeninus* | 0 | 0 | 8 | 15 | 32 | 38 | 9 | 102 | 29.31% |
| *Saccostrea* spp. | 3 | 1 | 55 | 57 | 35 | 7 | 1 | 159 | 45.69% |
| *Trichomya hirsuta* | 0 | 1 | 4 | 0 | 2 | 0 | 0 | 7 | 2.01% |
| **Total** | | | | | | | | **348** | **100.00%** |

**Table 6-7 TCB 75b Square B shellfish species weight in grams by XU.**

| **Taxon** | **XU1** | **XU2** | **XU3** | **XU4** | **XU5** | **XU6** | **XU7** | **Total wt** | **%wt** |
|---|---|---|---|---|---|---|---|---|---|
| *Anadara trapezia* | 0.43 | 14.11 | 72.7 | 0 | 0 | 0 | 0 | 87.24 | 3.14% |
| *Bembicium auratum* | 0 | 0 | 0.55 | 0.19 | 0 | 0 | 0 | 0.74 | 0.03% |
| *Cerithium* sp. | 0 | 0 | 13.01 | 0 | 0 | 2.62 | 0 | 15.63 | 0.56% |
| *Conuber sordidum* | 0 | 0 | 0 | 1.5 | 35.07 | 0 | 0 | 36.57 | 1.32% |
| *Donax deltoides* | 1.33 | 2.79 | 0 | 0 | 0 | 0 | 0 | 4.12 | 0.15% |
| *Fluviolanatus subtorta* | 0.09 | 0 | 0 | 0 | 0 | 0 | 0 | 0.09 | 0.00% |
| *Isognomon* spp. | 0 | 26.86 | 427.66 | 43.84 | 0 | 0 | 0 | 498.36 | 17.93% |
| *Nerita balteata* | 0 | 0 | 0.33 | 0.34 | 0 | 0 | 0 | 0.67 | 0.02% |
| *Pyrazus ebeninus* | 0 | 0 | 26.06 | 106.23 | 473.68 | 229.78 | 47.29 | 883.04 | 31.77% |
| *Saccostrea* spp. | 4.45 | 4.43 | 384.51 | 426.87 | 302.63 | 73.81 | 18.28 | 1214.98 | 43.72% |
| *Trichomya hirsuta* | 0 | 0.6 | 1.52 | 0.07 | 0 | 0 | 0 | 2.19 | 0.08% |
| Indeterminate | 0.43 | 0 | 0 | 0.91 | 20.35 | 10.38 | 3.58 | 35.65 | 1.28% |
| **Total** | **6.73** | **48.79** | **926.34** | **579.95** | **831.73** | **313.97** | **69.15** | **2779.28** | **100.00%** |

**Table 6-8 TCB 75b combined MNI from Square A and Square B.**

| **Taxon** | **Square A** | **Square B** | **Total MNI** | **% MNI** |
|---|---|---|---|---|
| *Anadara trapezia* | 13 | 11 | 24 | 1.91% |
| *Bedeva paivae* | 2 | 0 | 2 | 0.16% |
| *Bembicium* spp. | 6 | 4 | 10 | 0.80% |
| Ceriths | 14 | 7 | 21 | 1.59% |
| *Conuber sordidum* | 36 | 16 | 52 | 4.14% |
| *Ergalatax contracta* | 1 | 0 | 1 | 0.08% |
| *Donax deltoides* | 4 | 2 | 6 | 0.48% |
| *Fluviolanatus subtorta* | 0 | 1 | 1 | 0.08% |
| *Isognomon* spp. | 67 | 35 | 102 | 8.12% |
| Mactridae | 1 | 0 | 1 | 0.08% |
| *Nerita balteata* | 14 | 4 | 18 | 1.43% |
| *Patelloida mimula* | 6 | 0 | 6 | 0.48% |
| *Pyrazus ebeninus* | 137 | 102 | 239 | 19.03% |
| *Saccostrea* spp. | 604 | 159 | 763 | 60.75% |
| *Trichomya hirsuta* | 4 | 7 | 11 | 0.88% |
| **Total** | **909** | **348** | **1257** | **100.00%** |

**Table 6-9 Volume-corrected MNI estimates for all shell, and individual dominant species, for TCB 75b Squares A and B.**

| **Square A** | | **SU1 m$^3$** | **SU2 m$^3$** | **Total** | **Square B** | | **SU1 m$^3$** | **SU2m$^3$** | **Total** |
|---|---|---|---|---|---|---|---|---|---|
| | | 0.053 | 0.178 | 0.23 | | | 0.053 | 0.178 | 0.23 |
| All shell | MNI | 909 | 0 | 909 | All shell | MNI | 348 | 0 | 348 |
| | MNI/m3 | 17314 | 0 | 3952 | | MNI/m3 | 0 | 0 | 1513 |
| *Anadara trapezia* | MNI | 13 | 0 | 13 | *Anadara trapezia* | MNI | 11 | 0 | 11 |
| | MNI/m3 | 248 | 0 | 57 | | MNI/m3 | 210 | 0 | 48 |
| *Conuber sordidum* | MNI | 36 | 0 | 36 | *Conuber sordidum* | MNI | 16 | 0 | 16 |
| | MNI/m3 | 686 | 0 | 343 | | MNI/m3 | 305 | 0 | 70 |
| *Isognomon* spp. | MNI | 67 | 0 | 67 | *Isognomon* spp. | MNI | 35 | 0 | 35 |
| | MNI/m3 | 1276 | 0 | 291 | | MNI/m3 | 667 | 0 | 152 |
| *Pyrazus ebeninus* | MNI | 132 | 5 | 137 | *Pyrazus ebeninus* | MNI | 102 | 0 | 102 |
| | MNI/m3 | 2514 | 28 | 596 | | MNI/m3 | 1943 | 0 | 443 |
| *Saccostrea* spp. | MNI | 601 | 3 | 604 | *Saccostrea* spp. | MNI | 105 | 0 | 105 |
| | MNI/m3 | 11448 | 17 | 2626 | | MNI/m3 | 2000 | 0 | 457 |

Although there is a difference in scale, both squares exhibit trends in shell discard. *Saccostrea* spp. discard peaks in both squares at XU4, and shell weight is highest in XUs 3 to 5 in both squares (Tables 6-2, 6-3, and 6-7). Measures of richness, evenness and diversity (see Chapter 4) reflect low to moderate species diversity and richness, and the dominance of *Saccostrea* spp. in the assemblages, albeit less marked for Square B (Table 6-10).

**Table 6-10 Molluscan diversity measures for TCB 7b Squares A and B.**

| **Diversity Measure** | **Square A** | **Square B** |
|---|---|---|
| NTAXA | 14 | 11 |
| Individuals | 909 | 348 |
| Simpson’s Index (1-D) | 0.528 | 0.691 |
| Shannon Index of Diversity (′H) | 1.209 | 1.506 |
| Shannon Index of Evenness (E) | 0.458 | 0.6279 |

### Square B taxon-specific analysis

#### *Saccostrea spp.*

*Saccostrea* was the most abundant species in Square B, with a NISP of 2699 (Table 6-4), and an MNI of 159 (Table 6-5). The rank order did not change with volume-corrected estimates of MNI (Table 6-9). Heights were obtained for 72 valves, lengths for 71 valves, and depths for 47 valves: the descriptive statistics are detailed in Table 6-11.

**Table 6-11 Descriptive statistics for Saccostrea spp. height, length and depth for TCB 75b Square B SU1b.**

| Attribute | N | Minimum | Maximum | Mean | Range | Std. Deviation |
|---|---|---|---|---|---|---|
| Valve height mm | 72 | 14.96 | 65.36 | 36.0917 | 50.40 | 11.52514 |
| Valve length mm | 71 | 6.4 | 42.10 | 24.0065 | 35.7 | 7.47222 |
| Valve depth mm | 47 | 2.71 | 26.9 | 10.0589 | 24.9 | 4.83316 |

Single sample $t$ test results indicated that there may be statistically significant differences in both valve height ($t$=26.572, $df$= 71, $p$ <0.001) and valve length ($t$=27.07, $df$= 70, $p$ <0.001). However, further non-parametric Kolmogorov-Smirnov testing indicated a normal distribution for valve height and valve length ($D$=0.044, $p$>0.1 and $D$=0.038, $p$>0.1 respectively); plotting the size frequency confirmed a generally normal distribution (Figure 6-3). Single sample $t$ test results indicated that there may be statistically significant differences in valve depth ($t$=14.26, $df$=46, $p$<0.001) and further non-parametric Kolmogorov-Smirnov tests confirmed this with a test statistic of $D$= 0.162 and $p$ <0.05. Plotting the depth frequencies indicated that the valve depths did not conform to a normal distribution curve (Figure 6-3).

*Saccostrea* spp. males reach sexual maturity at a height of 20mm (Catterall and Poiner 1987:120), therefore seven (9.7%) of the 72 valves can be considered juveniles or sub-adults as they are between 14.96 and 19.56mm. The majority of the valves from Square B fall into the 25 – 50mm range with a peak in the 35-40mm range (Figure 6-3) suggesting that the shellfish were harvested from a relatively mature population not subjected to over-exploitation.

Two valves exceeded 60mm in height. Twenty-five of the 159 valves (15.72%) included in the MNI exhibited the elongated hinges or beaks described by Galtsoff (1964:16; Appendix A; Figure 5-4) as indicative of 'old' oysters, reinforcing the contention that the population from which they were obtained included mature individuals. Only 19 of the valves (11.94%) exhibited evidence of being cemented to other oysters, suggesting that the bed from which they were obtained was not tightly-packed or clustered. Eleven valves (6.91%) were found cemented to two *Pyrazus ebeninus* shells (Figure 6-4), a phenomenon noted by Smith (1985), while a further 12 (7.5%) had flat bases, implying that they grew directly either on rock or a firmly packed surface. Valve depth and morphology are environmentally influenced and Galtsoff (1964) noted that oysters attached to a pebble or shell, and so raised slightly from the bottom, had deep radially ribbed lower valves which offer greater resistance to dislodgement by currents or waves. The mean depth of the *Saccostrea* spp. is 10.06mm and the frequency distribution is skewed towards depths between 2.71mm and

12.5mm. This skewing implies that the majority of the oysters were not raised from the bottom sufficiently enough for them to develop tide-resistant characteristics. Unfortunately the depths of the valves attached to *Pyrazus ebeninus* shells could not be measured.

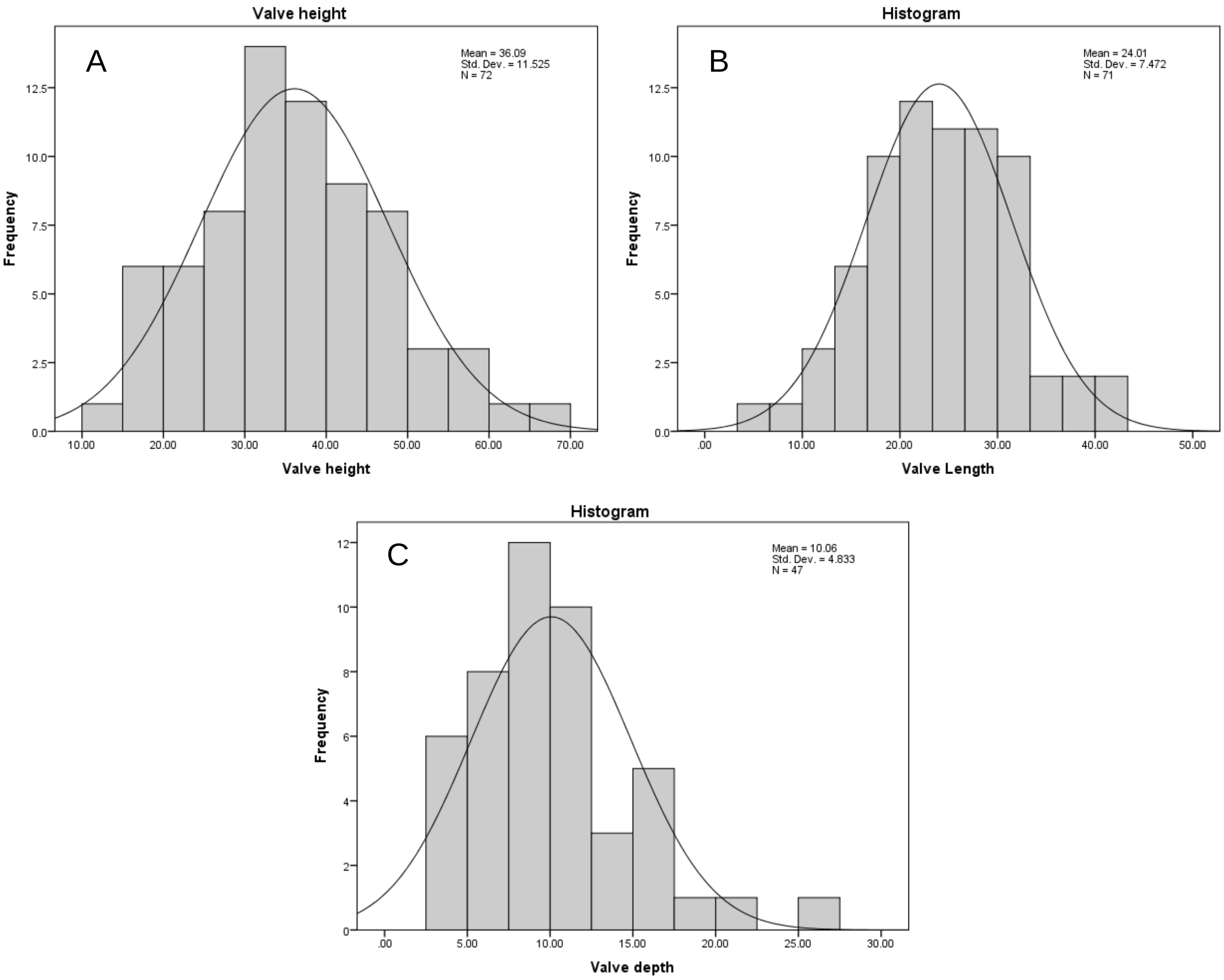

**Figure 6-3 Histogram of *Saccostrea* spp. size frequency plotted against normal distribution curve for valve height (A), valve length (B) and valve depth (C).**

**Figure 6-4 Oysters attached to Hercules Club whelk shells from TCB 75b Square B. Dorsal view left, ventral view right.**

The fragmentation ratio for *Saccostrea* spp. (NISP: MNI) was 16.97, similar to that in SU3 at Booral Shell Mound. The calculation of sedimentation rates after the method described by Stein *et al*. (2003) for deposition of sediments above the date of cal 308 BP (at the base of the midden 21cm below ground surface) is 6.16cm/100 years, reflecting an intermediate rate of deposition. Materials at this rate of deposition are generally buried before becoming mixed (Stein *et al*. 2003:313). A moderately robust species (see Robins and Stock 1990), it is likely that the small numbers of *Saccostrea* spp. in the lowest levels were trampled at the commencement of midden deposition. This effect would have been exaggerated by the location of the shells within thinner deposits on the edge of the midden. None of the shells exhibited evidence of burning, implying that they were opened at low temperature fires, and therefore the integrity of the shell matrix was not weakened as a result.

### *Pyrazus ebeninus*

*Pyrazus ebeninus* was the second most abundant species in Square B, with a NISP of 410 (Table 6-5) and an MNI of 102 (Table 6-6). The rank order did not change with volume-corrected estimates of MNI (Table 6-9). The MNI was derived from a count of whole specimens (n=6), and apertures and apertural lips from broken or partial shells. All broken and partial shells demonstrated breakage patterns consistent with cultural processing for the method for removal of the snail, i.e. breaking off the top of the shell (apex) to break the suction (see e.g. Meehan 1982). The breakages observed are unlikely to be the result of natural processes due to the robustness of adult Hercules Club whelk shells and the likelihood that humans are their only successful predators (Dr. John Healy, Queensland Museum, pers. comm., 2012; Appendix A). Additionally, the breakage pattern was consistent, with the majority of shells (62.85%) broken at the level of the second or third whorl. As only six complete specimens were recovered, meaningful statistical analysis of shell height was not possible. However, it may be noted that these specimens had an average height of 62.55mm, within the range (50-70mm) at which sexual maturity is reached (Vohra 1965).

As to be expected from such robust shells, the fragmentation ratio was low at 4.01. None of the shells exhibited evidence of burning, implying that they were cooked on low temperature fires, and as a result the integrity of the shell matrix was not weakened.

### *Isognomon spp.*

*Isognomon* spp. (commonly known as toothed pearl oyster, mangrove oyster or tree oyster) was the second most abundant species in terms of NISP (1129), but ranked third in the MNI (35) (Table 6-5 and Table 6-6). The rank order did not change with volume-corrected estimates of MNI (Table 6-9). Although the common names for the taxon imply association with mangroves (Carpenter and

Niem 1998), they also attach to rocks or other shells by their byssal threads (Healy *et al*. 2011:171). Only nine complete valves were recovered, rendering meaningful statistical analyses of shell height and/or shell length impossible. *Isognomon ephippium*, the species recorded by McNiven (1990a; 1991c), can reach a length (the maximum dimension across the valve, measured parallel to the hinge) of 140mm but more commonly 100mm (Carpenter and Niem 1998:191). Length measurements were obtained from nine valves and ranged from 20mm to 64.96mm, with a mean value of 44.26mm (std. dev. 5.9). Mean length was 44.26mm, with a standard deviation of 13.99. No literature is available on the overall growth rates of *Isognomon* spp., but it would appear from the potential adult size that the valves from Square B are juveniles or sub-adults. None of the shells exhibited evidence of burning, implying that they were opened at low temperature fires. Nevertheless, *Isognomon* spp. shells are thin, fragile and subject to extensive post-mortem de-lamination. It is therefore unsurprising that the fragmentation ratio is high, and at 32.25 is almost twice that recorded for *Saccostrea*.

### *Conuber sordidum*

*Conuber sordidum* is the fourth most abundant species in both Square A and Square B (Table 6-8 and Table 6-9). Although it does not usually appear on the ‘economic species’ lists from southeast Queensland middens (although see Hall 1980, 1984 and Hall and Bowen 1989 for examples from Moreton Island), it is nevertheless a useful environmental indicator. Commonly known as the leaden or dirty sand snail, it is a carnivorous gastropod which buries itself in sandy sediments in order to ambush its prey, including soldier crabs, bivalves, and some other species of sand snail (Healy *et al*. 2011:133). It typically grows to a maximum height of 40mm to 50mm. Height measurements were obtained for 15 individuals from Square B and ranged from 6.61mm to 36.1mm, with a mean value of 22.34mm, suggesting that the majority of the individuals were sub-adult. The shell is robust, with a fragmentation ratio for Square B of 1.8. None of the shells exhibited evidence of burning or exposure to high temperatures. Given the combined total of *C. sordidum* from both squares (n=52), and the snails’ habits, it seems an unlikely candidate for casual collection or by-catch, however no other explanation is immediately obvious (see Meehan 1982 re collection methods for partially buried molluscs). Carnivorous or scavenging gastropods are known to clump together in groups (Fisheries Research Consultants 1994:26) and it may be that the *C. sordidum* shells reflect an opportunistic exploitation of an aggregated resource.

*Anadara trapezia*

The low number of Anadara trapezia (NISP= 33, MNI= 11, volume-corrected MNI estimate=48) is somewhat surprising given that the species frequently occurs in high numbers in SEQ middens (e.g. Hope Island and Bribie Island) and that it also occurs in similar habitats to those occupied by Pyrazus ebeninus (see Appendix A). Length measurements were obtained from 10 valves and ranged from 30.13mm to 51.47mm, with a mean value of 35.72mm (std. dev. 5.9). This length range indicates that the individuals were sexually mature adults (see Appendix A). The valves are robust; the fragmentation ratio for Square B was 3. None of the shells exhibited evidence of burning, implying that they were opened at low temperature fires.

*Trichomya hirsuta*

The numbers of *Trichomya hirsuta* from TCB 75b are surprisingly low given that the species commonly occurs in estuarine middens. The MNI of seven was derived from nine valves (including two paired specimens) with a shell height range of 8.18mm and 15.32mm in height, and a mean value of 10.49mm. With the exception of one pair of valves, all are considered juveniles, suggestive of by-catch and/or evidence of a recently established population. The fragmentation ratio was 6.1, which is low considering the thin walled nature of the valves. However, as noted at Booral Shell Mound, juvenile mussels appear more resistant to trampling and breakage than larger specimens. None of the shells exhibited evidence of burning.

*Donax deltoides*

*Donax deltoides* (pipi) is a common species in surf coast middens, dominating deposits in similar locations that formed after c1000 BP (McNiven 2006). It occurs in small numbers in estuarine middens that have surf coast access but never in sufficient abundance to suggest dietary significance. The *D. deltoides* at TCB 75b could have been obtained from Rainbow Beach or Teewah Beach, most likely from the former due to the shorter distance. The combined MNI for TCB 75b was 6; a length of 33.6 from an incomplete valve from Square B indicates that the individual had probably reached sexual maturity. The regularly occurring low abundance suggests that the shellfish were introduced to the sites for non-dietary purposes (e.g. as raw materials for tool manufacture). This hypothesis is explored further in later chapters.

***'Other' molluscan species***

The remaining molluscan species most probably represent by-catch or collection for non-dietary purposes. All are useful environmental indicators. McNiven (1990a; 1991c) lists *Cerithidea largillierti* (mud creeper, MNI=14) among the Square A species; *Cerithium* sp. (creeper, NISP=7, MNI=7) was identified in Square B. Although belonging to different families (Potamididae and Cerithiidae respectively), they are morphologically very similar (Wilson 1993) with some differentiating characteristics that do not survive archaeologically (apertural morphology, varix, rib morphology on the whorls). Both are detrital grazers on sandy-muddy estuarine sediments and similar species in both families grow to heights of 40mm to 50mm. The seven Ceriths from Square B ranged in height from 26.32mm to 36.04mm, with a mean value of 31.09, suggesting that the individuals were sub-adult. The sizes combined with the very low abundance add supports to the by-catch hypothesis. None of the shells exhibited evidence of breakage to extract the snail.

*Nerita balteata* (NISP=4, MNI=4) is an algal grazer that lives high in the intertidal zone on the trunks and branches of mangroves, and grows to a height of 40mm (Appendix A). All the specimens recovered from Square B were broken and individual heights could not be obtained. The *Patelloida mimula* recorded in Square A is a limpet which inhabits sheltered estuaries and bays, usually associated with *Saccostrea* spp. (Wilson 1993:34) and therefore most likely represents by-catch. *Bedeva paivae* and *Cronia contracta* are both carnivorous gastropods, which prey on *Saccostrea* spp. and most likely represent oyster by-catch. *Bembicium* spp. (periwinkles) are grazing gastropods, with each species preferring slightly different habitats. *Bembicium nanum* was reported for Square A, however the species prefers moderately exposed rocky shores (Wilson 1993) which is at odds with the Tin Can Bay inlet environment. It is possible that the species may have been mis-identified. *Bembicium auratum* was identified from Square B and this prefers less exposed environments, is found on mangroves and often in estuaries (Wilson 1993). The heights of two shells from Square B were 7.25mm and 8.39mm, indicating that they were sub-adults. *Fluviolanatus subtorta* is a bivalve found in brackish water and coastal lagoons (Lamprell and Healy 1998:250) while Mactridae (trough clams) are deep-burrowing bivalves preferring sand or sandy-mud sediments (Healy *et al*. 2011:180).

### Non-molluscan invertebrate remains

A total of 12 crustacean fragments with a combined weight of 1.05g were recovered from XUs 3 to 6. The level of fragmentation prevented identification beyond the family level of Portunidae, but mud crabs (*Scylla serrata*) and sand crabs (*Portunus pelagicus*) occur within Tin Can Bay and Tin Can Inlet, and are known to occur in Aboriginal midden deposits in SEQ (see e.g. Alfredson 1984).

### Vertebrate remains

Two fragments of fish bone weighing 0.01g and a worn *Sillago* spp. otolith weighing 0.08g were recovered. Terrestrial vertebrates were represented by 16 fragments of unburnt bone weighing 0.09g, two burned bone fragments weighing 0.23g, and four burned fragments of long bone weighing 0.01g. The level of fragmentation prevented taxonomic identification of the burned bone, but the size and morphology suggest the bones belong to an animal the size of a small rodent. McNiven (1991c:93) noted two fragments of unburnt bone in XU1 of Square A, but was unconvinced that they represented discard by Aboriginal people, as he had observed bone fragments in recent dingo scats near the site and considered that the bone could equally represent weathered dingo faecal material (see McNiven 1990b for a detailed discussion of the taphonomy of faunal remains from blowouts along the Cooloola Coast, including the consumption of fish and shellfish by dingoes). The fish bone from Square B was similarly unburnt; the *Sillago* sp. otolith was worn whereas the associated molluscan remains were not. There was no clear evidence on the otolith of either mastication or gastric etching to support the possibility that it represented weathered dingo faecal material, however the worn nature of the element suggests secondary rather than primary deposition in the midden.

### Charcoal

Charcoal was recovered from seven of the upper nine excavation units of SU 1b in Square B (Table 6.4), and in all Square A excavation units (Table 6-3). Both squares exhibit vertical, i.e. chronological, variations in the amount of charcoal per excavation unit, however as discussed elsewhere excavation units are arbitrary analytical units which may be inappropriate for assessing fine-grained chronological changes. Whether the apparent variations through the SU are evidence of hearths in the vicinity is a moot point, as the vegetation mosaic in the area (*Melaleuca*, *Eucalyptus*, *Banksia* and Cypress forest) is comprised of fire-prone species; the increased charcoal: shell ratio may simply be an artefact of more frequent fire regimes during the period of midden formation compared to that of less frequent site use evidenced by the low shell weights below the midden deposit. Environmental reconstructions from nearby Carlo Creek (Krull *et al*. 2004) suggest that the period leading up to the commencement of the midden formation was associated with increased rainfall and higher groundwater levels. Moss *et al*. (2011) reported decreased charcoal in the deposits at Myora Springs on North Stradbroke Island associated with La Niña conditions at approximately the same period.

### Stone artefacts

McNiven (1990a:198, 1991c:94) recorded 170 artefacts totalling 151.12g manufactured from seven different raw materials (quartz, silcrete, andesite, oxide, basalt, and unknown) from Squares A and B. All andesite flaked artefacts (n=7) and seven silcrete flakes were found within the midden in XUs one to nine, and a further five silcrete flakes were recovered from XUs 10 to 21 below it (McNiven 1990a:200, 1991c:94). The original data (McNiven1990a:404, 1991c:104; reproduced in Table 6-4) show artefacts were recovered from 16 of the 21 excavations units in Square B, totalling

10.09g. However, the accessioned material from TCB 75b Square B received from the Queensland Museum contained 11 flaked artefacts from only five XUs, totalling 7.85g and manufactured from only two raw materials, silcrete (n=10) and andesite (n=1). The material did include the tabular ferruginous sandstone (oxide) manuport described by McNiven (1990a:200, 1991c:94), although its weight was not included in the original artefact weights for Square B but instead for Square A (Tables 6-3 and 6-4). As McNiven (1990a, 1991c) does not state how many artefacts came from each particular excavation square it is impossible to assess what artefacts originally excavated from Square B are missing from the Queensland Museum boxes; it may be that they are stored with the material from Square A. However, as was apparent when the excavated material from Booral Shell Mound held by the Queensland Museum was compared to the assemblage documented by Frankland (1990a), not all materials from the site were lodged with the Museum when the sites were accessioned and their current location is unknown; the same set of circumstances may apply to the Tin Can Bay artefacts. In McNiven's description (1990a:198, 1991c:94), 148 of the 170 artefacts were manuports, predominantly of quartz (n=133), and it was conjectured that the majority of these were accidentally introduced to the site while attached to another resource, e.g. in soil attached to plant foods. Given that the artefact assemblage from Square B as examined consists of 11 flakes, and that McNiven (1990a:198, 1991c:94) stated that there were 22 flakes in total from both squares, it appears that half of the flakes recovered from the site have therefore been analysed. When the ferruginous sandstone manuport is included, the total artefact weight from Square B is 141.69g; the total weight presented by McNiven (1990a:198) was 151.12g. There are discrepancies between the artefact weights per XU recorded in the present study and those presented by McNiven (1990a:403-404; Table 6-3, Table 6-4). What can be said is that, with the exception of the lack of information about the raw materials on which the other 11 artefacts were made, and the artefact attributes, the present study accounts for the majority (93.75%) of the recovered assemblage by weight, for 50% of the flaked artefacts, and for 76.9% of the silcrete artefacts.

The small suite of artefacts recovered from Square B does not lend itself to any discussion of distance-decay models, production, discard, and rationing practices, or changes in raw material availability. Nevertheless, certain observations can be made on the artefacts for the purposes of comparison across the larger dataset in the present study. The artefact raw materials are not available in the immediate vicinity of the site, but two of them can be found in the general area. Andesite outcrops at Double Island Point, and the ferruginous sandstone or oxide large manuport could have derived from the numerous creeks on the western side of the Cooloola Sandmass, as well as Teewah Beach or Rainbow Beach (McNiven 1990a:329, 1991c:94), where similar material forms spectacular exposed banding. McNiven (1990a:328) states that the nearest potential outcrops of silcrete are at Wolvi Mountain and Mt Condoo approximately 28km to the southwest; raw material from these areas could have been transported closer to the Tin Can Inlet region in the form of water-borne cobbles in the various creeks which drain from the area. As none of the TCB 75b stone artefacts exhibited any cortex, however, this hypothesis is difficult to prove.

*Volume-corrected density estimates*

The volume-corrected estimates of stone artefact discard for Square B are presented in Table 6-12. No similar estimates were possible for Square A.

*Whole flakes*

The attributes of the three whole flakes from Square B are presented in Table 6-13. All the flakes were tertiary, with no cortex. The two silcrete flakes exhibited one dorsal scar each, while the andesite flake had no dorsal scars and in profile was very flat.

*Retouched flake*

The attributes of the retouched flake from XU5 are presented in Table 6-14. Morphologically the artefact is a backed flake. McNiven (1991c:100) reported a 'unique find' of a backed flake in a private collection of artefacts from deflated deposits found in the intertidal zone in the vicinity of Cameron Point Sites 62 and 63 believed to date to within the last 800 years. This suggests that the manufacture and use of backed flakes persisted in the region over a period of some 500 years.

*Broken flakes*

The attributes of the four broken flakes are presented in Table 6-15. All were distal flake portions exhibiting transverse breakage indicative of treadage, whilst one also exhibited longitudinal breakage suggesting that the initial break may have occurred during manufacture. None of the broken flakes exhibited cortex; two had one dorsal scar each, and a third two dorsal scars.

*Flaked pieces*

The attributes of the three flaked pieces are presented in Table 6-16. All are silcrete, and two are very small.

*Manuport*

The attributes of the odd ferruginous manuport are presented in Table 6-17. McNiven (1991c:94) was of the opinion that the manuport could have derived from any of the many creeks which drain the western side of the Cooloola sandmass, or from Teewah Beach or Rainbow Beach where layers of the material form bands within the Pleistocene dunes (coincidentally creating the famous ‘Coloured Sands’). He also noted that the item exhibited “neither flaking nor use-wear and, at present, its function(s) remain unknown”. It is possible that the manuport was transported as a potential pigment source.

**Table 6-12 Volume-corrected estimates of numbers of stone artefacts for TCB 75b Square B.**

| **TCB 75b Sq B** | **SU1** | **SU2** | **Total** |
|---|---|---|---|
| Volume | 0.0525 | 0.1775 | 0.23 |
| N | 8 | 4 | 12 |
| N/m$^3$ | 152 | 23 | 52 |

**Table 6-13 Attributes of whole flakes from TCB 75b Square B.**

| Category | Raw Material | Colour | Wt g | Width mm | Length mm | Thickness mm | Plat. Thickness mm | Plat. Width mm | Plat. Type | Term. | Retouch/Dam | Dorsal scar Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Whole flake | Silcrete | Light yellowish brown | 0.16 | 9.1 | 11.31 | 1.92 | 1.22 | 5.23 | Flaked | Feather | Damage distally | 1 |
| Whole flake | Silcrete | Light reddish brown | 0.11 | 7.93 | 9.2 | 1.85 | 1.56 | 8.38 | Flaked | Feather | 0 | 1 |
| Whole flake | Andesite | Very dark grey | 0.92 | 15.1 | 19.73 | 2.28 | 2.72 | 9.7 | Flaked | Snap | 0 | 0 |

**Table 6-14 Attributes of retouched flake from TCB 75b Square B.**

| Category | Raw Material | Colour | Wt g | Width mm | Length mm | Thickness mm | Plat. Thickness mm | Plat. Width mm | Plat. type | Retouch/Dam. | Max length ret.mm | Min length ret.mm | Term. | Dorsal scar number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retouched flake | Silcrete | Grey | 3.94 | 17.75 | 27.36 | 9.13 | 3.5 | 5.29 | Flaked | Ret. left margin | 9.69 | 3.38 | Feather | 2 |

**Table 6-15 Attributes of broken flakes from TCB 75b Square B.**

| Category | Raw material | Colour | Wt g | Width mm | Length mm | Thickness mm | Dorsal scar number | Retouch/Damage | Breakage | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| Broken flake | Silcrete | Grey with dark pink specks | 0.82 | 10.09 | 16.44 | 4.96 | 1 | Damage right margin | Longitudinal and transverse | Right distal portion |
| Broken flake | Silcrete | Grey | 0.08 | 5.28 | 10.48 | 3.8 | 2 | 0 | Transverse | Distal half |
| Broken flake | Silcrete | Yellowish red | 0.08 | 9.78 | 7.85 | 1.46 | 1 | 0 | Transverse | Distal half |
| Broken flake | Silcrete | Light grey | 0.1 | 5.14 | 8.89 | 2.64 | 0 | 0 | Transverse | Distal half |

**Table 6-16 Attributes of flaked pieces from TCB 75b Square B.**

| Category | Raw material | Colour | Wt g | Maximum dimension mm |
|---|---|---|---|---|
| Flaked piece | Silcrete | Grey | 1.58 | 20.55 |
| Flaked piece | Silcrete | Reddish yellow | 0.05 | 8.14 |
| Flaked piece | Silcrete | Grey | 0.01 | 5.83 |

**Table 6-17 Description of manuport from TCB 75b Square B.**

| Category | Raw material | Colour | Wt g | Maximum dimension mm | Description |
|---|---|---|---|---|---|
| Manuport | Ferruginous sandstone | Dark red | 131.6 | 99.89 | 10.05mm thick, laminar, ‘oxide’ |

### *Cameron Point Site 62*

This site is situated on the northern side of Cameron Point, some 2km north of TCB 75b (Figure 6-1). The site is exposed for approximately 40m along a 2m high erosion face (McNiven 1990a:200, 1991c:97) at the foot of which are lag deposits of stone artefacts and midden debris. As with TCB 75b, the overall site area could not be estimated because of poor surface visibility (McNiven 1990a:201) but naturally eroded sections indicate that it is more than 5m wide (McNiven 1991c:97). The surrounding vegetation differed from that at TCB 75b, being composed of Forest Red Gum and coastal cypress forest. Three contiguous 50cm x 50cm pits (Squares A, B, and C) were excavated in an area of relatively dense surface midden deposits. Squares B and C were each excavated to a depth of 52cm in 13 excavation units using the Johnson (1979, 1980) bucket method with the excavated material dry-sieved through 3mm mesh. The excavated volume of each square was 0.125m$^3$. In the original study Square B was analysed in full, with stone artefacts from Square C also sorted and classified. No analysis was undertaken for Square A due to disturbance by large tree roots.

Two major stratigraphic units were identified (Figure 6-5). SU1 had a maximum depth of 22cm and consisted of loose dark grey sand with a variable pH of 4.0 to 5.5; it contained the bulk of the molluscan remains. SU2 unconformably underlay SU1 and extended from 13cm below the surface with a variable thickness (29-37cm) to the base of the pit. The sediments graded from grey sand with a pH of 6.0 to light grey with a pH of 4.0, with SU2 containing most of the stone artefacts (McNiven 1990a:202, 1991c:97).

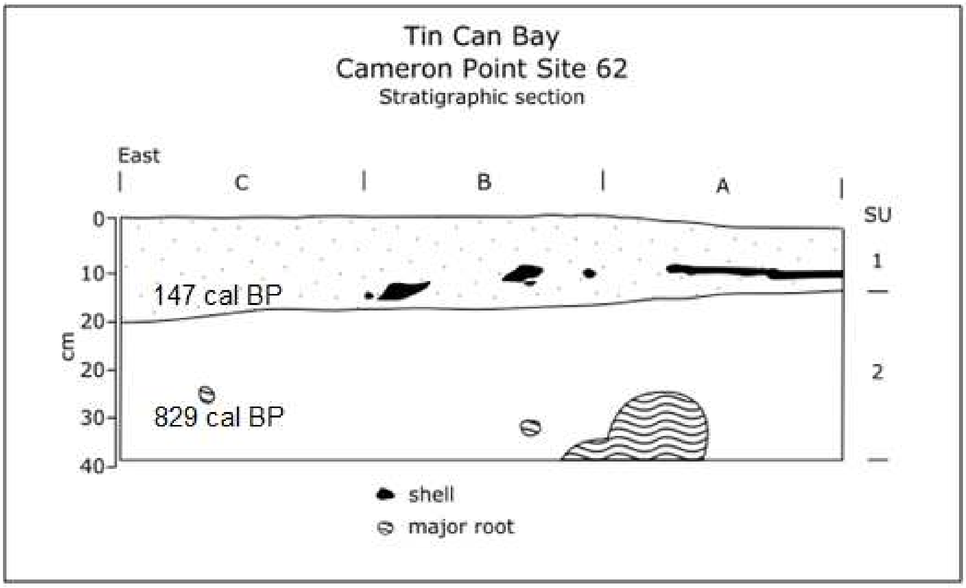

**Figure 6-5 Stratigraphic section for CP 62 (after McNiven 1991c:97). Stippling indicates the midden deposit.**

McNiven (1990a:203, 1991c:98) reported two radiocarbon dates on charcoal obtained from the base of SU1 in Square B at XU6, and on charcoal obtained from XU10 in SU2 at a mean depth of 30cm. The first sample (Beta-34400) returned a conventional date of 190±50 BP with a calibrated age of 199 BP, and the second sample (Beta-34401) produced a conventional date of 950±60 BP with a calibrated age of 807 BP (Table 6-18). Ulm and Reid (2000:19) reported median calibrated ages of 147 BP for the upper sample, and 829 BP for the lower sample, and these are the ages employed here.

**Table 6-18 Radiocarbon age determinations for CP 62 (from McNiven 1990a, 1991c; Ulm and Reid 2000:19).**

| SU | XU | Depth cm | Sample | Laboratory code | Conventional 14 C date | 2σ calibrated age range |
|---|---|---|---|---|---|---|
| 1 | 6 | 17 | Charcoal | Beta-34400 | 190±50 BP | 304(273,189,147,13, 4)0 |
| 2 | 10 | 30 | Charcoal | Beta-34401 | 950±60 BP | 952(906,861,829,811,794)698 |

## Molluscs

A total of 2854g of shellfish comprising an MNI of 332 (2656 per m$^3$) from six taxa was recovered from Square B. As with TCB 75b, the assemblage was dominated by *Saccostrea* spp.; the next most abundant species was *Pyrazus ebeninus,* followed by three *Trichomya hirsuta* and one each of *Cerithidea largillierti* and *Nerita balteata* (Table 6-19). Shell weights were recorded to the level of XU11 (Table 6-20) although no MNI was recorded below XU7 because of preservational conditions and a lack of diagnostic features for MNI calculation. No pipi (*Donax deltoides*) was excavated, but one valve was noted on the erosional face at the southern end of the site. McNiven (1991c:98) considered that all the species could be obtained from the intertidal zone adjacent to the site, while the pipi most likely came from Rainbow Beach some 6km away, although an origin of Teewah Beach, 13km distant (Figure 6-1), could not be discounted.

**Table 6-19 Shellfish taxa and MNI by XU for Square B, CP 62 (after McNiven 1990a:205, 1991c:98).**

| Taxa | XU1 | XU2 | XU3 | XU4 | XU5 | XU6 | XU7 | Total MNI | %MNI |
|---|---|---|---|---|---|---|---|---|---|
| *Anadara trapezia* | 0 | 0 | 1 | 4 | 10 | 2 | 0 | 17 | 5.12% |
| *Cerithidea largillierti* | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0.30% |
| *Nerita balteata* | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0.30% |
| *Pyrazus ebeninus* | 4 | 0 | 2 | 18 | 9 | 3 | 1 | 37 | 11.14% |
| *Saccostrea* spp. | 1 | 2 | 8 | 151 | 89 | 20 | 2 | 273 | 82.23% |
| *Trichomya hirsuta* | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 3 | 0.90% |
| **Total** | **5** | **2** | **11** | **173** | **113** | **25** | **3** | **332** | **100.00%** |

Table 6-20 CP 62 Square B data recordings (after McNiven 1990a:404).

| XU | Mean depth cm | XU wt kg | Charcoal wt g | Shell wt g | Bone wt g | Artefact wt g | pH |
|---|---|---|---|---|---|---|---|
| 1 | 3 | 4.5 | 10.02 | 47.1 | 0 | 0 | 5 |
| 2 | 5 | 5.5 | 15.4 | 4 | 0.1 | 0 | |
| 3 | 9 | 6.1 | 9.64 | 111.5 | 0 | 0 | 4 |
| 4 | 12 | 8 | 6.41 | 1689.6 | 0.01 | 0 | |
| 5 | 14 | 7.3 | 33.79 | 884.6 | 0.04 | 0.24 | 5.5 |
| 6 | 17 | 7.6 | 35.21 | 109.1 | 0 | 6.84 | |
| 7 | 21 | 9 | 4.98 | 6.8 | 0 | 8.32 | 6 |
| 8 | 24 | 9.5 | 7.65 | 1.3 | 0 | 1.05 | |
| 9 | 27 | 10.1 | 14.68 | 0.1 | 0 | 0.2 | 5 |
| 10 | 30 | 10.5 | 15.42 | 0.3 | 0 | 213.06 | |
| 11 | 35 | 11.3 | 12.78 | 0.1 | 0 | 2.29 | 5 |
| 12 | 43 | 20.7 | 5.8 | 0 | 0 | 0.29 | |
| 13 | 50 | 17.7 | 1.24 | 0 | 0 | 0.71 | 4 |
| **Total** | | **127.8** | **173.02** | **2854.5** | **0.15** | **233** | |

The present study employed an analysis of the previously unsorted (other than the stone artefact component) contents of Square C. There was a difference in the composition of the shellfish assemblage, in that mussels, ceriths, and nerites were entirely absent, and there was an occurrence of *Conuber sordidum*. No shells at all were recovered from top two XUs, and the species diversity was low for an estuarine midden. This latter aspect is discussed further below. The NISP was 1025 (Table 6-21), with a total MNI of 182 (Table 6-22), with an estimated density of 1456 per m$^3$ (Table 6-23). Reflecting the fewer MNI, the shell weight (Table 6-24) is lower than that recorded for Square B. As for TCB 75b, the shellfish data from Square C is initially presented here by XU to provide a comparison with those previously published, while the subsequent discussion is framed within the context of SU1.

Table 6-21 CP 62 Square C molluscan taxa NISP by XU.

| Species | XU3 | XU4 | XU5 | XU6 | Total NISP | % NISP |
|---|---|---|---|---|---|---|
| *Anadara trapezia* | 0 | 5 | 16 | 7 | 28 | 2.73% |
| *Conuber sordidum* | 0 | 0 | 2 | 0 | 2 | 0.20% |
| *Pyrazus ebeninus* | 1 | 8 | 48 | 21 | 78 | 7.61% |
| *Saccostrea* spp. | 2 | 329 | 494 | 92 | 917 | 89.46% |
| **Total** | | | | | **1025** | **100.00%** |

Table 6-22 CP 62 Square C molluscan taxa MNI by XU.

| Species | XU3 | XU4 | XU5 | XU6 | Total MNI | % MNI |
|---|---|---|---|---|---|---|
| *Anadara trapezia* | 0 | 3 | 5 | 2 | 10 | 5.49% |
| *Conuber sordidum* | 0 | 0 | 2 | 0 | 2 | 1.10% |
| *Pyrazus ebeninus* | 1 | 6 | 18 | 3 | 28 | 15.38% |

**Table 6-22 (continued) CP 62 Square C molluscan taxa MNI by XU.**

| | | | | | | |
|---|---|---|---|---|---|---|
| *Saccostrea* spp. | 2 | 89 | 47 | 4 | 142 | 78.02% |
| **Total** | | | | | **182** | **100.00%** |

**Table 6-23 Volume-corrected MNI estimates for CP62 Squares B and C.**

| **CP62 Sq B** | | **SU1 m$^3$** | **SU2 m$^3$** | **Total** | **CP 62 Sq C** | | **SU1 m$^3$** | **SU2 m$^3$** | **Total** |
|---|---|---|---|---|---|---|---|---|---|
| | | 0.0425 | 0.0825 | 0.125 | | | 0.0425 | 0.0825 | 0.125 |
| All shell | MNI | 332 | 0 | 332 | All shell | MNI | 182 | 0 | 182 |
| | MNI/m3 | 7812 | 0 | 2656 | | MNI/m3 | 4282 | 0 | 1456 |
| *Anadara trapezia* | MNI | 17 | 0 | 17 | *Anadara trapezia* | MNI | 10 | 0 | 10 |
| | MNI/m3 | 400 | 0 | 136 | | MNI/m3 | 235 | 0 | 80 |
| *Pyrazus ebeninus* | MNI | 37 | 0 | 37 | *Pyrazus ebeninus* | MNI | 28 | 0 | 28 |
| | MNI/m3 | 871 | 0 | 296 | | MNI/m3 | 659 | 0 | 224 |
| *Saccostrea* spp. | MNI | 273 | 0 | 273 | *Saccostrea* spp. | MNI | 142 | 0 | 142 |
| | MNI/m3 | 6424 | 0 | 2184 | | MNI/m3 | 1721 | 0 | 1136 |
| *Trichomya hirsuta* | MNI | 3 | 0 | 3 | *Conuber sordidum* | MNI | 2 | 0 | 2 |
| | MNI/m3 | 71 | 0 | 24 | | MNI/m3 | 47 | 0 | 16 |

**Table 6-24 CP 62 Square C molluscan taxa weight in grams by XU.**

| **Species** | **XU3** | **XU4** | **XU5** | **XU6** | **Total wt g** | **% wt** |
|---|---|---|---|---|---|---|
| *Anadara trapezia* | 0 | 14.19 | 77.18 | 14.33 | 105.7 | 8.02% |
| *Conuber sordidum* | 0 | 0 | 1.15 | 0 | 1.15 | 0.09% |
| *Pyrazus ebeninus* | 17.48 | 183.93 | 320.74 | 18.1 | 540.25 | 40.98% |
| *Saccostrea* spp. | 17.54 | 231.07 | 408.89 | 13.13 | 670.63 | 50.87% |
| Indeterminate | 0 | 0 | 0 | 0.55 | 0.55 | 0.04% |
| **Total** | 35.02 | 429.19 | 807.96 | 46.11 | **1318.28** | **100.00%** |

Measures of richness, evenness and diversity (see Chapter 4) reflect low to moderate species diversity and richness, and the dominance of *Saccostrea* spp. in the assemblages, albeit less marked for Square C (Table 6-25).

**Table 6-25 Molluscan diversity measures for CP 62 Squares B and C.**

| **Diversity Measure** | **Square B** | **Square C** |
|---|---|---|
| NTAXA | 6 | 4 |
| Individuals | 332 | 182 |
| Simpson's Index (1-D) | 0.3087 | 0.3644 |
| Shannon Index of Diversity (′H) | 0.6351 | 0.6906 |
| Shannon Index of Evenness (E) | 0.3545 | 0.4982 |

## Square C taxon specific analysis

*Saccostrea spp.*

*Saccostrea* spp. was the most abundant taxon in Square C, with a NISP of 917 (Table 6-19), and an MNI of 142 (Table 6-20). Heights were obtained for 50 valves, lengths for 52 valves, and depths for 39 valves; the descriptive statistics are detailed in Table 6-26.

**Table 6-26 Saccostrea spp. height, length and depth for CP 62 Square C.**

| Attribute | N | Range | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|---|
| Valve height mm | 50 | 57.48 | 9.69 | 67.17 | 39.4686 | 12.89428 |
| Valve length mm | 52 | 53.09 | 5.50 | 58.59 | 27.0594 | 11.44094 |
| Valve depth mm | 39 | 20.49 | 2.54 | 23.03 | 12.9677 | 4.67346 |

Single sample *t* test results indicated that there may be statistically significant differences for all three variables (Table 6.27), which may relate to the modal distribution. However, further non-parametric Kolmogorov-Smirnov testing (Table 6-28) and the size-frequency histograms (Figure 6-6) indicate normal distributions.

**Table 6-27 Single sample t test results for Saccostrea spp. height, length and depth for CP 62 Square C.**

| One-Sample Test | | | | | | |
|---|---|---|---|---|---|---|
| | Test Value = 0 | | | | | |
| | t | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference | |
| | | | | | Lower | Upper |
| Valve height | 21.644 | 49 | .000 | 39.46860 | 35.8041 | 43.1331 |
| Valve length | 17.055 | 51 | .000 | 27.05942 | 23.8742 | 30.2446 |
| Valve depth | 17.328 | 38 | .000 | 12.96769 | 11.4527 | 14.4827 |

**Table 6-28 Kolmogorov-Smirnov results for *Saccostrea* height, length and depth for CP 62 Square C.**

| One-Sample Kolmogorov-Smirnov Test | | | | |
|---|---|---|---|---|
| | | Valve height | Valve length | Valve depth |
| N | | 50 | 52 | 39 |
| Normal Parameters[a,b] | Mean | 39.4686 | 27.0594 | 12.9677 |
| | Std. Deviation | 12.89428 | 11.44094 | 4.67346 |
| Most Extreme Differences | Absolute | .086 | .114 | .068 |
| | Positive | .069 | .114 | .051 |
| | Negative | -.086 | -.084 | -.068 |
| Test Statistic | | .086 | .114 | .068 |
| Asymp. Sig. (2-tailed) | | .200[c,d] | .087[c] | .200[c,d] |
| a. Test distribution is Normal. | | | | |
| b. Calculated from data. | | | | |
| c. Lilliefors Significance Correction. | | | | |
| d. This is a lower bound of the true significance. | | | | |

Four of the 49 valves (8%) are juveniles or sub-adults as they measure between 9.69mm and 15.85mm. As demonstrated in Figure 6-6, the majority of the valves from Square C fall into the 25 – 55mm range with a peak at 35 – 40mm and a second, smaller, peak at 45 – 50mm suggesting that the shellfish were harvested from a relatively mature population not subject to over-exploitation. Three valves exceeded 60mm in height. None of the 142 valves included in the MNI exhibited the elongated hinges or beaks indicative of 'old' oysters (Galtsoff 1964). Only five of the valves (0.1%) exhibited evidence of being cemented to other oysters suggesting that, as at TCB 75b, the bed from which they were obtained was not tightly packed or clustered. Twenty-eight valves (19.71%) were cemented to eight *Pyrazus ebeninus* shells; one of the *Pyrazus* was literally covered by seven *Saccostrea* spp. lower valves. While only three valves had flat bases suggesting they grew directly on rock or a firmly packed surface, ten (7.04%) were noted to be deeply fluted or ribbed. The valves resemble the descriptions provided by Kent (1992:4; Appendix A) of sand and bed oysters. The mean valve depth is 12.96mm and, as Figure 6-6 demonstrates, the majority of the valves are between 7.5mm and 17.5mm in depth.

Taken with the high occurrence of valves attached to *Pyrazus* shells the data suggest that although there was an adult (sexually mature) population of *Saccostrea* spp. provisioning the area around CP 62, it was not growing in clusters or reefs and was instead based around firm substrates and Hercules Club whelk shells for support.

The fragmentation ratio for *Saccostrea* was 6.45, considerably lower than that for TCB 75b. None of the shells exhibit evidence of burning, indicating that they were opened over low temperature fires.

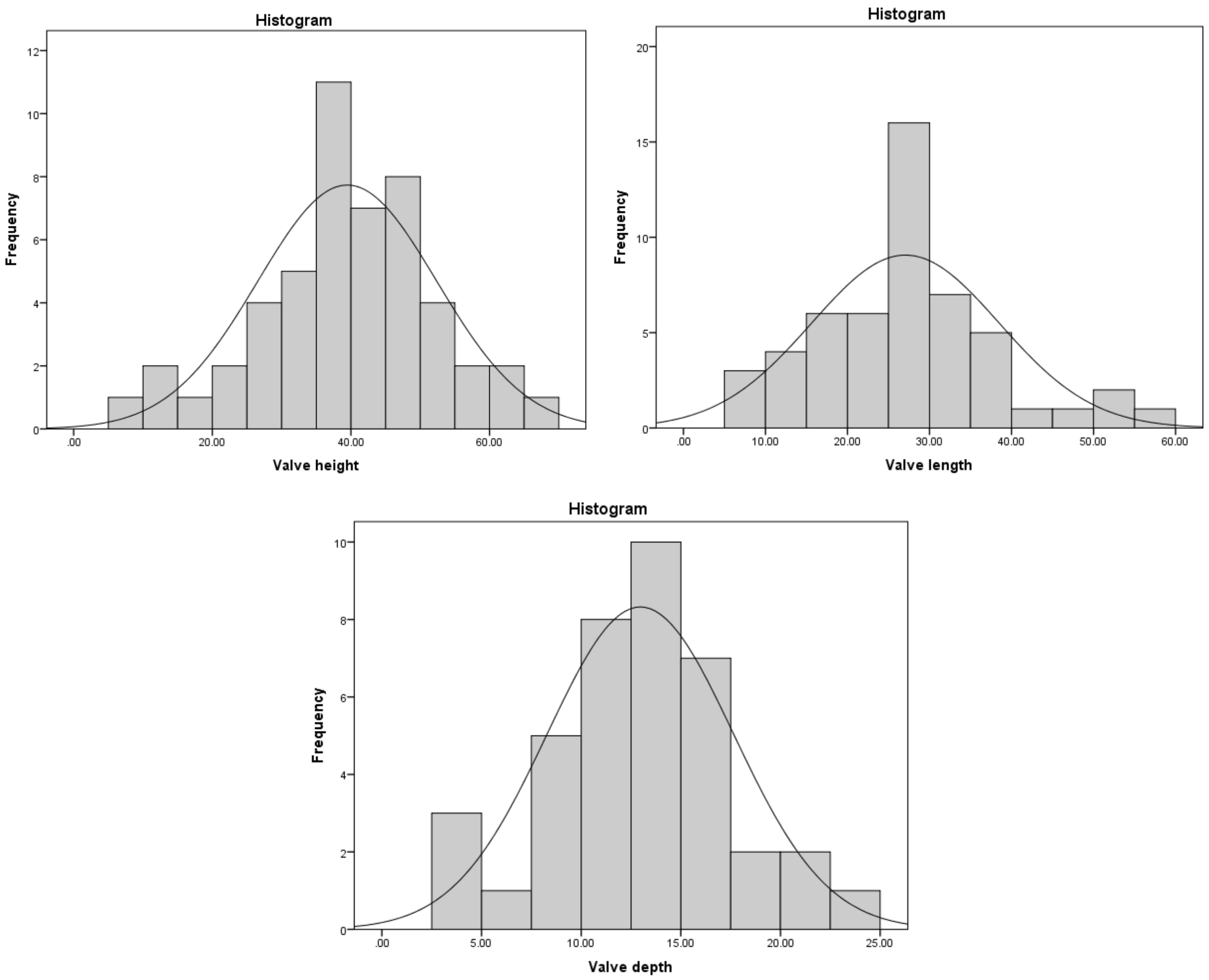

**Figure 6-6 Histogram of frequency of *Saccostrea* valve height, length and depth for CP 62 Square C plotted against normal distribution curve.**

### *Pyrazus ebeninus*

*Pyrazus ebeninus* was the second most abundant species in Square C, with a NISP of 78 and MNI of 28 (Tables 6-19 and 6-20). The breakage patterns observed were similar to those observed at TCB 75b. Only two complete specimens were recovered, rendering statistical analyses of shell height impossible. The specimens were 59.66mm and 60.08mm in height, within the range at which sexual maturity is reached (Vohra 1965). The fragmentation ratio was low at 2.78. Meehan (1982) noted that *Telescopium* and *Terebralia* specimens took three to four minutes to cook on a fire, before the shells were broken to extract the meat. This short exposure to heat does not leave evidence of burning (see also Robins and Stock 1990), and none was observed on the Square C *P. ebeninus* shells.

### *Anadara trapezia*

The *Anadara trapezia* MNI was surprisingly low at 10, with a NISP of 28. Although length measurements were obtained from eleven valves, this sample is too small for a statistically valid analysis. The lengths ranged from 20.4mm to 40.75mm with a mean value of 32.98mm (std. dev. 5.47), placing the majority in the range of sexually mature adults. The fragmentation ratio was low at 2.8. None of the shells exhibited evidence of burning, indicating that they were opened over low temperature fires.

### Other Molluscs and non-Molluscan Invertebrates

Two *Conuber sordidum* were recovered. The shell heights were 8.04mm and 15.33mm, representing a juvenile and a sub-adult. The fragmentation ratio was 1. Neither of the shells exhibited evidence of burning. One plate of a crustacean of the class Cirripedia (barnacle) weighing 0.09g was recovered.

### Vertebrate faunal remains

One *Sillago ciliata* (summer whiting) otolith 8.05mm long and 0.09g in weight was recovered from XU2. McNiven (1990a:206, 1991c:100) recorded an unburnt summer whiting otolith weighing 0.10g from XU2 in Square B. Given the similarity in weights it is likely that the two form a pair. As for TCB 75b, McNiven (1990a:206, 1991c:100) expressed doubts about the discard of the otolith, as dingo faeces containing fish bones had been observed near the site. Again as for TCB 75b, the otolith did not exhibit obvious evidence of chewing or gastric etching, but it was unworn, suggesting the possibility of primary rather than secondary deposition.

In Square B 0.15g of bone (including the otolith, the only identifiable element) was recovered and in Square A (presumably the only analysis on that square) there were four fragments of bone – one from a macropod long bone, weighing 0.32g, and one burnt and calcined piece perhaps from a mammal, weighing 26g (McNiven 1991c). In comparison, 282 bone fragments totalling 1.92g were recovered from Square C. Two fragments with a total weight of 0.01g were unidentifiable, while 266 of the fragments (1.83g) came from long bones of a small mammal or lizard, and the remaining 14 fragments (0.08g) from ribs of a small mammal or lizard. All the bones were burned black, suggesting a non-dingo source of discard.

### Charcoal

Charcoal weight for Square C was 147.33g. The bag of charcoal from XU6, weighing 24.31g was labelled “Left over after charcoal removed for C14”, but it is unclear if charcoal from Square C was included in the sample for age determination. There was no statistically significant variation in charcoal weights throughout SU1 (*D*= 0.195, *p*=0.190).

### Stone artefacts

As with TCB 75b there were discrepancies between the stone artefactual material originally reported for CP 62 Squares B and C, and the accessioned material borrowed from the Queensland Museum. In the original study 101 stone artefacts totalling 249.36g were recovered from Squares B and C, comprising 11 whole and broken flakes, one flaked piece, one core, and 88 manuports. Eight raw material types were noted: quartz, sandstone, oxide, silcrete, andesite, chert, quartzite, and unknown. Most of the artefacts (n=59, 58.4%) were quartz pebbles or fragments considered manuports inadvertently introduced to the site while attached to another resource, e.g. in soil attached to plant foods, with the same origin possible for the other manuports (McNiven 1991c:100). It is not specified which artefacts came from which square but as with Tin Can Bay 75b there are discrepancies between the artefact weights per XU recorded in the present study and those in the original (McNiven 1990a:405; Table 6-29); the artefact categories directly associated with the midden deposit (i.e. those from XUs 5 and 6) are similarly unspecified.

**Table 6-29 CP 62 Square C data recordings (after McNiven 1990a:405).**

| XU | Mean depth cm | XU Wt kg | Artefact Wt g (original) | Artefact Wt g (present study) |
|---|---|---|---|---|
| 1 | 2 | 2.2 | 0.00 | 0.00 |
| 2 | 4 | 4.6 | 0.00 | 0.00 |
| 3 | 8 | 6.7 | 0.00 | 0.00 |
| 4 | 10 | 6.3 | 0.00 | 0.00 |
| 5 | 13 | 6.6 | 0.21 | 0.00 |
| 6 | 17 | 8.4 | 8.66 | 0.00 |
| 7 | 20 | 9.8 | 4.32 | 0.00 |
| 8 | 24 | 9 | 0.17 | 0.50 |
| 9 | 27 | 10.1 | 0.10 | 0.18 |
| 10 | 31 | 10.5 | 0.19 | 213.36 |
| 11 | 36 | 11.5 | 0.04 | 2.32 |
| 12 | 43 | 20.7 | 0.12 | 0.23 |
| 13 | 50 | 18.2 | 1.55 | 0.00 |
| | | | **15.36** | **216.59** |

In all, 16 artefacts weighing 216.59g and manufactured on four raw materials were recorded for Square C during the present study, all from SU2 below the midden deposit: one whole flake; 13 flaked pieces; and one core. The volume-corrected estimate for artefact discard is 194 per $m^3$. Silcrete was the most common raw material (n=11), followed by quartz (n=3), quartzite (n=1) and unknown (n=1). The potential raw material sources are the same as those for TCB 75b. The stone artefact attributes are detailed in Tables 6-30 to 6-32.

*Whole flakes*

The different colours of the two whole flakes may indicate two different raw material sources; however silcrete can vary substantially in colour across single outcrops. Both were tertiary flakes with no cortex, and no evidence of platform preparation. One flake had three dorsal scars which could indicate a degree of core rotation (Table 6-30).

*Flaked pieces*

Flaked pieces dominated the artefact categories (n=13, 81.25%), and may represent evidence of artefact re-sharpening or manufacture at the site (Table 6-31). Their small size means that they are subject to ready vertical movement through sediments and may not be in their original depositional context (see e.g. Richardson 1992).

*Core*

The core is perhaps the most interesting artefact in the assemblage. It comes from XU10, the excavation unit from which the median $^{14}$C age of 829 cal BP was obtained, and provides evidence of plant processing at or in the vicinity of the site prior to the deposition of the midden. It has a bevel (Table 6-32), and represents a re-used bevel edge tool. McNiven (1991c:100) recorded 12 bevel edged tools and ten bevel flakes in the deflated assemblage on the intertidal flats adjacent to CP 62 which he considered to be strong evidence for plant food processing at the site. This in situ artefact provides secure dating evidence for Aboriginal subsistence activities in the area. The exhausted core may also provide some evidence for raw material/artefact curation as it has three platforms, four flake scars, and seven step fractures.

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**Table 6-30 Attributes of whole flakes from CP 62 Square C.**

| Category | Raw Material | Colour | Wt g | Width mm | Length mm | Thickness mm | Plat. Thickness mm | Plat. Width mm | Plat. Type | Term. | Retouch/Dam | Dorsal Scar Number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flake | Silcrete | Reddish yellow | 0.18 | 8.47 | 9.65 | 2.33 | 2.51 | 6.97 | Flaked | Feather | 0 | 2 |
| Flake | Silcrete | Grey | 3.08 | 18.53 | 26.48 | 5.63 | 6.2 | 17.55 | Flaked | Feather | Distal margin dam | 3 |

**Table 6-31 Attributes of flaked pieces from CP 62 Square C.**

| Category | Raw material | Colour | Wt g | Maximum dimension mm |
|---|---|---|---|---|
| Flaked piece | Unid. | Light grey | 0.1 | 6.47 |
| Flaked piece | Quartz | White | 0.16 | 6.28 |
| Flaked piece | Quartz | White | 0.06 | 4.77 |
| Flaked piece | Silcrete | Dark yellowish brown | 0.15 | 5.53 |
| Flaked piece | Silcrete | Dark yellowish brown | 0.03 | 7.37 |
| Flaked piece | Quartz | White | 0.07 | 6.13 |
| Flaked piece | Silcrete | Light grey | 0.11 | 7.47 |
| Flaked piece | Silcrete | Grey | 0.09 | 7.39 |
| Flaked piece | Silcrete | Yellowish grey | 0.51 | 13.54 |
| Flaked piece | Quartzite | Grey | 1.44 | 20.15 |
| Flaked piece | Silcrete | Yellowish grey | 0.37 | 11.24 |
| Flaked piece | Silcrete | Dark reddish grey | 0.2 | 15.2 |
| Flaked piece | Silcrete | Reddish yellow | 0.03 | 6.26 |

**Table 6-32 Attributes of core from CP 62 Square C.**

| Category | Raw Material | Colour | Wt g | Length mm | Width mm | Max Dim. mm | Plat. Number | Scar no | Max scar mm | Min scar mm | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Core | Silcrete | Yellowish grey | 210.01 | 47.06 | 62.92 | 72.75 | 3 | 4 | 39.08 | 10.99 | Exhausted, 7 step fractures, bevel. Re-used bevelled pounder. |

## *Discussion*

The data presented above have demonstrated that Aboriginal people have been using the eastern periphery of Tin Can Bay for at least the last 900 years. Initial use of the estuarine coastal zone which commenced around 829 cal BP at CP 62 may have been sporadic, and based around factors other than utilisation of molluscan and fish resources as evidenced by specialised plant-processing tools. TCB 75b demonstrates exploitation of a relatively low diversity of molluscs from 308 cal BP, and CP 62 rather later at 147 cal BP. This discussion section considers the nature of the use of both sites.

The artefactual evidence suggests that the raw materials employed at both CP 62 and TCB 75b remained constant over a period of some 800 years, suggesting that mechanisms for their procurement, most likely a form of embedded procurement, were well established and stable, reflecting the initial model suggested by McNiven (1999; cf. Hiscock 1994; see also Chapters 1 and 2). In common with many southeast Queensland artefact assemblages (Smith 2003), there are few formal tool types. The core with the bevelled edge from Square C at CP 62 indicates plant processing activities at or near the site, supporting McNiven's (1991c) assertion based on the artefacts from the deflated intertidal assemblage. Importantly, the backed artefact from TCB 75b demonstrates that, although the site reflects a marine-based economy based principally on the exploitation of *Saccostrea* spp., other subsistence and/or manufacturing activities also took place at the site, as there are no ethnographic references to or archaeological evidence of backed artefacts associated with mollusc procurement or processing.

The low species diversity at both sites, and most particularly the absence or minimal occurrence of *Anadara trapezia* and *Trichomya hirsuta*, is surprising given the abundance of those taxa, most notably *Trichomya hirsuta*, elsewhere in the region e.g. Booral Shell Mound. The absence is therefore unlikely to reflect taste-preference, foraging choice, or differential processing and discard. The presence of the species elsewhere in the region suggests a relationship between environmental conditions and micro-habitat structure affecting species distribution. For example, although *Pyrazus ebeninus* and *Anadara trapezia* inhabit broadly similar habitat zones, *Pyrazus* are mobile surface detrital feeders and *Anadara* are less mobile burrowing filter feeders, suggesting sedimentary structure and input, as well as nutrient input, will likely have an impact in combination with salinity, water temperature, and wave energy. The absence of *Trichomya hirsuta* indicates a lack of suitable structures on which to settle (Gosling 2003), and this is discussed further below. The species composition therefore appears to be closely related to the environmental and ecological conditions prevailing during the period of occupation.

Dredge *et al*. (1977) identified a low-saline wedge in the southern inlet, and that its hydrology was strongly influenced by the inflow of freshwater from springs and creeks on the western side of the Cooloola sand mass. They also noted extensive seagrass beds related to the stability of the local watershed, with a resultant lack of silt in the estuary (Dredge *et al*. 1977:11). Their mangrove and seagrass map (reproduced in Figure 6-7) shows the intertidal zone at Poverty Point near the location of TCB 75B has seagrass beds but is devoid of mangroves, while CP 62 in the intertidal zone west of the mouth of Cameron Creek has neither. In 1994, Fisheries Research Consultants (FRC) reported that many of the seagrass beds recorded by Dredge *et al*. had contracted, become sparser, or disappeared entirely; local fishermen advised that the seagrass beds were always in a state of flux (FRC 1994:4-8). Factors affecting seagrass distribution include salinity, temperature, light exposure and intensity, currents, tidal exposure, sediment and nutrient characteristics, and flood events; responses to these differ according to individual seagrass species (FRC 1994:10; McKenzie and Campbell 2003; McKenzie *et al*. 2014). Mangroves similarly have a mosaic-like distribution affected by salinity levels, soil characteristics including drainage, and, importantly, latitude and temperature – many of the mangrove species in the inlet are at or near the southern limits of their distribution (FRC 1994:116), and the areas in which they occur have also varied since regular monitoring commenced during the 1980s. It is clear therefore that Tin Can Inlet is a dynamic environment, and that this is reflected both in the fauna recovered from the archaeological deposits as well as more broadly in terms of their overall current occurrence. FRC (1994:25) identified three factors influencing the distribution and abundance of molluscs as depth, sediment character, and the presence/absence of seagrass beds and associated flora, while acknowledging that the distribution and biology of the macro-molluscs of the region remain poorly known. What is apparent from the FRC report is that the archaeological molluscan evidence accurately reflects the occurrence, distribution and abundance of molluscan species in the adjacent intertidal areas.

The substrates in the Great Sandy Strait and Tin Can Inlet are mostly soft and range from silts and muds to coarse shelly sands (FRC 1994:25); these are not typically associated with *Trichomya hirsuta* or *Isognomon* spp. which require hard surfaces (rocks or mangrove roots) on which to attach themselves, and these taxa were entirely absent during the FRC survey although mangroves were recorded. Generally speaking, there was a high correspondence between species diversity and abundance, and the presence of seagrass beds. However, *Anadara trapezia* were observed to occur more commonly in bare substrates or beds of *Cymodocea serrulata* than in beds of the dominant *Zostera capricorni*, the density of which may prevent spatfall larvae from penetrating the sediments and settling. Detrital-feeding whelks and carnivorous gastropods were present in all seagrass beds. The distribution and abundance of *Saccostrea* spp. was noted to be linked to the availability of suitable substrates on which spatfall could settle and attach, and that mud whelks commonly served this purpose (FRC1994:27). As suggested above, the molluscan assemblages at TCB 75b and CP 62 are therefore accurate reflections of localised micro-habitats. The juvenile mussels at TCB 75b most likely represent tidally-transported isolated spat that managed to settle, but the local conditions did not support development of a viable colony. Similarly, the isolated occurrence of *Isognomon* spp. suggests a change in local environmental conditions approximately 200 years BP that allowed the establishment of a small but viable population for a short period.

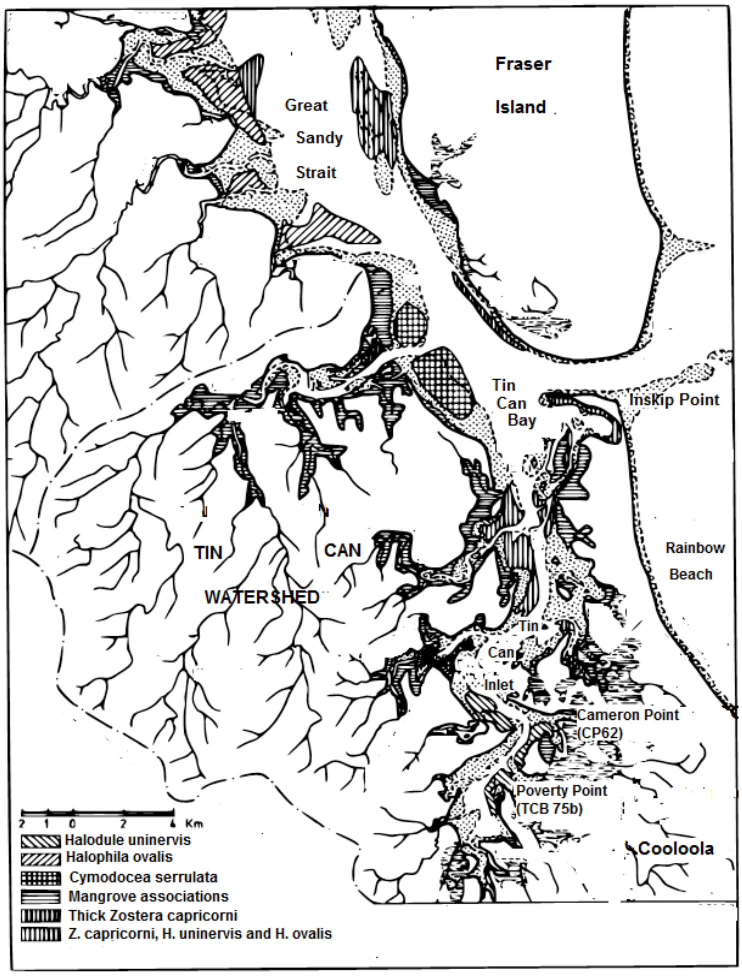


**Figure 6-7 Mangrove and seagrass areas in the study area (after Dredge *et al.* 1977: Appendix 1 Figure 2).**

The minimal occurrence of *Anadara trapezia* in both sites indicates that the adjacent seagrass beds were not conducive to settlement of larvae and establishment of colonies, while the absence of hard substrates for development of oyster reefs is indicated by the morphology of the oyster shells as well as the high proportion of valves attached to *Pyrazus ebeninus* shells.

The explanation for the absence of vertebrate remains at the sites is less straightforward. As McNiven (1991c:102) observed, the acidity of the sediments is unlikely to account for the dearth of vertebrate remains from the sites, especially as more bone was recovered from CP 62 which exhibited more persistently acidic pH levels. Terrestrial vertebrate species in the region, and for wallum zones in general, are low in both diversity and abundance, although the backed artefact from TCB 75b hints at their exploitation and perhaps also of birds (see Robertson 2002; Robertson and Attenbrow 2008; Robertson *et al*. 2009). The lack of fish bone in the assemblages may reflect the recovery procedures as the excavated material was sieved through 3mm mesh; smaller mesh sizes (e.g. 1mm) may have enhanced recovery (see e.g. Ross and Duffy 2000; Ross and Tomkins 2011; Ulm 2002; Walters 1979; but see Vale and Gargett 2001 for a contrary view). McNiven (1985, 1991c) noted that fish bones were macroscopically absent in middens sections along the coast, but the assertion that the discard of fish remains were spatially and/or temporally separated from the discard of molluscan remains (McNiven 1991c:102) seems unlikely. Ethnographic analogies must be used cautiously, but Eipper (1841), Nique and Hartenstein (1841), and Petrie (1904) do not mention differential locations for consumption of fish, shellfish, or terrestrial and avian fauna. The role of dingoes in the removal of fish and other vertebrate remains is acknowledged but their impact has yet to be adequately quantified (McNiven 1990b; Ulm 2002; Walters 1984). It is suggested that, as McNiven has observed (1991c), the absence of medium or large terrestrial vertebrates is due to the fact that they were never present at the sites. Similarly, although there is strong ethnographic evidence for a significant fishing component in subsistence activities, this is not supported by the archaeological evidence (even with the consideration of recovery techniques), and it is suggested that at TCB 75b and CP 62 at least, this activity did not contribute a large part of the diet.

The distinct chronological phases of resource use at TCB 75b and CP 62, and their implications of increased exploitation of local marine resources in the past 200-300 years, were interpreted by McNiven (1991c, 1999) as evidence of social fissioning, and secondary augmentation of long-term human activity possibly related to the 19th century European acquisition of lands resulting in Aboriginal exploitation of previously marginal subsistence environments. While these social factors cannot be dismissed, the date of 308 cal BP for TCB 75b indicates pre-European exploitation of the estuarine resources. The dynamic environment of the inlet is also a consideration, but from the evidence presented in Chapter 3 it is clear that the tidal regimes were well established by 800-900 years ago. Although direct chronological correlations are lacking from the environmental reconstructions from Fraser Island, there is evidence of a decrease in rainforest Araucarian species at c450 BP (Donders *et al*. 2006), and an increase in dry sclerophyll species, Myrtaceae (including *Eucalyptus* spp.), Casuarinaceae, *Leptospermum*, *Melaleuca*, Poaceae, and *Callitris* in the upper levels of the Wathumba and Moon Point fenlands (Moss *et al*. 2015). Taken together, these may indicate an increase in mixed woodland and forest vegetation zones which now occur on the eastern periphery of the inlet, and which have demonstrated a high correlation with sites containing midden deposits. While there may have been an associated impact on the development of favourable habitats for the molluscan species reflected in the middens, it is the change in the vegetation structure which allowed a move from more specialised resource-based ephemeral occupation based around plant exploitation in the rainforest/swamp areas evidenced by the bevel tools in the deflated artefact assemblage, to more intensive use of the marine/estuarine resources fostered by more favourable camping or longer-term residential loci. There is no evidence of over-exploitation or resource depression in the *Saccostrea* spp. from either site.

## *Conclusion*

TCB 75b and CP 62 are part of the extensive midden complexes which fringe much of the eastern periphery of Tin Can Bay Inlet. It is proposed that the sites reflect a change from early use of the area for plant resource exploitation with a minor molluscan component, to a more intensive use of estuarine resources as the vegetation zones conducive to favourable living conditions developed. Further excavation of the midden complexes is desirable, as is the metrical re-analysis of existing shell and stone assemblages, to better define site use, composition and chronology, as well as the environmental factors influencing occupation in addition to potential differential use of sites from north to south. The cultural and the environmental/ecological factors influencing site location and use are developed further in Chapter 9.

# 7. Bribie Island Sites

## Introduction

This chapter presents the results and discussion of the analysis of two sites on Bribie Island - White Patch 3 (WP3) and Bribie Island 9 (BI9). It outlines the findings of the initial analysis of WP3 (Crooks 1982), before turning to a more detailed presentation of the material analysed during the present study. This includes issues in the quantification of molluscan remains, and discussion of the composition of the assemblages relative to environmental and ecological influences. The details of the analysis of the materials from BI9 are presented and discussed, as is the importance of the site to considerations of the occupation of Moreton Bay during the marine transgression.

## Bribie Island

Bribie Island is the northernmost island of Moreton Bay (Figure 7-1). It is separated from the mainland on the north and west by Pumicestone Passage, and bounded on the south and east by Moreton Bay and the Pacific Ocean. Pumicestone Passage is quite narrow, approximately 1.5km at its widest point, with an average depth of <2m. In the north near Bell's Creek it can be waded at very low tides. The Passage is a "mesotidal, elongate back-barrier lagoon estuary with a tidal inlet at either end" (Lang *et al*. 1998:89), divided into three parts: northern and southern tidal deltas, a microtidal central muddy estuarine basin fed on the west by three small tidal creeks, and bay-head deltas at Elimbah and Coochin Creeks, also on the western side.

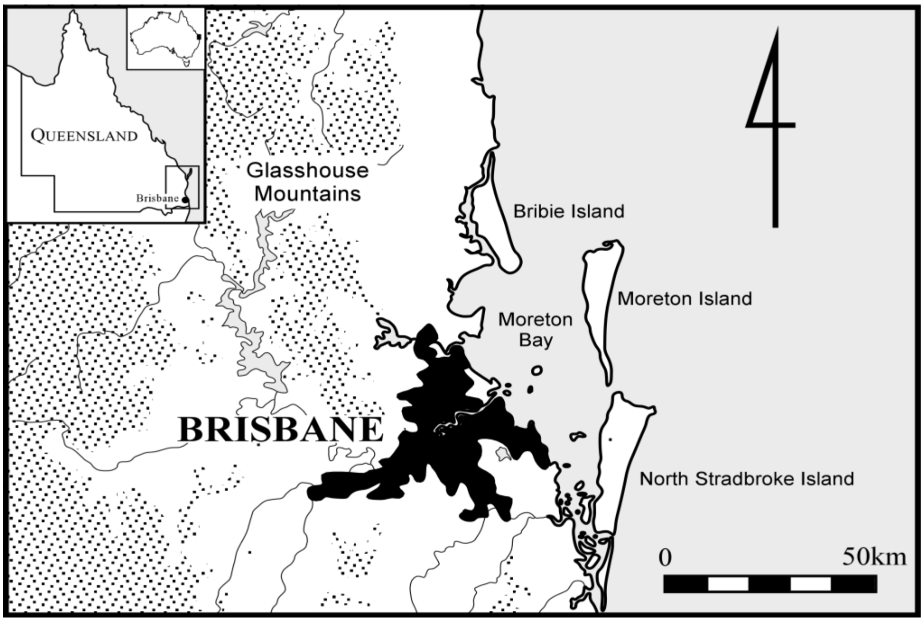


**Figure 7-1 Location of Bribie Island within Moreton Bay (Smith 2006).**

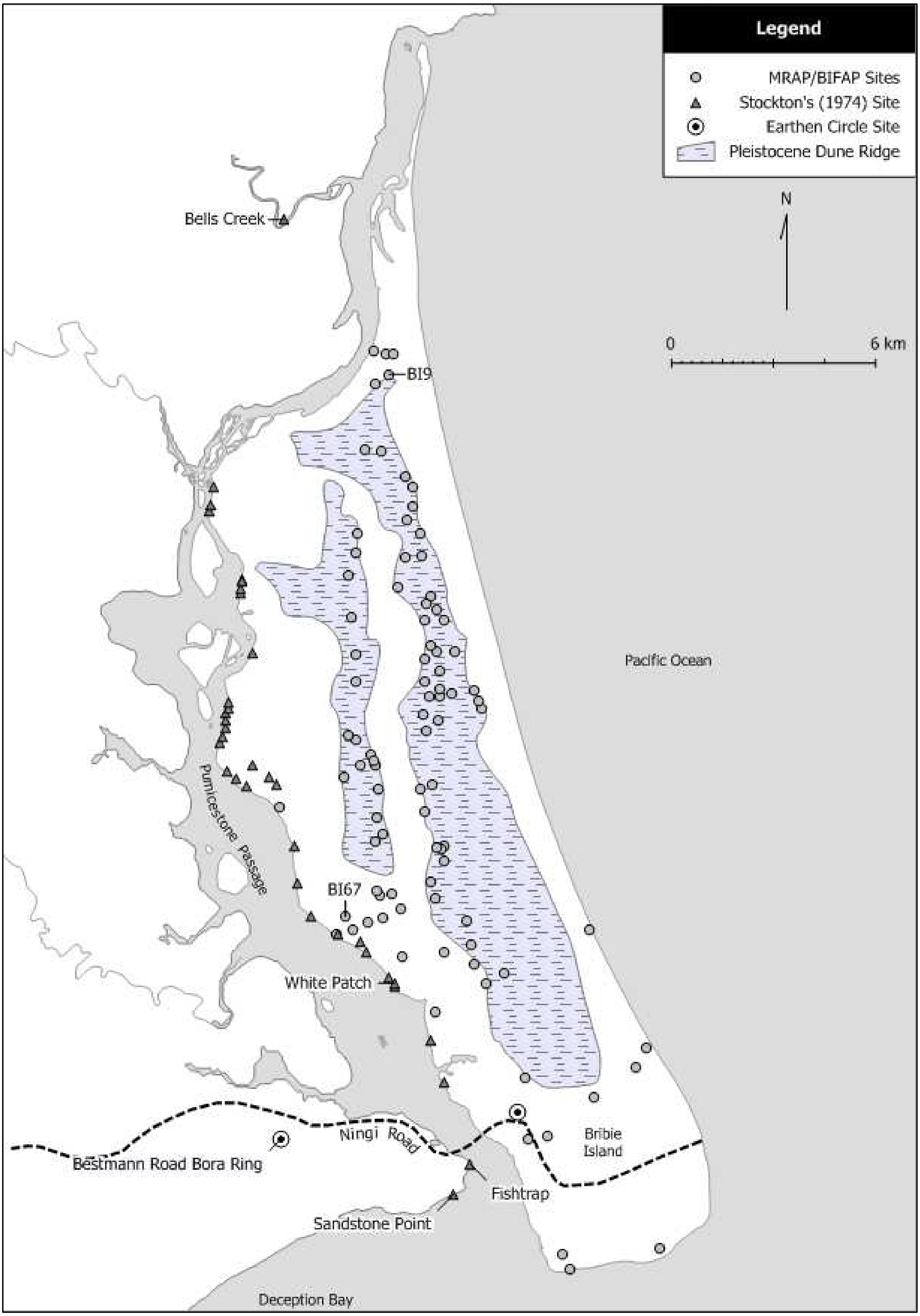


**Figure 7-2 Location of sites on Bribie Island (after Smith 2006).**

The island is 32km long and up to 8km wide, and mostly between 5m to 10m in elevation, although some areas rise to 15m. It is largely composed of north-south trending remnant Pleistocene aeolian dunes, with east-west trending Holocene dunes over the southern quarter of the Island, with the soil matrix composed entirely of podzols and siliceous sands (Hekel *et al*. 1979:8-9; Willmott and Stevens 1988). In east-west cross section the terrain exhibits low peaks and swales. There is no stone, other than outcrops of coffee rock. A central barrier swamp extends north-south through the island fed from the northwest by Westaway Creek. There are also numerous small standing areas of water, and lagoons on the eastern side some of which are now breached and open to the sea. Bribie Island is typical of the coastal lowlands or wallum country characterised by Coaldrake (1961:5). Petherick *et al.* (2008b:7) suggest that the wallum floristic communities, dominated by *Banksia* species, developed in the area throughout the Holocene. Bribie Island National Park covers approximately two-thirds of the island, and includes a 4000ha commercial plantation which covers most of the Pleistocene dune ridges. More than 120 sites have been recorded on the Island with most of these identified as part of MRAP and the Bribie Island Forest Archaeological Project (BIFAP) (Smith 1992, 1997, 1999, 2003, 2006; Figure 7-2).

### *White Patch 3*

In 1974 Haglund excavated five midden sites (White Patch 1-5) recorded by Stockton (1974) on a sand ridge eroding landward on the southwest coast of Bribie Island facing Pumicestone Passage near White Patch (Figure 7-2), in the central microtidal estuarine basin (Lang *et al*. 1998). The sites are approximately 300m southeast of site BI67, a large (c3km$^2$) undated midden scatter with cultural material to a depth of 50cm (MRAP files; Smith 1992, 2003). The original vegetation comprised littoral species, *Melaleuca quinquenervia* (broad leaved paperbark) and *Banksia aemula* (wallum banksia), with some *Eucalyptus intermedia* (pink bloodwood) (Smith 2003:43). The notes and some material from the excavations were lodged with the Queensland Museum, but otherwise the work remained largely unreported until Crooks' (1982) BA Honours thesis. The general condition and content of four of the middens was considered poor, with White Patch 3 (WP3) considered to be in the best condition because of a relatively more sheltered position, and was also the "richest" in "archaeological debris" (Crooks 1982:49). Crooks had access to Haglund's field notes, preliminary reports, photographs, and the stone artefacts from all sites, but not the faunal assemblage, which she reported on the basis of Haglund's notes. She analysed the stone artefact assemblages in addition to an assemblage collected from the beach at White Patch over a period of some 20 years by a local resident, Mr Ted Clayton, and held at the Queensland Museum.

The maximum extent of the WP3 midden is unrecorded, but the original plan indicates 35m$^2$, on a ridge with contours from 5.5m to 6.5m in height. There are no details available regarding excavation methods or techniques for recovery of cultural material. Six squares totalling 4.5m$^2$ (Ulm 2002:81) were excavated; the analysis here is based on the WP3 material from square C50 held by the Queensland Museum. The estimated volume of the C50 excavation is 0.125m$^3$. The stratigraphic profile for squares C50 and C51 is reproduced in Figure 7-3 with the original unmatched scale bars retained. There is no accompanying description of the strata labelled 1.1 to 1.5, other than that there was an overlying humic layer, and that "The midden deposit forms a single unit composed of many distinct strata" (Haglund in Crooks 1982:60). Similarly, the two charcoal samples obtained for dating purposes came "from Level 'b' " and "Level 'd' " (Haglund in Crooks 1982:64-65), although the levels are not otherwise mentioned or described, and no depths are provided. It is presumed that Level 'b' equates to the level labelled 1.2, and Level 'd' to the level labelled 1.4.

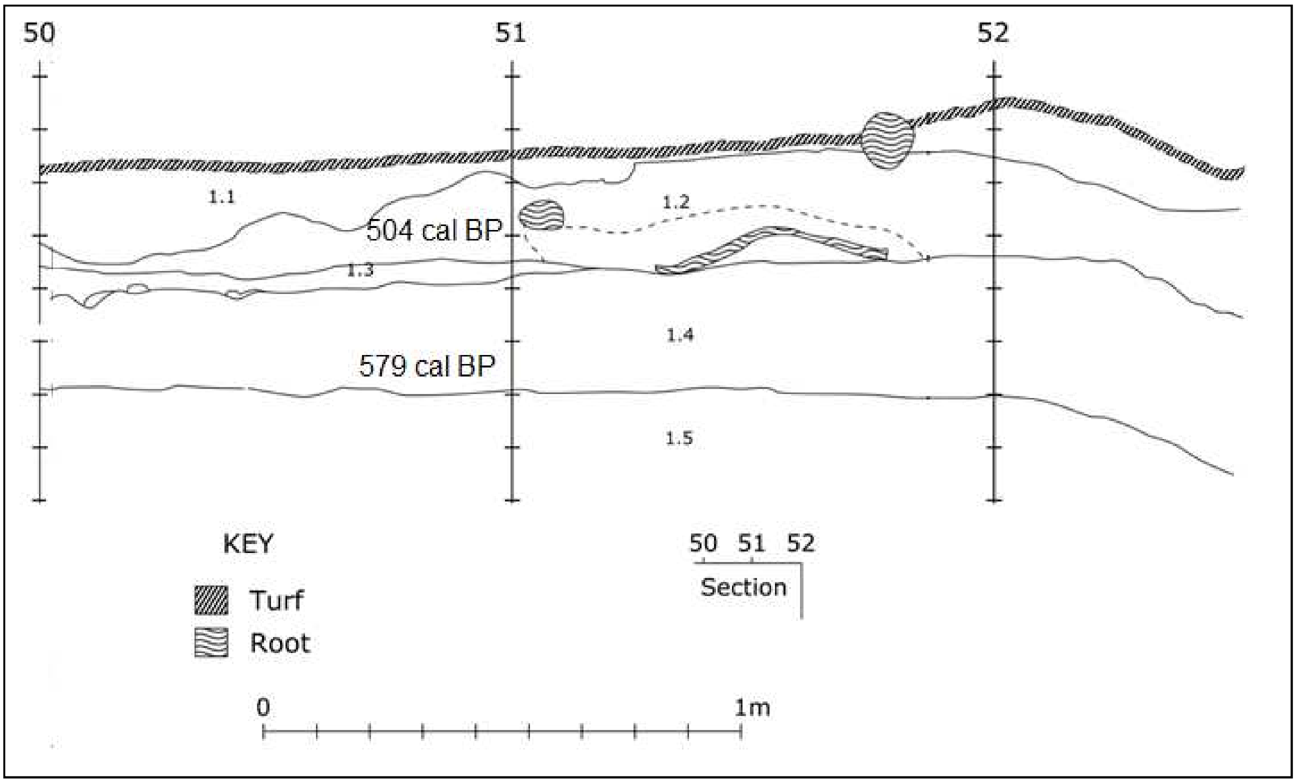


**Figure 7-3 Stratigraphic profile of WP3 square C50 with approximate locations of 14C age determinations (after Crooks 1982:62). Descriptions of strata are not available.**

Gillespie and Temple (1979:104) in their report on Sydney University Natural Radiocarbon Measurements state that the upper sample (SUA-480) came from the top of the midden deposit, and the lower (SUA-481) from the base of the midden 25cm below. This information must have been provided by Haglund when the samples were submitted, and it must therefore be assumed that the scale bar to the right of the profile is the more correct although the exact location within the stratigraphic profile of the dating samples remains unknown. The upper sample returned a date of 450±95 BP, and the lower sample a date of 670±95 BP (Gillespie and Turner 1979:104; Haglund in Crooks 1982:64-65). Ulm and Reid (2000:37) reported median ages of 504 cal BP and 579 cal BP respectively (Table 7-1), and these are the ages used here.

**Table 7-1 Radiocarbon age determinations for WP3 square C50 (after Crooks 1982; Ulm and Reid 2000:37).**

| SU | XU | Depth cm | Sample | Laboratory code | Conventional 14 C date | 2σ calibrated age range |
|---|---|---|---|---|---|---|
| 1.2? | ? | Uncertain | Charcoal | SUA-480 | 450±95 BP | 625(504)296 |
| 1.4? | ? | Uncertain | Charcoal | SUA-481 | 670±95BP | 734(649,579,570)510 |

## Molluscs

The molluscan remains for WP3 C50 were originally quantified solely by weight, with a total of 7731g. Weights for individual species were not provided, but instead presented as percentages per spit (Crooks 1982:63). Four main species were identified: whelk (presumably *Pyrazus ebeninus*), cockle (*Anadara trapezia*), oyster (*Saccostrea* spp.), and mussel (*Trichomya hirsuta*). A fifth category, 'other', was also included. The molluscan weights by percentage by spit are reproduced in Figure 7-4.

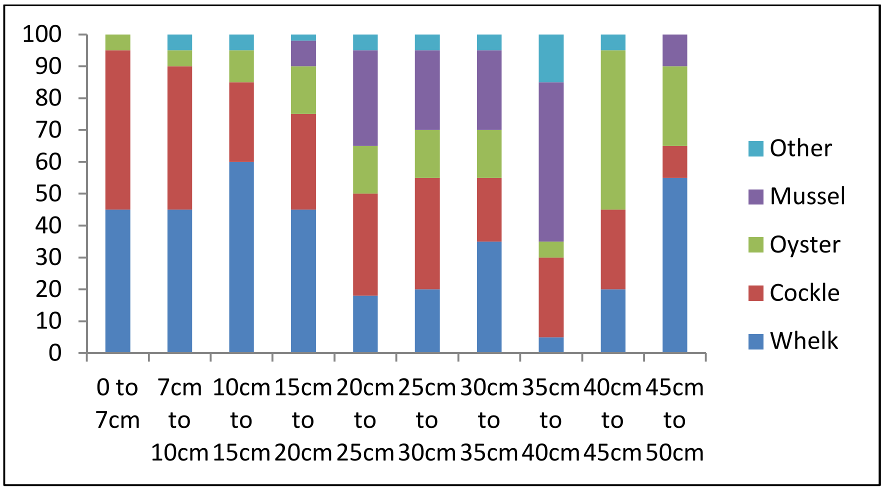


**Figure 7-4 Molluscan weights by percentage per spit. All values are approximate (adapted from Crooks 1982:63).**

In order to attempt meaningful analysis of the shellfish and other cultural remains relative to the layers depicted in the stratigraphic profile rather than the arbitrary spits, stratigraphic units have been ascribed (Table 7-2). Some overlap between the stratigraphic units is inevitable as a result of the excavation within arbitrary spits.

**Table 7-2 Ascribed stratigraphic units (after Haglund in Crooks 1982). No descriptions of the strata are available.**

| Stratigraphic Unit | Spit | Original stratigraphic designation |
|---|---|---|
| SU1 | 0-7cm<br>7-10cm | 1.1 |
| SU1-2 | 10 -15cm | Lower 1.1, mostly 1.2 |
| SU2-3 | 15 -20cm | Lower 1.2, mostly 1.3 |
| SU3-4 | 20 -25cm | Mostly 1.3, upper 1.4 |
| SU4 | 25 - 30cm<br>30-35cm<br>35-40cm | 1.4 |
| SU5 | 40-45cm<br>45-50cm | 1.5 |

Eighteen molluscan species were recorded for C50 in the present study, with a total NISP of 6508 (Table 7-3), a total MNI of 771 (Table 7-4) with an estimated density of 6168 per $m^3$ (Table 7-5), and a total weight of 6292.21g (Table 7-6). The total weight is less than that recorded by Crooks (1982). This discrepancy is not surprising given that the molluscan remains from the 25-30cm spit (980g) were not lodged with the Queensland Museum (and therefore unavailable for analysis), although the difference between the two total weights is greater than the value of that spit. As with the other sites a conservative approach to identifying the taxa to genera and species was taken (see Chapter 4).

**Table 7-3 Molluscan NISP by SU for WP3 Square C50.**

| **Taxon** | **SU1 NISP** | **SU1-2 NISP** | **SU2-3 NISP** | **SU3-4 NISP** | **SU4 NISP** | **SU5 NISP** | **Total NISP** | **%Total NISP** |
|---|---|---|---|---|---|---|---|---|
| *Acrilla acuminata* | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0.02% |
| *Anadara trapezia* | 146 | 198 | 124 | 89 | 105 | 24 | 686 | 10.54% |
| *Bembicium auratum* | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 0.03% |
| *Chama* spp. | 0 | 1 | 0 | 5 | 4 | 2 | 12 | 0.18% |
| *Conuber sordidum* | 0 | 5 | 5 | 0 | 4 | 0 | 14 | 0.22% |
| *Donax deltoides* | 17 | 7 | 20 | 17 | 7 | 0 | 68 | 1.04% |
| *Figuladra mattea* | 0 | 0 | 0 | 4 | 0 | 0 | 4 | 0.06% |
| *Herpetopoma* sp. | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 0.03% |
| Hiatellidae | 0 | 0 | 4 | 1 | 0 | 0 | 5 | 0.08% |
| Land snail | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0.03% |
| Lucinidae | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0.02% |
| *Monoplex* sp. | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0.02% |
| *Nassarius jonasii* | 0 | 0 | 2 | 1 | 1 | 0 | 4 | 0.06% |
| *Pyrazus ebeninus* | 48 | 102 | 98 | 48 | 27 | 7 | 330 | 5.07% |
| Ranellidae | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0.02% |
| *Saccostrea* spp. | 34 | 30 | 177 | 164 | 102 | 108 | 615 | 9.65% |
| *Scutus* sp. | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0.02% |
| *Trichomya hirsuta* | 13 | 17 | 264 | 2406 | 1988 | 58 | 4746 | 72.93% |
| **Total** | **273** | **361** | **697** | **2736** | **2242** | **199** | **6508** | **100.00%** |

**Table 7-4 Molluscan MNI by SU for WP3 Square C50.**

| **Taxon** | **SU1 MNI** | **SU1-2 MNI** | **SU2-3 MNI** | **SU3-4 MNI** | **SU4 MNI** | **SU5 MNI** | **Total MNI** | **% Total MNI** |
|---|---|---|---|---|---|---|---|---|
| *Acrilla acuminata* | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0.00% |
| *Anadara trapezia* | 33 | 63 | 42 | 35 | 47 | 7 | 227 | 29.44% |
| *Bembicium auratum* | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 0.26% |
| *Chama* sp. | 1 | 0 | 0 | 5 | 2 | 1 | 9 | 1.17% |
| *Conuber sordidum* | 0 | 5 | 5 | 0 | 4 | 0 | 14 | 1.82% |
| *Donax deltoides* | 1 | 5 | 1 | 6 | 3 | 0 | 16 | 2.08% |
| *Figuladra mattea* | 0 | 0 | 0 | 4 | 0 | 0 | 4 | 0.52% |
| *Herpetopoma* sp. | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 0.26% |
| Hiatellidae | 0 | 0 | 4 | 1 | 0 | 0 | 5 | 0.65% |
| Land snail | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0.26% |
| Lucinidae | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0.13% |
| *Monoplex* sp. | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0.13% |
| *Nassarius jonasii* | 0 | 0 | 2 | 1 | 1 | 0 | 4 | 0.52% |
| *Pyrazus ebeninus* | 29 | 51 | 47 | 16 | 17 | 6 | 166 | 21.53% |
| Ranellidae | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0.13% |
| *Saccostrea* spp. | 3 | 14 | 22 | 23 | 32 | 75 | 169 | 21.92% |
| *Scutus* sp. | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0.13% |
| *Trichomya hirsuta* | 3 | 2 | 31 | 69 | 39 | 2 | 146 | 18.94% |
| **Total** | **71** | **142** | **157** | **161** | **149** | **91** | **771** | **99.87%*** |

*Correct to two decimal places.

**Table 7-5 Volume-corrected MNI estimates for WP3 C50.**

| **WP3 C50** | | **SU1 $m^3$** | **SU1-2 $m^3$** | **SU2-3 $m^3$** | **SU3-4 $m^3$** | **SU4 $m^3$** | **SU5 $m^3$** | **Total** |
|---|---|---|---|---|---|---|---|---|
| | | 0.025 | 0.0125 | 0.0125 | 0.0125 | 0.0375 | 0.025 | 0.125 |
| All shell | MNI | 71 | 142 | 157 | 161 | 149 | 91 | 771 |
| | MNI/m3 | 2840 | 11360 | 12560 | 12880 | 3973 | 3640 | 6168 |
| *Anadara trapezia* | MNI | 33 | 63 | 42 | 35 | 47 | 7 | 227 |
| | MNI/m3 | 1320 | 5040 | 3360 | 2800 | 1253 | 280 | 1816 |
| *Donax deltoides* | MNI | 1 | 5 | 1 | 6 | 3 | 0 | 16 |
| | MNI/m3 | 40 | 400 | 80 | 480 | 80 | 0 | 128 |
| *Pyrazus ebeninus* | MNI | 29 | 51 | 47 | 16 | 17 | 6 | 166 |
| | MNI/m3 | 1160 | 4080 | 3760 | 1280 | 453 | 240 | 1328 |
| *Saccostrea* sp. | MNI | 3 | 14 | 22 | 23 | 32 | 75 | 169 |
| | MNI/m3 | 120 | 1120 | 1760 | 1840 | 853 | 3000 | 1352 |
| *Trichomya hirsuta* | MNI | 3 | 2 | 31 | 69 | 39 | 2 | 146 |
| | MNI/m3 | 120 | 160 | 2480 | 5520 | 1040 | 80 | 1168 |

**Table 7-6 Molluscan taxa by weight by SU for WP3 Square C50.**

| **Taxon** | **SU1 wt g** | **SU1-2 wt g** | **SU2-3 wt g** | **SU3-4 wt g** | **SU4 wt g** | **SU5 wt g** | **Total wt g** | **%Total wt g** |
|---|---|---|---|---|---|---|---|---|
| *Acrilla acuminata* | 0 | 0 | 0 | 0 | 0.9 | 0 | 0.9 | 0.01% |
| *Anadara trapezia* | 396.66 | 721.42 | 431 | 474.28 | 200.52 | 47.82 | 2271.7 | 36.10% |
| *Bembicium auratum* | 0 | 0 | 0.32 | 0 | 0.32 | 0 | 0.64 | 0.01% |
| *Chama* sp. | 0.86 | 0 | 0 | 7.57 | 0.84 | 0.33 | 9.6 | 0.15% |
| *Conuber sordidum* | 0 | 6.68 | 5.3 | 0 | 4.85 | 0 | 16.83 | 0.27% |
| *Donax deltoides* | 6.41 | 12.45 | 4.34 | 28.06 | 7.21 | 0 | 58.47 | 0.93% |
| *Figuladra mattea* | 0 | 0 | 0 | 12.57 | 0 | 0 | 12.57 | 0.20% |
| *Herpetopoma* sp. | 0 | 0 | 1.64 | 0 | 0.28 | 0 | 1.92 | 0.03% |
| Hiatellidae | 0 | 0 | 0.49 | 0.24 | 0 | 0 | 0.73 | 0.01% |
| Land snail | 0.09 | 0 | 0 | 0 | 0 | 0 | 0.09 | 0.00% |
| Lucinidae | 0.29 | 0 | 0 | 0 | 0 | 0 | 0.29 | 0.00% |
| *Monoplex* sp. | 0 | 0 | 0.17 | 0 | 0 | 0 | 0.17 | 0.00% |
| *Nassarius jonasii* | 0 | 0 | 0.16 | 0.08 | 0.06 | 0 | 0.3 | 0.00% |
| *Pyrazus ebeninus* | 443.31 | 680.23 | 685.29 | 231.32 | 209.7 | 95.54 | 2345.39 | 37.27% |
| Ranellidae | 0 | 0 | 0 | 1.09 | 0 | 0 | 1.09 | 0.02% |
| *Saccostrea* sp. | 25.16 | 69.85 | 174 | 196.18 | 121.68 | 298.67 | 885.54 | 14.07% |
| *Scutus* sp. | 0 | 0 | 0 | 0 | 0.34 | 0 | 0.34 | 0.01% |
| *Trichomya hirsuta* | 1.86 | 7.63 | 109.28 | 354.81 | 192.79 | 19.27 | 685.64 | 10.90% |
| **Totals** | **874.64** | **1498.26** | **1411.99** | **1306.2** | **739.49** | **461.63** | **6292.21** | **100.00%** |

It is apparent from Tables 7-3, 7-4, and 7-6, that the quantification of relative abundance of the shellfish species by weight alone presented by Crooks (1982:63) is likely biased due to differential taxonomic size and robusticity. By comparison, the rank order of 'economic' species by total NISP are *Trichomya hirsuta*, *Anadara trapezia*, *Saccostrea* spp., *Pyrazus ebeninus*, and *Donax deltoides*, and by total MNI *Anadara trapezia*, *Saccostrea* spp., *Pyrazus ebeninus*, *Trichomya hirsuta* and *Donax deltoides*.

### *Molluscan Richness and Diversity*

The application of the measures described in Chapter 4 for assessing taxonomic richness, evenness, and diversity broadly indicate the dominance of a few species relative to the NTAXA, as well as moderate to high species diversity and richness (Table 7-7).

**Table 7-7 Diversity measures for WP3 Square C50.**

| **Diversity Measure** | |
|---|---|
| NTAXA | 16 |
| MNI | 771 |
| Simpson's Index (1-D) | 0.782 |
| Shannon Index of Diversity ( ′H) | 1.714 |
| Shannon Index of Evenness ( E) | 0.618 |

*Anadara trapezia*

The *Anadara trapezia* NISP of 686 accounted for 10.54% of the total NISP while the MNI of 227 accounted for 29.44% of the total MNI. Lengths were obtained for 278 unbroken valves (*A. trapezia* are equivalves and for this purpose there was no need to distinguish between right and left valves), and the descriptive statistics are detailed in Table 7.8.

**Table 7-8 Descriptive statistics for A. trapezia valve lengths in mm by SU for WP3 square C50.**

| SU | N | Minimum | Maximum | Mean | Range | Std. deviation |
|---|---|---|---|---|---|---|
| SU1 | 40 | 24.32 | 45.59 | 33.42 | 21.27 | 4.81 |
| SU1.2 | 96 | 18.67 | 49.79 | 32.48 | 31.12 | 5.67 |
| SU2.3 | 42 | 12.00 | 48.59 | 33.73 | 36.59 | 6.92 |
| SU3.4 | 53 | 11.20 | 50.32 | 33.77 | 39.12 | 7.62 |
| SU4 | 28 | 10.76 | 41.60 | 32.55 | 30.84 | 5.74 |
| SU5 | 19 | 7.86 | 38.75 | 20.79 | 30.89 | 10.74 |

The results of a Shapiro-Wilk test of normality (SU1 $W$=0.975, $df$=40, $p$=0.517; SU1.2 $W$=0.991, $df$=96, $p$=0.797; SU2.3 $W$=0.967, $df$=42, $p$=0.269; SU3.4 $W$=0.948, $df$=53, $p$=0.021; SU4 $W$=0.813, $df$=28, $p$=0.000; SU5 $W$=0.882, $df$=19, $p$=0.023) indicated that valve lengths did not follow a normal distribution. Levene's test of homogeneity of variance indicated that the variances for each SU were significantly different ($L$=6.586, $df1$=5, $df2$=272, $p$=.000). ANOVA was used to compare mean size by SU, with the results ($F$=12.66, $df$=5, *72*, $p$=.000) indicating a significant difference across the SUs. As the assumption of homogeneity of variance was violated, additional nonparametric robust tests of equality of means were conducted, with the results of both the Welch ($W$=5.114, $df1$=5, $df2$= 86.3, $p$=*.000*) and Brown-Forsythe ($B$=10.431, $df1$=5, $df2$=91.38. $p$=.000) also being significant. Plotting the frequencies demonstrated that while SUs 1-4 generally conform to a normal distribution, SU5 does not (Figure 7-5), reflecting the low minimum, maximum and mean valve lengths.

Smaller valves (<30mm) account for 42% of the individuals in SUs 4 and 5. The relative frequency of larger, sexually mature valves (i.e. those ≥ 30mm in length [Appendix A]) increases in the upper levels from 58% to 70.79%. The combination of valve size with proportions of juveniles suggests that the population at the commencement of the midden formation may have been a recently established colony, with the valve lengths representing a recently settled cohort, the majority of which were less than one year old. The *A. trapezia* valve lengths as well as increased relative abundance in the upper units do not demonstrate evidence of over-exploitation or resource depression during the formation of the midden.

The fragmentation ratios (NISP: MNI) for the site are low (SU1 4.42; SU1-2 3.14; SU2-3 2.95; SU3-4 2.54; SU4 2.23; and SU5 3.42). The calculation of sedimentation rates after the method described by Stein *et al*. (2003) for deposition of sediments between the base and top of the midden is 33.33cm/100 years, toward the higher end of an intermediate rate of deposition. A relatively robust species, it is likely that the *A. trapezia* in the lowest level were trampled at the commencement of midden deposition. The discarded shells became more protected as the deposits accumulated and the fragmentation ratios dropped accordingly, while those at the top were trampled following abandonment of the site. None of the shells exhibited evidence of burning, implying that they were opened at low temperature fires.

### *Saccostrea spp.*

The *Saccostrea* spp. NISP of 615 accounted for 9.65% of the total NISP, while the MNI of 169 accounted for 29.44% of the total MNI. Heights were obtained from 46 complete lower valves or cups from SUs 1-2 to 5 (no complete valves were recovered from SU1); the descriptive statistics are detailed in Table 7-9. Although a smaller sample than that of complete upper valves or lids (n=111), the lower valves of *Saccostrea* spp. exhibit morphological responses to the substrates to which they attach, and to environmental changes. They are also better indicators of the overall size of individuals due to the variability in hinge height which is not reflected in the upper valves. It is acknowledged that the individual SU samples are small and do not lend themselves to meaningful statistical analyses. Despite these sample size issues, the information provides an approximate indication of valve height variation through the midden deposit. The mean values for all SUs indicate sexually mature males (≥20 mm), while the maximum values for all SUs indicates the presence of sexually mature females (≥50mm) (Catterall and Poiner 1987:120; Appendix A). This indicates the harvesting of a relatively mature population not subject to over-exploitation.

**Table 7-9 Descriptive statistics for Saccostrea lower valve heights in mm by SU for WP3 square C50.**

| SU | N | Minimum | Maximum | Mean | Range | Std. deviation |
|---|---|---|---|---|---|---|
| 1-2 | 5 | 21.19 | 65.86 | 45.31 | 44.67 | 19.22 |
| 2-3 | 19 | 16.22 | 57.37 | 29.09 | 41.15 | 13.06 |
| 3-4 | 7 | 25.27 | 60.14 | 45.85 | 34.87 | 11.32 |
| 4 | 8 | 12.77 | 58.00 | 24.17 | 45.23 | 14.78 |
| 5 | 7 | 38.03 | 63.06 | 53.60 | 25.03 | 10.67 |

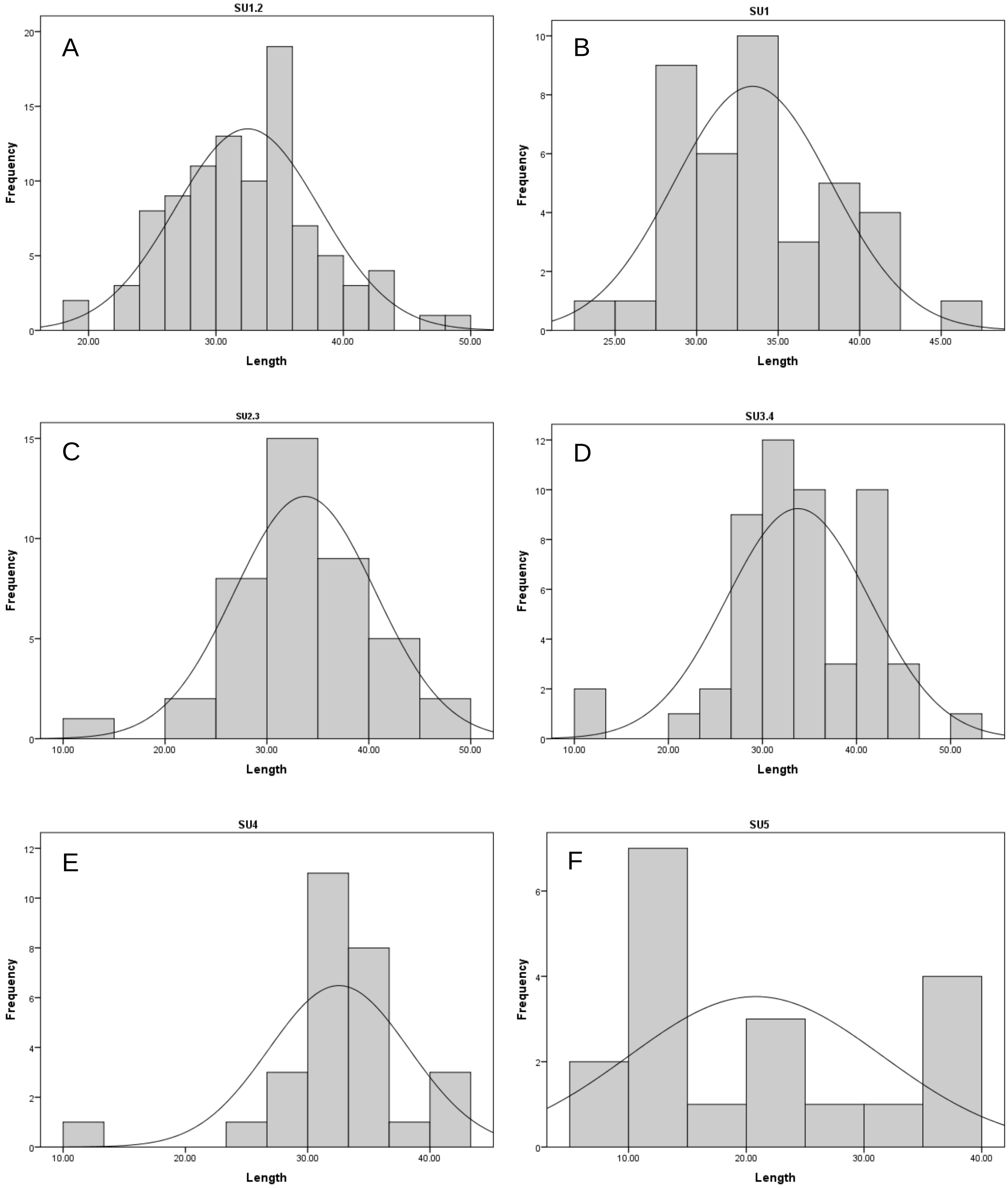


**Figure 7-5  Size frequency histograms of *A.trapezia* valve lengths for SU1 (A), SU1.2 (B), SU2.3 (C), SU3.4 (D), SU4 (E) and SU5 (F).**

Nine of the 19 complete lower valves (47.36%) from SU2.3 exhibited very thin shell structure, and were flattened along one lateral margin, indicating growth directly either on rock or a firmly packed surface. Another lower valve was cemented to at least three other fragmented lower valves. Two of the complete lower valves in SU3.4 were cemented to two other valves, while in SU5 four whole lower valves (57.14%) were cemented together. SU4 also had two complete lower valves and two partial lower valves that exhibited very thin shell structure. SU2.3 and SU4, coincident with the thin-walled valves, also had the lowest minimum valve heights, with SU4 also having the lowest mean value. It is again acknowledged that the sample sizes are small, however the co-occurrence of thin walled and smaller valves is unlikely to be unrelated. Post-depositional taphonomic factors including physical degradation and particularly chemical alteration must be a consideration, as roasting over high heat can cause the conchiolin which forms the periostracum of valves to degrade and become friable; these types of valves usually also have a covering of small re-crystallised calcium carbonate fragments. Slow degradation of the conchiolin by bacterial decomposition or oxidation (e.g. oxygen dissolved in water) leaves valves with exposed calcium carbonate prisms (Kent 1992:15). The WP3 *Saccostrea* spp. remains did not otherwise exhibit evidence of exposure to high temperatures (e.g. change in colour), nor did they exhibit calcium carbonate prisms. Ante-mortem factors such as those described by Gosling (2003:7) and which result in thinning of the conchiolin include mechanical abrasion, fouling organisms (e.g. algal blooms), parasites and diseases. The condition of the whole valves suggests that they were not tightly packed in clusters or on oyster reefs and this may have rendered them more susceptible to abrasion by suspended sediments during freshwater flood events (from the tributary creeks flowing into Pumicestone Passage and the Brisbane River) or extreme tidal ranges influenced by storms. Equally there may have been two episodes during the formation of the midden when the oysters were exposed to diseases that affected both their growth rates and shell structure (see Appendix A).

The fragmentation ratios by SU are variable (SU1 11.33; SU1-2 2.14; SU 2-3 8.04; SU3-4 7.13; SU4 3.18; and SU5 1.44). The relatively higher fragmentation ratios in SU2-3 and SU3-4 perhaps reflect thin valves or more intensive site use, while those in SU1 suggest post-depositional trampling.

*Pyrazus ebeninus*

The *Pyrazus ebeninus* NISP of 330 accounted for 5.07% of the total NISP and the MNI of 166 accounted for 21.53% of the total MNI. Only six complete specimens were recovered, rendering meaningful statistical analysis of shell height impossible. Three of the four specimens recovered from SU1-2 measured 70.67mm, 69.18mm, and 59.05mm within the range (50-70mm) at which sexual maturity is reached (Vohra 1965); the fourth was a sub-adult measuring 42.25mm. The specimen from SU2-3 measured 66.63mm and that from SU3-4 57.63mm. All broken and partial shells demonstrated breakage patterns consistent with the ethnographically recorded method for removal of the snail, i.e. breaking off the top of the shell to break the suction (see e.g. Meehan 1982). The breakages observed are unlikely to be the result of natural processes due to the robustness of adult *Pyrazus ebeninus* shells and the likelihood that humans are their only successful predators (John Healy, pers. comm., 2012, Appendix A). The breakage pattern was also consistent, with the majority of shells (60.84%) broken above the level of the second whorl.

The fragmentation ratios by SU were low, as is to be expected from such robust shells (SU1 1.65; SU1-2 2; SU2-3 2.08; SU3-4 3; SU4 1.58; and SU5 1.44). None of the shells exhibited evidence of burning, implying that they were cooked on low temperature fires, and therefore the integrity of the shell matrix was not weakened as a result.

### *Trichomya hirsuta*

The *Trichomya* NISP of 4746 accounted for 72.93% of the total NISP although the MNI of 146 accounted for only 18.94% of the total MNI. Heights were obtained for 40 unbroken valves from SU2-3, SU3-4 and SU4. The descriptive statistics are detailed in Table 7-10. The individual SU sample sizes are larger than those for the *Saccostrea* spp. whole valves, and the Shapiro-Wilk test of normality (which accommodates sample sizes <50) indicated a normal distribution for valve heights (SU2-3 $W$=.940, $df$=15, $p$=.388; SU 3-4 $W$=.915, $df$=17, $p$=.124; SU4 $W$=.926, $df$=18, $p$=.163) and significant differences in the valve heights. Given the sample sizes, a Kruskal-Wallis test was employed as a non-parametric alternative to ANOVA to test the differences in heights between SUs. The results indicate significant differences between all SUs: for SUs 2-3 and 3-4, $x^2$=8.129, $df$=1, $p$=.004; for SUs 2-3 and 4, $x^2$=5.868, $df$=1, $p$=.015; and for SUs 3-4 and 4, $x^2$=5.868, $df$=1, $p$=.015.

**Table 7-10 Descriptive statistics for Trichomya hirsuta valve heights in mm by SU for WP3 Square C50.**

| SU | N | Minimum | Maximum | Mean | Range | Std. deviation |
|---|---|---|---|---|---|---|
| 2-3 | 15 | 8.60 | 25.57 | 16.40 | 16.97 | 5.43 |
| 3-4 | 17 | 11.00 | 51.83 | 30.55 | 40.83 | 14.23 |
| 4 | 18 | 12.50 | 39.67 | 23.21 | 27.17 | 8.05 |

Only four juvenile *Trichomya hirsuta* valves (≤ 10mm) were identified in the total whole valve count. None of the whole valves approached the maximum size of 65mm recorded for the species (Appendix A), although this could be a reflection of the maintenance of a smaller population (Whitaker 2008) or the location of the mussel beds and tidal availability for exploitation (Thakar *et* *al*. 2015). The fragmentation ratios were remarkably high in SU3-4 (34.86), SU4 (50.97) and SU5 (29), but much lower in SU1 (4.33), SU1-2 (8.5) and SU2-3 (8.51). None of the valves exhibited evidence of high-temperature burning which may have compromised structural integrity. Campbell (2012:6) commented that mussel shells are extraordinarily fragile, which renders them the most badly fragmented shells in the archaeological record, although this in itself does not explain the differing levels of fragmentation throughout the deposit which do not correspond with those of the other species. It may relate to valve area and valve angle relative to thickness, whereby larger individuals become more fragmented. Equally, it may represent differential effects of post-depositional processes on taxa with different morphologies.

*Donax deltoides*

*Donax deltoides* comprised 1.04% of the total NISP with a count of 68, and 2.08% of the total MNI with a count of 16. As Crooks (1982) does not mention the species individually, it must have been included in the 'other' category although it commonly occurs in and often dominates surf coast middens after about c.1000 BP (e.g. McNiven 2006), and occasionally occurs in estuarine middens, although never in sufficient numbers to suggest that it was a significant dietary component at those locations. The nearest source for *D. deltoides* is the surf beach on the east coast of Bribie Island, currently some 6.5km from WP3. Erosion rates (Smith 1992, 2003) suggest that at the time of the formation of the midden at WP3 the eastern coastline would have been some distance further away; the central swamp may also have been an impediment to direct access (Smith 2003). An articulated pair of valves measuring 43.8mm in length and a right valve measuring 40.51mm was recovered from SU1-2. A further five valves from SU3-4 had an average value of 44.41mm, and a whole valve from SU4 measured 55.25mm. The valve lengths potentially indicate that a sexually mature population (Appendix A) was being harvested, although the sample size is small. None of the valves exhibited evidence of burning or exposure to high temperatures. Fragmentation through the SUs was variable (SU117; SU1-2 1.4; SU2-3 20; SU3-4 2.83; and SU4. 2.33) with the high values skewed by the low number of individuals identified. No *D. deltoides* was recorded below 35cm.

Of most importance, however, was the recovery of a *D. deltoides* artefact from SU3-4. It is not reported by Haglund in Crooks (1982), and may have been overlooked in the initial sorting when *D. deltoides* was included in the 'other' category. The artefact is made on the longest *D. deltoides* valve in the assemblage (55.85mm); it has a 17.74mm diameter aperture in the middle of the valve, usewear along the posterior and ventral margins, and smoothing on the inner surface. Microscopically, there are fractures around the edges of the aperture and on the margins suggesting an anthropogenic origin rather than post-depositional modification (see Harris *et al*. in press)

(Figures 7-6 to 7-9). In addition, the patterning does not resemble that described by McNiven (1990b) for bivalves predated upon by dingoes or birds of prey.

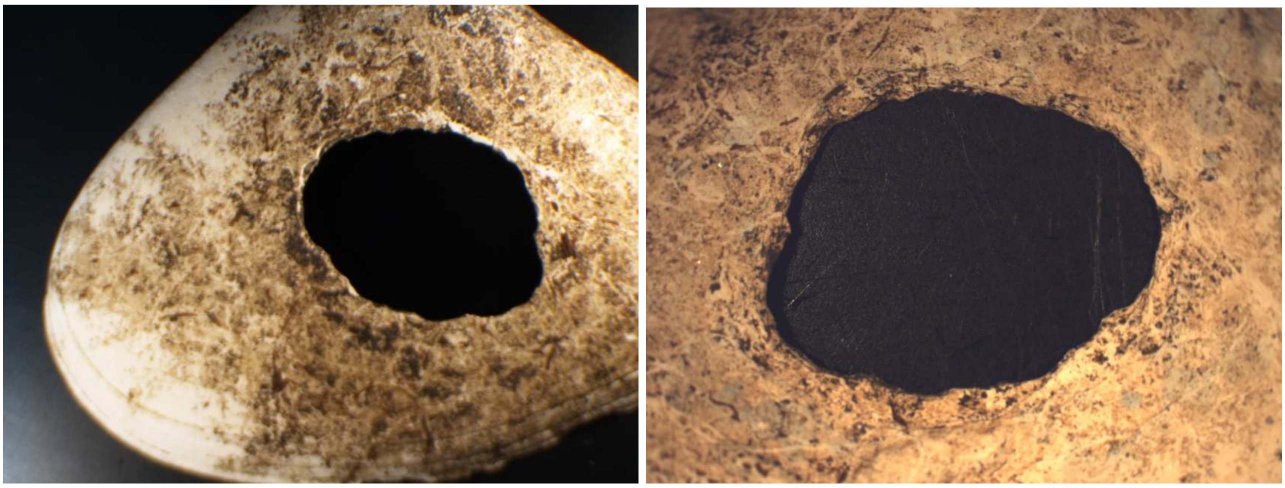


**Figure 7-6 External view of *D. deltoides* artefact from WP3 square C50 (left), Inner view of aperture in D. deltoides artefact from WP3 square C50 at 6.7x (right) (Photo by Gail Robertson 2014)**

**Figure 7-7 Multiple step fractures on aperture in *D. deltoides* artefact from WP3 square C50 at 30x (left), Internal view of edge rounding on D. deltoides artefact from WP3 square C50 at 6.7x (right) (Photos by Gail Robertson 2014).**

**Figure 7-8 Edge rounding on *D. deltoides* artefact from WP3 square C50 at 25x (left), External view of edge rounding and micro-cracks on D. deltoides artefact from WP3 square C50 at 15x (right) (Photos by Gail Robertson 2014).**

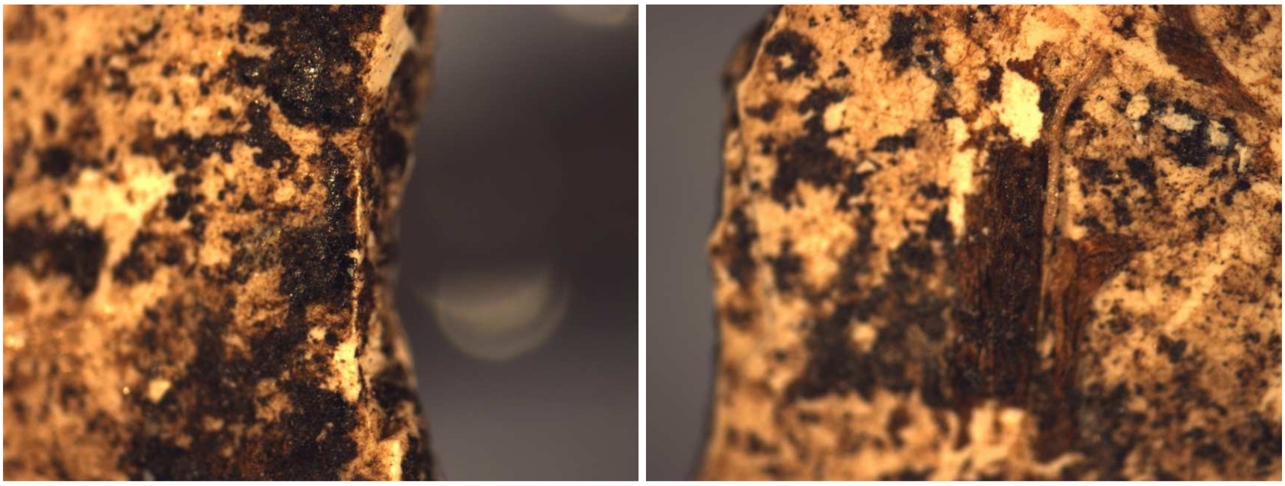


**Figure 7-9 Polish on edge of aperture in *D. deltoides* artefact from WP3 square C50 at 45x (left), Plant fibres near edge of aperture in D. deltoides artefact from WP3 square C50 at 30x (right) (Photos by Gail Robertson 2014).**

Ethnographic analogy must be used cautiously in view of the age of WP3, but Petrie (1904:101) described the use of shells in spear making; after saplings were scraped clean of bark with a shell,

> ... another shell – a freshwater mussel – or in the case of coast tribes, a yugari (Donax) [sic], was used as a spokeshave. A small hole was made in the centre of the shell, and it was held in the palm of the hand, and so with this the sapling was sharpened to a point. (Referred to in Dr. Roth's Bulletin, No.7, page 21, Fig. 109.).

Roth (1904:21) provides slightly more detail based on information from Petrie; the concave side of the shell was cupped in the palm, and the upper edge of the "artificial hole" was used to scrape the tip to a point, with the shavings passing through the shell hole. Roth also illustrated the tool (Figure 7-10) although it must be his reconstruction of how the tool was used rather than direct observation, as he comments (1904:21) that Petrie's information is from the "old Brisbane days". The usewear on the artefact from WP3 does not exactly match that which might be expected from Roth's description, but he also describes (1904:22) the use in the Moreton District (from information provided by Petrie) of *Donax* valves for cutting bark, and for splitting the "distal extremity of the wommera [sic] (for fixation of the peg)".

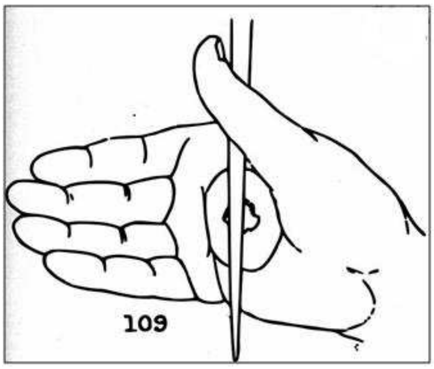


**Figure 7-10 Use of *Donax* tool (after Roth 1904 Figure 109).**

### *'Other' molluscan species*

The remaining shellfish species most probably represent by-catch or collection for non-dietary purposes. All are useful environmental indicators. As noted in the BSM chapter *Chama* spp. (jewel box), like oysters, settle and grow on the shells of other molluscs (alive and dead) including *Saccostrea* spp., rocks and dead coral (Healy and Potter 2010:240). As such, the *Chama* spp. in WP3 are most likely by-catch from oyster collection. All of the individuals were juveniles and sub-adults, with heights ranging from 9.07mm to 29.97mm. None of the shells exhibited evidence of burning or exposure to high temperatures. The carnivorous *C. sordidum* (dirty or leaden sand snail) burrows into sandy sediments and can aggregate in groups (FRC 1994). As at TCB 75b the presence of this snail may indicate opportunistic exploitation of a grouped resource. *C. sordidum* is the principal predator of adult *A. trapezia* (Appendix A), and can be found in association with that species. At WP3, however, there is little correlation between the relative abundance of these taxa. All the *C. sordidum* shells were from sub-adults and none exhibited evidence of exposure to high temperatures. The habitats of the remaining molluscan taxa are summarised in Table 7-11.

**Table 7-11 Habitats of 'other' molluscan taxa from WP3 Square C50.**

| Taxon | Common name | Habitat | Size |
|---|---|---|---|
| *Acrilla acuminata* | Acuminated ladder shell | Nearshore intertidal zone on sandy or muddy sand substrate | To 40mm. C50 specimen sub-adult 23.98mm. |
| *Bembicium auratum* | Gold-mouthed periwinkle | Intertidal zone, usually on mangroves. | To 20mm. C50 specimens sub-adults 8.58mm and 9.18 mm. |
| *Herpetopoma* sp. (most likely *H. atrata*). | Top snail | Intertidal and shallow subtidal zones, on *Zostera* beds and sandy patches. | To 15mm. C50 specimen sub-adult 9.73mm. |
| Hiatellidae | Rock-borer clams | Intertidal and subtidal zones attached by byssus to rock crevices or other shells. | To 50mm. C50 specimens juvenile and sub-adults 5.06mm to 12.09mm. |
| Lucinidae | Lucina clams | Littoral sand. | Varies with species from 25mm to 100mm. C50 specimen 15.8mm. |
| *Monoplex* spp. | Triton shells | Predator; sandy or rocky substrates from intertidal zone to 200m. | Varies with species from 26mm to 140mm. C50 specimen 13.2mm. |
| *Nassarius jonasii* | Jonas' Dog Whelk | Predator/scavenger on intertidal to shallow subtidal sandy muddy sediments. | To 13mm. C50 specimens 7.77mm, 8.24mm and 8.95mm. |
| Ranellidae | Triton shells | Predator; sandy or rocky substrates from intertidal zone to 200m. | Varies with species from 26mm to 140mm. C50 specimen 24.64mm. |
| *Scutus* sp. | Hoof Shield limpet | Under stones and in crevices in shallow water. | To 35mm. C50 specimen 22.77mm. |

### Terrestrial molluscs

At least two types of land snail were recovered. Four specimens of *Figuladra (syn. Sphaerospira) mattea* (Pale Banded Snail) 23.8mm, 27.26mm, 27.68mm and 29.27mm in diameter were identified in SU3-4. This snail grows to 35mm, and lives in and around logs, tree stumps and fallen leaves in open forests, woodlands and vine thickets (Stanisic 1995; Stanisic *et al*. 2010). It is not recorded ethnographically as a food item, although this does not preclude it being harvested for consumption in the past. In this context it is useful in environmental reconstruction. Two other specimens of land snail measuring 3.52mm and 11.6mm were recovered from SU1 but could not be further identified.

### Non-molluscan invertebrate remains

Two fragments of Portunidae (crab) exoskeleton weighing 0.45g were recovered from SU1-2. Two Cirripedia (barnacle) plates weighing 1.15g were recovered SU4. The former may be evidence of consumption of mud crabs or sand crabs at or near the site, but the sample is very small; the latter may have been introduced to the site on mollusc shells.

### Vertebrate faunal remains

The vertebrate faunal remains from the original excavations were identified by the Curator of Fishes and the Curator of Mammals at the Queensland Museum (Crooks 1982:67). Haglund (in Crooks 1982:68-69) recorded a jaw from an unidentified fish species at a depth of 23cm in C50, and fish bone at depths of 25-35cm and 35-40cm although the number of specimens is not provided. A jaw from an unidentified marsupial was recorded in the 20-25cm spit, and fragments of bone from an unidentified mammal at depths of 30-35cm and 35-40cm. No jaws (fish or marsupial) were identified in the present study. The vertebrate remains are detailed in Table 7-12. The colour of the bones suggested exposure to a low temperature fire (see e.g. Asmussen 2009). In the original study fish remains were also reported for square B50 (four *Acanthopragus australis* [yellowfin bream] jaw fragments; one *Rhabdosargus sarba* [tarwhine] jaw fragment; and one fragmented *Arius* [catfish] bone); B52 (17 yellowfin bream jaws, four jaw fragments and "1 large spec."; a tarwhine jaw fragment; and unidentified fragments/vertebrae); C52 ("4 specimens" and fragments of yellowfin bream, and unidentified fragments/vertebrae; and E52 (tarwhine jaw fragment and a bream fragment) (Crooks 1982:68-69). A *Wallabia bicolor* (swamp wallaby) jaw and an unidentified marsupial bone were reported for square B50; a swamp wallaby jaw fragment for B52; an unidentified marsupial tooth and unidentified mammal bone fragments for C51; and unidentified mammal bone fragments for F52 (Crooks 1982:68-69).

**Table 7-12 Vertebrate remains from WP3 Square C50.**

| SU | Depth | Taxon | Element | NISP | Wt g | Comments |
|---|---|---|---|---|---|---|
| 1 | Top 7cm | Fish | Vertebra | 1 | 0.01 | Partial |
| 1-2 | 10 to 15 | Fish | Vertebrae | 10 | 0.06 | Brown |
| 1-2 | 10 to 15 | Fish | Bone | 1 | 0.01 | Fragment |
| 1-2 | 10 to 15 | Mammal | Proximal end ?radius | 1 | 0.12 | Burnt, brown, broken |
| 2-3 | 15 to 20 | Mammal | Mid shaft long bone | 1 | 0.25 | Burnt, brown, broken |
| 2-3 | 15 to 20 | Fish | Vertebra | 1 | 0.01 | Brown |
| 2-3 | 15 to 20 | Fish | Bone | 16 | 0.15 | Burnt, brown, broken |
| 3-4 | 20 to 25 | Fish | Bone | 5 | 0.04 | Brown |
| 4 | 30 to 35 | Fish | Vertebra | 1 | 0.02 | Brown |
| 4 | 30 to 35 | Unidentified | Bone | 29 | 0.29 | Brown, fragmented |

### Charcoal

Charcoal fragments were found throughout the midden deposit except for SU3-4, with the largest amount (13.88g) recovered from SU1. The fragments are most likely the result of burning in the surrounding fire-prone vegetation, rather than evidence of increased use of the site, as there is no associate increase in discard of molluscan or other faunal remains.

### Stone artefacts

There are discrepancies between the stone artefacts recorded by Haglund (in Crooks 1982:70) – a total of one flake, eight flaked pieces and “some manuports” – and those analysed in the current study. It is also unclear whether the stone artefacts analysed as part of the current study were also included in Crooks’ (1982) analysis of material then held by the Queensland Museum, but it seems unlikely.

#### *Flakes*

Two unprovenanced silcrete flakes (Table 7-13) were recorded. Both exhibited cortex on the platforms, and one also had cortex on the dorsal surface, suggesting they may have been manufactured locally on imported cores. The morphology can best be described as squat and thick. One broken silcrete flake was recorded for SU1-2 (Table 7-14).

#### *Flaked pieces*

These were the most numerous of the flaked artefacts (n=11, Table 7-15), however locations are recorded for only six. All but one was made on silcrete, with quartz the other raw material.

### *Manuports*

All the manuports were of ochreous ironstone (Table 7-16), a type of ferruginous sandstone that is also commonly found in surface midden scatters all over the island (Smith 2003), and colloquially known locally as goat droppings. Their purpose is uncertain: they may have been pigment sources although no use-wear was noted, or perhaps used as some kind of border for hearths, or for defining utility areas.

### *Volume-corrected estimates*

The volume-corrected estimates of stone artefact discard are presented in Table 7-17.

**Table 7-13 Attributes of whole flakes from WP3 Square C50.**

| Excavation Unit | Category | Raw Material | Colour | Wt g | Width mm | Length mm | Thickness mm | Plat. Thickness mm | Plat. Width mm | Plat. Type | Cortex % | Term. | Retouch/Dam. | Dorsal scar number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Unrecorded | Whole flake | Silcrete | Light brownish grey | 49.83 | 39.04 | 50.88 | 21.25 | 5.66 | 16.07 | Cortical broken | 45 | Feather | D right m | 4 |
| Unrecorded | Whole flake | Silcrete | Dark yellowish brown | 48.07 | 39.38 | 48.72 | 17.27 | 17.68 | 27.41 | Cortical | Plat. only | Feather | D all m | 8 |

**Table 7-14 Attributes of broken flake from WP3 Square C50.**

| SU | Category | Wt g | Colour | Raw material | Length mm | Width mm | Thickness | Dorsal scar number | Retouch/damage | Breakage | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-2 | Broken flake | 0.44 | Brown grey | silcrete | 12.93 | 13.28 | 2.37 | 0 | Nil | Transverse snap | Distal end |

**Table 7-15 Attributes of flaked pieces from WP3 Square C50.**

| SU | Category | Raw material | Colour | Wt g | Maximum dimension mm |
|---|---|---|---|---|---|
| Unrecorded | Flaked piece | Silcrete | Grey | 41.89 | 56.35 |
| Unrecorded | Flaked piece | Silcrete | Dusky red | 8.82 | 39.42 |
| Unrecorded | Flaked piece | Silcrete | Dark grey | 12.21 | 29.1 |
| Unrecorded | Flaked piece | Silcrete | Very dark grey | 1.68 | 22.47 |
| Unrecorded | Flaked piece | Quartz | White | 0.6 | 19.12 |
| 2-3 | Flaked piece | Silcrete | Dusky red | 1.26 | 13.72 |
| 2-3 | Flaked piece | Silcrete | Very dark grey | 0.18 | 9.64 |
| 3-4 | Flaked piece | Silcrete | Yellowish brown | 0.09 | 7.75 |
| 3-4 | Flaked piece | Silcrete | Dusky red | 0.44 | 15.56 |
| 3-4 | Flaked piece | Silcrete | Very dark grey | 0.39 | 11.3 |
| 3-4 | Flaked piece | Silcrete | Dusky red | 0.34 | 10.71 |

**Table 7-16 Manuports from WP3 Square C50.**

| SU | Category | Raw Material | Colour | Weight |
|---|---|---|---|---|
| Unrecorded | Manuport | Ochreous ironstone | Dark reddish brown | 40.88 |
| 1-2 | Manuport | Ochreous ironstone | Red brown | 0.07 |
| 3-4 | Manuport | Ochreous ironstone | Dark reddish brown | 0.52 |
| 3-4 | Manuport | Ochreous ironstone | Dark reddish brown | 0.81 |
| 4 | Manuport | Ochreous ironstone | Dark reddish brown | 8.14 |
| 4 | Manuport | Ochreous ironstone | Dark reddish brown | 0.27 |
| 4 | Manuport | Ochreous ironstone | Dark reddish brown | 0.44 |
| 4 | Manuport | Ochreous ironstone | Dark reddish brown | 0.53 |
| 4 | Manuport | Ochreous ironstone | Dark reddish brown | 0.35 |
| 4 | Manuport | Ochreous ironstone | Dark reddish brown | 5.6 |
| 5 | Manuport | Ochreous ironstone | Dark reddish brown | 2.8 |
| 5 | Manuport | Ochreous ironstone | Dark reddish brown | 0.42 |
| 5 | Manuport | Ochreous ironstone | Dark reddish brown | 0.96 |
| 5 | Manuport | Ochreous ironstone | Dark reddish brown | 0.25 |

**Table 7-17 Volume-corrected estimates of stone artefact discard at WP3 C50.**

| WP3 C50 | SU1-2 | SU2-3 | SU3-4 | SU4 | SU5 | Total |
|---|---|---|---|---|---|---|
| Volume $m^3$ | 0.0125 | 0.0125 | 0.0125 | 0.0375 | 0.025 | 0.125 |
| N | 2 | 2 | 6 | 6 | 4 | 20 |
| $N/m^3$ | 160 | 160 | 480 | 160 | 160 | 160 |

## *Discussion*

WP3 provides a snapshot of exploitation of mainly estuarine resources over a relatively short period of time, c.500-580 cal BP. The site should be considered in the context of a more or less continuous scatter of middens along the central west coast of Bribie Island (Figure 7-2) exhibiting similar characteristics, although their contemporaneity has not been determined, and also BI67 with which it may be associated.

The molluscan remains, as might be expected, are evidence of a marine-based subsistence economy exploiting locally available resources from an estuarine environmental mosaic including intertidal and subtidal zones, seagrass beds, sandy, sandy muddy, and muddy sediments, and soft and hard substrates. *Saccostrea* spp. is present throughout the midden with the valve heights indicating a mature population at the commencement of deposition. There is evidence of decreased valve heights in SU 2-3 and SU4 (although it is acknowledged that the sample sizes are very small) preceded and succeeded by larger valves; the cause of the decrease is unlikely to be resource depression. Disease or sub-optimal environmental conditions may be factors. Another possibility is that, as for the *T. hirsuta* specimens, tidal regimes and ease of access may influence the valve height variations observed. *A. trapezia* valve length increases through the deposit indicating a maturing and stable population. The land snails provide evidence for open forest and woodland in the immediate vicinity at a time described by Moss *et al*. (2011:137) as a return to La Niña-type conditions.

Although only 35 specimens of fish bone were recovered from the upper five SUs, none of which could be identified to species, the fish remains recorded by Haglund (Crooks 1982:68-69) suggest that fish, particularly bream, formed a significant part of the diet. Despite the identification of a swamp wallaby jaw (Crooks 1982:69) at the site, there is nothing to indicate that terrestrial mammals formed a significant part of the diet at this location (see also McNiven 1994; Chapters 5 and 6).

The artefact assemblage in the current analysis is fairly small and restricted in artefact categories, however the observation can be made of artefact manufacture and/or maintenance (and use) at or near the site from the evidence of the flaked pieces, while the multiple dorsal scars on the whole flakes indicate core rotation. Crooks (1982:200-204) recorded 38 flakes from WP3 (all with some degree of breakage) with the majority (n=29) made on silcrete, six on chert, three on mudstone, and one on comendite. There is no record of the level of dorsal scarring on the flakes, but all of the flaked pieces (n=80) exhibited multiple dorsal scars, with one having nine. In addition to the dominant silcrete, raw materials included quartz, chert, and quartzite. Two silcrete multi-platform cores, two silcrete bevel-edged artefacts and 22 sandstone manuports were also recorded. This relatively small range of raw materials is also reflected in the surface scatters at nearby BI67, which includes andesite, chert, quartz, rhyolite, silcrete, and silicified wood. All of the raw materials occur within 60km of the Island (Smith 2003:154, 163).

The shell tool is potential evidence for the manufacture and/or maintenance of wooden or other plant-based items. Residue analysis would be useful in determining its use, and this is being performed as part of further work by the curatorial staff at the Queensland Museum. What it does provide is evidence that the manufacture and use of shell tools has been occurring for at least the last 600 years and probably for much longer. It is contended that the reason that *D. deltoides* occur in low numbers in estuarine contexts may be for potential use as tools and not for their dietary value. Further research is required to assess the extent of shell tool use vs. subsistence remains across the region.

There is no evidence of resource depression or over-exploitation at WP3. Given the richness of the estuarine environment, people just moved somewhere else around 500 years ago. The midden scatters along Pumicestone Passage (Figure 7-2) attest to the availability of habitat patches for exploitation.

### *Bribie Island 9*

Bribie Island 9 (BI9) is an extensive, discontinuous, midden scatter of approximately 9km$^2$ in the northeast of the Island (Smith 2003, 2006), and approximately 14 km north of WP3. It covers an area of low ridges and depressions in what was formerly a mix of open heath sedgeland, *M. quinquenervia* (broad leaved paperbark) and *Eucalyptus tereticornis* (forest red gum) woodland at the northernmost extent of the Pleistocene dune ridges (see Smith 1992, 2003 for a comprehensive discussion of vegetation patterns). Immediately prior to clearing the native vegetation for the creation of the commercial pine plantation in the late 1950s, areas of the northern section of the Island were described by a former forestry worker as parkland with stands of Bribie Island pines (*Callitris columellaris*) considered to have been managed by the former Aboriginal inhabitants (Smith 1992:17). The same informant also described a bora ring to the southwest of the site which was destroyed during the native vegetation clearance. BI9 is approximately 1km southeast of Pumicestone Passage, and 1.5km west of the present surf coastline which is subject to active ongoing erosion (Smith 1992, 2003; Figure 7-1). Three 50cm x 50cm pits along a ridgeline within the site were excavated in 1992 by the Field Archaeology class from the then School of Anthropology and Sociology at the University of Queensland, under the direction of Jay Hall. This section reports on the re-analysis of material from pit T4/P1.

T4/P1 was excavated to a depth of 85cms in 24 XUs; all excavated material was dry sieved through nested 6mm and 3mm sieves (MRAP files). The total volume of the excavation was 0.237m$^3$. Five stratigraphic units were identified (Figure 7-11) and described (original Roman numeral designations have been retained) as:

SUI: A layer of humus, pine needles, decomposing leaf litter and fern roots;
SUII: Patchy black and light grey sandy loam containing some cultural material;
SUIII: Dense shell layer in very dark brown sedimentary matrix;
SUIV: Dark sandy loam containing some shell and stone artefacts; and
SUV: Very light grey to off-white sand layer with no cultural material (MRAP files).

Charcoal for dating purposes was obtained from the base of the dense shell layer and returned a conventional radiocarbon age of 200±80 BP (Smith 1992). A further charcoal sample from a depth of 70cm in SUIV returned a conventional $^{14}$C age of 3280±80 BP (Smith 1992). These were later calibrated by Ulm and Reid (2000:19; Table 7-18) and the median calibrated ages are employed in the current discussion. Calculation of the rate of sediment accumulation based on the method described by Stein *et al*. (2003) suggests a slow rate (1.5cm/100 years), with cultural material being mixed in the process of deposition.

**Table 7-18 14C determinations from BI9 T4/P1 (Smith 1992; Ulm and Reid 2000:19).**

| SU | Depth cm | Sample | Laboratory code | Conventional 14 C date | 2σ calibrated age range |
|---|---|---|---|---|---|
| III | 20 | Charcoal | Beta-56565 | 200±80 BP | 430(276,173,149,9,4)0 |
| IV | 70 | Charcoal | Beta-56566 | 3280±80 BP | 3687(3469)3273 |

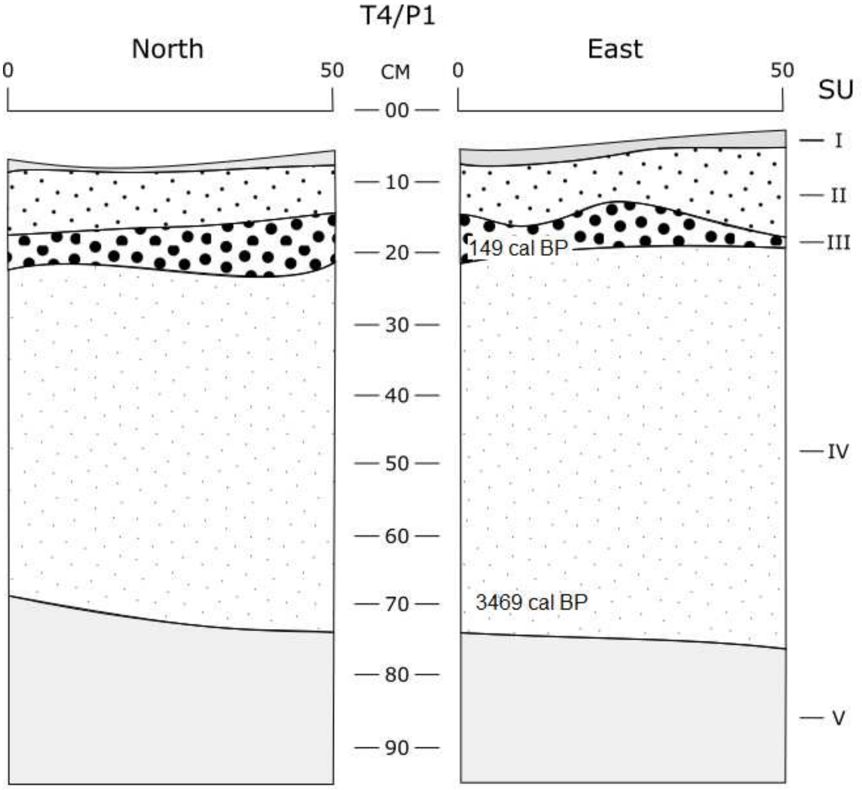


**Figure 7-11 Stratigraphic profile of BI9 T4/P1 with locations of $^{14}$C determinations (after Smith 1992).**

## Molluscs

Molluscan remains were recorded for SUII, SUIII and SUIV. The species richness (n=7) was quite low and, despite the site's central location in terms of accessing both the surf beach and Pumicestone Passage, strongly focussed on estuarine species (Tables 7-19 to 7-22). *Trichomya hirsuta* was notably absent suggesting that, as at Tin Can Bay, micro-habitat variability affects species distribution in Pumicestone Passage.

**Table 7-19 Molluscan taxa by NISP by SU from BI9 Square T4/P1.**

| **Taxon** | **SUII** | **SUIII** | **SUIV** | **Total NISP** | **% Total NISP** |
|---|---|---|---|---|---|
| *Anadara trapezia* | 189 | 890 | 50 | 1129 | 39.48% |
| *Bembicium auratum* | 0 | 2 | 0 | 2 | 0.07% |
| *Conuber sordidum* | 0 | 3 | 0 | 3 | 0.10% |
| *Donax deltoides* | 6 | 129 | 6 | 141 | 4.93% |
| Land snail | 0 | 0 | 6 | 6 | 0.21% |
| *Pyrazus ebeninus* | 7 | 7 | 1 | 15 | 0.52% |
| *Saccostrea* spp. | 202 | 1243 | 114 | 1606 | 54.51% |
| Trochidae | 5 | 0 | 0 | 5 | 0.17% |
| **Totals** | **409** | **2274** | **177** | **2860** | **100.00%** |

**Table 7-20 Molluscan taxa MNI by SU from BI9 Square T4/P1.**

| **Taxon** | **SUII** | **SUIII** | **SUIV** | **Total MNI** | **% Total MNI** |
|---|---|---|---|---|---|
| *Anadara trapezia* | 43 | 340 | 8 | 391 | 71.61% |
| *Bembicium auratum* | 0 | 2 | 0 | 2 | 0.37% |
| *Conuber sordidum* | 0 | 3 | 0 | 3 | 0.55% |
| *Donax deltoides* | 1 | 13 | 2 | 16 | 2.93% |
| Land snail | 0 | 0 | 1 | 1 | 0.18% |
| *Pyrazus ebeninus* | 3 | 5 | 1 | 9 | 1.65% |
| *Saccostrea* spp. | 12 | 94 | 14 | 120 | 21.98% |
| Trochidae | 4 | 0 | 0 | 4 | 0.73% |
| **Total** | **63** | **457** | **26** | **546** | **100.00%** |

**Table 7-21 Molluscan taxa weight by SU from BI9 Square T4/P1.**

| **Taxa** | **SUII** | **SUIII** | **SUIV** | **Total wt g** | **% Total wt g** |
|---|---|---|---|---|---|
| *Anadara trapezia* | 432.54 | 4022.78 | 58.14 | 4513.46 | 81.15% |
| *Bembicium auratum* | 0 | 1.14 | 0 | 1.14 | 0.02% |
| *Conuber sordidum* | 0 | 20.54 | 0 | 20.54 | 0.37% |
| *Donax deltoides* | 1.94 | 95.91 | 1.09 | 98.94 | 1.78% |
| Land snail | 0 | 0 | 2.89 | 2.89 | 0.05% |
| *Pyrazus ebeninus* | 20.36 | 25.4 | 2.04 | 47.8 | 0.86% |
| *Saccostrea* spp. | 107.77 | 633.8 | 43.41 | 784.98 | 14.11% |
| Trochidae | 0.22 | 0 | 0 | 0.22 | 0.00% |
| Indeterminate | 2.23 | 75.74 | 14.1 | 92.07 | 1.66% |
| Totals | 565.06 | 4875.31 | 121.67 | 5562.04 | 100.00% |

**Table 7-22 Volume-corrected MNI estimates for BI9 T4/P1. Estimates are based on only those SUs containing molluscan material.**

| **BI 9** | | **SUII $m^3$** | **SUIII $m^3$** | **SUIV $m^3$** | **Total** |
|---|---|---|---|---|---|
| | | 0.025 | 0.025 | 0.138 | 0.188 |
| All shell | MNI | 63 | 457 | 26 | 546 |
| | MNI/m3 | 2520 | 18280 | 189 | 2912 |
| *Anadara trapezia* | MNI | 43 | 340 | 8 | 391 |
| | MNI/m3 | 1720 | 13600 | 58 | 2085 |
| *Donax deltoides* | MNI | 1 | 13 | 2 | 16 |
| | MNI/m3 | 40 | 520 | 15 | 85 |
| *Pyrazus ebeninus* | MNI | 3 | 5 | 1 | 9 |
| | MNI/m3 | 120 | 200 | 7 | 48 |
| *Saccostrea* spp. | MNI | 12 | 94 | 14 | 120 |
| | MNI/m3 | 480 | 3760 | 102 | 640 |

### *Molluscan Richness and Diversity*

The application of the measures described in Chapter 4 for assessing taxonomic richness, evenness, and diversity indicate the dominance of a few species relative to the NTAXA, as well as low to moderate species diversity and richness (Table 7-23).

**Table 7-23 Molluscan richness and diversity indices for BI9 Square T4/P1.**

| **Diversity measure** | |
|---|---|
| NTAXA | 8 |
| MNI | 546 |
| Simpson’s Index (1-D) | 0.4376 |
| Shannon Index of Diversity (′H) | 0.8399 |
| Shannon Index of Evenness (E) | 0.4039 |

## Taxon-specific analyses

### *Anadara trapezia*

*Anadara trapezia* was the most abundant species by MNI (391, 71.61%) and weight (4513.46g, 81.15%), and the second most abundant species by NISP (1129, 39.48%) (Tables 7-19 to 7-22). No *A. trapezia* were identified below a depth of 51cm. The condition of the shell at the top of SUIV was noted to be more degraded than that in SUIII. Lengths were obtained for 625 unbroken valves across the three SUs, and the descriptive statistics are detailed in Table 7-24.

**Table 7-24 Descriptive statistics for A. trapezia valve lengths in mm by SU for BI9 square T4/P1.**

| SU | N | Minimum | Maximum | Mean | Range | Std. deviation |
|---|---|---|---|---|---|---|
| II | 45 | 17.73 | 43.19 | 32.91 | 25.46 | 5.13 |
| III | 573 | 20.45 | 57.48 | 34.77 | 37.03 | 4.23 |
| IV | 7 | 24.33 | 48.10 | 32.61 | 23.77 | 7.65 |

A Shapiro-Wilk test of normality returned varying results: for SUII, *W*=.975, *df*= 45, *p*=.347; for SUIII, *W*=.978, *df*=573, *p*=.000; and for SUIV, *W*=.856, *df*=7, *p*=.140, suggesting that there may be a significant difference in the valve lengths between SUIII and the other SUs. Field (2014:184) cautions that the Shapiro-Wilk test may return significant results for small and unimportant effects in large samples, and this appears to be the case for SUIII. Testing for homogeneity of variance returned the result *L*=2.832, *df 1*=2, *df2*=622, *p*=.06, indicating no violation of the assumption of means test, and no significant difference in valve length variance between the SUs. ANOVA results did suggest a significant difference (*F*=4.585, *df*=2, *p*=.011), which is likely an artefact of highly variable sample sizes across SUs. The robust Welch (*W*=2.933, *df1*=2, *df2*=14.338, *p*=.086 and Brown-Forsythe (*B*=2.067, *df1*=2, *df2*=12.287, *p*=.168) results indicated no significant differences in *A. trapezia* lengths between the SUs.

Plotting the frequencies highlights the valve lengths and frequencies for SUII and SUIII (Figure 7-12) demonstrates that the majority of the valves in SUII were between 27.5mm and 42.5mm, while for SUIII the peak in valve length occurs between 28.58 and 42.84mm. These data indicate that the majority of *A. trapezia* harvested were from a sexually mature population with individuals between one and three years old (Appendix A). Based on the established criteria (as discussed in the methods), this would suggest that there is no evidence of over-exploitation or resource depression.

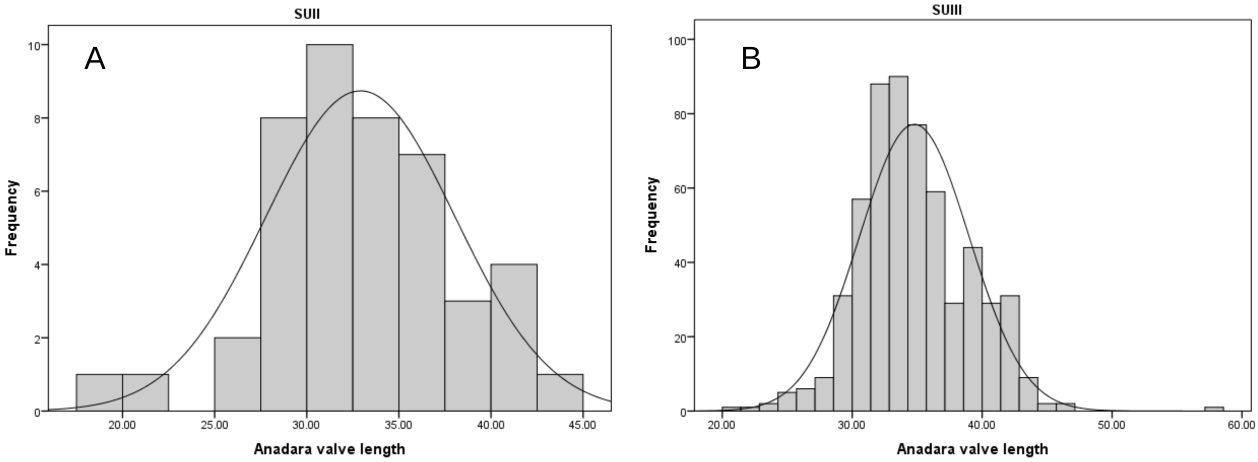


**Figure 7-12 Frequency plots of *A. trapezia* valve lengths for SUII (A) and SUIII (B) for BI9 Square T4/P1.**

Forty-four (7.67%) of the complete valves in SUIII exhibited distinct lines or growth interruptions in one or more locations, while a further 43 (7.5%) had predatory drill holes in the umbones. None exhibited evidence of burning. Of the species commonly found in southeast Queensland middens, *A. trapezia* is the most sensitive to changes in water temperature and salinity and is restricted to areas where salinity changes are relatively small or occur very gradually (Alfredson 1984; Rainer *et al.* 1979). Reduced salinity affects the organism's metabolic rate, hence slowing growth (Rainer *et al.* 1979). It is likely that rapid temperature changes and restricted access to food produce the same results. Dixon (1975) noted that individuals stressed by environmental factors such as low temperature and salinity gaped open and were sluggish. Alfredson (1984) produced an interruption in growth in *A. trapezia* specimens by placing them in an atidal (a salt water tank) environment and withholding food. Carpenter and Niem (1998: 142) note that the presence of haemoglobin enables *Anadara* spp. to colonise habitats of low oxygen concentration. It is possible that such factors produced the growth interruptions noted in SUIII. As to be expected of a robust species, the fragmentation ratios were low (SUII 4.39, SUIII 2.61, and SUIV 6.25).

*Saccostrea spp.*

*Saccostrea* spp. had the highest NISP (1606, 54.51%) and was the second most abundant species in terms of MNI (120, 21.98%) and weight (784.98g, 14.11%) (Tables 7-19 to 7-22). Most specimens occurred in SUIII and immediately below it, with the condition of the shell at the top of SUIV noted to be more degraded than that in SUIII, in line with the *A. trapezia* observations. There was a small concentration of fragments in SUIV at a depth of 55cm and a single fragment at 71cm, close to the location of the charcoal used in the radiocarbon age determination. Heights were obtained from 44 SUIII lower valves and the descriptive statistics are at Table 7-25. The fragmentary condition of shells from the other SUs precluded measurement.

**Table 7-25 Descriptive statistics for Saccostrea valve height from SUIII in BI9 Square T4/P1.**

| **SUIII** | **N** | **Minimum** | **Maximum** | **Mean** | **Range** | **Std. Deviation** |
|---|---|---|---|---|---|---|
| Valve height | 44 | 17.00 | 63.82 | 38.21 | 46.82 | 11.84 |

The results of a subsequent Shapiro-Wilk test of normality which is robust for sample sizes <50 indicated no significant difference ($W$=0.972, $df$=44, $p$=0.345), but Figure 7-13 demonstrates a distinctly bimodal distribution. A one-sample $t$ test suggested that there may be a significant difference in valve length ($t$=21.397, $df$=43, $p$=0.000).

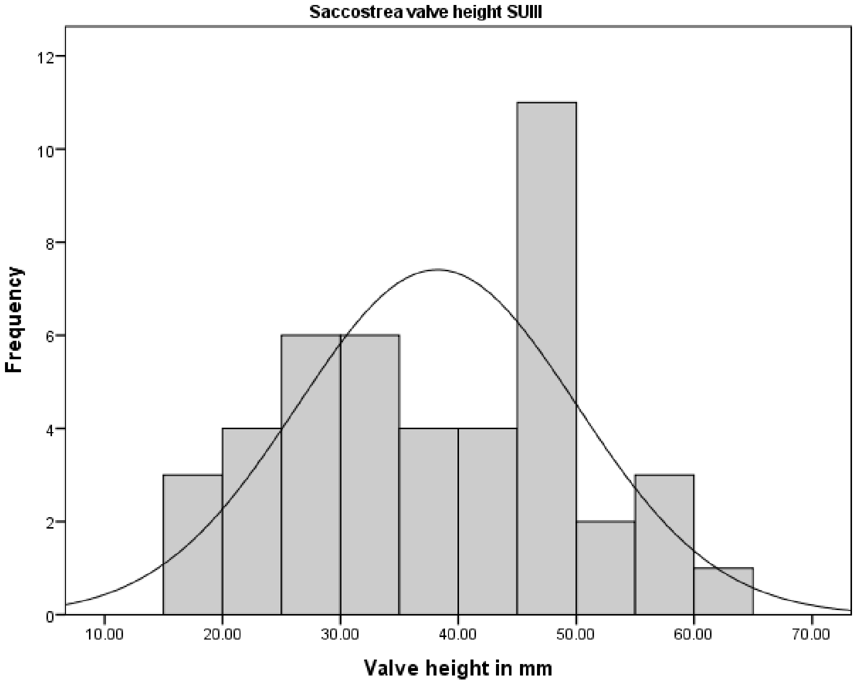


**Figure 7-13 Plot of *Saccostrea* spp. valve lengths for SUIII in BI9 Square T4/P1.**

Nineteen (43.18%) of the complete lower valves were cemented together in clumps of two or three; five lower valves (11.36%) had flat bases, while another had grown over a rounded object such as a tree root. Ten valves (22.72%) exhibited the elongated hinges described by Galtsoff (1964) as indicative of ‘old’ oysters. Four lower valves (one of which was 20.37mm deep) exhibited prominent radial ribs suggestive of resistance to currents (Galtsoff 1964). Taken together, this evidence suggests that the oysters were growing in a variety of locations, but not necessarily tightly packed in oyster reefs or beds. The range of valve heights indicates that an established, sexually mature, population was being exploited. None of the valves or fragments exhibited evidence of burning. The fragmentation ratios were 13.38 for SUIV, 13.22 for SUIII, and 16.83 for SUII.

### *Donax deltoides*

*D. deltoides* was the third ranked in species in NISP (141, 4.93%), MNI (16, 2.93%) and weight (98.94g, 71.78%) (Table 7-19 to 7-22), but did not occur below 36cm. Only five whole valves were recovered, from SUIII, measuring 30.8mm, 35.37mm, 46.34mm, 51.94mm and 56.86mm in length. While these lengths indicate that a mostly sexually mature population was harvested, pipi size classes can be differentially distributed through intertidal and subtidal zones (see Appendix A). None of the valves or fragments exhibited evidence of burning; the fragmentation ratios (SUII 6, SUIII 9.92, and SUIV 3) were variable.

### *Pyrazus ebeninus*

The relative abundance of *P. ebeninus* (NISP 15, 0.52%; MNI 9, 1.65%; and weight 47.8g, 0.86%) (Tables 7.19 to 7.22) is low compared to that of *A. trapezia* which occupies broadly similar habitats; no individuals were identified below 30cm in depth (i.e. just below the main midden deposit). Only two complete specimens, an adult (51.99mm in height) and a sub-adult (15.92mm) from the base of SUII were identified. Four specimens from SUIII exhibited patterns typical of breakage of the shell to extract the snail, but the sample is very small. None of the specimens exhibited evidence of burning; the fragmentation ratios (SUII 2.33, SUIII 1.4, and SUIV 1) reflect not only the robusticity of the shells but also their low abundance.

### ***'Other' molluscan species***

There are low abundances of *C. sordidum*, *B. auratum* and Trochidae (top snails) (Tables 7-17 and 7-18), and all most likely represent by-catch. *C. sordidum* is the principal predator of adult *A. trapezia* (Appendix A) but only one complete individual, an adult measuring 43.66mm, was recovered from SUIII. As noted above (Table 7-11), *B. auratum* and top snails (e.g. *Herpetopoma* spp.) occur in the intertidal and subtidal zones, on mangroves (*B. auratum*) and on sandy patches and *Zostera* beds (Trochidae). The three complete individuals (one Trochidae and two *B. auratum*) were sub-adults. None of the specimens in this category exhibited evidence of burning.

### *Terrestrial molluscs and non-molluscan invertebrate remains*

Six fragments and one partially complete individual (height 27.2mm) of an unidentifiable species of land snail were recovered from the top of SUIV. One fragment of Portunidae exoskeleton weighing 0.01g was recovered from the top of SUIV.

## Vertebrate faunal remains

A total of 106 unburnt bone fragments weighing 2.01g was recovered from SUII, SUIII, and SUIV. The condition of the bone allowed identification only to broad categories. The results are presented Table 7-26.

**Table 7-26 Vertebrate faunal remains from BI9 Square T4/P1.**

| SU | Taxon | NISP | Element | Wt g |
|---|---|---|---|---|
| SUII | Unidentified | 1 | Fragment | 0.01 |
| SUIII | Small mammal | 2 | Long bone mid shafts | 0.25 |
| SUIII | Fish | 20 | Vertebrae | 1.04 |
| SUIII | Fish | 70 | Fragments | 0.37 |

**Table 7-26 (continued) Vertebrate remains from BI9 Square T4/P1**.

| | | | | |
|---|---|---|---|---|
| SUIII | Unidentified | 8 | Fragments | 0.26 |
| SUIV | Fish | 3 | Fragments | 0.07 |
| SUIV | Unidentified | 2 | Fragments | 0.01 |
| **Total** | | **106** | | **2.01** |

## Charcoal

Small amounts of charcoal were recovered from SUIII (10.92g) and SUIV (9.41g), with the largest amount (18.53g) recovered from SUII. As this is above the main midden deposit with its basal date of 149 cal BP, it is most likely the result of burning in the surrounding fire-prone vegetation, as increased charcoal values were also found in the upper levels of the other two excavated squares which lacked dense shell deposits (MRAP files).

## Stone artefacts

A total of 56 stone artefacts made on five raw materials was recovered from T4/P1. Interestingly, the majority (n=37, 66.07%) came from SUIV below the midden, and manuports were found only in SUIV. No stone occurs naturally on Bribie Island, and therefore all raw materials are imported (Smith 2003).

### *Raw materials*

The occurrence of raw materials by SU, and possible raw material provenances, are summarised in Tables 7-27 and 7-28.

**Table 7-27 Distribution of raw material type by SU at BI9 square T4/P1.**

| **SU** | **Chert** | **Quartz** | **Quartzite** | **Sandstone** | **Silcrete** |
|---|---|---|---|---|---|
| SUII | 0 | 3 | 0 | 3 | 1 |
| SUIII | 2 | 4 | 0 | 3 | 3 |
| SUIV | 1 | 14 | 9 | 3 | 9 |
| SUV | 0 | 0 | 0 | 0 | 1 |
| **Total** | **3** | **21** | **9** | **9** | **14** |

**Table 7-28 Possible provenances of raw materials from BI9 Square T4/P1 (after Smith 2003).**

| **Raw material** | **Possible provenance (primary sources)** |
|---|---|
| Chert | Kurwongbah Beds<br>Neranleigh-Fernvale Beds |
| Quartz | Glasshouse Mountains |
| Quartzite | Intrusions in Landsborough Sandstones |
| Sandstone | Landsborough Sandstones |
| Silcrete | Intrusions in Landsborough Sandstones; Cape Moreton (Gunumbah) |

*Flakes*

Ten whole flakes made on four raw materials (quartz, quartzite, sandstone, and silcrete) were recovered (Table 7-29). One secondary flake from SUIV exhibited 50% cortex on the dorsal surface; all but one flake exhibited two or more dorsal scars indicating rotation of the core from which they came. Eight broken flakes made on five raw materials (chert, quartz, quartzite, sandstone, and silcrete) were recovered (Table 7-30). All were tertiary flakes without cortex; none exhibited retouch or edge damage, and with the exception of one right split cone, exhibited transverse breaks usually associated with trampling.

*Cores*

Two silcrete cores were recorded, one from SUIII and one from SUIV (Table 7-31). Both were multi-platform.

*Flaked pieces*

As commonly occurs in SEQ assemblages, this was the most populated category with 33 specimens made on five raw materials (chert, quartz, quartzite, sandstone, and silcrete) (Table 7-32). The majority of the flaked pieces (n=22, 69.7%) came from SUIV and continued down to its base. One flaked piece was recovered from SUV. Due to the small size of many of the artefacts, vertical displacement through the sediments cannot be ruled out (e.g. Richardson 1992). Statistical analysis was not performed as the contributions of individual raw materials to the total in each SU were too few.

*Manuports*

One quartz and two sandstone manuports were recorded for SUIV (Table 7-33).

*Volume-corrected estimates of artefact discard*

The volume-corrected estimates of stone artefact discard are presented in Table 7-34.

**Table 7-29 Whole flake attributes from BI9 Square T4/P1.**

| SU | Category | Raw Material | Colour | Wt g | Width mm | Length mm | Thickness mm | Plat. Thickness mm | Plat. Width mm | Plat. Type | Plat. prep. | Cortex % | Term. | Ret. or Damage | Dorsal scar number |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUII | Whole flake | Sandstone | Very dark greyish brown | 1.3 | 11.82 | 24.52 | 4.53 | 3.28 | 7.55 | Flaked | Nil | 0 | Feather | Nil | 0 |
| SUII | Whole flake | Quartz | White, grey and brown streaks | 18.8 | 30.8 | 45.34 | 13.64 | 3.15 | 17.59 | Flaked | Gen. | 0 | Feather | Nil | 6 |
| SUIII | Whole flake | Quartz | White | 0.46 | 21.39 | 21.43 | 3.3 | 1.46 | 6.32 | Crushed | Nil | 0 | Feather | Nil | 2 |
| SUIV | Whole flake | Silcrete | Dark reddish brown | 5.01 | 24.02 | 28.47 | 7.73 | 9.68 | 20.77 | Multi flakes | Nil | 0 | Feather | Dam. distal, rt margin | 3 |
| SUIV | Whole flake | Silcrete | Grey with some maroon | 1.48 | 22.82 | 18.33 | 3.77 | 3.53 | 11.81 | Multi flakes | Gen. | 0 | Feather | Nil | 2 |
| SUIV | Whole flake | Quartzite | Grey | 0.26 | 6.83 | 14.68 | 3.26 | 2.83 | 5.59 | Flaked | Gen. | 0 | Feather | Nil | 2 |
| SUIV | Whole flake | Quartzite | Grey | 0.44 | 9.72 | 13.56 | 3.89 | 3.76 | 6.25 | Flaked | Nil | 0 | Step | Nil | 2 |
| SUIV | Whole flake | Quartzite | Light reddish brown | 18.74 | 36.04 | 41.55 | 8.59 | 8.6 | 22.32 | Multi flakes | Gen. | 0 | Hinge | Dam. rt margin | 3 |
| SUIV | Whole flake | Quartzite | Grey | 1.95 | 17.94 | 21.88 | 5.46 | 4.08 | 7.09 | Crushed | Nil | 50 | Feather | Dam. rt margin | 2 |
| SUIV | Whole flake | Quartzite | Grey | 1.33 | 16.53 | 26.63 | 3.61 | 1.95 | 11.86 | Flaked | Nil | 0 | Feather | Dam. distal margin | 2 |

**Table 7-30 Broken flake attributes from BI9 Square T4/P1.**

| SU | Category | Raw Material | Colour | Wt g | Length mm | Width mm | Thickness mm | Plat. thickness mm | Plat. Width mm | Plat. Type | Plat. Prep | Cortex % | Dorsal Scar number | Ret. or damage | Break | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUII | Broken flake | Sandstone | Very dark greyish brown | 0.09 | 7.47 | 8.02 | 1.49 | 0 | 0 | Nil | Nil | 0 | 0 | Nil | Trans | Distal half |
| SUII | Broken flake | Sandstone | Very dark greyish brown | 4.61 | 24.38 | 23.44 | 11 | 0 | 0 | Nil | Nil | 0 | 0 | Nil | Trans | Distal half |
| SUIII | Broken flake | Silcrete | Dark grey | 0.39 | 5.44 | 12.37 | 5.08 | 0 | 0 | Nil | Nil | 0 | 0 | Nil | Trans | Medial fragment |
| SUIV | Broken flake | Chert | Brown | 3.48 | 26.34 | 16.08 | 9.59 | 0 | 0 | Nil | Nil | 0 | 3 | Nil | Trans | Distal half |
| SUIV | Broken flake | Chert | Brown | 0.63 | 11.31 | 10.86 | 3.97 | 0 | 0 | Nil | Nil | 0 | 0 | Nil | Trans/long | Distal end |
| SUIV | Broken flake | Silcrete | Grey | 0.27 | 13.68 | 6.23 | 3.19 | 0 | 0 | Nil | Nil | 0 | 0 | Nil | Long. | Right split cone |
| SUIV | Broken flake | Quartzite | Grey | 1.02 | 15.09 | 13.96 | 3.78 | 0 | 0 | Nil | Nil | 0 | 2 | Nil | Trans | Medial section |
| SUIV | Broken flake | Quartz | White | 0.29 | 12.62 | 6.32 | 3.7 | 1.13 | 4.78 | Crushed | Nil | 0 | 3 | Nil | Trans | Proximal end |

**Table 7-31 Attributes of cores from BI9 Square T4/P1.**

| SU | Category | Raw Material | Colour | Wt g | Length mm | Width mm | Max dim. mm | Plat. Number | Scar no | Max scar mm | Min scar mm |
|---|---|---|---|---|---|---|---|---|---|---|---|
| XU5 | Core | Silcrete | Yellowish brown | 22.18 | 27.4 | 44.59 | 46.72 | 2 | 8 | 15.53 | 7.36 |
| XU11 | Core | Silcrete | Yellow | 18.57 | 41.5 | 30.96 | 41.6 | 3 | 12 | 32.03 | 4.49 |

**Table 7-32 Attributes of flaked pieces (FP) from BI9 Square T4/P1.**

| SU | Category | Raw material | Colour | Wt g | Max. Dim. mm | Comments |
|---|---|---|---|---|---|---|
| SUII | FP | Quartz | Yellowish brown | 0.02 | 4.21 | |
| SUII | FP | Silcrete | Dark grey | 0.03 | 8.65 | |
| SUII | FP | Quartz | white | 0.03 | 7.1 | |
| SUIII | FP | Quartz | White | 0.01 | 5.45 | |
| SUIII | FP | Chert | Yellow | 0.01 | 4.74 | |
| SUIII | FP | Sandstone | Very dark greyish brown | 0.07 | 7.07 | |
| SUIII | FP | Quartz | White | 0.01 | 2.97 | |
| SUIII | FP | Quartz | White | 0.01 | 5.95 | |
| SUIII | FP | Sandstone | Very dark greyish brown | 0.06 | 7.62 | |
| SUIII | FP | Sandstone | Very dark greyish brown | 0.34 | 12.44 | |
| SUIV | FP | Quartz | White | 0.04 | 7.71 | |
| SUIV | FP | Quartz | White | 0.01 | 5.01 | |
| SUIV | FP | Quartz | Clear | 0.01 | 6.41 | |
| SUIV | FP | Silcrete | Pinkish grey | 0.31 | 12.67 | |
| SUIV | FP | Sandstone | Dark greyish brown | 0.16 | 12.41 | |
| SUIV | FP | Silcrete | Grey | 0.1 | 11.41 | |
| SUIV | FP | Silcrete | Grey | 0.07 | 6.54 | |
| SUIV | FP | Quartz | White | 0.01 | 7.58 | |
| SUIV | FP | Silcrete | Grey | 0.03 | 7.22 | |
| SUIV | FP | Silcrete | Brown | 0.02 | 5.12 | |
| SUIV | FP | Silcrete | Brownish Yellow | 0.11 | 8.71 | |
| SUIV | FP | Quartzite | Dark grey | 0.55 | 12.34 | |
| SUIV | FP | Quartz | White | 3.24 | 30.72 | Dorsal 100% cortex; split quartz cobble. |
| SUIV | FP | Quartzite | Dark grey | 0.63 | 20.6 | |
| SUIV | FP | Quartz | White | 0.01 | 3.95 | |
| SUIV | FP | Quartz | White | 0.01 | 3.16 | |
| SUIV | FP | Quartzite | Dark grey | 0.04 | 6.42 | |
| SUIV | FP | Quartz | Clear | 0.01 | 2.9 | |
| SUIV | FP | Quartz | White | 0.01 | 4.73 | |
| SUIV | FP | Quartz | White | 0.03 | 6.25 | |
| SUIV | FP | Quartz | Clear | 0.03 | 7.74 | |
| SUIV | FP | Quartz | Clear | 0.01 | 4.35 | |
| SUV | FP | Silcrete | Dark greyish brown | 0.01 | 2.92 | |

**Table 7-33 Manuports from BI9 Square T4/P1**

| SU | Category | Raw Material | Colour | Wt g | Max. Dim. |
|---|---|---|---|---|---|
| SUIV | Manuport | Sandstone | Very dark reddish brown | 32.35 | 57.37 |
| SUIV | Manuport | Sandstone | Very dark reddish brown | 4.96 | 20.56 |
| SUIV | Manuport | Quartz | Light reddish brown | 0.07 | 4.73 |

**Table 7-34 Volume- corrected estimates of stone artefact discard for BI9 Square T4/P1.**

| **BI9 T4/P1** | **SUII** | **SUIII** | **SUIV** | **Total** |
|---|---|---|---|---|
| SU Volume $m^3$ | 0.025 | 0.025 | 0.1375 | 0.1875 |
| N | 7 | 11 | 37 | 55 |
| $N/m^3$ | 280 | 440 | 269 | 293 |

## *Discussion*

The data from BI9 demonstrate that Aboriginal people have been using Bribie Island for at least the past 3500 years, although initial use of the area may have been sporadic and based around factors other than utilisation of molluscan resources. This section considers the nature of the use of the site, how it may have changed, and what factors may have influenced the changes.

SUIV is the dominant feature in the T4/P1 stratigraphic profile (other than the midden), differing from the strata below and above it, and consideration must be given to the processes leading to its formation. Although the environmental reconstructions from Fraser and North Stradbroke Islands frustratingly lack much late-Holocene detail, it would appear from the sediments and the chronology at BI9 that, from around 3500 cal BP, a vegetation pattern on a stable dune system developed that allowed for an increased deposition of organic material and the accumulation of a sandy loam or humus podzol (Thompson 1992). This period falls within that of proposed late-Holocene decreased aridity and the expansion of open woodland taxa for the region (e.g. Donders *et al*. 2006; Moss *et al*. 2013; Petherick *et al*. 2009), while Petherick *et al*. (2008b:7) cite the early Holocene onset of *Banksia* in the pollen record at Native Companion Lagoon on North Stradbroke Island as possible evidence of the first development of wallum heath which occurred throughout the Holocene.

The earliest evidence of site use is a silcrete flaked piece from SUV, below the $^{14}$C age determination of 3469 cal BP (Figure 7-11; Table 7-29). However as noted above, the small size of flaked pieces renders them highly susceptible to vertical movement (see Richardson 1979), and the artefact may have originated in SUIV.

The number of raw materials is low compared to the 18 raw materials recorded by Smith (2003:153) for the BI9 surface material. Although the T4/P1 raw materials also occurred in the surface material, the artefact categories from the surface material included flakes, retouched flakes, broken flakes, flaked pieces, cores, bevel artefacts and manuports. However, it is dangerous to extrapolate interpretation of an entire site on the basis of one pit, and the reverse is equally true - the greater BI9 area may reflect a number of different activities and associated foci that may or may not be contemporaneous with T4/P1. What is clear from the stone artefact evidence is that, with the exception of manuports, the same categories of artefacts occur within SUIV and the midden deposit in SUIII; the greater artefact abundance in SUIV reflects its longer period of deposition. It is therefore inferred the same types of activities were being undertaken. Although the artefact assemblage is small, it has the hallmarks of a technology used in low-risk environments (Hiscock 1994; see also Smith 2003), suggesting that the resource base serving BI9 was reliable and assured. The raw materials found in T4/P1 all occur within 60km of the Island. Possible provenances were presented in Table 7-28. It is interesting to note that the same raw materials are present at the site from its inception until its abandonment, suggesting that the sources exploited remained accessible throughout.

The low species richness and diversity in BI9, and most particularly the absence or minimal occurrence of *T. hirsuta* and *P. ebeninus*, is surprising given the abundance of those taxa, particularly *P. ebeninus* noted elsewhere on the Island, e.g. WP3 and the numerous surface midden scatters (Smith 1992, 2003). The absence is therefore unlikely to reflect taste-preference, foraging choice, or differential processing and discard. The presence of the species elsewhere suggests a relationship between environmental conditions and micro-habitat structure affecting species distribution. This relationship has been demonstrated for TCB 75b and CP 62 in Tin Can Bay Inlet, and at BSM in the GSS, and is suggested as the reason for the relatively low species diversity at BI9, and also the low occurrence of *P. ebeninus*, probably due to the lack of suitable *Zostera* beds in the vicinity. Smith (1992) noted that *P. ebeninus* was relatively more common in middens scatters in the south of the island than in the north. The absence of *T. hirsuta* indicates a lack of suitable structures on which to settle (Gosling 2003). McNiven (1994:46-47) remarked on the paucity of *Donax deltoides* remains at the Maroochy River sites in view of their proximity, like BI9, to the oceanic coast, and concluded that estuarine resources in late Holocene southeast Queensland exerted a greater subsistence ‘pull’ (Jochim 1976) than ocean beach resources, such as pipi, due to the greater diversity and abundance of potentially edible shellfish in estuaries. As has been suggested for WP3, *Donax* may have been as a raw material as well as a food. It is interesting to note that no pipi was identified below 36cm, a depth roughly equivalent to 1169 BP, around the time when pipi begins to dominate surf coast middens. Although the data are minimal, dietary contribution by fishing is indicated by the vertebrae and other bone fragments in SUIII. The small mammal bones may reflect use of terrestrial species.

The taphonomic factors affecting the assemblage impact significantly on its appearance and consequent interpretation. The pH levels for T4/P1 SUIV were 6.5, trending acid-neutral, with a pH of 7 in SUIII. Levels recorded elsewhere on the island were 4.5 (MRAP files; Smith 1992), more closely reflecting the acidic nature of the podzols which form the basis of all sediments on the Island. The pH levels at T4/P1 indicate an anthropogenic element, the result of the decomposition of large amounts of organic, alkaline, material (i.e. shell) in acidic soil, ultimately raising the pH level. The pH levels may also have been affected by the suggested expansion of woodland or wallum vegetation in the area. Taken together, a case may be made for low level, perhaps sporadic, use of the BI9 ridge from about 3500 years ago. Shellfish were exploited and consumed/deposited at the site, along with stone artefactual evidence of tool use, manufacture/maintenance, and discard. The acidic soils inhibited preservation of the shellfish themselves, with the stone artefacts remaining as evidence of occupation. The increased deposition of alkaline organic remains gradually raised the pH level. The midden deposit in SUIII represents relatively more intensive use of the site over a short period. This scenario accounts for the greater abundance of artefacts in SUIV below the midden (and deposited over a longer timeframe), and also for the occurrence of fragmented shell within SUIV, which became more frequent, in a relatively degraded condition, in the upper levels near the interface with SUIII (e.g. Claassen 1998; Hughes 1977; Stein 2001; Sullivan 1993). The location of BI9 may have served, as suggested by Smith (1992, 2003; see also Steele 1984), as a transit stopover point from the mainland to Moreton Island and vice versa, as well as serving an historically-recorded pathway along the eastern surf beach (Uniacke 1823 in Mackaness 1979).

## *Conclusion*

Surface midden and artefact scatters occur all over Bribie Island. However, it is difficult to draw any conclusions about occupation and use of the island as a whole from WP3 and BI9, as they represent only 1.66% of the sites recorded on the island, and are the only dated sites. The necessity for further excavation of coastal and sub-coastal sites on the island to obtain series of $^{14}C$ age determinations in order to better understand the sequence and the nature of occupation, and the influencing factors, is clear. Nonetheless this chapter has characterised a relatively short-term occupation some 500 years ago at WP3, and provided evidence of the antiquity of shell tool use in the Moreton Region. Importantly, BI9 has demonstrated use of the island and exploitation of estuarine resources for at least the last 3500 years. This early use was initially sporadic and/or low level, with evidence of greater intensity of site use in the past 200 years. The implications of the evidence from BI9 for broader interpretations of the chronology of occupation of the study area are explored further in the final chapter.

# 8. Hope Island and St. Helena Island

## *Introduction*

This chapter presents the results and discussion of a literature-based re-analysis of two sites excavated and reported during the 1980s: Hope Island in the Gold Coast area, the most southerly part of the study region, and St. Helena Island, an island in central Moreton Bay (Figure 1-1). The sites were selected for re-analysis on the basis that the midden assemblages were multi-species, and had two or more radiocarbon age determinations. Their locations also offer environmental counterpoints to the sites in northern Moreton Bay and the Great Sandy Region. Literature-based re-analyses were undertaken as the original excavated material from both sites was unavailable; the Hope Island material has been incorporated into an interpretive display at the Yugambeh Museum, and the whereabouts of the St. Helena material is presently unknown. The sites also offered the opportunity to test the applicability of a 'retro-fit' of literature-based data in the context of paradigm shifts and environmental reconstructions developed since the original analyses.

## *Hope Island*

The Hope Island site was an extensive midden deposit on the southern bank of the Coomera River approximately 5km from its mouth in Moreton Bay (Hall 1999; Walters *et al.*1987). Although now modified, the Coomera River is a river-dominated estuary with a tide-dominated delta (Ozcoast Geoscience Australia 2015) i.e. a river directly connected with the sea via channels. Characteristics of tide-dominated deltas include associated low elevation vegetated floodplains and swamps; infilling by terrigenous and marine sediments; tidal sandbanks; and large tidal ranges associated with high levels of turbidity (Ryan *et al.* 2003:63). During the mid-Holocene climatic optimum a transgressive barrier/back barrier dune system which eventually developed into South Stradbroke Island enclosed the embayment into which the river discharged (Neil 1998:10). In the 1980s the Gold Coast region experienced what was at the time an unprecedented level of development, and Hope Island was incorporated into Sanctuary Cove, 'the ultimate resort' (Figure 8-1). The salvage excavation, undertaken in association with representatives of the Kombumerri, became known as 'the ultimate site'.

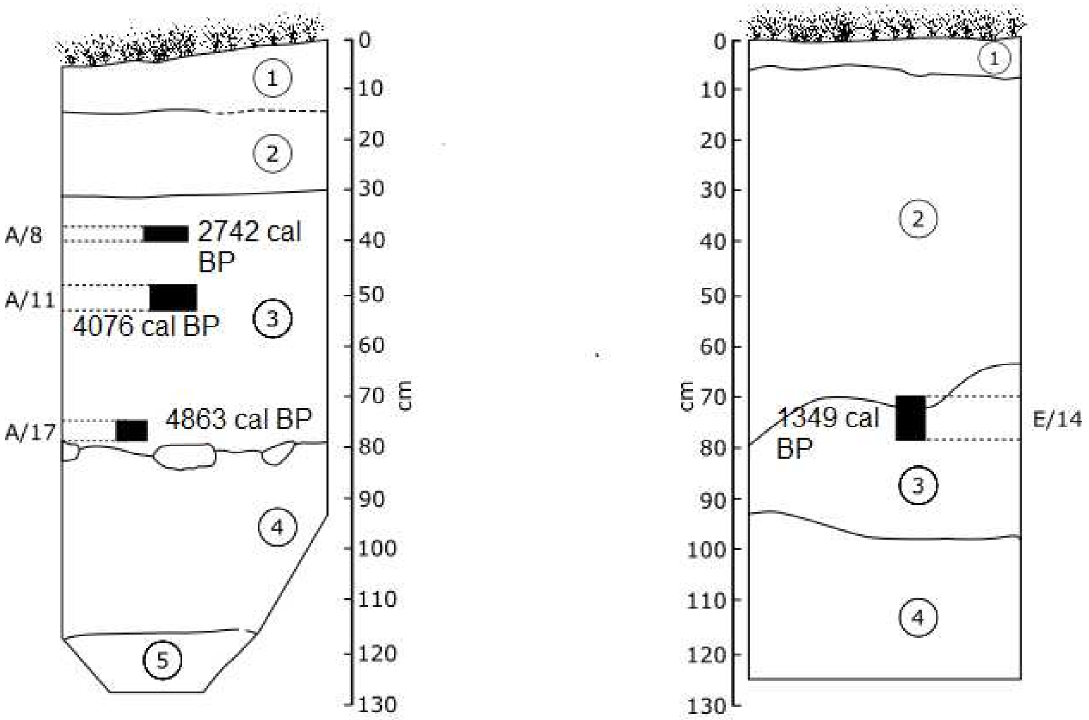
Surveys had located a thick bed of shell exposed in the river bank, with shell in varying densities scattered up to 45m away. Three contiguous 50cm x 50cm pits, A, B and C, were excavated in the area exhibiting the greatest surface density of shell, and two further contiguous 50cm x 50cm pits, E and F, were excavated on the river bank over the exposed shell bed (Walters *et al.* 1987:82). Excavation followed the Johnson (1980) bucket method with excavation units equivalent to the amount of deposit required to fill a 10 litre bucket, while conforming to stratigraphic boundaries where possible. The excavated material was wet-sieved through 3mm mesh. Only material from Squares A and E was analysed, with the remainder retained by the Kombumerri representatives should further questions or considerations arise (Walters *et al*. 1987:85). The total volume of excavated sediments was 0.257m$^3$ for Square A, and 0.365m$^3$ for Square E.

**Figure 8-1 Hope Island showing the site location.**

Five stratigraphic units were described for Square A, and four for Square E (Figure 8-2). A total of four $^{14}$C age determinations on charcoal were obtained, one from Square E and three from Square A. The decision was made on financial grounds to sacrifice further determinations from the upper levels of Square A in order to obtain a near-basal determination for Square E (Walters *et al*. 1987:88). Metal and glass were observed in the upper 12cm of the excavation, and it was assumed that this layer dated at least to the European period, thus providing a relative chronology with a terminus ante quem. The age determinations were recalibrated by Ulm and Reid (2000:23) (Table 8-1), and the median values are used in the present discussion.

**Table 8-1 Radiocarbon age determinations for Hope Island (after Walters *et al.* 1987:88; Ulm and Reid 2000:23)**

| Square/XU | Depth cm | Sample | Laboratory code | Conventional $^{14}$C age | 2σ calibrated age range |
|---|---|---|---|---|---|
| E/14 | 78 | Charcoal | Beta-20800 | 1500±80 BP | 1533(1349)1264 |
| A/8 | 35 | Charcoal | Beta-20797 | 2600±70 BP | 2837(2742)2363 |
| A/11 | 50 | Charcoal | Beta-20798 | 3720±70 BP | 4240(4076,4032,3990)3834 |
| A/17 | 75 | Charcoal | Beta-20799 | 4350±220 BP | 5579(4863)4298 |



Layer 1 is shell in dark grey sand; Layer 2 is shell in pale grey sand; Layer 3 is dense shell in grey ashy sediment; Layer 4 is sparse shell in dark brown sediment with many rocks; Layer 5 is pale yellow sterile sand. Provenances of dated charcoal samples are shown.

Layer 1 is sparse fragmented shell in dark grey sand; Layer 2 is dense shell in grey sand; Layer 3 is sparse shell in brown gravelly sediment; Layer 4 is bedrock. Provenance of dated charcoal sample is shown.

**Figure 8-2 Stratigraphic profiles of Hope Island Squares A and E (after Walters *et al.* 1987:84) showing locations of radiocarbon determinations..**

### *Molluscan remains*

The total shellfish MNI for Square A was 8605, with the MNI for Square E 5695. Frustratingly, MNI were recorded only for those taxa considered to be economic, although "varying numbers of non-economic species were present throughout the deposit" (Walters *et al*. 1987:85), including small littorinids and limpets. As the excavation units were also the units of analysis, the total bivalve MNI was calculated using the MNI of the greater number of left or right valves in each excavation unit; this approach tends to aggregate the numbers of shellfish present when calculating in arbitrary spits rather than stratigraphic units (Grayson 1984). Gastropod MNI for each XU was calculated by adding the greater number of spires or apertures from partial shells to the number of whole specimens. Shell weights were not recorded. Walters' *et al*. (1987) original data are reproduced in Tables 8-2 and 8-3 with the addition of the corresponding stratigraphic unit numbers, and summarised by SU in Tables 8-4 and 8-5. Volume-corrected MNI estimates are presented in Tables 8-6 and 8-7.

**Table 8-2 Molluscan data from Hope Island Square A (after Walters *et al*. 1987:86).**

| **SU** | **XU** | **Depth cm** | ***Anadara trapezia*** | ***Trichomya hirsuta*** | ***Saccostrea* spp.** | ***Batillaria australis*** | ***Pyrazus ebeninus*** | ***Donax deltoides*** |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 3.8 | 5 | 0 | 289 | 11 | 12 | 1 |
| 1 | 2 | 6.8 | 4 | 0 | 408 | 13 | 13 | 0 |
| 2 | 3 | 12.3 | 3 | 0 | 571 | 20 | 20 | 0 |
| 2 | 4 | 14.5 | 2 | 0 | 542 | 26 | 7 | 0 |
| 2 | 5 | 24.8 | 6 | 0 | 451 | 11 | 6 | 1 |
| 3 | 6 | 28.3 | 15 | 2 | 307 | 6 | 7 | 0 |
| 3 | 7 | 32.5 | 10 | 0 | 484 | 3 | 2 | 1 |
| 3 | 8 | 35 | 52 | 0 | 580 | 4 | 10 | 1 |
| 3 | 9 | 40.3 | 122 | 0 | 400 | 5 | 34 | 0 |
| 3 | 10 | 44.3 | 153 | 0 | 493 | 3 | 69 | 0 |
| 3 | 11 | 49 | 225 | 4 | 458 | 10 | 51 | 3 |
| 3 | 12 | 52.5 | 106 | 12 | 351 | 2 | 26 | 0 |
| 3 | 13 | 55.3 | 113 | 17 | 606 | 5 | 26 | 0 |
| 3 | 14 | 60.5 | 104 | 8 | 364 | 4 | 8 | 0 |
| 3 | 15 | 64.5 | 89 | 9 | 297 | 3 | 15 | 0 |
| 3 | 16 | 71.5 | 60 | 2 | 123 | 7 | 11 | 1 |
| 3 | 17 | 75 | 39 | 0 | 64 | 0 | 3 | 0 |
| 4 | 18 | 79.5 | 24 | 1 | 27 | 0 | 19 | 0 |
| 4 | 19 | 85 | 11 | 0 | 29 | 0 | 6 | 0 |
| 4 | 20 | 89.5 | 4 | 0 | 49 | 2 | 1 | 0 |
| 4 | 21 | 96.5 | 1 | 0 | 12 | 0 | 1 | 0 |
| 4 | 22 | 102.8 | 1 | 0 | 6 | 0 | 0 | 0 |
|  |  | **Total** | **1149** | **55** | **6911** | **135** | **347** | **8** |

**Table 8-3 Molluscan data from Hope Island Square E (after Walters *et al*. 1987:86).**

| **SU** | **XU** | **Depth cm** | ***Anadara trapezia*** | ***Trichomya hirsuta*** | ***Saccostrea* spp.** | ***Batillaria australis*** | ***Pyrazus ebeninus*** |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 6.8 | 1 | 1 | 141 | 3 | 0 |
| 1 | 2 | 12 | 0 | 1 | 238 | 6 | 7 |
| 2 | 3 | 16 | 1 | 0 | 282 | 5 | 8 |
| 2 | 4 | 21.8 | 0 | 1 | 437 | 34 | 4 |
| 2 | 5 | 27.5 | 0 | 4 | 500 | 39 | 2 |
| 2 | 6 | 36 | 0 | 4 | 575 | 27 | 0 |
| 2 | 7 | 38.8 | 0 | 1 | 494 | 31 | 2 |
| 2 | 8 | 43.8 | 0 | 2 | 550 | 43 | 0 |
| 2 | 9 | 48.3 | 1 | 2 | 481 | 36 | 4 |
| 2 | 10 | 52.8 | 0 | 0 | 356 | 25 | 13 |
| 2 | 11 | 58.3 | 0 | 0 | 364 | 35 | 14 |

**Table 8-3 (continued) Molluscan data from Hope Island Square E (after Walters et al. 1987:86).**

| SU | XU | Depth cm | *Anadara trapezia* | *Trichomya hirsuta* | *Saccostrea* spp. | *Batillaria australis* | *Pyrazus ebeninus* |
|---|---|---|---|---|---|---|---|
| 2 | 12 | 65 | 0 | 0 | 485 | 47 | 7 |
| 2 | 13 | 70.5 | 2 | 0 | 190 | 14 | 4 |
| 3 | 14 | 77.8 | 3 | 0 | 149 | 3 | 7 |
| 3 | 15 | 86.5 | 0 | 0 | 6 | 0 | 0 |
| 3 | 16 | 93.5 | 0 | 0 | 3 | 0 | 0 |
| 3 | 17 | 96 | 0 | 0 | 0 | 0 | 0 |
| | | **Total** | **8** | **16** | **5251** | **348** | **72** |

**Table 8-4 Summary of molluscan MNI by SU for Hope Island Square A.**

| Taxon | SU1 | SU2 | SU3 | SU4 | Total MNI | %Total MNI |
|---|---|---|---|---|---|---|
| *Anadara trapezia* | 9 | 11 | 1088 | 41 | 1149 | 13.35% |
| *Trichomya hirsuta* | 0 | 0 | 54 | 1 | 55 | 0.64% |
| *Saccostrea* spp. | 697 | 1564 | 4527 | 123 | 6911 | 80.31% |
| *Batillaria australis* | 24 | 57 | 52 | 2 | 135 | 1.57% |
| *Pyrazus ebeninus* | 25 | 33 | 262 | 27 | 347 | 4.03% |
| *Donax deltoides* | 1 | 1 | 6 | 0 | 8 | 0.09% |
| **Total** | **756** | **1666** | **5989** | **194** | **8605** | **100.00%** |

**Table 8-5 Summary of molluscan MNI by SU for Hope Island Square E.**

| Taxon | SU1 | SU2 | SU3 | Total MNI | %Total MNI |
|---|---|---|---|---|---|
| *Anadara trapezia* | 1 | 4 | 3 | 8 | 0.14% |
| *Trichomya hirsuta* | 2 | 14 | 0 | 16 | 0.28% |
| *Saccostrea* spp. | 379 | 4714 | 158 | 5251 | 92.20% |
| *Batillaria australis* | 9 | 336 | 3 | 348 | 6.11% |
| *Pyrazus ebeninus* | 7 | 58 | 7 | 72 | 1.26% |
| **Total** | **398** | **5126** | **171** | **5695** | **100.00%** |

**Table 8-6 Volume-corrected MNI estimates for Hope Island Square A.**

| **Sq A** | | **SU1 $m^3$** | **SU2 $m^3$** | **SU3 $m^3$** | **SU4 $m^3$** | **Total** |
|---|---|---|---|---|---|---|
| | | 0.017 | 0.045 | 0.1255 | 0.0695 | 0.257 |
| All shell | MNI | 756 | 1666 | 5989 | 194 | 8605 |
| | MNI/m3 | 44471 | 37022 | 47721 | 2791 | 33482 |
| *Anadara trapezia* | MNI | 9 | 11 | 1088 | 41 | 1149 |
| | MNI/m3 | 529 | 244 | 8669 | 590 | 4471 |
| *Pyrazus ebeninus* | MNI | 25 | 33 | 262 | 27 | 347 |
| | MNI/m3 | 0 | 0 | 0 | 0 | 1350 |
| *Saccostrea sp.* | MNI | 697 | 1564 | 4527 | 123 | 6911 |
| | MNI/m3 | 41000 | 34756 | 36072 | 1770 | 26891 |
| *Trichomya hirsuta* | MNI | 0 | 0 | 54 | 1 | 55 |
| | MNI/m3 | 0 | 0 | 0 | 0 | 214 |
| *Batillaria australis* | MNI | 24 | 57 | 52 | 2 | 135 |
| | MNI/m3 | 1471 | 733 | 2088 | 388 | 525 |

**Table 8-7 Volume-corrected MNI estimates for Hope Island Square E.**

| **Sq E** | | **SU1 m$^3$** | **SU2 m$^3$** | **SU3 m$^3$** | | **Total** |
|---|---|---|---|---|---|---|
| | | 0.03 | 0.146 | 0.189 | | 0.365 |
| All shell | MNI | 398 | 5126 | 171 | | 5695 |
| | MNI/m3 | 13267 | 35050 | 906 | | 15603 |
| *Anadara trapezia* | MNI | 1 | 4 | 3 | | 8 |
| | MNI/m3 | 33 | 27 | 16 | | 22 |
| *Pyrazus ebeninus* | MNI | 7 | 58 | 7 | | 72 |
| | MNI/m3 | 233 | 397 | 37 | | 197 |
| *Saccostrea sp.* | MNI | 379 | 4714 | 158 | | 5251 |
| | MNI/m3 | 12633 | 32232 | 837 | | 14386 |
| *Trichomya hirsuta* | MNI | 2 | 14 | 0 | | 16 |
| | MNI/m3 | 67 | 96 | 0 | | 44 |
| *Batillaria australis* | MNI | 9 | 336 | 3 | | 348 |
| | MNI/m3 | 300 | 2297 | 16 | | 953 |

### *Molluscan Richness and Diversity: Inter-square Comparisons*

The measurements of richness and diversity have been strongly influenced by the decision of Walter *et al*. (1987) to report only the taxa considered to be economic. All indices reflect low values (Table 8-8).

**Table 8-8 Diversity indices for Hope Island Square A and Square E.**

| **Diversity Measure** | **Square A** | **Square E** |
|---|---|---|
| NTAXA | 6 | 5 |
| Individuals | 8605 | 5695 |
| Simpson's Index (1-D) | 0.3352 | 0.1459 |
| Shannon Index of Diversity (′H) | 0.6784 | 0.3266 |
| Shannon Index of Evenness (E) | 0.3786 | 0.2029 |

## Taxon specific analysis

### *Saccostrea* spp.

*Saccostrea* spp. was the dominant taxon in both squares, although its relative abundance and that of the other recorded species varied across the SUs (Tables 8-4 and 8-5). Plots of the relative abundances by SU (Figure 8-3) clearly illustrate the differences in discard, rendering statistical analysis unnecessary in this instance.

The data suggest that although levels of exploitation varied, the local environment was suitable for the growth of oysters from at least 4863 cal BP. This early date for a coastal site raises questions about the timing of local shoreline regression and progradation, and the development (or continuation) of a marine economy.

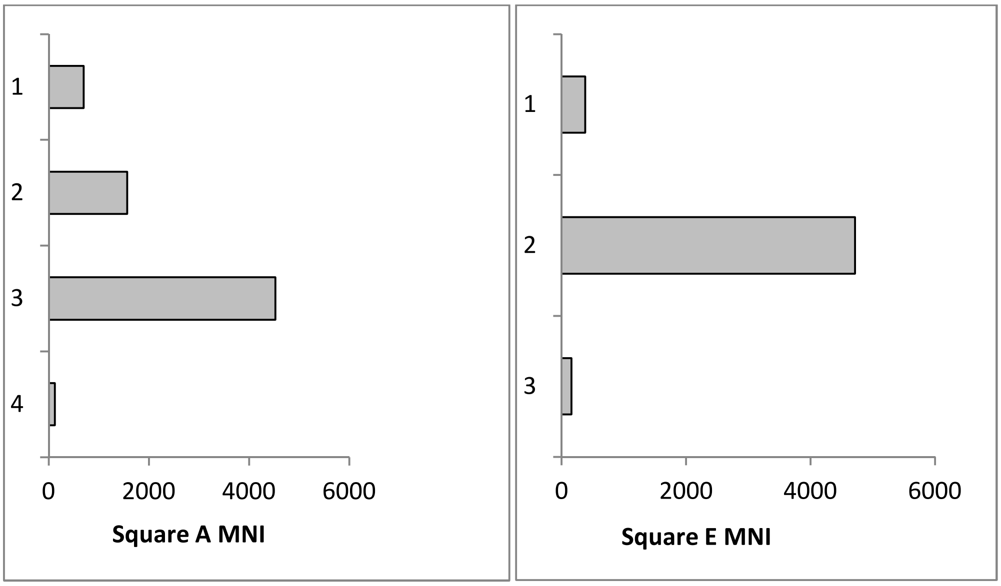


**Figure 8-3 Relative abundances of *Saccostrea* spp. by SU at Hope Island Squares A and E.**

*Anadara trapezia*

*A. trapezia* was the second most abundant taxon in Square A (MNI=1149, 13.35%) but not in Square E (MNI=8, 0.14%) (Table 8-4 and Table 8-5). The results of a Shapiro-Wilk test of normality for *A. trapezia* MNI in Square A (SU2 *W=0.964, df=3, p=0.637*; SU3 *W=0.947, df=12, p=0.596*; SU4 *W=0.827, df=5, p=0.132*) indicated that relative abundance followed a normal distribution. No result was returned for SU1 because of the small sample size (see Field 1984). The Levene result (*L=3.805, df3=2, df2=18, p=.0.28*) demonstrated that the assumption of homogeneity of variances was violated, while the ANOVA result indicated that there was a difference in the group means (*F=5.680, df=3, p=0.006*). The robust Welch (*W=7.080, df1=3, df2=6.481, p=0.018*) and Brown-Forsythe (*B=22.702, df1=3, df2=12.019, p=0.000*) results indicated significant differences in abundance across the SUs. Post hoc Tukey HSD indicated no significant differences in the abundance of *A. trapezia* between SU1 and the other SUs (SU2 *Mean= 1.833, p=1.000;* SU3 *Mean=-86.167, p=.124;* SU4 *Mean=-3.700, p=1.000*). SU3 was slightly different from SU2 (*Mean=88.000, p=.049*) and SU4 (*Mean 82.467, p=.022).* The overall MNI in Square E did not allow meaningful statistical analysis.

The abundance of *A. trapezia* in Square A SU3 and the relatively low abundances in the other SUs, and low occurrence in Square E raises questions about whether there were changes in dietary preferences, cultural practices or local habitats suitable for *A. trapezia*, or if the exploitation in Square A SU3 was sufficient to depress the resource in the period after 2742 cal BP.

*Pyrazus ebeninus and Batillaria australis*

The two gastropod taxa are reported together as they have broadly similar habitat requirements and commonly occur together on mudflats and seagrass beds. *P. ebeninus* was present in all SUs in both squares although the abundances varied (Tables 8-2 to 8-5); overall it was more common in Square A. The Levene statistic for Square A *L= 2.752, df 1=3, df2=18, p=.073* indicated homogeneity in variance across the SUs, and the ANOVA result (*F=1.192, df=3, p=.341*) also demonstrated no significant difference. The robust Welch result (*W=1.710, df1=3, df2=6.105, p=.262*) confirmed equal variance, while the Brown-Forsythe result (*B=3.452, df1=3, df2= 16.001, p=.042*) suggested a very slight difference at the 0.05 level. Statistical analyses for *P. ebeninus* in Square E were not performed because of the small sample size (MNI=7) in both SU1 and SU3. The MNI of *B. australis* in Square A SU4 was two, and therefore was excluded from the statistical analyses. The Levene statistic *L=.832, df1=2, df2=13, p=.457* indicated homogeneity of variance, although the ANOVA result was *F=34.298, df=2, p=.000.* The robust Welch statistic (*W=19.343, df1=2, df2=2.031, p=.048*) indicated a very slight difference at the 0.05 level, while the Brown-Forsythe result (*B=29.283, df1=2, df2= 1.513, p=.062*) indicated no significant difference across the SUs. Post hoc Tukey HSD testing indicated significant differences between the three SUs (Table 8-9).

**Table 8-9 Tukey HSD results for B. australis in Hope Island Square A.**

**Multiple Comparisons**

**Dependent Variable: *B. australis***

| | **(I) SU** | **(J) SU** | **Mean Difference (I-J)** | **Std. Error** | **Sig.** | **95% Confidence Interval** | |
|---|---|---|---|---|---|---|---|
| | | | | | | **Lower Bound** | **Upper Bound** |
| Tukey HSD | 1 | 2 | -11.000* | 2.886 | .006 | -18.62 | -3.38 |
| | | 3 | 6.750* | 2.204 | .023 | .93 | 12.57 |
| | 2 | 1 | 11.000* | 2.886 | .006 | 3.38 | 18.62 |
| | | 3 | 17.750* | 2.204 | .000 | 11.93 | 23.57 |
| | 3 | 1 | -6.750* | 2.204 | .023 | -12.57 | -.93 |
| | | 2 | -17.750* | 2.204 | .000 | -23.57 | -11.93 |

* The mean difference is significant at the 0.05 level.

Statistical analyses for *B. australis* in Square E were not performed because of the small sample sizes in SU1 (MNI=9) and SU3 (MNI=3)**,** however it can be noted that the increased relative abundance of *B. australis* in Square E coincided with the decline in *P. ebeninus* values. *B. australis* occupies a greater range of substrates than *P. ebeninus*, including sand, sandy mud, pebbles and rocks as well *Zostera* beds; it lives in high-density colonies and is usually the dominant mollusc in the areas where it occurs (Ewers 1967:584-585). *P. ebeninus* is the larger of the two species, with a maximum height of 100mm, while maximum shell height for *B. australis* is 49mm, although this is dependent upon substrate and water depth. Walters *et al*. (1987) do not specify why *B. australis* was included in the tally of economic species but presumably the specimens were of sufficient size to suggest their suitability for consumption.

*Trichomya hirsuta*

The low abundances of *T. hirsuta* in both squares (Square A MNI=55, 0.64%; Square E MNI=16, 0.28%) (Tables 8-4 and 8-5) did not allow for meaningful statistical analyses. Mussels are often found in association with oysters (Healy and Potter 2010:238), although this is not always the case, and mussels usually require some type of structure on which to attach and establish colonies. The *T. hirsuta* in the Hope Island middens suggest that the local environment which formed the foraging range did not have suitable habitats to support the development or long-term maintenance of viable colonies.

*Donax deltoides*

The low abundance of *D. deltoides* suggests that the species was not a significant dietary component. At the time of the midden deposition the closest source was most likely the surf beach on the back-barrier dune which developed into South Stradbroke Island. It may be that access to the resource was difficult, and also that at the time the midden was deposited it was not a preferred food item (see McNiven 2006). It was suggested in the Bribie Island chapter that the presence of *D. deltoides* in estuarine middens may reflect their use as a raw material rather than as a dietary component, but the antiquity of shell tool manufacture and use in the Moreton Region has not yet been established, and such an inference is not possible for the Hope Island middens.

### Other excavated material

Charcoal and small amounts of fragmented bone were found throughout the excavations (Table 8-10). The bone could not be identified to taxon. A terrestrial vertebrate tooth was found in Square A at the base of SU2, and a terrestrial vertebrate mandible with teeth in Square E SU1. Four stone flakes were found in Square A SU3, three from a depth of 28.3cm and one from a depth of 60.5cm, but there is no further description of the items or raw material(s). The volume-corrected density of stone artefacts is 15 per m$^3$. The small number of artefacts relative to the abundance of molluscan remains suggests the site was not used for the manufacture or maintenance of stone tools. Non-artefactual rubble occurred throughout the deposit. Red ochre was found at a depth of 64.5cm in Square A SU3, and at 86.5cm and 93.5cm at the base of SU3 in Square E, but the form and quantities were not specified. Metal and glass objects were recovered from the upper three XUs

(SU1 and the upper level of SU2) of Square E, but the objects were not further described (Walters *et al.*1987:85, 87).

**Table 8-10 Hope Island charcoal and bone weights by Square and SU.**

| Square A | | | Square E | | |
|---|---|---|---|---|---|
| **SU** | **Charcoal Wt g** | **Bone Wt g** | **SU** | **Charcoal Wt g** | **Bone Wt g** |
| 1 | 12.6 | 2.8 | 1 | 46.6 | 0.13 |
| 2 | 22.7 | 2 | 2 | 142.7 | 9.8 |
| 3 | 37.4 | 5.4 | 3 | 3.6 | 0 |
| 4 | 6.9 | 0.2 | | | |

## *Discussion*

Hope Island was a salvage excavation with limited funding provided by the developer, and intended to minimise damage to the site; the investigators had specific, basic, questions concerning the deposits, most particularly the age of the midden, the nature of the food consumed there, and the activities undertaken (Walters *et al.* 1987:82). The data obtained and the levels of analyses undertaken were sufficient to answer those questions in terms of providing a very broad characterisation of the deposit and its constituent components, but can otherwise be considered to be low-resolution.

Calculation of sedimentation rates after the method described by Stein *et al.* (2003) for sediments in Square A between the dates of 4863 cal BP at 75cm in SU3 XU17 and 4076 cal BP at 50cm in SU3 XU11 is 17cm/100 years, an intermediate rate of deposition; the rate of deposition between 4032 cal BP and 2742 cal BP at 35cm in SU3 is in the slow range at 1cm/100 years. These rates of deposition and abundance of molluscan remains suggest that site use was relatively more intense in the period following the establishment of the midden, and that use of the site was continuous albeit less intense after 4076 cal BP. This is reflected in the abundance of the material discarded above the main, dense, midden deposit. Similar calculations for Square E are not possible in view of the single age determination from the excavation, although the observation can be made that deposition of the ~70cm of SU2, the bulk of the sediments, appears to have been relatively more rapid than sediment accumulation in Square A; the relatively high charcoal values in Square E SU2 also suggest relatively more intense site use. Walters *et al.* (1987:93) suggested that evidence of European occupation commences at a depth of approximately 12cm in Square E and that by extension XU4 in SU2 of Square A represents the last phase of prehistoric occupation in that area of the midden. In an internal contradiction, the authors also suggest (1987:91) on the basis of suggested age-depth calibration, that the upper five or six XUs (SUs 1 and 2) in Square A should be contemporaneous with the base of Square E; the sandy matrices are described as similar (Figure 8-2) as are the distributions and abundances of shellfish (Figure 8-3). The two excavations are separated by approximately 30m and there is no information regarding the intermediate deposits between them. Walters *et al*. do not discuss the potential impacts of European use of Hope Island on the integrity of the upper levels of the midden deposits (including the presence of the mandible in Square E SU1), although they describe the surface as "littered with debris from European campers and fishing people. Squatter-type camps and huts had apparently been here for many years as Hope Island had been a popular fishing place" (1987:81).

Walters *et al*. (1987:92) reasonably posited that Square A, further from the present river bank, was first occupied during a higher river level. The deposits from Square E are suggested to represent evidence of use of a section of the river bank newly exposed either by falling sea levels or increased sedimentation. One of the characteristics of tide-dominated deltas described by Ryan *et al*. (2003:63) is infilling by terrigenous and marine sediments; Neil (1998) also describes progradation of mainland sediments, changes in tidal regimes and reductions in water depths, and changes in biomass (e.g. seagrass) distribution in the Moreton Bay region since the mid-Holocene. As river levels dropped and/or the channel changed due to increased sedimentation then the patterning of molluscan habitats may also have changed. However the continued occurrence and dominance of *Saccostrea* spp. throughout the deposits suggests that habitats suitable for oysters were at least stable within the foraging range of the site, although less so for mussels. The high numbers of *A. trapezia* in SU3 at the base of Square A are followed by very low abundances in the rest of the deposit, and also in Square E. This may be evidence of initial over-exploitation of the resource resulting in long-term depression of the species, but in the absence of information regarding valve size this inference must remain speculative. The abundance of *P. ebeninus* peaks with that of *A. trapezia*, and it may be that local seagrass beds were patchily distributed or, as noted for Tin Can Bay, often in flux; low abundances in the other SUs may reflect the patchy distribution and availability of the shellfish. *B. australis* is able to colonise a greater variety of habitats than *P. ebeninus*; the small littorinids and limpets mentioned in passing are evidence of exploitation of hard substrates (and perhaps by-catch with mussels and oysters), and it may be that these may have been the source of the mud whelks in Square E SU2. In view of Ewers' (1967) comments regarding the tendency to local dominance of *B. australis*, the high numbers may simply reflect the density of the resource.

On the basis of the available data, little more can be added to the Walters *et al*. (1987) discussion and interpretation of the site. At or slightly before 4863 cal BP, during a period marked by environmental dynamism and fluctuating sea levels, a group of people practising a specialised marine economy began to occupy the river bank at Hope Island, and did so at varying levels of intensity until sometime after 1349 cal BP, possibly until the arrival of Europeans in the area after 1825. The degree of shell discard could also indicate an economic transition prior to contact.

## *St. Helena Island*

St. Helena Island is located in central Moreton Bay, approximately 6km from the mouth of the Brisbane River (Figure 1-1). The climate is subtropical with warm, wet summers when the majority of the annual 1350mm rainfall occurs, and cooler, dry winters with average daytime temperatures of 25°C during summer and 15°C during winter (Bureau of Meteorology 2005). The island is fringed by a relic coral reef on the western and eastern sides, while the eastern side also still supports live corals. The area of the island above the high water mark is approximately 88ha, however the intertidal zone with the relic reefs covers an area in excess of 400ha (Alfredson 1983; 1984:14; Figure 8-4). The original vegetation prior to the establishment of a penal colony on the island in 1867 was dense vine forest, with an area of grassland and mangrove flats (Alfredson 1984:18). Prior to the clearance of the native vegetation the island supported large camps of flying-foxes (*Pteropus* sp.), whose preferred habitats include dense canopies in rainforests and mangroves, but there is little or no information available regarding other species which may have inhabited the island. The island was gazetted as a National Park in 1980.

**Figure 8-4 St. Helena Island showing the extensive fringing intertidal zone. The location of the midden is marked (Google Earth).**

### The excavation

The St. Helena Island midden designated LB:C52 on the Department of Environment and Heritage site register, and partly excavated by Alfredson (1984) was exposed in the face of a beach rock (coffee rock) quarry approximately 100m from the present shoreline in the south western area of the island (Figure 8-5). The midden face was approximately 50cm deep and 30m wide, exhibiting a relatively uniform horizontal layering, with varying densities of shell and bone, and levels of fragmentation, observed vertically through the deposit. There were no sterile sand layers visible (Alfredson 1984:28). Five distinct sedimentary units were visible beneath a thin layer of turf (Alfredson 1984:30):

1. Compact dark brown sand and fragmented shell c. 8cm thick;
2. Dark grey sand with shell exhibiting less fragmentation than the layer above, c. 10cm thick;
3. Dark grey sand with densely packed shell, predominantly oyster and whelk, c. 15cm thick;
4. Dark grey sand with less densely packed shell but with whole mussel shells, c.15cm thick; and
5. An underlying layer of sterile reddish brown sand.

The excavation took place as part of the development of a management plan for the Aboriginal sites on the island, including a stone artefact scatter (LB:C53) to the east of the midden. A 50cm x 50cm pit was excavated immediately behind the exposed face using the Johnson (1979, 1980) bucket method popular at the time. Alfredson (1984:42) chose this method for its speed of execution, as an excavation unit is deemed complete when the material excavated fills a ten litre bucket, and is therefore less time-consuming than taking repeated elevations to maintain a specific spit depth. She conceded, however, that strict horizontal control "was inhibited by the fact that some of the excavated material, such as whole whelks and dugong bone, were greater in depth than a single excavation unit" (Alfredson 1984:43). In all, 16 units with a total volume of 0.142m$^3$ were excavated to a depth of approximately 50cm. Excavation units 2-4 roughly correlate with SU1, excavation units 5-8 with SU2, excavation units 9-12 with SU3, and excavation units 13-16 with SU4. The mesh size for sieves used in the field was 2mm; in the laboratory material was dry sieved through nested Endicott sieves of 125µm, 250µm, 500 µm, 1mm, 2mm, 4mm, 8mm, and 16mm mesh (Alfredson 1984:43-44). Although the discussion of the selection of material for analysis is rather confused (Alfredson 1984:43-44, 48), it would appear that a 75% sample based on weight from each XU was sieved with all material from the >4mm fraction sorted and analysed, "while only enough of the 2-4mm material was sorted to keep the sorted material over 75%" (Alfredson 1984:48).

Faunal material was recovered from all excavation units (Alfredson 1984:52-66). Invertebrate faunal remains mainly consisted of marine and terrestrial molluscs, with some crustacean fragments also present in XUs 4-16 (base of SU1 through to the base of SU4). The vertebrate faunal remains comprised fish bones, some dugong bones in XUs 5 and 6 at the interface of SUs 1 and 2, fragments of marine turtle carapace in XUs 4-9 (SUs 1and 2), fragments of freshwater turtle carapace in XUs 12-16 (base of SU3 and all of SU4), and bearded dragon (*Amphibolorus barbatus*) mandibular fragments and vertebrae (and also the possible remains of the frilled lizard *Chlamydosaurus kingii*) in five XUs from SUs 3 and 4. The grey-headed flying-fox (*Pteropus poliocephalus*) was identified on the basis of dentition, temporal, and frontal bones; fragmented long bones were also present in XUs 2-16 (i.e. SU1-SU4). Fish bone was the most numerous of the vertebrate remains (NISP=579). Alfredson (1984:73) considered that the material from units 2 to 5 (i.e. all of SU 1 and the top of SU2) represent disturbed quarry spoil as units 2-4 contained beach rock gravel and grit that was absent from the lower units. The uppermost layer containing very fragmented shell and beach rock fragments was restricted to the periphery of the quarry, as augering at 20m, 30m and 40m from the pit showed that the compacted layer of relatively complete shells immediately underlay the grass. Also, the disturbed area contained a bottle glass flake underlying dugong bone. Alfredson (1984) interpreted this as evidence of the contact period post-1824, and possibly associated with the dugong processing facility established in the early 1860s.

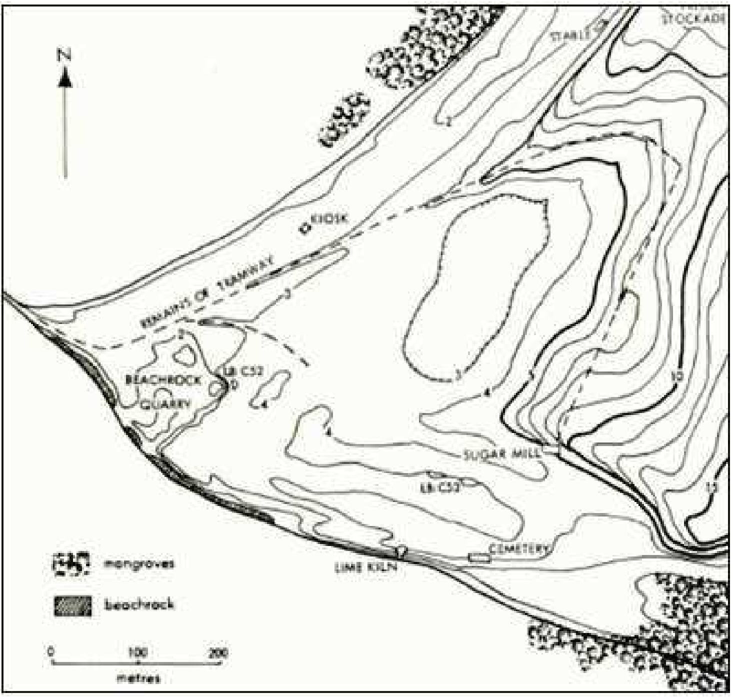


**Figure 8-5 Southwest St. Helena Island showing the location of site LB:C52 (after Alfredson 1983, 1984).**

Radiocarbon age determinations on *Saccostrea* sp. were obtained from a depth of 21.5cm in XU9 at the top of SU3, and from a depth of 36cm in XU13 at the top of SU4. Ulm and Reid (2000:33) revised the calibrated ages, and their median values are those used in the present discussion (Table 8-11). Calculation of sedimentation rates after the method described by Stein *et al*. (2003) was in the slow range at 1.58cm/100 years.

**Table 8-11 Radiocarbon determinations from St. Helena Island LB:C52.**

| SU/XU | Depth cm. | Sample | Laboratory code | Conventional $^{14}$C age | 2σ calibrated age range |
|---|---|---|---|---|---|
| SU3/9 | 21.5 | *Saccostrea* | Beta-6140 | 1370±60 | 1031(912)766 |
| SU4/13 | 36 | *Saccostrea* | Beta-6141 | 2240±20 | 1986(1825)1677 |

## Molluscan remains

Alfredson (1984:52-55) reported 3383 individual shells from 24 gastropod and 16 bivalve taxa (Table 8-12). The dominant species as noted by Alfredson (1984:52) were among those traditionally considered as economic, i.e. *Saccostrea* spp. (rock oyster), *T. hirsuta* (hairy mussel) and *P. ebeninus* (Hercules Club mud whelk), although both *Velacumantus* (now *Batillaria*) *australis* (Australian mud whelk, MNI=200) and *Clypeomorus tuberculatus* (creeper, MNI=365) were more numerous. Alfredson (1984:53) commented that these species, along with *Thalotia comtessel* (top shell, MNI=159), included a very high proportion of juveniles; this was also the case at Booral Shell Mound, where juvenile Hercules Club whelks and mud whelks occurred in very high numbers relative to adult specimens. Table 8-13 presents the volume-corrected MNI estimates for all of the molluscan remains, as well as those for the dominant economic species.

**Table 8-12 Molluscan remains from St. Helena Island by SU (after Alfredson 1984:54). Taxonomy is as originally reported.**

| Taxon | SU1 | SU2 | SU3 | SU4 | Total MNI | % Total MNI |
|---|---|---|---|---|---|---|
| *Acrosterigma reeveanum* | 0 | 1 | 0 | 1 | 2 | 0.06% |
| *Amusium balloti* | 1 | 2 | 0 | 0 | 3 | 0.09% |
| *Anadara trapezia* | 4 | 10 | 8 | 5 | 27 | 0.80% |
| *Antigona chemnitzii* | 1 | 1 | 1 | 1 | 4 | 0.12% |
| *Arca* sp. | 0 | 2 | 5 | 8 | 15 | 0.44% |
| *Atactodea striata* | 1 | 3 | 1 | 2 | 7 | 0.21% |
| *Austrocochlea constricta* | 7 | 6 | 1 | 1 | 15 | 0.44% |
| *Barbatia pistachia* | 1 | 3 | 4 | 1 | 9 | 0.27% |
| *Bedeva paivae* | 3 | 3 | 11 | 3 | 20 | 0.59% |
| *Bembicium auratum* | 2 | 6 | 19 | 13 | 40 | 1.18% |
| *Bittium* sp. | 0 | 1 | 0 | 0 | 1 | 0.03% |
| *Cerithidea anticipata* | 1 | 0 | 0 | 0 | 1 | 0.03% |
| *Chama* sp. | 9 | 24 | 14 | 3 | 50 | 1.48% |
| *Clypeomorus tuberculatus* | 52 | 151 | 137 | 25 | 365 | 10.79% |
| *Corbula vicaria* | 1 | 0 | 1 | 0 | 2 | 0.06% |
| *Donax deltoides* | 0 | 1 | 1 | 0 | 2 | 0.06% |
| Erycinidae | 2 | 0 | 1 | 4 | 7 | 0.21% |
| *Euchelus atratus* | 0 | 12 | 37 | 8 | 57 | 1.68% |
| *Lippistes* sp. | 0 | 0 | 1 | 0 | 1 | 0.03% |
| *Littorina scabra* | 1 | 0 | 0 | 0 | 1 | 0.03% |
| *Micrelenchus* | 2 | 11 | 17 | 4 | 34 | 1.01% |
| *Nassarius burchardi* | 2 | 13 | 20 | 2 | 37 | 1.09% |
| *Nassarius dorsatus* | 0 | 1 | 0 | 0 | 1 | 0.03% |
| *Nassarius pauperus* | 0 | 0 | 1 | 0 | 1 | 0.03% |
| *Notoacmea* sp. | 0 | 8 | 49 | 17 | 74 | 2.19% |
| *Notospisula trigonella* | 0 | 0 | 1 | 1 | 2 | 0.06% |
| *Polinices sordidus* | 0 | 1 | 1 | 0 | 2 | 0.06% |
| Pyramidellidae sp. | 0 | 0 | 0 | 1 | 1 | 0.03% |

**Table 8-12 Molluscan remains from St. Helena Island by SU (after Alfredson 1984:54).**

| | | | | | | |
|---|---|---|---|---|---|---|
| *Pyrazus ebeninus* | 21 | 85 | 73 | 9 | 188 | 5.56% |
| *Pyrene varians* | 0 | 5 | 1 | 0 | 6 | 0.18% |
| *Rissoina triticea* | 0 | 0 | 1 | 0 | 1 | 0.03% |
| *Saccostrea commercialis* | 52 | 319 | 496 | 82 | 949 | 28.05% |
| *Siphonaria* sp. | 0 | 1 | 15 | 1 | 17 | 0.50% |
| *Tapes turgida* | 0 | 1 | 0 | 0 | 1 | 0.03% |
| *Thalotia comtessel* | 20 | 44 | 75 | 20 | 159 | 4.70% |
| *Trichomya hirsuta* | 115 | 375 | 434 | 140 | 1064 | 31.45% |
| Triphoridae sp. | 1 | 5 | 2 | 1 | 9 | 0.27% |
| Turridae sp. | 0 | 0 | 1 | 0 | 1 | 0.03% |
| *Velacumantus australis* | 52 | 88 | 53 | 7 | 200 | 5.91% |
| *Venerupis exotica* | 1 | 3 | 1 | 2 | 7 | 0.21% |
| **Total** | **352** | **1186** | **1483** | **362** | **3383** | **100.00%** |

**Table 8-13 Volume-corrected MNI estimates for total molluscan remains and dominant economic species for St. Helena Island.**

| **St. Helena** | | **SU1 $m^3$** | **SU2 $m^3$** | **SU3 $m^3$** | **SU4 $m^3$** | **Total** |
|---|---|---|---|---|---|---|
| | | 0.0188 | 0.020 | 0.0425 | 0.0425 | 0.1238 |
| All shell | MNI | 352 | 1186 | 1468 | 361 | 3367 |
| | MNI/m3 | 18773 | 59300 | 34541 | 8494 | 27208 |
| *Clypeomorus tuberculatus* | MNI | 52 | 151 | 137 | 25 | 365 |
| | MNI/m3 | 2773 | 7550 | 3224 | 588 | 2949 |
| *Pyrazus ebeninus* | MNI | 21 | 85 | 73 | 9 | 188 |
| | MNI/m3 | 1120 | 4250 | 1718 | 212 | 1519 |
| *Saccostrea* sp. | MNI | 52 | 319 | 496 | 82 | 949 |
| | MNI/m3 | 2773 | 15950 | 11671 | 1929 | 7669 |
| *Trichomya hirsuta* | MNI | 115 | 375 | 434 | 140 | 1064 |
| | MNI/m3 | 6133 | 18750 | 10212 | 3294 | 8598 |
| *Batillaria australis* | MNI | 52 | 88 | 53 | 7 | 200 |
| | MNI/m3 | 2773 | 4400 | 1247 | 165 | 1616 |

## Molluscan Richness and Diversity

The H and E values for St. Helena are moderate, while the value for Simpson’s index is moderate to high (Table 8-14).

**Table 8-14 St. Helena measures of diversity.**

| **Diversity Measure** | |
|---|---|
| NTAXA | 40 |
| Individuals | 3383 |
| Simpson’s Index (1-D) | 0.8004 |
| Shannon Index of Diversity (′H) | 2.08 |
| Shannon Index of Evenness (E) | 0.5638 |

## Taxonomic trends

The trends for the six most abundant species (*Clypeomorus tuberculatus*, *Pyrazus ebeninus*, *Saccostrea* spp., *Thalotia comtessel*, *Trichomya hirsuta* and *Batillaria australis*) all demonstrated an increase in discard in SUs 2 and 3. Alfredson (1984) considered the increase in relative abundance of *P. ebeninus* in SUs 2 and 3 to be significant. However, a Spearman’s rho (*r*= -.400, *p*=0.600, n=188) indicated no significant correlation. The increased abundances reflect the relatively more intense use of the site, rather than any significant changes in discard.

*Fish*

A total of 579 fish bones were recovered from the excavation. The majority (n=402) could be identified only as Pisces, and 103 could be identified to the family Sparidae. The remaining specimens could be identified to genus and species. They included bream (*Acanthopragus australis*, n=31) and tarwhine (*Rhabdosargus sarba*, n=2), both members of the Sparidae family, sand whiting (*Sillago ciliata*, n=19), mullet (*Mugil cephalus*, n=10), eel-tailed catfish (*Plotosus anguillaris*, n=6), weasel shark (*Rhizoprionodon taylori*, n=3), and stonefish (*Synanceia horrida*, n=3).

*Land Snails*

Eight species of land snail - *Pupoides pacificus*, *Pleuropoma draytonensis*, *Eremopeas tuckeri*, *Charopida* species A and B, an undescribed species, and Camaenidae sp. - were recovered from XUs 5 to 16, although the number of individual specimens is not provided. The land snail community was considered to be strong evidence of the lowland subtropical vine forest previously common in southern Queensland and northern New South Wales (Alfredson 1984:55).

**Stone artefacts**

Nine pieces of fine grained material including quartz, silcrete and chert were recovered during the excavation; however only three could be definitely be identified as artefacts, and were unmodified flakes. Two of the flakes, one on quartz and one on chert, were recovered from XU2 and XU3 in SU1, and the third, made on quartz, came from a more secure location in XU16 at the base of SU4. One piece of heat fractured material was recovered from XU12 at the base of SU3, and another from XU14 in SU4. Volume-corrected estimates of stone artefact discard are 107 for SU1, and 24 for SU4. St. Helena Island is composed of Landsborough sandstone and Tertiary basalts; Alfredson (1984:84) stated that there was an abundant source of stone artefact raw material at the island’s southern end.

## Discussion

Alfredson (1984:74) extrapolated an age of 2700 years BP for the base of the midden at SU4 XU16, noting a marked increase in shell density in XUs 8-10 (the interface of SUs 2 and 3) dating to between 600 and 1350 BP. Her interpretation (1984:85) was one of at least 2500 years of Aboriginal use of the island based around the littoral resources, seasonal availability of *Pteropus* spp., and the availability of freshwater and stone material sources. The posited date of 2700 BP for commencement of exploitation is suggested to coincide with a rapid period of progradation in Moreton Bay, including the development of mudflats between the mainland and the island which increased the island's accessibility by decreasing the exploitation risk associated with crossing the Bay by canoe at low tide. Increased sedimentation would have lead to expansion of the fringing littoral resources, indicated by the increase in shell deposition and in particular the "marked increase from unit 10" in the relative abundance of *P. ebeninus*, which as a detrital grazer was considered a better indicator of mudflats than hard substrate suspension feeders like *Saccostrea* spp. and *T. hirsuta* (Alfredson 1984:81).

As the statistical analysis demonstrated, there is no significant difference in the relative abundance of *P. ebeninus* and it cannot therefore be relied on as an indicator of the development or expansion of mudflats in this instance. *Velacumantus (Batillaria) australis* may occupy a variety of habitats in high densities (Ewers 1967); *Clypeomorus* spp. usually prefers coarse rocky substrates in the intertidal zone, and can also occur in very dense populations (Wilson 1993 Vol.1:120). Increased discard rates of *Saccostrea* spp. and *T. hirsuta* which prefer hard substrates, and also for *Thalotia comtessel* (*Calthalotia comtessi*, Comtesse's Top Shell), which inhabits rocks and rubble high in the intertidal zone, all indicate exploitation of the rocky fringing reef habitat. The preferred habitats of the 'other' St. Helena molluscan taxa are listed in Table 8-15.

**Table 8-15 Preferred habitats of the 'other' molluscan taxa from St. Helena Island LB:C52.**

| **Taxon** | **Preferred habitat** |
|---|---|
| *Acrosterigma reeveanum*<br>Reeve's Heart Cockle | Littoral sand. |
| *Amusium balloti*<br>Saucer Scallop | Sand to 18m. |
| *Anadara trapezia*<br>Mud Ark, cockle | Littoral sand and mud, seagrass beds. |
| *Antigona chemnitzii*<br>Chemnitz's Cockle | Littoral sand. |
| *Arca* sp.<br>Arks | Depending on species, intertidal sand/mud/seagrass flats or attached by byssus subtidally to rock or shells. |
| *Atactodea striata*<br>Striated Little Trough Shell | Littoral sand. |
| *Austrocochlea constricta*<br>Common Periwinkle | Rocky shores and mud flats. |
| *Barbatia pistachia*<br>Banded Ark | Attached by byssus to rock or debris in shallow or deeper water. |
| *Bedeva paivae*<br>Oyster drill | Intertidal and shallow subtidal, rocks or coral reefs. |
| *Bembicium auratum*<br>Gold-mouthed periwinkle | Sheltered estuarine on mangroves/rocky shores. Algal grazer. |
| *Bittium* sp.<br>Creeper | Coral rubble. |

**Table 8-15 Preferred habitats of the 'other' molluscan taxa from St Helena IslandLB:C52.**

| Taxon | Preferred habitat |
|---|---|
| *Cerithidea anticipata*<br>Blunt Creeper | Mangroves. |
| *Chama* sp.<br>Jewel Box | Cemented to shell or coral in intertidal and subtidal zones. |
| *Corbula vicaria*<br>Basket shell | Littoral sand. |
| *Donax deltoides*<br>Pipi or eugarie | Littoral sand (surf). |
| Erycinidae (Lasaeidae)<br>Lasaea | Varies according to species. Attached to rocks or under stones, corals, mussel beds, shelly sand. |
| *Euchelus atratus*<br>Blackish Margarite | Rocky shores. |
| *Lippistes* sp. | Rocky intertidal. |
| *Littorina scabra (Littoraria scabra)*<br>Mangrove periwinkle | Rocky shores, mangroves. |
| *Micrelenchus (Cantharidus)*<br>Kelp Shell | Intertidal and shallow subtidal; seagrass and algae. |
| *Nassarius burchardi*<br>Burchard's Dog Whelk | Bays and estuaries, intertidal and shallow subtidal. |
| *Nassarius dorsatus*<br>Channelled Dog Whelk | Bays and estuaries, intertidal and shallow subtidal. |
| *Nassarius pauperus*<br>Poor Dog Whelk | Muddy sand in subtidal zone. |
| *Notoacmea* sp.<br>True Limpet | In rocks and rubble or on vertical rock faces. |
| *Notospisula (Spisula) trigonella*<br>Triangular Trough Shell | Muddy intertidal and shallow subtidal. |
| *Polinices sordidus (Conuber sordidum)*<br>Dirty Sand Snail | Muddy sand flats. |
| Pyramidellidae sp.<br>Pyramid Shells | Shallow sandy. |
| *Pyrene (Euplica) varians*<br>Variable Dove Shell | Coral reef and rocky shore. |
| *Rissoina (Schwartziella) triticea* (no designated common name) | Hard substrates. |
| *Siphonaria* sp.<br>False Limpet | Rocky substrates. |
| *Tapes turgida (conspersus)*<br>Venus cockle | Littoral sand. |
| Triphoridae sp.<br>Sinistral Creepers | Clean hard (but not rock) substrates. |
| Turridae sp.<br>Turrids or Screw Shells | Mostly soft substrates but also rock and coral reefs. |
| *Venerupis exotica (Irus carditoides)*<br>Venus Cockle | In rock crevices in shallow water. |

As can be seen from Table 8-15, the 'other' molluscan taxa are almost equally divided between hard and soft substrate habitats. While the assemblage provides evidence for mud flats, mangroves, rocky substrates and fringing reefs at both at the commencement of the midden's deposition and continued use, when combined with the dominant species it indicates a foraging preference for species hard substrate and mangrove species. Alfredson (1984) interpreted the presence of *D. deltoides* as the remains of a meal gathered elsewhere, however it is an open surf beach species; the nearest locations from which it could be gathered are the east coasts of Moreton Island or North Stradbroke Island which are both more than 20kms away. The very low abundance suggests that it was not of dietary significance and its presence may indicate its use in the manufacture or maintenance of other items of material culture (e.g. Petrie 1904; see also Chapter 7).

The radiocarbon age determinations of 1825 cal B and 912 cal BP essentially cover the deposition of SU3 (XUs 9-12) and the uppermost level of SU4, at a low rate of accumulation. Alfredson (1983, 1984) noted that the density of bone was greater in the lower levels of SU3 and in SU4, and that the proportion of fish and bat bone was higher compared to the shell component than in the upper levels of the excavation. This was interpreted as evidence of an emphasis on these particular resources when the crossing to the island was more dangerous, i.e. before the progradation of the mudflats; as the risk associated with water-crossing was reduced, foraging became more generalised and the deposit came to more closely resemble mainland middens (Alfredson 1983:84). This aspect of the model is difficult to test, as only counts for the fish bones are provided; there are no numbers for the flying-fox bones which continued throughout the deposit. Although bone weights per XU are provided, they are composite weights and the relative contributions of fish, bat, dugong etc. are not discussed. Nevertheless, it would appear that after the posited early, seasonally-based, exploitation of the island's resources based around flying-fox and fish, exploitation of shellfish resources, particularly oyster and mussel, increased in the period after 1825 cal BP. The levels of site usage may have continued to be low-level and/or seasonal, as noted historically by observers such as Petrie (1904), and as indicated by the slow rate of accumulation for the deposit.

### *Conclusion*

This literature-based re-analysis has had mixed success. In the case of Hope Island, the lack of additional data concerning the non-economic species constrained the interpretation of environmental factors that may have influenced the distribution and availability of shellfish, as well as the timing and nature of the progradation of the river bank. Nevertheless the data suggest that a fully developed marine-focused economy was operating in the area c5000 years ago. For St. Helena Island, however, the availability of data on all shellfish taxa from the excavation has allowed the potential to explore the preferred foraging zones through time, and also test Alfredson's (1983,1984) assertion that there was a marked increase in *P. ebeninus* numbers linked with the expansion of mudflats.

# 9. Discussion and Conclusion

## *Introduction*

In the first chapter the broad question of whether there is evidence of a relationship between Aboriginal behaviour and mid to late Holocene environmental change in coastal southeast Queensland was posed. The aims of the thesis as well as a number of questions specific to the southeast Queensland region were outlined. The utility of the conceptual framework for the analysis and interpretation, historical ecology, in providing a long-term, historical dataset for the evaluation of human-environmental interactions and the structure of past ecosystems and landscapes was established, as was its particular applicability to the study of small-scale economies. This chapter commences with a brief review of the palaeoenvironmental evidence before moving to a summary and discussion of the results of the re-analyses of the sites in the context of the research aims and questions, including preferred species, taxonomic richness and diversity, evidence for over-exploitation and resource depression, and the nature of the stone artefact assemblages. These speak to considerations of broader settlement strategies, aspects of seasonal mobility, and considerations of population size linked to a number of proxy indicators. These are all issues that are being played out internationally, in a range of different contexts. The implications of the findings for previous models of long-term change in the region are discussed, and an overview of the study region during the Holocene is provided.

## *Holocene environmental variability in southeast Queensland*

The palaeoenvironmental reconstructions presented in Chapter 3 demonstrate Holocene climatic variability and environmental change for the study region. With some exceptions, however, the reconstructions tend to be broad-scale and coarse-grained, with differing levels of temporal resolution and control. These concerns aside, the reconstructions have been useful as the context for changes in resource structuring and habitat variation. The picture from the combined data is one of a period of climate amelioration leading into the early Holocene (Figure 3-9). In some areas (Old Lake Comboo on Fraser Island and Native Companion Lagoon on North Stradbroke Island), there is evidence of relatively drier conditions, and a small increase in MAAT of ~+1$^{o}$ compared to current temperatures for the period c7500 to 5500 cal BP. There is some variation in the records for the period immediately following, with Native Companion Lagoon and Old Lake Comboo indicating a return to relatively wetter conditions at c5500 cal BP while the other climatic records indicate the onset of a relatively more arid period of variable duration depending on location. All records indicate more variable environmental conditions over the past 1500 to 2500 years. At Myora

Springs on North Stradbroke Island there is evidence of an El Niño event between 800 to 500 years ago, with more favourable La Niña conditions after 500 years ago. These highly variable inter-regional and intra-regional fluctuations reflect the potential for localised climatic/environmental shifts, as well as for masking some of the broader effects over the greater southeast Queensland region. Nevertheless, the data provide a baseline against which to assess changes observed in the molluscan and other data. The estuarine modelling indicates that mudflats and associated habitats would have formed during the transgressive phase of the Holocene sea level change and been maintained throughout the highstand. It is probable that the tidal regimes during the highstand were at least broadly similar to those experienced today, and that sea levels of between +1.m to +1.5m compared to the present levels, over an extended period, allowed for the development of an extensive mosaic of mudflats and mangals. As the sea level retreated after c2000 cal BP, the extent of these intertidal features increased.

## *Comparison of molluscan trends*

The sites analysed for this study are distributed over a range of estuarine and tidal environments, but all are located in, or adjacent to, similarly constructed floristic communities comprising open forest and woodland. With the exception of Booral Shell Mound, surface evidence of the midden deposits was in the form of shell scatters. The chronology of the sites covers the period from c4863 cal BP up until, and perhaps after, European settlement in the southeast Queensland region in the early to mid 19th century.

### Inter-site measures of diversity

The estuarine environments of the Great Sandy Strait and Moreton Bay support a diverse array of molluscan and other marine species, with Moreton Bay described by Hall (1982:91) as a “seafood supermarket”. It seemed somewhat surprising, therefore, that given the overall species richness, the diversity indices at the sites, particularly at Booral Shell Mound and St. Helena Island, reflect mostly low to moderate values (Table 9-1). Reference to the broader archaeomalacological literature, however, suggests that this is not uncommon, and can be due to a range of factors, including species density, behaviour, foraging strategies, habitat structure, and site location (e.g. at ecotonal transitions/boundaries).

The values for Booral Shell Mound reflect the dominance of two taxa, *Saccostrea* spp. and *Trichomya hirsuta*. The St. Helena assemblage exhibited a higher diversity relative to the other sites (although still classified as moderate rather than high in terms of index values), which may reflect the island’s immediate marine environmental zones, but the values still reflect the dominance of *Trichomya hirsuta* and *Saccostrea* spp. A similar mix of environmental zones also occurs in the vicinity of Booral Shell Mound, and the differences between the sites' diversity values is probably due to the differing overall molluscan abundances. Although broad parallels can be drawn between the values of the Hope Island assemblages, and those of Tin Can Bay 75b and Cameron Point Site 62 in that there are similar NTAXA, those from Tin Can Bay 75b and Cameron Point Site 62 reflect the actual NTAXA at the sites. The NTAXA from Hope Island are somewhat artificial values based on the decision to exclude species perceived as non-economic from the original analysis. The values for the two Bribie Island sites, while still relatively low, do exhibit inter-site differences. White Patch 3 exhibits higher diversity, richness, and evenness than Bribie Island 9, most likely due to both the lower NTAXA and number of individuals at Bribie Island 9.

**Table 9-1 Diversity measures by site.**

| **Site** | **NTAXA** | **Individuals** | **Simpson's Index (I-D)** | **Shannon Index of Diversity (H)** | **Shannon Index of Evenness (E)** |
|---|---|---|---|---|---|
| Booral Shell Mound Sq. B | 42 | 9425 | 0.643 | 1.624 | 0.4344 |
| Bribie Island 9 | 8 | 546 | 0.4376 | 0.8399 | 0.4039 |
| Cameron Point 62 Sq. C | 4 | 182 | 0.3644 | 0.6906 | 0.4982 |
| Hope Island Sq. A | 6 | 8605 | 0.3352 | 0.6784 | 0.3786 |
| Hope Island Sq. E | 5 | 5695 | 0.1459 | 0.3266 | 0.2029 |
| St. Helena Island | 40 | 3383 | 0.8004 | 2.08 | 0.5638 |
| Tin Can Bay 75b Sq. B | 11 | 348 | 0.691 | 1.506 | 0.6279 |
| White Patch 3 | 16 | 771 | 0.782 | 1.714 | 0.618 |

### Preferred species and habitat zones

*Saccostrea* spp. is the first or second ranked species by MNI in each site, regardless of location (Table 9-2). This dominance is not a factor of differential preservation or other taphonomic processes, nor is it an artefact of the sampling strategy or methodology employed for quantifying the molluscan remains in the sites. The condition of the shell from all sites was generally good, and with comparable fragmentation ratios. The accumulation rates were also similar across the sites (slow to intermediate, with the uppermost deposit at Bribie Island 9 being the exception) indicating that the cultural material was subject to similar processes of mixing, treadage etc. following deposition. In the re-analyses of the assemblages, no distinction was made between potentially economic and non-economic taxa. The measures for quantification of the shell, as outlined in Chapter 4, are robust. While resource availability and levels of exploitation have been demonstrated to be significantly influenced by micro-habitats and locally-specific environmental factors (Chapters 5 to 8), the ability of *Saccostrea* spp. to successfully colonise a variety of substrates

(Appendix A) is likely a factor in its ubiquity. The tendency to aggregate in large clumps or reefs means that the taxon is an easy target for mass collection practices (see e.g. Whitaker 2008; Chapter 5), and its preference for intertidal habitats renders it relatively easily accessible. Size selectivity can be impacted by the different methods of harvesting – stripping and plucking – modelled by Whitaker (2008). Dietary preference may well be a contributing factor – that oysters were simply a favourite food (see Eipper 1841). Although *Trichomya hirsuta* is abundant at both Booral Shell Mound and St. Helena, the requirement of a hard substrate restricts its distribution compared to that of *Saccostrea* spp., and, based on current and previous landscape structures and geomorphological data, this accounts for its low abundance in deposits at Tin Can Bay 75b, Cameron Point Site 62, and it absence from Bribie Island 9. The relative abundances of the five highest ranked taxa indicate that, at least for the sites in this study, the most productive environmental zone and the one harvested most frequently, was the rocky intertidal zone. This is also reflected in the taxa which make minor contributions to the overall abundance measures at Booral Shell Mound and St. Helena (Chapter 6 and Chapter 8).

The species composition of the Tin Can Bay and Bribie Island sites particularly was strongly dependent on the localised environments or micro-habitats, and demonstrated considerable variability over fairly short distances. Tin Can Bay 75b and Cameron Point Site 62 are approximately 2kms apart but exhibit quite different relative abundances in shared species, which is also reflected in Table 9-2. There are also taxa, e.g. *Isognomon* spp., which occur at Tin Can Bay 75b (10.06% of the total MNI) but are entirely absent from Cameron Pont Site 62. Similar circumstances obtain in Pumicestone Passage, where White Patch 3 in the central microtidal basin exhibits greater taxonomic richness than Bribie Island 9 located c14kms to the north close to the northern tidal delta. *Trichomya hirsuta*, which accounts for almost 73% of the total NISP and 19% of the total MNI in the White Patch 3 assemblage, is absent from Bribie Island 9 although the relative abundance of *Saccostrea* spp. is comparable. *Anadara trapezia*, commonly considered to be one of the major components of Aboriginal middens in the region (e.g. Healy and Potter 2010), was present in large numbers only on Bribie Island in the past 500 years. Other than the lower levels of Hope Island Square A, its relative abundance in the deposits is low. *Anadara trapezia* is sensitive to changes in salinity levels, and also prefers soft substrates with some seagrass cover (Appendix A); these factors together may restrict its distribution. The apparent abundance of *A. trapezia* in midden deposits as suggested by Healy and Potter (2010) may be the result of the species' robusticity and resistance to breakage. These traits may lead to it being more visible than other species within the deposits.

**Table 9-2 Five highest ranked taxa by percentage of MNI for each site.**

| **Taxon Rank** | **BSM Square B** | **TCB 75b Square B** | **CP Site 62 Square C** | **White Patch 3** | **Bribie Island 9** | **Hope Island A** | **Hope Island E** | **St. Helena** |
|---|---|---|---|---|---|---|---|---|
| **1** | *Saccostrea* spp. 56.48 % | *Saccostrea* spp. 45.69% | *Saccostrea* spp. 67.57% | *A. trapezia* 29.44% | *A. trapezia* 71.61% | *Saccostrea* spp. 80.31% | *Saccostrea* spp. 92.2% | *T. hirsuta* 31.45% |
| **2** | *T. hirsuta* 16.87% | *P. ebeninus* 29.31% | *P. ebeninus* 28.38% | *Saccostrea* spp. 21.92% | *Saccostrea* spp. 21.9% | *A. trapezia* 13.35% | *B. australis* 6.11% | *Saccostrea* spp. 28.05% |
| **3** | *N. balteata* 1.94% | *Isognomon* spp. 10.06% | *A. trapezia* 2.7% | *P. ebeninus* 21.53% | *D. deltoides* 2.93% | *P. ebeninus* 4.03% | *P. ebeninus* 1.26% | *C. tuberculatus* 10.79% |
| **4** | *Chama* spp. 1.54 % | *C. sordidum* 4.6% | *C. sordidum* 1.35% | *T. hirsuta* 18.94% | *P. ebeninus* 1.65% | *B. australis* 1.57% | *T. hirsuta* 0.28% | *B. australis* 5.91% |
| **5** | *P. ebeninus* 1.45% | *A. trapezia* 3.11% | None | *D. deltoides* 2.08% | *C. sordidum* 0.55% | *T. hirsuta* 0.64% | *A. trapezia* 0.14% | *P. ebeninus* 5.56% |

## Impacts of human predation

As Ash *et al*. (2013), Giovas *et al*. (2010), Giovas *et al*. (2013), and Jerardino (1997) observe, the determination of human impacts on molluscan populations is a complex process. Factors include natural fluctuations in molluscan demographics, the differential effects of foraging practices which may also be seasonal, increase in species size due to cultural and/or ecological causes, zones of exploitation, and local environmental influences.

Acknowledging these factors, application of the criteria outlined in Chapter 4 to measure the impact of human predation pressure on molluscan populations (i.e. decreases in mean shell length, changes in the abundance of easily procured and/or processed species, and a decrease in the relative abundance of preferred species) revealed no clear evidence of over-exploitation or resource depression. Although a decrease in mean valve height was noted for *Saccostrea* spp. in SU2 at Booral Shell Mound, and a decrease in mean *Trichomya hirsuta* valve height was noted for SU1, the differences are at a small scale. As suggested, the changes noted may be associated with harvesting practices as well as environmental factors such as tidal regimes (Chapter 5; Thakar *et al*. 2015; Whitaker 2008). There are no significant variations in the age-size structures of the populations at the sites, suggesting that the levels of exploitation were sufficiently low or sporadic enough to maintain viable, sexually mature populations. *Anadara trapezia* comprised almost a quarter of the molluscan assemblage in SU3 of Hope Island Square A, but is virtually absent from all other SUs in both Square A and Square E (Chapter 8). However, this is not taken to be evidence of prolonged resource depression following a period of over-exploitation from which the population could not recover. There is a similar decline, although not as drastic, in the relative abundance of *Pyrazus ebeninus* which broadly shares the same habitat preferences. The most likely explanation is that shifting sediments in a dynamic estuarine context led to localised habitat variations that did not support large populations of either taxon.

### Changes in resource exploitation

Foraging behaviour across the study area was found to be relatively stable with little variation observed. Booral Shell Mound is the only site with evidence of significant change in the exploitation in marine resources, with a sharp rise in the relative abundance of *Nerita balteata* in the upper levels. This increase is coincident with the increased climate variability at c2500 cal BP noted in the Fraser Island palaeoenvironmental reconstructions, falling sea levels, and a MAAT $1^{o}$ lower than current day temperatures (Figure 3-9). Increasing climatic variability, associated with increased effective precipitation following an arid period may have increased runoff, both from the Cooloola sandmass and Fraser Island, as well as the Mary River catchment. Increased freshwater and sediment levels would have favoured the expansion of mangal *Nerita balteata* habitat, thus increasing the availability of this resource for the people using the foraging zone around the mound. While there may also have been changes in dietary preferences, or cultural reasons which may account for increased exploitation of the snails, similar increases are not observed elsewhere in the study region, suggesting that the phenomenon is a discrete local event linked to restricted environmental variability.

### Abundance of small gastropods

The high incidence of small gastropods (Potamididae/Batillariidae) noted at Booral Shell Mound was also observed by Alfredson (1984) at St. Helena Island. Ulm (2006) also recorded incidences of very small gastropods and bivalves in sites on the southern Curtis Coast. Meehan (1982) recorded the modern collection and consumption of small gastropods in Arnhem Land, but like Faulkner (2013) and Hiscock (2008), the application of ethnographic analogy to sites that are two or three thousand years old (or older in the case of Ulm’s Seven Mile Creek mound) is treated here with caution. In addition to considerations of time depth, there are also issues of scale and resolution surrounding comparison, as well as historical context/contingency, and environmental differences (i.e. tropical vs. sub-tropical to temperate). In the Moreton Region, Petrie (1904) noted that periwinkles were roasted over fire, but provides no further description of the species. The low elevations of the St. Helena site and the Seven Mile Creek mound render them vulnerable to the effects of storm surges which may redeposit molluscan material, but this is unlikely to be the case for Booral Shell Mound (c10m ASL) other than in exceptional circumstances (see Rowland and Ulm 2010). At Booral Shell Mound, the MNI value of Potamididae/Batillariidae juveniles was 704. Only 45 of these (6.39%) exhibited evidence of weathering or drill holes caused by borers, and there was little or no evidence of rolling. The high concentrations of freshly settled juvenile

*Pyrazus ebeninus* observed by Vohra (1965; Chapter 5; Appendix A) can reasonably be extrapolated for *Batillaria australis*. Gathering practices for clustered species on sandy/sandy-muddy substrates (e.g. scooping up the shells by hand), especially if they are not fully exposed by a low tide, would inevitably involve the collection of juveniles as well as larger individuals. Rowland (1994) suggested that the presence of small shells may indicate their intentional collection for non-dietary purposes, including as utilitarian items, or as medicines. Despite this view, the interpretation favoured here is that they represent by-catch.

### Southeast Queensland shell mounds

The shell mound at Booral is the most distinctive site in the present study. Discussions of the reasons for mound construction are beyond the scope of this thesis, but the drivers of mounding behaviour remain a source of debate (see e.g. Bailey 1975; Bourke 2000; Brockwell 2006; Clune 2002; Faulkner 2013; Morrison 2003, 2013, 2015; O'Connor 1999). Shell mounds have been recorded across much of northern Australia; in Queensland the best known are the large and conspicuous *Tegillarca*-dominated mounds in the area around Weipa on Cape York Peninsula (e.g. Bailey 1977, 1994; Bailey *et al*. 1994; Morrison 2003, 2010, 2013a, 2013b, 2014, 2015; Shiner and Morrison 2009; Shiner *et al*. 2013; Stone 1995). The phenomenon of mound building during the mid to late Holocene is not restricted to the north, however, and shell mounds occur in all parts of the mainland, as well as Tasmania. The *Tegillarca*-dominated mounds which occur in northern Australia differ from mounded deposits in southeast Queensland, the southern Gulf of Carpentaria, and some parts of Western Australia. What ties these things together at one level is that they are mounded, but the nature of site formation, the structure and dominant constituents are actually quite different. Are they shell mounds in the sense of primarily shell with little to no bone, stone or sediment, or are they largely earth and shell mounds? (see Brockwell 2006). There are most likely significant differences in the behaviours that contribute to these different mounded shell deposits, even where sites may manifest archaeologically in very similar ways (Hiscock and Faulkner 2006; Faulkner 2013; Morrison 2003, 2010, 2013a, 2013b, 2014, 2015; Shiner and Morrison 2009; Shiner *et al*. 2013).

More locally, "immense mounds" of oyster shells, containing stone artefacts and ash layers, were recorded as being used for road base at Tewantin on the Noosa River in 1877 (McNiven 1994; *The Queenslander* 23 June 1877:12). Young (1926) recorded a mound composed of *Donax deltoides* on North Stradbroke Island overlooking Eighteen Mile Swamp. Long-term Bribie Island resident Ted Clayton described a shell mound 2-3m high at Bongaree, on the prograded Holocene dunes at the southern end of the island, in what is now the car park of the local supermarket (see Smith 1992).

To the south of the study area, Bailey (1975) recorded *Saccostrea*-dominated mounds up to 400m long and 4m high along the Richmond River in northern New South Wales.

Ulm (2006) recorded a mound at Seven Mile Creek on the southern Curtis Coast approximately 0.8m deep covering an area of approximately 200m$^2$ which accumulated over a relatively short period from 3947 cal BP to 3608 cal BP. Although quantified only by weight, as at Booral *Saccostrea* spp. was the dominant molluscan species, and also as at Booral, species richness was high, with some 50 taxa identified (Ulm 2006:85). A number of very small gastropods and bivalves assumed to be by-catch were included in the deposit. Vertebrate remains were confined to four fish taxa, and the stone artefact assemblage was dominated by flaked pieces, with all raw materials available in the immediate vicinity (Ulm 2006:92). Morphometric analysis on the third ranking species by weight (8.5%), *Anadara trapezia*, led Ulm (2006:85, 92) to conclude that the abandonment of the mound did not result from the over-exploitation of this species, although no similar analysis was undertaken for the dominant *Saccostrea* spp. Ulm (2006:95) instead suggested that site abandonment was linked to changes in regional settlement strategies that were not principally reliant on coastal resources.

As Ulm (2006:94) noted, Seven Mile Creek and Booral Shell Mound are isolates, and not part of a series of mounds. No other middens were associated with the Seven Mile Creek Mound. Booral Shell Mound differs in that it was in use at the same time as the nearby Booral Homestead Midden although the relationship between the two is unclear (Chapter 5). There is no evidence of a hiatus or period of abandonment demonstrated at Booral Shell Mound, although its establishment post-dates both the onset and cessation of discard at the Seven Mile Creek mound site. The two sites share a similar taxonomic composition, but otherwise their traits differ. The period of occupation reflected at Seven Mile Creek was short and relatively intense, while the occupation of Booral Shell Mound was low level and perhaps episodic over a period of some 2300 years, suggesting that there are regional variations in both the establishment and continuing use of the mounds. The behavioural aspects and the place of these sites within socio-economic structures are also likely to be very different. The cessation of cultural discard at Booral Shell Mound at c806 BP is not coincident with any recorded major variation in environmental conditions, nor is there evidence of over-exploitation or depression of the principal molluscan species prior to the abandonment of the mound. Therefore, the conclusion must be drawn that the abandonment of the mound was linked to changing socio-economic or socio-cultural behaviour, although the precise nature of the changes remains unclear. That exploitation of marine-based resources continued in the broader Great Sandy Region is evidenced by the many middens along Tin Can Bay inlet and on the Cooloola sandmass (Chapter 2 and Chapter 6).

## *Other faunal remains*

One of the characteristics which the sites share is the relative paucity of faunal remains other than molluscs, although as Attenbrow (1992) noted there is no good reason for shell middens to be expected to contain anything other than shell. It has been suggested that the low abundance or absence of terrestrial faunal remains is related to differential processing and/or consumption sites. Historical observations suggest that fishing was a daily activity (e.g. Petrie 1904; see also Hall 1982), but the levels of exploitation of fish resources do not correspond with the archaeological record. The low numbers of fish bone in most of the sites can *perhaps* be ascribed to recovery procedures. However, Ulm (2006) used 3mm sieves specifically in order to obtain samples comparable to those from sites previously excavated in southeast Queensland, and recovered fish bone from all sites for which preservational conditions were favourable. Thus, it can be argued that either fish remains were consumed and/or discarded elsewhere (McNiven 1989), an explanation favoured by Walters *et al*. (1987) for the absence of fish bone at Hope Island, or that non-human predators consumed the remains before they could be incorporated into the deposits (see also McNiven 1990b; Walters 1988). It may also be the case that the fishing practices observed from the mid-19th century differed from those in the more distant past. The absence of elements from large marine vertebrates such as dugong (the exception being St. Helena Island) and turtle, which could certainly reasonably be expected to be identified in a 3mm sieve fraction, suggests that these large prey items were not only infrequently hunted, but also were processed and perhaps discarded close to the point of capture as observed by Petrie (1904:68; see also Meehan 1988).

## *Stone artefacts*

### Technological change

There was little evidence for technological change *per se* over time in the stone artefact assemblages in the study. Only three formal implements were identified: the backed artefact dating to 2752 cal BP and the poorly-executed blade from approximately 10cm above the basal date of 3133 cal BP at Booral Shell Mound, and the backed artefact at Tin Can Bay 75b above the basal date of 308 cal BP. Hiscock and Hall (1988b) reported backed artefacts in the assemblage from the hinterland Platypus Rockshelter (Figure 1-1) dating to within the past 1000 years, although they were cautious in ascribing the manufacture of the artefacts to that period, as they may have eroded from earlier sediments at the rear of the rockshelter. More broadly in eastern Australia, backed artefacts were produced throughout the Holocene (see e.g. Attenbrow *et al*. 2009; Hiscock and Attenbrow 2004). The other stone artefacts associated with the formal implements belong to the same categories identified throughout the deposits, i.e. flakes, broken flakes, flaked pieces, manuports, and a low number of cores. Rather than evidence of technological change, the assemblages suggest technological continuity, with the most parsimonious explanation for the very low number of formal implements being that such tools were not required in a primarily marine-focused economy (e.g. Bailey 1975). The core from Cameron Point dating from 829 cal BP, from below the midden deposit, was a re-used bevelled artefact of the type associated with plant-processing. There is evidence of these artefacts at c5500 cal BP at Teewah Beach 26 (McNiven 1991b), and their use was observed to continue into the historical period (e.g. Bancroft 1894; Nique and Hartenstein 1841; Petrie 1904). The stone artefacts from White Patch 3 and Bribie Island 9 exhibit similar characteristics to those in the Great Sandy Region sites (see also McNiven and Hiscock 1988; McNiven *et al*. 2002). Smith (2003:171) considered general patterning of small artefact size, dominance of flaked pieces, and few formal implements, as a reflection of "opportunistic (or expedient) techniques of manufacture and reduction, typical of exploitation of low risk resources and a reliable supply of raw materials".

### Raw materials

A relatively small range of raw materials for stone artefacts in the sites in the region was identified, and is presented in Table 9-3. The Booral Shell Mound assemblage is dominated by locally available raw materials, with mudstone occurring in abundance adjacent to the site and chert occurring on Big Woody Island. The ochreous material occurs widely in the Cooloola sandmass. Clarkson and Bellas (2014:327) noted that chert is the most common raw material in terms of overall abundance, although silcrete occurs in greater numbers of sites, in the Moreton Region to the south. Quartz and quartzite occur far less commonly, as do volcanic raw materials. The source for the andesite flake at Tin Can Bay 75b is most likely in the vicinity of Double Island Point (approximately 15km distant) where the material outcrops (McNiven 1990a; Chapter 6). Sandstone occurs at the southern end of Tin Can Inlet (Figure 4-4). The potential sources for the other raw materials in the Great Sandy Region sites are less clear-cut. There were fewer raw materials identified in Booral Shell Mound Square A (mudstone, chert, chalcedony, and quartz) and Frankland (1990) suggested the Mary River as a possible source, with the implication that the materials were fluvially transported from other regions in the catchment. Mt. Wolvi to the southwest of the area is also a potential silcrete source. Locations from which the raw materials for Bribie Island may have derived were presented in Chapter 7, and included the Glasshouse Mountains on the contiguous mainland, as well as the quarry at Cape Moreton on Moreton Island. The raw materials may also have been obtained in the form of cobbles from the numerous waterways on the contiguous mainland (e.g. Nolan 1986). Alfredson (1984) considered that St. Helena Island had the potential to provide a range of lithic raw materials. However, Clarkson and

Bellas (2014:327) cautioned that not all geological formations necessarily contain suitable raw materials for flaking. In the absence of petrological analyses the broader potential sources must remain speculative.

**Table 9-3 Raw material occurrence by site.**

| Raw material | BSM | TCB75b | CP62 | WP3 | BI9 | St. Helena |
|---|---|---|---|---|---|---|
| Andesite | 0 | 1 | 0 | 0 | 0 | 0 |
| Chert | 98 | 0 | 0 | 0 | 3 | 1 |
| Ferruginous | 0 | 1 | 0 | 0 | 0 | 0 |
| Mudstone | 343 | 0 | 0 | 0 | 0 | 0 |
| Ochreous | 78 | 0 | 0 | 14 | 0 | 0 |
| Pumice | 5 | 0 | 0 | 0 | 0 | 0 |
| Quartz | 5 | 0 | 3 | 1 | 21 | 2 |
| Quartzite | 1 | 0 | 1 | 0 | 9 | 0 |
| Sandstone | 2 | 0 | 0 | 0 | 9 | 0 |
| Silcrete | 23 | 10 | 11 | 13 | 14 | 6 |

## *Implications for previous long-term models of occupation*

The findings of this study both challenge and complement previously posited long-term models of occupation for southeast Queensland. The dramatic increase in the establishment of sites in the past 1000 years of the Holocene has been suggested to reflect a re-ordering of land use (e.g. Hall and Hiscock 1988a: McNiven 1999; Ulm and Hall 1996). Hall and Hiscock (1988a) and Ulm and Hall (1996) suggested that restricted mainland movement westward as a result of the land space there being "filled" in a traditional socio-economic organisational sense, led to increased use of the coastal zone and migration onto the offshore islands. Increased numbers of sites may indicate increased population pressure, which may be reflected in the patterning of molluscan resource exploitation, including increased use of plant foods, a change in terrestrial resource use shifting emphasis on smaller-bodied molluscs, and incorporation of previously less-preferred species.

### Site establishment and intensity of use

Previous models for site establishment and use, as well as more intensified exploitation of estuarine resources, have suggested that the progradation of tidal mud flats subsequent to late Holocene sea level falls was a significant influence. More particularly, this has been applied to occupation of the islands of Moreton Bay (e.g. Hall 1984; Hall and Bowen 1989; Hall and Robins 1984; Chapter 2). However this relationship has not been unequivocally demonstrated in the present study. Figures 9-1 and 9-2 summarise the volume-corrected densities of molluscan and stone artefact discard in the study sites (Chapter 5 to Chapter 8). Figure 9-1 indicates that two of the three sites established prior to the Holocene marine regression, Hope Island Square A and Booral Shell Mound, exhibit more intensive exploitation of estuarine resources than those established following the sea level fall.

The density of stone artefacts is by far the greatest at Booral Shell Mound (Figure 9-2). Bribie Island 9 exhibits a much higher density of stone artefact discard than Hope Island Square A. In comparison to the sites established after the sea level fell, artefact discard is considerably higher at Bribie Island 9 than at St. Helena and Tin Can Bay 75b, which share similar densities of artefact discard. The differences in discard between Bribie Island 9, White Patch 3, and Cameron Point 62 are less marked.

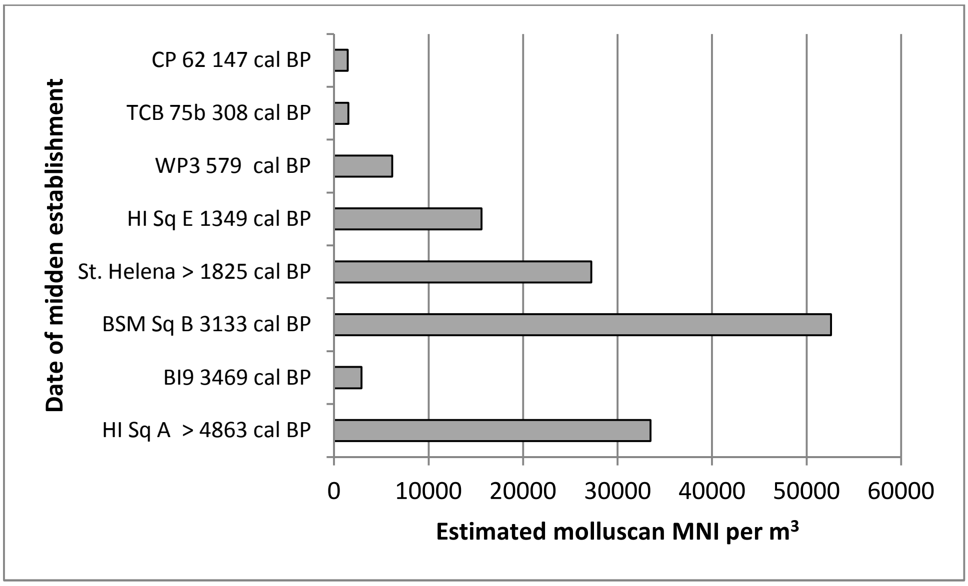


**Figure 9-1 Volume-corrected estimates of molluscan MNI for each site.**

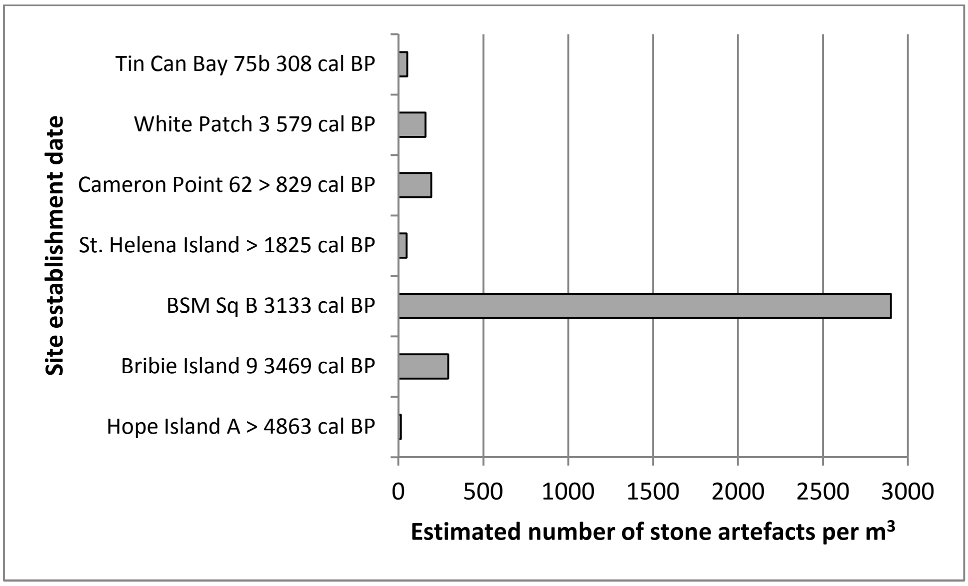


**Figure 9-2 Volume-corrected estimates of stone artefacts for each site.**

Hope Island and Booral Shell Mound were first occupied during the highstand, and both occur within broadly similar estuarine systems (Chapter 3, Chapter 5, and Chapter 8). The Hope Island

Square A molluscan assemblage indicates low levels of resource exploitation when the site was established prior to 4863 cal BP, with relatively more intense, although variable, occupation in the period between 4863 cal BP and 2742 cal BP. There is a gradual decline in intensity of site use, reflected in the decreased abundance of material discarded above the main dense midden deposit. The main deposit in Hope Island Square E, some 30m closer to the present shoreline, commences around 1349 cal BP, following both a decline in sea level and progradation of the shoreline (Walters *et al*. 1987). The most intense period of occupation at Booral Shell Mound was immediately following its establishment at 3133 cal BP, with variable but less intense periods of occupation following 2752 cal BP until discard at the site ceased around 806 cal BP. These trends are at odds with the previously posited models which suggest an intensification of, or increase in, site use in the late Holocene, although it must be acknowledged that the sample size is small.

Bribie Island 9 represents use of the northern area of Bribie Island over a period of 3500 years, commencing prior to the marine regression. The sedimentary accumulation rate is low, suggesting infrequent or low levels of occupation (Chapter 4, Chapter 7). Nevertheless the periods of occupation were of sufficient intensity to allow for the deposition of organic material, e.g. mollusc shells, to alter the pH levels of the sedimentary matrix. The volume-corrected density of molluscan remains (Figure 9-1) is most likely an under-representation of the levels of site use due to the poor preservation of shells in SUIV, affecting both NISP and MNI determinations. The suite of stone artefact raw materials and artefact categories throughout the deposit indicates that similar activities were being undertaken throughout the period of occupation. The upper level of the deposit at Bribie Island 9 dating from 149 cal BP indicates far more rapid accumulation and intensive site use. The ethnohistorical accounts record the eastern coast of Bribie Island as a pathway frequented by travellers between the calm water canoe routes from Moreton and North Stradbroke Islands, and the northern area of the island as the crossing point to the mainland near Caloundra. The proximity of Bribie Island to the mainland may be an influencing factor for its early use, although the current easy access at low tide may not have always been the case during higher sea levels. The island may have offered access to resources perhaps otherwise unavailable, or, an access point for the other bay islands. The possibility that there may have been use associated with the bora ground to the southwest of the midden complex (Chapter 7) could also account for the use of the site, although the antiquity of bora grounds and the socio-cultural networks they represent has not been yet been firmly established. However, the possibility that the more intensive site use after 149 cal BP may be associated with the bora ground cannot be discounted. Nique and Hartenstein (1841:27) report a gathering of 2000 people at Toorbul for ceremonial activities (a ‘festival and a fight’, McNiven 1992c). Eipper (1841) records a group of 600 to 1000 people on Bribie Island. This is unlikely to represent the permanent population of the island, and is more probably a gathering for ceremonies at one (or more) of the three bora grounds once on the island.

White Patch 3 and Tin Can Bay 75b, established during the late Holocene, do not exhibit intensive levels of occupation, instead reflecting slow to intermediate rates of accumulation of deposit, and low shell fragmentation ratios (Chapters 6 and 7). Cameron Point Site 62 demonstrates a high fragmentation ratio for *Saccostrea* spp., although this is not the case for the other species at the site, and may reflect different methods of processing the valves (see Meehan 1982). While White Patch 3 does exhibit a higher density of molluscan remains than Tin Can Bay 75 and Cameron Point 62 (Figure 9-1), all three sites are parts of extensive midden complexes (Figures 6-1 and 7-2), and cannot be considered in isolation from them; the characteristics observed at the sites may not be typical for the complexes as a whole. St. Helena, for which shell fragmentation data is not available, demonstrates a slow accumulation rate for the deposits, which may be the result of the seasonal use of the site suggested by Alfredson (1984; Chapter 8). The volume-corrected density of molluscan discard is, however, the third highest in the present study behind Booral Shell Mound and Hope Island Square A.

Drawing on the comparative literature in Chapter 2, the New Brisbane Airport Site was first occupied around 5494 cal BP, with occupation continuing until the recent past (Hall and Lilley 1987). The evidence suggests that a mixed marine and terrestrial economy was practiced prior to 4322 cal BP, coincident with the densest discard of stone artefacts. Levels of artefact discard decline above this time. Wallen Wallen Creek on North Stradbroke Island, although believed to have been occupied at least sporadically since the late Pleistocene (Neal 1989; Neal and Stock 1986; Chapter 2), demonstrated increased site use in the period following 4835 cal BP.

Further to the north on the Cooloola sandmass, Teewah Beach 26 demonstrates evidence of occupation from 5533 cal BP to 398 cal BP. The lower levels of occupation are dominated by stone artefacts including bevelled flakes and cores, indicating re-use of the bevelled artefacts associated with plant processing, as well as two grindstones. The midden deposit dominated by *Donax deltoides* is bracketed by dates of 952 cal BP and 398 cal BP, suggests a change in late-Holocene resource exploitation in the area, but not necessarily intensification of site use. The absence of faunal remains below the main midden is not due to the taphonomic processes operating at Bribie Island 9, as the pH levels throughout the site are 7.0 to 8.0. There are vertical and chronological differences in artefact discard, with the highest levels of discard occurring at the base of the deposit, and two peaks associated with the molluscan component of the deposit (McNiven 1990a, 1991c; Chapter 2). Although the geomorphological context of truncated foredunes differs from the sites in

Moreton Bay, and the effects of the Holocene transgression would have impacted the region differently, the site demonstrates use of the coastal zone over a period of 5500 years.

What is clear from the data presented here is that people were using the coastal region prior to the expansion of the mudflats after the marine regression. The sea level and estuarine modelling, and the molluscan data, support the notion that a rich suite of faunal resources was available to the regions occupants throughout the mid Holocene. The fall in sea level allowed for an expansion of the *area* of estuaries and tidal mudflats, thereby increasing the potential resource base but not changing its basic character. There is little evidence, within the sites that comprise the current dataset, of more intensive use in the upper levels. In fact, the density of discard of cultural material is generally lower in the later sites than the earlier sites. The intensification noted for the late Holocene is therefore reflected in an increased number of sites across the region, but with the maintenance of low site accumulation rates, and minimal resource impacts. It may be evidence of population variability linked with an increased resource base (in terms of area), changing foraging patterns, and socio-economic reorganisation in a complex, non-linear pattern in the more recent past.

The findings of the present study provide support for some aspects of the socio-cultural models proposed by e.g. Bowen (1989), Hall and Hiscock (1988a), Hall and Robins (1984), and Ulm and Hall (1996) for the more intensive use of the coastal region and off-shore islands in the last 1000 years as evidenced by the increased number of sites dating from this period. There is no evidence in the environmental data to suggest significant climatic changes influenced the changing settlement patterns. The continuing low-impact levels of exploitation of the molluscan resources suggest that these were in sufficient abundance to support the resident population, with no evidence of over-exploitation or resource depression. However, there is no evidence of intensified levels of overall marine exploitation associated with population increases such as those implied by Hall and Hiscock (1988a:15).

### Fissioning model

McNiven's (1992a, 1999; Chapter 2) model of cultural change and restructuring of land-use patterns in the greater Cooloola region was based in part on the premise of diminishing availability of rainforest-based resources, related to the onset of drier conditions in the last 3000 years. However the environmental reconstructions now available indicate that, although there was a period of mid-Holocene aridity, climatic conditions were more variable after c2500 cal BP (Chapter 3). In particular, Donders *et al*. (2006:435; Chapter 3) note a significant expansion in rainforest species such as Araucariaceae at Lake Allom after 3000 cal BP, albeit associated with evidence of increased regional fire events. Rainforest species on Fraser Island suffer a decline at or about 450 cal BP. As has been noted, regional environmental change may be highly variable even in geographically similar areas. Nevertheless the environmental evidence suggests that the diminution of rainforest occurred considerably later than the period McNiven (1992a, 1999) posited as marking a division between coastal and inland peoples. Another marker of the division into coastal and inland groups was the decrease in the use of silcrete at Teewah Beach 26, considered to be evidence of lack of or reduced access to sources of the exotic inland raw material. No such decrease in silcrete discard was found at Booral Shell Mound Square B, where artefacts made on the raw material occur throughout the sequence. Silcrete discard increases in the upper levels of the excavation, suggesting a change in site use. There is no evidence of increased population pressure in terms of over-exploitation or resource depression in the molluscan assemblage, and the rate of accumulation of deposit slows toward the period when discard ceased sometime around 806 cal BP. Similarly, the sites at Tin Can Bay 75b and Cameron Point Site 62, which have midden deposits dating from 308 cal BP and 147 cal BP respectively, have small artefact assemblages, the major component of which is silcrete. Neither site has evidence of molluscan over-exploitation or resource depression. McNiven (1991c) considered that the increase in shellfishing observed in the past few hundred years represented a secondary augmentation of human activity i.e. the exploitation of marine resources in an area previously used for the exploitation of terrestrial, particularly plant, resources. Acknowledging that the reasons for the secondary augmentation as part of the Recent Phase developments over the past 1000 years were likely variable and complex, McNiven (1991c:103) suggests that increases in shellfishing in the upper levels may have been in part a response to European incursion into the region. However, both sites pre-date European arrival. Cameron Point has a near-basal date of 829 cal BP, suggesting that initial occupation began in the Recent Phase around the time discard ceased at Booral Shell Mound. This is some evidence for the changes in land-use and resource exploitation that McNiven has suggested, but at a much later date than that originally proposed. The data presented in this thesis suggest refinements to the model rather than refuting it. These refinements take the form of environmental, chronological, and economic patterning, that shift some elements forward in time. The key behavioural mechanisms which underscore the model are not altered.

### *Coastal Southeast Queensland: an historical ecology model*

The historical ecology theoretical framework employed in this study differs from that underlying the previous models in that it views humans as keystone species within ecosystems, both impacting on, as well as being impacted by, shifting environmental parameters. Historical ecology focuses on the environmental and cultural factors that contribute to the evolution of a particular landscape or seascape. Bearing this in mind, the following discussion offers a somewhat different perspective on the Holocene occupation of coastal southeast Queensland than the models outlined above, the majority of which tend to be linear in nature. The models are not necessarily mutually exclusive, but the addition of an historical ecological approach adds a further dimension to the explication of occupation and human behaviour in coastal southeast Queensland during the mid to late Holocene.

The evidence from the present study indicates that the density of cultural discard in the form of molluscan remains is highest in the sites established at around 5000 cal BP and 3000 cal BP, Hope Island Square A and Booral Shell Mound. Bribie Island 9 was also established at c3500 cal BP. While the relative density of molluscan remains at Bribie Island 9 is much lower than that estimated for Hope Island Square A and Booral Shell Mound, this is the result of the taphonomic processes in train at the site. The deposition of organic remains was sufficient to alter the pH of the sediments which are more alkaline than those at other, more recent, sites on the island; the podzols on Bribie Island are acidic. It can reasonably be speculated that the density of discard was much higher than the NISP and MNI recorded in this study indicate. The establishment of the midden at St. Helena Island pre-dates 1852 cal BP, around the time that the marine regression began, and the site evidences the third-highest volume-corrected molluscan discard rate in the study. Hall and Lilley (1987) considered that the New Brisbane Airport site established at 5494 cal BP represented exploitation of coastal resources in the early mid-Holocene, with the highest artefact density occurring at 4329 cal BP. By comparison, the sites established later in the chronological sequence exhibit lower densities of molluscan discard (Figure 9-1).

The morphometric analyses of the molluscan remains have demonstrated no evidence of resource-depression or over-exploitation. These data suggest that the prey species were resilient to exploitation, and that the impact of that exploitation was at a low level. The spatial distribution of molluscan species has been demonstrated to be strongly correlated with ecological factors such as the availability of suitable habitats linked to the dynamic nature of estuarine environments. There is not a uni-directional or linear model of mudflat expansion throughout the late Holocene. The environmental evidence indicates that the estuaries of Southeast Queensland are active and in a constant state of flux, resulting in a mosaic of differently constructed environmental zones. These shifting sediment regimes and changes in the structure of seagrass populations are more likely to impact species such as *Anadara trapezia* and *Pyrazus ebeninus*, than those species which inhabit intertidal or subtidal areas associated with rocky or other hard substrates. Species such as *Saccostrea* and *Trichomya hirsuta* are more likely to be affected by changes in water turbidity and sediment load. The terrestrial environment is relatively more stable, and a common factor in the location of the sites in the study is that the majority are located in areas of open forest or woodland, or, as in the case of St. Helena Island, adjacent to vine forest.

That the people living in Coastal Southeast Queensland were exploiting resources other than molluscs is evidenced by faunal remains such macropods, possums, flying-foxes, dugong, turtle, and lizards (Chapters 5 to 8). Alfredson (1984) does not quantify the flying-fox remains from St. Helena, instead stating that they were present throughout the deposits. However, in the majority of sites the faunal component of the assemblages is either very minor or entirely absent. The scarcity of terrestrial faunal remains suggests that a limited range of subsistence activities was undertaken at the sites (see e.g. Faulkner 2006; McNiven 1989; Walters *et al*. 1987), and may also reflect the depauperate terrestrial fauna associated with wallum floristic communities. Evidence of plant processing is in the form of the re-used bevelled artefact from Tin Can Bay 75b.

There are only three formal implements in the artefact assemblages. Two of these are from Booral Shell Mound, dating to the period between c3000 cal BP and 2752 cal BP, while the third, from Tin Can Bay 75b, postdates 308 cal BP. The artefactual evidence suggests that coastal Southeast Queensland in the mid to late Holocene was a low-risk environment for a hunter-gatherer population (Hiscock 1994).

Taken together, the artefactual evidence and the nature of the marine resource base in the study region suggest that the population, throughout the period from the early mid-Holocene until the historical period, was semi-sedentary. Molluscan species are not as seasonally restricted as other terrestrially-based resources, and allow a lowering of mobility (e.g. Faulkner 2006, 2013). Although relatively few fish bones were identified in the present study, they have been identified in greater numbers at Booral Shell Mound (Frankland 1990), and at other sites in the study region (e.g. see Alfredson 1984; Nolan 1986; Walters 1986, 1992). In his study of age classes and the season of death of fish remains from eight sites in the study region, Walters (1992b) demonstrated that there was no seasonality in the availability of fish resources in Southeast Queensland. While the occurrence and harvest of some species (e.g. *Sillago* spp., whiting) varied during the year, other species such as mullet (*Mugil* spp.) were available, and harvested, all year round. Walters (1992b:33) thus refuted other models (e.g. Morwood 1986) of nomadic populations following resource gluts, and who inhabited the coastal areas only while the gluts lasted before departing inland.

The density data in the present study indicate that early in the study period, from c5000 BP and prior to the commencement of the marine regression, the exploitation of molluscan resources was more localised than later in the Holocene. Following the regression and the greater areal availability of estuarine environments, the population dispersed across the region but continued much the same foraging behaviour. This is not to say that the socio-economic and socio-cultural processes remained unchanged, or that there were not fluctuations in population size. That there was some re-structuring is evidenced by the cessation of discard at Booral Shell Mound at 806 cal BP, and the change in site use at Cameron Point Site 62 between 829 cal BP and 147 cal BP. There are also increases in discard at White Patch 3 in the period between 579 cal BP and 504 cal BP, and Bribie Island 9 in the immediate pre-contact period. These may be associated with the socio-cultural networks described historically, and events such as the gatherings at Toorbul and Bribie Island described by Nique and Hartenstein (1841) and Eipper (1841) (see also Nolan 1986). There is however no unequivocal evidence of a population increase in the late Holocene based on the molluscan evidence.

## *Concluding remarks*

This study has demonstrated the utility of an historical ecological approach in exploring the existing dataset for coastal southeast Queensland. Employing the premise that socio-cultural elements, archaeological economic data, environmental and ecological data are inextricably linked (e.g. Milner 2013; Thompson *et al.* 2013) has allowed a more holistic approach to the southeast Queensland dataset than most of the previous theoretical frameworks permitted.

Although there is local variability demonstrated by the palaeoenvironmental data, the available information suggests that the floristic communities observed as the preferred location for coastal settlement had developed by the early Holocene. McNiven (1990a, 1991b; see also Ulm and Hall 1996) argued that the early evidence from c5500 cal BP of resource exploitation and occupation at Teewah Beach 26 reflected the localised adaption of an existing marine-terrestrial subsistence system that had been gradually moving westward with the transgressing coastline. This position is supported by the current study, with evidence of a fully developed marine economy at Hope Island at c4863 cal BP, and at Booral Shell Mound at 3133 cal BP. There is also evidence of a marine economy on Bribie Island from c3469 cal BP. In contrast to models of more intensive site use in the last 1000 years, the greatest densities of discard of molluscan material appear at Hope Island Square A, Booral Shell Mound, St. Helena Island, and Hope Island Square E which pre-date the increase . The findings of this research indicate that occupation of sites in the study region was mostly of low intensity.  The exceptions are the discard of molluscan material at White Patch 3 over a period of some 75 years and a relatively intense period of discard at Bribie Island 9 in the period following 149 cal BP. In all cases, however, there was no evidence of over-exploitation or resource depression, indicating that levels of exploitation did not exceed the capacity of the exploited molluscs to maintain viable breeding populations.  Increased population pressure associated with the dramatic increase in sites established after c1000 BP is not reflected in the principal molluscan species.  This suggests that the people who lived in the area from at least the mid Holocene practised a semi-sedentary lifestyle and, although perhaps based on the coast, may have moved throughout the region to take advantage of terrestrial, most likely seasonal, resources (Kelly 1992; Lilley 1984; see also Uniacke in Mackaness 1979), as well exploiting the off-shore islands.  These observations offer a different viewpoint from that of Robins *et al*. (2015:193) who suggested that the transgressive episode meant that humans living on or near the coast would have had to constantly adjust to new conditions for thousands of years.  The models of estuarine development outlined by Ryan *et al*. (2003; Chapter 3) and the sea level curve of Lewis *et al*. (2013; Figure 3-6) suggest that, rather than being relentlessly pursued by the incoming tide, people in the coastal zone would have had the opportunity to adapt to the new conditions after c8000 cal BP. Adaptation to an assured, low risk environment is also evidenced by the expedient stone tool technologies in the assemblages from the sites.  The study region evidences continuous, low intensity occupation, with low-level impacts on the marine environment throughout the mid to late Holocene. In short, this multi-disciplinary study based on a framework of historical ecology has provided a fresh approach to the interpretation of the archaeological dataset from coastal Southeast Queensland.  It has also demonstrated the value of the re-analysis of existing assemblages in the light of changing theoretical paradigms and analytical methods. It is an approach that can be applied to the re-analysis of other assemblages from the region, but also to the ongoing study of coastal sites not only in Australia but internationally.

# 10. References

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# 11. Appendix A

## *An introductory biology and ecology of the principal economic molluscan species in southeast Queensland coastal middens.*

The molluscan species most commonly found in coastal middens in the southeast Queensland region are *Anadara trapezia* (mud ark cockle), *Pyrazus ebeninus* (Hercules Club whelk or club whelk), *Saccostrea glomerata* or *S. cuccullata* (rock or hooded oyster; debate continues as to whether they are separate species), and *Trichomya hirsuta* (hairy mussel). Sometimes lumped together in the literature as 'estuarine species' (e.g. Hall 1999; McNiven 1990), the species occupy different environmental niches within estuarine systems as well as in other sheltered, relatively low-energy locations (e.g. the lee or western side of the Moreton Bay barrier islands - Moreton and North Stradbroke). The surf beach species, *Donax deltoides*, dominates coastal middens established after 1000 BP (McNiven 2006). Isolated occurrences of *Chama* spp. and *Nerita balteata* in high numbers have also been recorded (e.g. Alfredson 1984; Frankland 1990; the present study). What is remarkable, given the ubiquity of some of these species in the coastal archaeological record of SEQ and the resulting literature, is the dearth of readily accessible biological and ecological information regarding the species. With the notable exception of Faulkner (2006, 2009, 2010, 2013) species ecology is generally not discussed in the archaeological literature beyond basic habitat information. Understanding the ecology of the shellfish species including what time of the year they spawn, how quickly they grow, what size and age they reach maturity, how they react to changing environmental conditions like altered salinity levels (e.g. flood events) and temperature changes, when they are less good to eat (the seasonality in shellfish exploitation), the proportion of juveniles to adults, informs on subsistence practices and environmental changes and influences.

### *Anadara trapezia*

*A. trapezia* or mud ark cockle is the most common shellfish species found in middens in coastal southeast Queensland; the species is found along much of the eastern Australian coast from central Queensland to Port Phillip Bay in Victoria. Its preferred habitats are the intertidal to shallow sub-tidal (0 to 3m water depth) zones of estuaries and sheltered bays, with soft sandy-mud to mud sediments, and vegetative cover such as *Zostera* spp. (seagrass) where it usually lies partially buried (Gribben and Wright 2006; Hadfield and Anderson 1988; Wright and Gribben 2008) (Figure A-1).

**Figure A- 1** ***Anadara trapezia*** **in a seagrass bed (Ulm 2006).**

*A. trapezia* are commercially fished in southern New South Wales (Hadfield and Anderson 1988), but unlike the *A. granosa* fisheries in Malaysia and Thailand it is small-scale. The species has not been subject to detailed biological studies in growth and reproduction such as those by Broom (1982, 1985) for natural and seeded Malaysian *A. granosa* populations, which were useful for Faulkner's (2006, 2009, 2010, 2013) work on Arnhem Land *A. granosa*-dominated middens. Nevertheless several studies are available which inform on *trapezia* ecology, although only one refers specifically to a Queensland context.

*A. trapezia* are dioecious, free spawning, thick-shelled bivalves of the Arcidae family reaching between 70-80mm in length. They are suspension or filter feeders with short siphons (Gribben and Wright 2006; Wright and Gribben 2008). Spawning is generally agreed to take place in summer when water temperatures and phytoplankton levels are highest (Dixon 1975; Hadfield and Anderson 1988; Wright and Gribben 2008), although Nell *et al.* (1994) reported inducing spawning in October by artificially raising water temperature to 22$^{o}$C during a hatchery experiment. The larvae develop into pediveligers (with a small foot for locomotion as well as a velum for swimming/feeding) of about 220µm in width after approximately 14 days, following which spatfall or settling can theoretically occur but I found no literature regarding the actual period of the larval stage or the timing of spatfall. Unfortunately there are no details in the studies concerning the size or age at which *A. trapezia* reach sexual maturity; the individuals used in reproductive studies by Hadfield and Anderson (1988) were approaching maximum length. Broom (1982, 1983) observed spawning in *A. granosa* of 30mm in length in October with spatfall occurring in December, suggesting a larval stage of approximately 60 days. Alfredson (1984:134) suggests *A. trapezia* of 35-45mm in length from St. Helena Island in Moreton Bay are individuals in their third year, while those under 30mm are probably just over a year old, and individuals 50mm or longer are over three years of age. If Broom's Malaysian model for *A. granosa* is applicable, it would suggest that *trapezia* individuals of around 30mm are breeding size; that the larval stage may be about 60 days; and that spawning during summer would provide spatfall from late summer to autumn. Fish predate on the larvae and spatfall, but carnivorous gastropods such as *Bedeva* spp. and *Conuber sordidum* are the chief natural predators of more mature specimens. Unlike the other two major bivalve species, *A. trapezia* are relatively mobile and burrow within sediments using the foot which is not resorbed upon settlement.

The determination of seasonality based on growth patterns on bivalves is not a new concept (e.g. Clark 1968; Coutts 1970; Coutts and Higham 1971; Pannella and McClintock 1968), but is perhaps best demonstrated in cold climate zones where there are quite distinct seasons affecting shell growth. In my experience it is difficult discern growth rings macroscopically, however interruptions in growth are quite obvious and occur in a number of the specimens analysed for this study. These growth interruptions appear as distinct lines on the exterior of the shells and are caused by the slowing in growth of the shell. Of the species commonly found in southeast Queensland middens, *A. trapezia* is the most sensitive to changes in water temperature and salinity and is restricted to areas where salinity changes are relatively small or occur very gradually (Alfredson 1984; Rainer *et al.* 1979). Reduced salinity affects the organism's metabolic rate, hence slowing growth (Rainer *et al.* 1979). It is likely that rapid temperature changes and restricted access to food produce the same results. Dixon (1975) noted that individuals stressed by environmental factors such as low temperature and salinity gaped open and were sluggish. Alfredson (1984) produced an interruption in growth in *trapezia* specimens by placing them in an atidal (a salt water tank) environment and withholding food. As all *Anadara* species are filter feeders events such as the 2011 Brisbane River flood plume (Figure A-2) have the potential to catastrophically impact populations.

**Figure A- 2 The Brisbane River 2011 flood plume (*Courier Mail* 23 January 2011).**

Diggles (2011) found dead *A. trapezia* in Pumicestone Passage after the 2011 flood event, and Dixon (1975) recorded very high mortality rates at three Queensland locations and six locations in New South Wales following flood events during her research in the late 1960s-early 1970s. The *A. trapezia* in the present study are particularly good indicators of environmental stress.

## *Pyrazus ebeninus*

Commonly known as the Hercules club whelk or mud whelk, *P. ebeninus* occurs frequently in southeast Queensland middens. A member of the family Potamididae, they are the commonest gastropod species on the *Zostera* beds and mudflats in the Moreton Region (Vohra 1965) (Figure A-3). Distribution extends along the east coast from around Port Curtis in central Queensland to Victoria. Despite this abundance, they are not exploited commercially and with the exception of Vohra's (1965) comprehensive study surprisingly little has been written about their ecology.

**Figure A- 3 *Pyrazus ebeninus* on mudflats at Pumicestone Passage (T. Smith).**

In common with other Potamididae, *P. ebeninus* is a dioecious gastropod that occurs in brackish environments, on mudflats in estuaries and in association with mangrove communities (Carpenter and Niem 1998). The species is sexually dimorphic, with the females larger than the males (John Healy, Curator Marine Environments [Molluscs], Queensland Museum, pers. comm. 28 August 2012). It grows to approximately 100mm in height. It is not a filter feeder, but instead grazes on algae and detritus on the mudflats and in *Zostera* beds. Sand and overlying small animals are also swallowed, although the *Zostera* itself is not eaten (Vohra 1965:15). The animals are most active when submerged and also just after low tide when the sediments are still wet and soft (reaching a maximum speed of 1.25cm per minute), although activity levels appear to be also influenced by weather conditions (Vohra 1965:22).

*P. ebeninus* have been observed spawning between February and April (Vohra 1965), with the strings of eggs laid by the females fertilised by spermatophores from the males (Carpenter and Niem 1998). Veliger larvae of about 0.175mm in length develop within approximately 14 days, although it is unclear how quickly they settle. Post-settlement growth averages about 2mm per month until maturity; sexual maturity occurs between 50 to 70mm when the aperture lip begins to thicken (Vohra 1965). Crabs, fish and other gastropods are the main predators of the spatfall and juveniles (Vohra 1965), however as individuals mature their shells become so hard that, with the possible exception of some types of octopus, their only successful predators are humans (John Healy, pers. comm., 28 August 2012).

Experiments conducted by Vohra (1965) and Rainer *et al.* (1979) demonstrated that *P. ebeninus* is highly tolerant both of changing levels of salinity and rapid fluctuations in temperature. Individuals respond to both by withdrawing high up into their shells and sealing the apertures tightly with their opercula. This tolerance suggests that *P. ebeninus* is a highly resistant species that is likely to survive significant short-term environmental events.

### *Saccostrea species*

There is some debate as to whether the oysters found in middens in southeast Queensland are *Saccostrea glomerata* (Sydney rock oyster) or *Saccostrea cuccullata* (hooded rock oyster) (e.g. Buroker *et al.* 1979; Healy *et al.* 2011; Lam and Morton 2005; Thomson 1954). Oysters live attached to hard objects and are usually gregarious and often densely packed, leading to frequent morphological variability among individuals - what are described as separate species may in fact simply be ecophenotypical variations (Carpenter and Niem 1998:224). Carpenter and Niem (1998:232) in their FAO species identification guide offer this observation:

> The systematics of the genus *Saccostrea* has been very confused in the past and there is still no general agreement among authors about the number of species living in the Indo-West Pacific. However, as *Saccostrea cuccullata* is often considered to be the only species occurring in that area, this conservative opinion is adopted here.

In view of the ongoing debate the bivalves from the Ostreidae family and discussed in this study are simply referred to as *Saccostrea*, or colloquially as oysters.

*Saccostrea* individuals prefer hard substrates and can occupy marine, estuarine and mangrove areas in intertidal and shallow subtidal zones (Carpenter and Niem 1998). They are often densely packed together, and can form large subtidal reefs (Ogburn *et al.* 2007). In the wild *Saccostrea* are relatively small, measuring 60-80mm in height, although some specimens may reach 100mm; commercially they may be grown to larger sizes. The rock oyster is the most commercially important shellfish species in Australia, with a thriving industry in New South Wales and to a much lesser extent, southern Queensland. The taxon demonstrates distinct differences between the upper and lower valves, with the former being almost flat and the latter deeply cup-shaped with radial ribs (Figure A-4).

**Figure A- 4 *Saccostrea* sp. (Australian Museum).**

The range of variation in valve morphology in commercial rock oysters is much less than that found in wild populations because of the less-crowded husbandry practices which employ mesh trays (White and Beumer 1997). Kent (1992:4) suggests four growth forms related to the substrate on which the oysters are growing:

- Sand Oysters: short broad oysters from bars of coarse, firmly packed sand. Sand oysters are generally intertidal or in very shallow water and consequently have well-developed radial ribs and strongly coloured valves caused by exposure to sunlight.
- Bed Oysters: occur on mixed muddy sand, either singly or in loose clusters.
- Channel Oysters: large elongated oysters from soft mud, generally in deeper channels.
- Reef Oysters: small elongated oysters from densely clustered oyster reefs. Frequently intertidal, and like sand oysters radially ribbed with coloured markings.

While Kent's classifications make useful reference points for considering the morphology of the oysters in the current study, they are based on the American oyster *Crassostrea virginica* from a narrow geographic area of Maryland and hence are treated here cautiously. Galtsoff's publication (1964), although also based around *Crassostrea virginica*, includes observations made on members of the Ostreidae family in general. These include that "Oysters are frequently found so closely adhering to the substratum that their shells faithfully reproduce the configurations and detailed structures of the objects upon which they rest" (1964:2), a phenomenon frequently observed during the Booral Shell Mound analysis. Galtsoff also notes environmentally influenced morphology including: valves growing in calm water on flat surfaces have a tendency to acquire a round shape and to have poorly developed umbones, while those on soft substrates and overcrowded reefs were more likely to have long, slender, laterally compressed bodies with hook-like umbones. He cites Lamy (1929) who observed that oysters attached to a pebble or shell, and so raised slightly from the bottom, had deep radially ribbed lower valves which offer greater resistance to dislodgement by currents or waves (Galtsoff 1964:2).

*Saccostrea* are suspension filter-feeders. Generally speaking they are free-spawning and dioecious, although the sex of individuals changes with age (Carpenter and Niem 1998; Catterall and Poiner 1987; Gosling 2003). Rock oysters are available year-round in southeast Queensland, but their condition is poorer during the winter months, and they tend to be in peak condition during spawning. This occurs during spring and summer when water temperatures are higher, usually between September and February (White and Beumer 1997).

*Saccostrea* larvae take two to three weeks to develop into pediveligers (Smith 1985) at which time they are approximately 250-300µm in length (Gosling 2003). They then move about on their foot searching for an appropriate substrate to settle on. They have a preference for live oyster shells (hence the development of oyster shell reefs), and it has been suggested juvenile and adult oysters release pheromones to attract settling larvae (Gosling 2003). Oyster shells are commonly used as cultch (catching material) in commercial oyster fisheries and in Aboriginal oyster farms (Ross and Quandamooka 1996; Smith 1985) (Figure A-5). Oyster settling is irrevocable; a drop of 'cement' of similar composition to the oyster shell is applied from a gland in the foot and the larva attaches its lower valve (Gosling 2003), after which the foot is resorbed. Occasionally *Saccostrea* attach to live Hercules club whelks (*P. ebeninus*) which carry the oysters about until eventually the weight or the size of the oysters prevents movement and the whelk dies (Smith 1985). This phenomenon has been observed in this study in midden material from Tin Can Bay 75b and Cameron Point Site 62 (Figure A-6).

Specific information regarding the growth rate of *Saccostrea* spat is not available. Smith (1985:2) states that "within six weeks the oyster is the size of a small fingernail". Generally oysters take between two and four years to grow to maturity (Smith 1985; White and Beumer 1997). Catterall and Poiner (1987:120) comment that oysters mature as males at 20mm, and as females at 50-60mm.

Oyster larvae and oysters are prey for fish, crabs and stingrays (Smith 1985). Juveniles and adults are also prey species for carnivorous gastropods such as *Bedeva* spp.

**Figure A- 5 Commercial oyster beds at Toorbul Point c1910 (Sunshine Coast Library).**

**Figure A- 6 Oysters attached to Hercules club whelk shells from Tin Can Bay 75b. Dorsal view left, ventral view right (T. Smith).**

Rainer *et al.* (1979) found *Saccostrea* reasonably resistant to sudden changes in salinity, although there is some evidence that reduced salinity leads to immunosuppression (Dove and O'Connor 2007; Green and Barnes 2010). As suspension filter-feeders they are also susceptible to pollution by the sediment loads of flood events and run-off after heavy rain. *Saccostrea* populations have historically proved to be vulnerable to disease. The commercial industry was almost wiped out in the 1890s by mudworm (*Polydora* sp.) disease introduced to Australia in infected shipments of oysters from New Zealand in the early 1880s. New Zealand oysters were significantly cheaper than local oysters as they were not subject to royalty payments (Ogburn *et al.* 2007:278); by the late 1890s parasitic ‘worm disease’ had spread through all east coast commercial beds. Although the intertidal oyster industry in Queensland recovered during the period 1910-1920, there has never since been a recovery of natural beds of subtidal oysters in New South Wales or Queensland estuaries (Ogburn *et al.* 2007:278). Oysters in southeast Queensland are also affected by QX (‘Queensland Unknown’) disease identified in 1976 as being caused by the single-celled parasite Marteilia sydneyi which infects oysters between January and April; the parasite essentially causes the oyster to starve to death over a period of some weeks (Queensland Museum). Although there is no evidence that QX disease affected Saccostrea populations exploited by Aboriginal people in southeast Queensland, its presence in the current wild population demonstrates Saccostrea vulnerability to disease under certain conditions.

## *Trichomya hirsuta*

This member of the Mytilidae family occurs along the eastern and southern Australian coast, particularly in estuaries. Although locally abundant, it is not a commercially exploited species. In 1997 Goggin lamented that “despite the wide distribution and massive stable populations of *T. hirsuta* which occur in Australian waters, little is known of the biology of the species” (1997:59). Nineteen years on not much has changed. The content of this section therefore derives from what little published literature specific to *T. hirsuta* is available, extrapolation from information on other Mytilidae species particularly the commercial species *Mytilus edulis planulatus* or blue mussel, and personal observation.

The common name for the species derives from the bristles that cover the periostracum of living shells (Figure A-7). They are a dioecious, free spawning, bivalves with relatively thin shells, clumping together on rocks, artificial structures, or simply other mussel shells (Goggin 1997; Gosling 2003), Mussels tend to spawn during the cooler months of the year; in *M. edulis planulatus* gonad development begins when the water temperature falls below 21$^{o}$C and the mussels are generally ‘ripe’ by May. The data are (again) limited but suggest that the mussels are in peak spawning condition from June to September (Allen 1955). Mussels are sexually mature within their first year (Gosling 2003). Mussel pediveligers develop within two to four weeks of spawning; like oysters they move around looking for suitable substrates on which to settle by means of the byssus (anchor thread), but unlike oysters they are able to relocate within a short period if the need arises (Gosling 2003). and may play a role in the stabilisation of muddy sediments. The clumps are home to a variety of organisms including barnacles and other crustaceans, as well as small fish and worms (Morton 2008; Morton and Lutzen 2008).

**Figure A- 7 *Trichomya hirsuta*, the hairy mussel (Queensland Museum).**

There is no data available on the growth rates of *T. hirsuta* from spat to adult, although Goggin (1997) noted that individuals grew more quickly in Brisbane and Lake Macquarie than in other areas of distribution. The mussel larvae are prey for crabs, fish and starfish, while *T. hirsuta* juveniles and adults have been observed being preyed upon by the mud crab *Scylla serrata* (Williams 1978). The adult mussels exhibit variable maximum heights; Goggin (1997) reports heights between 60mm and 100mm (Goggin while Healy and Lamprell (1998) and Healy *et al*. (2011) suggest maximum heights of 65mm.

Wallis (1976) observed that the thermal tolerance of *T. hirsuta* was between 8-35$^{o}$C, reflecting its range of distribution, although the animals became much less active below 15$^{o}$C. High salinity levels aided resistance to thermal shock i.e. rapid changes in water temperature. In southeast Queensland estuaries the water is brackish rather than highly saline, but water temperature change tends to be gradual rather than dramatic and the hairy mussels are unlikely to suffer thermal shock during normal climatic events. As filter feeders they are of course vulnerable to pollution by the sediment loads of flood events and run-off after heavy rain. Diggles (2011) inspected three mussel clumps from Toorbul Point on 28 January 2011 and found that 70% of the mussels were dead, most of them fresh morts; this high incidence of mortality may be due to the combination of low salinity and high sediment load of the flood plume.

## *Nerita balteata*

Although there are no comprehensive ecological studies available regarding *Nerita balteata*, general observations may be made based on references to the shell texts. Nerites are characterised by Carpenter and Niem (1998:420) as algal grazers, with species often living quite high in the intertidal zone, where they are exposed to the air and sun for long periods. The tightly fitting operculum prevents desiccation surface of the mantle cavity which acts as a primitive lung. They are herbivorous, grazing nocturnally at low tide on fine algae and detritus, and sometimes forming very large colonies. Nerite sexes are separate, with internal fertilisation after which eggs are laid in capsules, attached to rocks or to nerite shells. Wilson (1993:40) states that *N. balteata* lives on the trunks and branches of mangrove trees; they feed on the algae and detritus found there (Figure A-8). The species grows to a height of approximately 40mm.

**Figure A- 8** ***Nerita balteata*** **on mangrove stalks (source uncredited).**

## *Chama spp.*

Frankland (1990) and McNiven (1994) include *Chama pacifica (*formerly *Chama reflexa*, commonly known as jewel box oyster) in the list of economic species for BSM, although they do not specify why. It is not a genus commonly recorded in the middens of southeast Queensland (although small numbers were found at St. Helena Island and White Parch 3 – see Alfredson 1984), and hence there is little local ecological or biological literature available. *Chama* spp. can grow up to 80mm, but more commonly to 60mm, and occur on rock or coral platforms in the intertidal zone, but can also occur to depths of 30m. They are fully cemented to the substrate. Studies conducted by Zurel *et al.* (2011) on invasive *C. pacifica* in the Eastern Mediterranean showed that the oyster could develop dense clumps on rocky substrate; that they are dioecious and free spawning; and that spawning tends to occur during spring and summer when the water temperature exceeds 21$^{o}$C. Healy and Potter (2010:240) note that chamids, like oysters, settle and grow on the shells of other molluscs (alive and dead), rocks and dead coral (Figure A-9). Further, during the 2005 Moreton Bay Benthic Survey it was observed that most shallow subtidal mussel and oyster clump samples contained one or more species of *Chama* cemented on in small clusters. Chamids were more common subtidally in the bay, as intertidally they were in intense competition with oysters and barnacles for appropriate settlement sites.

**Figure A- 9** ***Chama pacifica*** **(www.idscaro.ne).**

## *Donax deltoides*

*Donax deltoides*, pipi, is a beach or surf clam (Figure A-10) of the family Donacidae, commonly found along the east coast of Australia; it is the predominant species in SEQ surf coast middens, particularly those dating to within the last 1000 years (McNiven 2006). Its range extends from the vicinity of Fraser Island in Queensland, where it is also known as eugarie or wong, to the Eyre Peninsula in South Australia where it is known as Goolwa cockle; small-scale commercial *D. deltoides* fisheries operate in New South Wales and South Australia. *D. deltoides* is found in dense aggregations on inter-tidal and shallow sub-tidal sandy shores, usually on open, dissipative beaches (Ansell 1983; Murray-Jones 1999).

**Figure A- 10** ***Donax deltoides*** **(Queensland Museum).**

Surf clam species can comprise up to 80-98% of the macrobenthic infaunal biomass and play a crucial role in the food chain of sandy beaches (Ansell 1983; Murray-Jones 1999); the populations are subject to large, episodic fluctuations in abundance, apparently due to high recruitment variability and occasional mass mortalities (Murray-Jones and Steffe 1999:220). Long spells of hot, calm weather or large freshwater outflows from the Murray River have also been observed to lead to declining numbers in the South Australian fishery.

*Donax* spp. bury themselves vertically in beach sand and filter-feed on phytoplankton via a siphon. They are dioecious, broadcast spawners with a planktonic larval phase. Murray-Jones and Steffe (1999:220-22) note that pipis are 'serial spawners' with a prolonged spawning season and poorly defined spawning patterns. These characteristics allow the species to rapidly colonise new habitats and replenish depleted stocks, as recruits are present on beaches throughout the year. Nevertheless, during her five-year study of five beaches in New South Wales, Murray-Jones (1999) found juvenile mortality to be high, and that large numbers of recruits did not go on to establish cohorts. Cohorts at all five beaches were established only between July and December, but recruitment was consistent even where there were few adults, suggesting the stock-recruitment relationship is not strong (1999:154). Murray-Jones (1999:205) also found little genetic variation within pipi populations along a 1200km stretch of coastline, suggesting that pipi larvae move between regions and that the gene flow is bi-directional.

Spatio-temporal variability in *D. deltoides* distribution and abundance was found to be high (Murray-Jones 1999), with intra-site variability as high as or higher than inter-site variability. Measured densities could vary by several orders of magnitude over distances as short as 10 to 20m, and Murray-Jones attributed this to the high mobility of *Donax*. Pipis move about by extending a strong muscular foot out of their shell and crawling across the sand. They have also been observed 'leaping' using the foot (Ansell 1994). Active migration up and down the shore is achieved by surfacing and being moved about by wave action (Ansell 1983). Size classes were also commonly missing from samples, which was again attributed to mobility rather than mortality. Different size classes often occupied different heights on the shore, and the zone occupied by the different size classes varied over time. Small and medium specimens were most likely to be found in the swash (72% and 48% of samples respectively), large pipis (which have a maximum length of 60mm) were more evenly distributed in the swash (32%) and sub-tidal (30%) areas, with a slight increase (38%) in the inter-tidal zone. The distribution patterns were inconsistent over short time periods (days) and short distances (a few kilometres) (Murray-Jones 1999:205). Ansell (1994), and Defeo and McLachlan (2005) suggest that such variations may be due to local environmental factors, e.g.

differences in salinity and temperature, as well as the presence or absence of predators and food. Although these variations in size and distribution are probably insignificant in time-averaged archaeological contexts, they do present valuable considerations for one-off dinner camps or short term occupation sites and interpretations on the levels of predation or exploitation (over-exploitation) that may be drawn from them.

# 12. Appendix B

*Table B-1 Attributes of flaked pieces (FP) from Booral Shell Mound Square B.*

| SU | Category | Raw material | Colour | Wt g | Max dim mm | Comments |
|---|---|---|---|---|---|---|
| 1 | FP | Chert | Light olive brown | 0.04 | 7.39 | |
| 1 | FP | Chert | Dusky red | 2.08 | 28.11 | Heat shatter |
| 1 | FP | Chert | Dusky red | 0.35 | 14.44 | Heat shatter |
| 1 | FP | Chert | Red/dusky red | 1.69 | 25.12 | Heat shatter |
| 1 | FP | Chert | Dusky red | 0.97 | 13.87 | Heat shatter |
| 1 | FP | Chert | Dark reddish grey | 1.48 | 22.31 | Heat shatter |
| 1 | FP | Chert | Dusky red | 1.55 | 15.14 | Heat shatter |
| 1 | FP | Chert | Dusky red | 0.97 | 17.52 | Heat shatter |
| 1 | FP | Chert | Dusky red | 0.24 | 12.59 | Heat shatter, with potlids |
| 1 | FP | Chert | Dusky red | 0.62 | 21.22 | Heat shatter, with potlids |
| 1 | FP | Chert | Dusky red | 0.26 | 16.6 | Heat shatter |
| 1 | FP | Chert | Dusky red | 0.3 | 13.59 | Heat shatter |
| 1 | FP | Chert | Dusky red | 0.29 | 12.61 | Heat shatter |
| 1 | FP | Chert | Dusky red | 0.19 | 12.96 | Heat shatter |
| 1 | FP | Chert | Dusky red | 0.09 | 10.04 | Heat shatter |
| 1 | FP | Chert | Dusky red | 0.15 | 13.65 | Heat shatter |
| 1 | FP | Chert | Dusky red | 0.1 | 8.36 | Heat shatter, with potlids |
| 1 | FP | Chert | Dusky red | 0.08 | 7.3 | Heat shatter |
| 1 | FP | Chert | Dusky red | 0.06 | 9.8 | Heat shatter, with potlids |
| 1 | FP | Chert | Dusky red | 0.04 | 8.08 | Heat shatter, with potlids |
| 1 | FP | Chert | Dusky red | 0.03 | 9.08 | Heat shatter |
| 1 | FP | Chert | Dusky red | 0.88 | 23.67 | Angular, heated |
| 1 | FP | Chert | Dark reddish brown | 0.15 | 9.72 | Potlid |
| 1 | FP | Chert | Dark reddish brown | 5.11 | 26.71 | Potlid |
| 1 | FP | Chert | Dark reddish brown | 0.18 | 9.99 | |
| 1 | FP | Chert | Dark reddish brown | 0.28 | 8.91 | |
| 1 | FP | Mudstone | Moderate reddish brown | 1.73 | 29.09 | |
| 1 | FP | Mudstone | Moderate reddish brown | 1.11 | 21.14 | |
| 1 | FP | Mudstone | Moderate reddish brown | 0.36 | 14.83 | |
| 1 | FP | Mudstone | Moderate reddish brown | 0.66 | 15.41 | |

| SU | Category | Raw material | Colour | Wt g | Max dim mm | Comments |
|---|---|---|---|---|---|---|
| 1 | FP | Mudstone | Moderate reddish brown | 0.33 | 10.22 | |
| 1 | FP | Mudstone | Moderate reddish brown | 14.6 | 0.19 | |
| 1 | FP | Mudstone | Moderate reddish brown | 0.34 | 17.13 | |
| 1 | FP | Mudstone | Moderate reddish brown | 0.26 | 10.69 | |
| 1 | FP | Mudstone | Moderate reddish brown | 0.28 | 12.11 | |
| 1 | FP | Mudstone | Moderate reddish brown | 0.21 | 10.46 | |
| 1 | FP | Mudstone | Moderate reddish brown | 0.04 | 11.32 | |
| 1 | FP | Mudstone | Moderate reddish brown | 0.12 | 9 | |
| 1 | FP | Mudstone | Greyish orange pink | 1.05 | 10.99 | |
| 1 | FP | Mudstone | Greyish orange pink | 1.19 | 16.37 | |
| 1 | FP | Mudstone | Greyish orange pink | 3.64 | 16.85 | |
| 1 | FP | Mudstone | Greyish orange pink | 0.32 | 10.93 | |
| 1 | FP | Mudstone | Greyish orange pink | 0.35 | 11.39 | |
| 1 | FP | Mudstone | Greyish orange pink | 0.19 | 9.29 | |
| 1 | FP | Mudstone | Greyish orange pink | 0.92 | 18.14 | Heat shatter |
| 1 | FP | Mudstone | Dark reddish brown | 0.78 | 20.12 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.61 | 10.62 | Angular, heated |
| 1 | FP | Mudstone | Red | 0.17 | 12.76 | Heated, four potlids FS 63 obj 2 |
| 1 | FP | Mudstone | Dark reddish brown | 0.92 | 22.1 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.07 | 6.41 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.51 | 9.98 | Angular, heated |
| 1 | FP | Mudstone | Brown | 0.35 | 10.65 | |
| 1 | FP | Mudstone | Dark reddish brown | 0.06 | 6.14 | Heated |
| 1 | FP | Mudstone | Red | 0.18 | 10.44 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.06 | 11.03 | Heated |
| 1 | FP | Mudstone | Yellowish red | 0.04 | 7.36 | |
| 1 | FP | Mudstone | Brown | 0.06 | 7.18 | |
| 1 | FP | Mudstone | Dark reddish brown | 0.06 | 4.7 | Heated |
| 1 | FP | Mudstone | Red | 0.02 | 7.77 | Heated |
| 1 | FP | Mudstone | Red | 0.01 | 7.71 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.01 | 3.9 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.09 | 10.69 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.02 | 5.21 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.01 | 6.24 | Heated |

| **SU** | **Category** | **Raw material** | **Colour** | **Wt g** | **Max dim mm** | **Comments** |
|---|---|---|---|---|---|---|
| 1 | FP | Mudstone | Brown | 0.28 | 12.82 | |
| 1 | FP | Mudstone | Dark reddish brown | 0.43 | 18.28 | Heated |
| 1 | FP | Mudstone | Red | 0.35 | 12.47 | Angular, heated |
| 1 | FP | Mudstone | Red | 0.37 | 13.04 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.3 | 16.71 | Heated |
| 1 | FP | Mudstone | Yellowish red | 0.24 | 11.38 | |
| 1 | FP | Mudstone | Brown | 0.17 | 9.8 | |
| 1 | FP | Mudstone | Brown | 0.26 | 11.01 | |
| 1 | FP | Mudstone | Dark reddish brown | 0.44 | 13.48 | Heated |
| 1 | FP | Mudstone | Dar reddish grey | 0.19 | 20.3 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.1 | 8.84 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.03 | 5.95 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.1 | 9.02 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.12 | 9 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.06 | 8.09 | Heated |
| 1 | FP | Mudstone | Red | 0.17 | 10.03 | Heated |
| 1 | FP | Mudstone | Red | 0.11 | 9.84 | Heated |
| 1 | FP | Mudstone | Red | 0.09 | 8.72 | Heated |
| 1 | FP | Mudstone | Red | 0.07 | 6.87 | Heated |
| 1 | FP | Mudstone | Light yellowish brown | 0.02 | 8.31 | |
| 1 | FP | Mudstone | Dark reddish brown | 0.02 | 11.23 | Heat shatter |
| 1 | FP | Mudstone | Dark reddish brown | 0.2 | 14.79 | Heat shatter |
| 1 | FP | Mudstone | Dark reddish brown | 0.11 | 8.8 | Heat shatter |
| 1 | FP | Mudstone | Dark reddish brown | 0.07 | 7.29 | Two potlids, heat shatter |
| 1 | FP | Mudstone | Dark reddish brown | 0.09 | 8.16 | Heat shatter |
| 1 | FP | Mudstone | Black | 0.02 | 7.25 | Pot lid |
| 1 | FP | Mudstone | Red | 0.08 | 8.03 | Heated |
| 1 | FP | Mudstone | Grey | 0.16 | 9.23 | |
| 1 | FP | Mudstone | Red | 0.04 | 7.22 | Heated |
| 1 | FP | Mudstone | Grey | 0.05 | 7.47 | |
| 1 | FP | Mudstone | Grey | 0.04 | 7.96 | |
| 1 | FP | Mudstone | Grey | 0.06 | 5.47 | |
| 1 | FP | Mudstone | Grey | 0.03 | 6.93 | |
| 1 | FP | Mudstone | Grey | 0.02 | 5.87 | |
| 1 | FP | Mudstone | Grey | 0.03 | 7.21 | |

| SU | Category | Raw material | Colour | Wt g | Max dim mm | Comments |
|---|---|---|---|---|---|---|
| 1 | FP | Mudstone | Grey | 0.03 | 7.77 | |
| 1 | FP | Mudstone | Red | 0.04 | 5.2 | |
| 1 | FP | Mudstone | Brown | 0.06 | 6.39 | |
| 1 | FP | Mudstone | Light yellowish brown | 0.45 | 8.96 | |
| 1 | FP | Mudstone | Light yellowish brown | 0.06 | 8.12 | |
| 1 | FP | Mudstone | Light yellowish brown | 0.18 | 8.29 | |
| 1 | FP | Mudstone | Light yellowish brown | 0.07 | 7.23 | |
| 1 | FP | Mudstone | Light yellowish brown | 0.07 | 8.14 | |
| 1 | FP | Mudstone | Light yellowish brown | 0.04 | 7.04 | |
| 1 | FP | Mudstone | Light yellowish brown | 0.08 | 8.08 | |
| 1 | FP | Mudstone | Grey | 5.91 | 36.73 | |
| 1 | FP | Mudstone | Reddish grey | 0.17 | 11.08 | |
| 1 | FP | Mudstone | Reddish grey | 0.71 | 11.5 | |
| 1 | FP | Mudstone | Reddish grey | 0.41 | 17.47 | |
| 1 | FP | Mudstone | Reddish grey | 0.31 | 12.5 | |
| 1 | FP | Mudstone | Reddish grey | 0.28 | 13.55 | |
| 1 | FP | Mudstone | Reddish grey | 0.55 | 13.18 | |
| 1 | FP | Mudstone | Reddish grey | 0.51 | 11.11 | |
| 1 | FP | Mudstone | Red | 0.07 | 6.57 | Potlid |
| 1 | FP | Mudstone | Dark reddish brown | 0.25 | 15.05 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 3.19 | 26.72 | Heated |
| 1 | FP | Mudstone | Reddish grey | 0.7 | 21.2 | |
| 1 | FP | Mudstone | Dark reddish brown | 2.11 | 24.73 | |
| 1 | FP | Mudstone | Dark reddish brown | 0.05 | 7.46 | Heated, potlid |
| 1 | FP | Mudstone | Dark reddish brown | 0.02 | 5.37 | Heated, potlid |
| 1 | FP | Mudstone | Dark reddish brown | 0.04 | 7.6 | Heated, potlid |
| 1 | FP | Mudstone | Reddish grey | 0.94 | 18.38 | |
| 1 | FP | Mudstone | Reddish grey | 0.53 | 11.16 | |
| 1 | FP | Mudstone | Reddish grey | 0.48 | 9.23 | |
| 1 | FP | Mudstone | Reddish grey | 0.84 | 12.97 | |
| 1 | FP | Mudstone | Dark reddish brown | 0.03 | 8.79 | Heated, potlid |
| 1 | FP | Mudstone | Red | 0.07 | 5.3 | |
| 1 | FP | Mudstone | Dark reddish grey | 0.12 | 9.89 | Heated, potlid |
| 1 | FP | Mudstone | Red | 0.1 | 7.86 | |
| 1 | FP | Mudstone | Grey | 0.35 | 13.3 | |

| SU | Category | Raw material | Colour | Wt g | Max dim mm | Comments |
|---|---|---|---|---|---|---|
| 1 | FP | Mudstone | Grey | 0.19 | 14.55 | |
| 1 | FP | Mudstone | Grey | 0.34 | 11.38 | |
| 1 | FP | Mudstone | Grey | 0.34 | 7.76 | |
| 1 | FP | Mudstone | Grey | 0.11 | 10.42 | |
| 1 | FP | Mudstone | Grey | 0.23 | 8.16 | |
| 1 | FP | Mudstone | Grey | 0.18 | 13.05 | |
| 1 | FP | Mudstone | Grey | 0.19 | 10.09 | |
| 1 | FP | Mudstone | Grey | 0.27 | 10.5 | |
| 1 | FP | Mudstone | Grey | 0.22 | 10.55 | |
| 1 | FP | Mudstone | Grey | 0.1 | 9.58 | |
| 1 | FP | Mudstone | Grey | 0.14 | 11.03 | |
| 1 | FP | Mudstone | Grey | 0.09 | 6.43 | |
| 1 | FP | Mudstone | Grey | 0.15 | 10.22 | |
| 1 | FP | Mudstone | Grey | 0.15 | 6.44 | |
| 1 | FP | Mudstone | Grey | 0.07 | 7.01 | |
| 1 | FP | Mudstone | Grey | 0.1 | 9.41 | |
| 1 | FP | Mudstone | Grey | 0.11 | 7.85 | |
| 1 | FP | Mudstone | Grey | 0.07 | 8.32 | |
| 1 | FP | Mudstone | Grey | 0.01 | 6.5 | |
| 1 | FP | Mudstone | Grey | 0.03 | 7.7 | |
| 1 | FP | Mudstone | Dark reddish brown | 0.45 | <5 | 34 fragments |
| 1 | FP | Mudstone | Reddish grey | 0.83 | 13.42 | |
| 1 | FP | Mudstone | Dark reddish brown | 0.07 | 9.03 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.06 | 7.5 | Heated |
| 1 | FP | Mudstone | Reddish grey | 0.27 | 13.04 | Potlid |
| 1 | FP | Mudstone | Red | 0.12 | 9.16 | |
| 1 | FP | Mudstone | Grey | 0.1 | 10.74 | |
| 1 | FP | Mudstone | Grey | 0.08 | 11.57 | |
| 1 | FP | Mudstone | Grey | 0.05 | 10.15 | |
| 1 | FP | Mudstone | Grey | 0.06 | 11.62 | |
| 1 | FP | Mudstone | Grey | 0.04 | 7.88 | |
| 1 | FP | Mudstone | Red | 0.65 | 17.3 | |
| 1 | FP | Mudstone | Red | 0.23 | 11.6 | |
| 1 | FP | Mudstone | Yellowish red | 0.7 | 18.41 | |
| 1 | FP | Mudstone | Red | 0.18 | 11.56 | |

| SU | Category | Raw material | Colour | Wt g | Max dim mm | Comments |
|---|---|---|---|---|---|---|
| 1 | FP | Mudstone | Red | 0.07 | 11.21 | Potlids, heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.12 | 9.72 | Big potlid |
| 1 | FP | Mudstone | Dark reddish brown | 0.08 | 9.93 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.03 | 7.68 | |
| 1 | FP | Mudstone | Yellowish brown | 0.48 | 12.7 | |
| 1 | FP | Mudstone | Grey | 0.93 | 11.78 | |
| 1 | FP | Mudstone | Grey | 1.03 | 16.68 | |
| 1 | FP | Mudstone | Grey | 0.5 | 13.17 | |
| 1 | FP | Mudstone | Grey | 0.32 | 10.57 | |
| 1 | FP | Mudstone | Grey | 0.17 | 8.04 | |
| 1 | FP | Mudstone | Grey | 0.07 | 10.53 | |
| 1 | FP | Mudstone | Reddish grey | 38.53 | 36.6 | Tabular |
| 1 | FP | Mudstone | Red | 0.13 | 8.71 | |
| 1 | FP | Mudstone | Dark reddish brown | 0.72 | 20.87 | |
| 1 | FP | Mudstone | Dark reddish brown | 0.05 | 9.48 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.31 | 11.33 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.14 | 10.93 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.04 | 8.32 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.01 | 8.22 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.03 | 6.08 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.23 | 14.67 | |
| 1 | FP | Mudstone | Dark reddish brown | 0.04 | 6.52 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.02 | 6.75 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.03 | 6.56 | Heated |
| 1 | FP | Mudstone | Dark reddish brown | 0.09 | 9.03 | Heated |
| 1 | FP | Mudstone | Red | 0.15 | 9.2 | |
| 1 | FP | Mudstone | Yellowish red | 0.57 | 20.46 | |
| 1 | FP | Mudstone | Reddish grey | 1.13 | 25.11 | |
| 1 | FP | Silcrete | Dusky red | 1.14 | 21.05 | Heat shatter |
| 1 | FP | Silcrete | Dusky red | 3.78 | 26.71 | Heat shatter, with potlids |
| 1 | FP | Silcrete | Dark reddish grey | 0.91 | 19.74 | Heat shatter |
| 1 | FP | Silcrete | Light yellowish brown | 0.99 | 30.2 | |
| 1 | FP | Silcrete | Grey | 0.03 | 8.15 | |
| 1 | FP | Silcrete | Red | 0.01 | 7.95 | |
| 2 | FP | Chert | Yellowish brown | 0.14 | 11.77 | |

| SU | Category | Raw material | Colour | Wt g | Max dim mm | Comments |
|---|---|---|---|---|---|---|
| 2 | FP | Chert | Reddish black | 2.05 | 25.75 | |
| 2 | FP | Chert | Yellowish brown | 0.14 | 10.99 | |
| 2 | FP | Mudstone | Red | 0.09 | 9.36 | |
| 2 | FP | Mudstone | Yellow red | 0.66 | 17.37 | Heated, potlids |
| 2 | FP | Mudstone | Yellowish brown | 0.51 | 20.08 | |
| 2 | FP | Mudstone | Light red | 0.23 | 10.71 | |
| 2 | FP | Mudstone | Yellowish red | 0.23 | 9.61 | |
| 2 | FP | Mudstone | Yellowish red | 0.06 | 7.67 | |
| 2 | FP | Mudstone | Dark reddish brown | 0.06 | 10.22 | Heated |
| 2 | FP | Mudstone | Red | 0.03 | 6.7 | |
| 2 | FP | Mudstone | Red | 0.03 | 6.41 | |
| 2 | FP | Mudstone | Red | 0.05 | 6.03 | |
| 2 | FP | Mudstone | Red | 1.82 | 17.03 | |
| 2 | FP | Mudstone | Grey | 1.37 | 22.86 | |
| 2 | FP | Mudstone | Red | 0.75 | 20.41 | |
| 2 | FP | Mudstone | Red | 0.66 | 12.53 | |
| 2 | FP | Mudstone | Yellowish red | 1 | 16.51 | |
| 2 | FP | Mudstone | Red | 0.13 | 10.32 | |
| 2 | FP | Mudstone | Red | 1.78 | 23.2 | |
| 2 | FP | Mudstone | Red | 0.77 | 17.03 | |
| 2 | FP | Mudstone | Red | 0.37 | 15.11 | |
| 2 | FP | Mudstone | Red | 0.18 | 8.4 | |
| 2 | FP | Mudstone | Red | 0.06 | 10.24 | |
| 2 | FP | Mudstone | Red | 0.3 | 10.38 | |
| 2 | FP | Mudstone | Dark reddish brown | 0.69 | 10.69 | Heated, potlids |
| 2 | FP | Mudstone | Yellowish red | 0.17 | 10.91 | |
| 2 | FP | Mudstone | Grey | 0.13 | 8.04 | |
| 2 | FP | Mudstone | Grey | 0.11 | 8.85 | |
| 2 | FP | Mudstone | Dark reddish brown | 1.19 | 28.08 | Heated, potlid |
| 2 | FP | Mudstone | Red | 4 | 29.2 | |
| 2 | FP | Mudstone | Dark reddish brown | 0.42 | 24.47 | |
| 2 | FP | Mudstone | Grey | 0.28 | 14.41 | |
| 2 | FP | Mudstone | Grey | 0.76 | 14.04 | |
| 2 | FP | Mudstone | Red | 0.4 | 11.93 | |
| 2 | FP | Mudstone | Grey | 0.15 | 8.04 | |

| SU | Category | Raw material | Colour | Wt g | Max dim mm | Comments |
|---|---|---|---|---|---|---|
| 2 | FP | Mudstone | Grey | 0.47 | 13.23 | |
| 2 | FP | Mudstone | Grey | 0.21 | 17.18 | |
| 2 | FP | Mudstone | Dark reddish brown | 0.09 | 7.96 | |
| 2 | FP | Quartzite | Light red | 2.1 | 21.29 | |
| 2 | FP | Silcrete | Grey | 0.1 | 9.99 | |
| 3 | FP | Chert | Dark reddish brown | 0.2 | 7.21 | |
| 3 | FP | Chert | Yellowish brown | 0.16 | 12.2 | |
| 3 | FP | Chert | Dark reddish brown | 1.32 | 19.79 | |
| 3 | FP | Chert | Pink | 0.22 | 7.86 | |
| 3 | FP | Chert | Red | 0.05 | 8.76 | |
| 3 | FP | Chert | Yellowish brown | 0.14 | 11.9 | |
| 3 | FP | Chert | Cream | 0.12 | 12.77 | |
| 3 | FP | Chert | Pink | 0.14 | 9 | |
| 3 | FP | Chert | Reddish grey | 0.46 | 12.33 | |
| 3 | FP | Chert | Light brown | 0.66 | 15.04 | |
| 3 | FP | Chert | Cream | 0.38 | 18.17 | |
| 3 | FP | Chert | Cream | 0.12 | 9.72 | |
| 3 | FP | Mudstone | Dark reddish brown | 0.08 | 12.61 | |
| 3 | FP | Mudstone | Dark reddish brown | 0.07 | 7.88 | |
| 3 | FP | Mudstone | Red | 0.39 | 18.37 | Heated |
| 3 | FP | Mudstone | Red | 0.23 | 12.16 | |
| 3 | FP | Mudstone | Red | 0.06 | 8.57 | |
| 3 | FP | Mudstone | Reddish brown | 0.18 | 8.9 | |
| 3 | FP | Mudstone | Reddish brown | 0.14 | 9.39 | |
| 3 | FP | Mudstone | Reddish brown | 0.15 | 11.17 | |
| 3 | FP | Mudstone | Reddish brown | 0.23 | 15.06 | |
| 3 | FP | Mudstone | Light reddish brown | 2.76 | 20.68 | Angular |
| 3 | FP | Mudstone | Reddish brown | 0.29 | 13.5 | |
| 3 | FP | Mudstone | Reddish brown | 0.27 | 12.34 | |
| 3 | FP | Mudstone | Reddish brown | 0.1 | 7.93 | |
| 3 | FP | Mudstone | Yellowish brown | 0.03 | 5.66 | |
| 3 | FP | Mudstone | Red | 0.17 | 9.41 | |
| 3 | FP | Mudstone | Red | 0.05 | 9.5 | |
| 3 | FP | Silcrete | Red | 7.14 | 33.39 | |
| 3 | FP | Silcrete | Yellowish red | 0.13 | 13.03 | |

| SU | Category | Raw material | Colour | Wt g | Max dim mm | Comments |
|---|---|---|---|---|---|---|
| 3 | FP | Silcrete | Grey | 0.25 | 8.05 | |
| 4 | FP | Chert | Light brown | 0.17 | 9.43 | |
| 4 | FP | Chert | Light reddish brown | 0.26 | 14.13 | |
| 4 | FP | Chert | Light brown | 0.07 | 7.32 | |
| 4 | FP | Chert | Light reddish brown | 0.18 | 9.45 | |
| 4 | FP | Mudstone | Light red | 0.12 | 9.71 | |
| 4 | FP | Silcrete | Light brown | 0.08 | 7.56 | |