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The Application of Ecological Models and Trophic Analyses to Archaeological Marine Fauna Assemblages: Towards Improved Understanding of Prehistoric Marine Fisheries and Ecosystems in Tropical Australia

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A thesis submitted for the degree of Doctor of Philosophy in the College of Arts, Society and Education, James Cook University, Cairns

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Contributions by others to the thesis

Sean Ulm (James Cook University) provided advice with initial research design, survey strategy and sampling strategy and took overall responsibility for directing fieldwork undertaken as part of this study.

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ABSTRACT

This project focuses on the high-resolution analysis of archaeological marine fauna assemblages, using methodologies situated in an evolutionary ecology theoretical framework. These assemblages come from eight Kaiadilt archaeological sites across the South Wellesley Archipelago, which are a valuable dataset to examine not just dietary composition of foragers in the islands but also long-term patterns in the temporal and spatial availability of subsistence resources. This study also represents the first Australian investigation that applies trophic level analysis to archaeological marine fauna assemblages in order to explore anthropogenic effects on prehistoric fisheries (e.g. Bourque *et al.* 2008; Reitz *et al.* 2009; Quitmyer and Reitz 2006).

Located in the southern Gulf of Carpentaria, in the central north of Australia the study area for this project focuses on Bentinck, Sweers and Fowler Islands, three of the largest islands in the South Wellesley Archipelago and the traditional home of Kaiadilt people. A three phase cultural chronology spanning the past c. 3,500 years is suggested for the study area, based on a comprehensive suite of 128 radiocarbon dates collected from cultural deposits, combined with results from linguistic studies (see Memmott *et al.* 2016).

This archaeological research undertaken in collaboration with the Kaiadilt Aboriginal community has resulted in the recording of cultural places on their lands. Community engagement has been an integral part of this research and ultimately has contributed to the success of the project. At a regional level this thesis contributes to the discourse about Aboriginal subsistence practices in northern Australia for the late Holocene. The project provides a large dataset similar with those of other studies conducted internationally, and is therefore able to inform other research based within an ecological theory framework.

This research aims to (1) identify evidence for human subsistence strategies, in particular the diversity of marine species types exploited (diet-breadth) and patterns of habitat (patch) exploitation through time; (2) characterise temporal changes in the biomass contribution and population structure of particular species through development of taxa size/age profiles, which identifies, for example, declining efficiencies in marine exploitation and human harvest pressure on resources; and (3) identify and assess changes in marine trophic levels exploited and explore potential evidence of trophic cascades in the local ecosystem in order to determine anthropogenic impacts on local ecologies.

The project addresses these aims using methodologies based within an evolutionary ecology framework including the Diet-Breadth Prey Choice Model (MacArthur and Pianka 1966), the Patch Choice Model (Charnov and Orians 1973) and the Central-Place Forager Model (Metcalfe and Barlow 1992). All data are grouped into chronological units of 250-year intervals. While these units offer a broad temporal resolution that may obscure some fine-grained variances in individual datasets, they provide a method for characterising local assemblages in a way that they can be compared across the region (e.g. Ulm 2006).

Archaeological evidence indicates that marine shellfish, fish and invertebrates substantially contributed to diet in the South Wellesley Islands. A total of 124.3kg of marine faunal remains are examined for this study. People's foraging strategies were broad-based in terms of both range of habitats accessed and diversity of species collected. 62 molluscan taxa were identified in the study. Hiant venus clam (*Marcia hiantina*), rock oyster (*Saccostrea glomerata*), turban snails (*Lunella cinerea*) and longbums (*Telescopium telescopium*) were the main molluscs consumed. There is evidence for a long-term trend in changing habitat preferences that could reflect changing cultural preferences and/or changing environments affecting resource availability. From two locations on Bentinck Island we have signals that clearly imply changes in diet-breadth c. 500 cal BP, which were likely a response to an environmental event impacting mangrove habitats and therefore changing taxa abundances available for exploitation.

The study characterises the population structure of *M. hiantina* (the dominant species) through development of the taxon's profile and reviews temporal changes in densities and sizes. Although *M. hiantina* specimens exhibit some short-term reductions in mean size during seasonal bouts of intensive foraging, temporal patterns indicate that foraging efficiency was not compromised in the long-term.

A minimum of 15 species of fish, 1 species of shark and 1 species of turtle were identified from skeletal remains. There is also evidence throughout most periods at most sites of crustacea being foraged although it is difficult to determine numbers. Based on known habitats for the specimens identified (e.g. catfish, grass sweetlip, rockcod, mullet, longtom, whiting, wrasse) much of the fish would have been obtained from hunting in nearshore waters, either from around rocky/coral reefs, intertidal mangroves, estuaries or in the numerous constructed stone-walled intertidal fishtraps. The Central-Place Forager Model was used to explain disparity between ethnographic reports of fishing and hunting activities and the low quantities of fish and vertebrate bones identified in the analysed materials. I contend it is likely dugong, turtle and some fish were processed and consumed at the beach closer to the location of procurement, rather than returned to residential camps (see Tindale 1960:48, 71).

Trophic level analysis was used to establish the average trophic level for each 250-year period's marine biomass catch. Faunal data suggest that people targeted primarily the low trophic level shellfish during the early periods of occupation, before shifting their economic focus to a broader-based diet-breadth incorporating more fish, which in turn raised the mean trophic level of all site assemblages. A review of temporal changes in the mean trophic level of exploited resources indicates that hunter-gatherers had little long-term impacts on the overall fishery of the South Wellesley Islands.

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ABBREVIATIONS

ARC	Australian Research Council
AMS	Accelerator Mass Spectometry
BOM	Bureau of Meteorology
BP	Radiocarbon Years Before Present (AD 1950)
Cal BP	Calibrated Years Before Present
CRA	Calibrated Radiocarbon Age
ENSO	El Nino Southern Oscillation
IPO	Interdecadal Pacific Oscillation
ITCZ	inter-Tropical Convergence Zone
MNI	Minimum Number of Individuals
NISP	Number of Identified Specimens
OFT	Optimal Foraging Theory
PMSL	Present Mean Sea Level
sp.	Species (only one descending from a genus)
spp.	Species (more than one descending from same genus)
Sq.	Square
SU	Stratigraphic Unit
TARL	Tropical Archaeology Research Laboratory
XU	Excavation Unit

PART I: THE RESEARCH AND ITS CONTEXT

Chapter 1. Introduction: Investigating Marine Subsistence Practices in the South Wellesley Islands

1.1 Introduction

Globally there is growing interest in the role that humans have played in altering habitats and in contributing to the extinction of animals and plants, particularly in island settings that tend to be more ecologically sensitive than large continents (e.g. Anderson 1983, 1989, 1997, 2001, 2008; Burney 1997; Kirch 1997; Kirch and Hunt 1997; Lyman and Cannon 2004; Martin 2002; Morrison and Hunt 2007; Rainbird 2002; Steadman 1989, 1995, 2006). Despite marine habitats being actively exploited for millennia there are few reported human-induced extinctions in marine ecosystems; however, this may simply reflect the relative invisibility of anthropogenic impacts on fisheries versus terrestrial environments (Erlandson and Rick 2010:232).

For Australian hunter-gatherer economies ‘adapted to a coastal way of life’ (Bowdler 1977:205) the importance of fishing and shellfishing is well established. The archaeological record in Australia reflects subsistence changes in hunter-gatherer societies during the Holocene as they adapted to social pressures caused by increasing populations and unfavourable climatic conditions brought on by El Niño-Southern Oscillation (ENSO) events (Hiscock 2008:163; Shulmeister 1999). Lourandos (1983, 1985) sees the changes in socioeconomic processes as a catalyst for intensification in food production by Aboriginal societies, thereby enabling population growth (se also Lourandos and Ross 1994). Similarly, Barker (1991:108) argues that diversification of subsistence to include a greater emphasis on fishing in the Whitsundays, north Queensland, enabled long-term human occupation in the islands (see also Barker 1996, 2004). Hiscock (2008:179) notes increased concentration on foraging for shellfish in northern Australia during the late Holocene. Walters and colleagues report increased use of islands during the past millenium and large increases in fish bone in southeast Queensland sites (Walters 1989; Hall 1982; Ulm 2002; Ulm and Vale 2006). Based on coastal archaeological studies in Australia and overseas that point to anthropogenic causes for resource depletion (e.g. Anderson 2008; Bird *et al*. 2002; Braje et al. 2007; Butler 2000; Erlandson et al. 2004; Faulkner 2006, 2009, 2011a; Rowland 1999a), it is feasible to suggest that the significant increase in hunting and gathering activities reported in Australia would impact on associated ecosystems.

Investigations into the use of marine ecosystems generally rely on historical records, limiting studies in most areas of Australasia to the last few hundred years. Scientists have more recently come to recognise that coastal archaeological deposits can inform our understanding of the nature of past marine ecosystems and the history of anthropogenic impacts on marine fisheries, hence providing a valuable long-term perspective well beyond that available in the documentary and instrumental records (Erlandson and Rick 2010:232). Coastal archaeological sites in tropical Australia are characterised by sometimes large, stratified accumulations of marine shells, animal bones (especially fish, marine mammals and marine reptiles) and other detritus shaped by human foraging choices and the shifting frequency and abundance of taxa in the environment, creating repositories of significant information about 'human social behaviour and economic scheduling' (Barham *et al.* 2008:4). Researchers examining coastal middens in northern Australia tend to focus on questions regarding the antiquity of sites, the movement and social organisation of people and changes in patterns of resource exploitation (e.g. Bailey 1999; Barker 2004; Bourke 2000, 2005; Faulkner 2006; Faulkner and Clarke 2004; Morrison 2003; O'Connor 1999a, 1999b; Sim and Wallis 2008; Veth *et al.* 2007). Few pay particular attention to measuring potential long-term anthropogenic impacts on marine ecosystems (but see Faulkner 2006, 2009, 2011a).

1.2 The Study Area

The South Wellesley Islands, located in the southern Gulf of Carpentaria, are an ideal setting for a study investigating human-induced impacts on coastal and marine ecosystems. Preliminary research demonstrates that the islands and region have experienced major occupation changes over the past millennium (Memmott *et al.* 2016; Ulm *et al.* 2010). The study area for this project focuses on Bentinck, Sweers and Fowler Islands, three of the largest islands in the South Wellesley Islands and the traditional home of Kaiadilt people. These islands, along with the North Wellesley Archipelago, were created between 8,000 and 6,500 BP as sea-levels rose (Reeves *et al.* 2006, 2007, 2008). They comprise ancient weathered laterites and recent estuarine, beach and dune deposits.

At the time of European contact the Kaiadilt of Bentinck Island (South Wellesley Islands) supported one of the highest population densities of any Aboriginal Australian group and exhibited a specialised tool-kit for marine exploitation including the use of tidal fishtraps (Flinders 1814; Tindale 1962a). The earliest date recorded for occupation of the South Wellesley's is 3,483 cal BP at Jirrkamirndiyarrb, Bentinck Island (Memmott *et al.* 2016). This date coincides with the most recent phase in a pattern of island occupation suggested for the Gulf of Carpentaria (Sim and Wallis 2008). Across northern tropical Australia – for example, Groote Eylandt (Clarke 2002; Specht and McCarthy 2005), Sir Edward Pellew Islands (Sim and

Wallis 2008), and the western Torres Strait (David and McNiven 2004) – researchers report similar trajectories towards amplified settlement and use of offshore islands by Aboriginal people in the late Holocene, evidenced in the archaeological record by increased site numbers, increased site densities and the emergence of new site types such as shell mounds. Sim and Wallis (2008) argue that prior to c.1700 BP low-intensity occupation of islands in the region may have been linked to unfavourable climatic conditions caused by ENSO events (Shulmeister 1999), which prevented effective watercraft use and disrupted availability of littoral resources and consequently island use.

My research forms a component of the Australian Research Council (ARC)-funded 'Naïve Island Landscapes: People and Environmental Change in Tropical Sclerophyll Landscapes' (DP120103179) project involving a multidisciplinary team of scientists from the fields of archaeology, geomorphology and palynology. The overarching aim of the ARC project is to identify and measure the impacts of human arrival on the Australian environment, using the rich archaeological and palaeoenvironmental records of the South Wellesley Archipelago to produce integrated models of human-environment interaction during the late Holocene. The stimulus for this study derives from earlier research undertaken in 2006-2010 for another ARC-funded project (DP0663047) that investigated cultural change in isolated island environments, which focused on Lardil, Kaiadilt, Gangalida and Yangkaal speaking peoples of the North and South Wellesley Islands.

1.3 Research Overview

Erlandson and Rick (2008:11) define four key ways in which archaeologists can empirically measure human impacts on marine ecosystems by identifying and quantifying: (1) resource depletion and depression; (2) temporal changes in the size or age distributions of particular populations; (3) reductions in the geographic ranges of marine species; and (4) changes in marine trophic levels and trophic cascades.

The first three methods identified by Erlandson and Rick (2008) can be addressed within an evolutionary ecology framework. Archaeologists (e.g. Broughton 1997; Butler 2001; Grayson 2001; Nagaoka 2001; Winterhalder and Smith 2000) use evolutionary ecology models of diet breadth, optimal foraging, and resource intensification for investigating key problems associated with human population growth and its effects on the environment (see also Australian studies by Bird and Bliege Bird 1997; Clarkson 2004, 2006, 2007; Faulkner 2006, 2009, 2011a; Gould 1991, 1996; Rowland 1999a).

Trophic level analysis, the fourth method mentioned above, derives from approaches used by ecologists for quantifying historic human impacts on fisheries (Pauly *et al.* 1998, 2000). More recently archaeologists have effectively applied trophic level analysis to investigations of prehistoric fisheries, however none of these studies has taken place in Australia (e.g. Bourque *et al.* 2008; Quitmyer and Reitz 2006; Reitz 2004; Reitz *et al.* 2009; Wing 2001).

1.4 Objectives and Aims of the Study

The relatively recent human settlement of the South Wellesley Islands provides a unique opportunity to investigate Aboriginal impacts on undisturbed Australian ecosystems against a backdrop of natural environmental change. My project specifically focuses on high-resolution analysis of archaeological marine fauna assemblages, using an evolutionary ecology framework. These coastal Aboriginal archaeological marine deposits were excavated from archaeological sites in different geomorphic contexts across the South Wellesley Archipelago.

The aims of my project are to:

AIM 1: Identify and document high-resolution archaeological marine fauna assemblages across the study area, representing the full span of occupation and different geomorphic settings.

AIM 2: Employ a suite of models informed by an underlying ecological theoretical basis in order to assess the effects of past human interaction with marine ecosystems as evidenced in the archaeological record. Analysis of the archaeological deposits will provide evidence of human diet, in particular prey selection choices and habitat exploitation patterns through time.

AIM 3: Utilise marine trophic level analysis, a technique not previously applied in the Australian archaeology arena, in order to understand the human impacts on local ecologies.

1.4.1 Research Plan

Methodology

Utilising an evolutionary ecology framework I undertake high-resolution analysis of coastal Aboriginal archaeological marine fauna assemblages across selected sites in the South Wellesley Islands. This involves (a) using a suite of optimal foraging theory models that characterise changes in the biomass contribution to diet and the diversity of marine species types exploited; and (b) using marine trophic level assessment techniques that measure long-term changes in marine ecosystems.

The major tasks of my research include:

1. Excavations of selected open coastal sites located on various parts of the island in different geomorphic contexts;
2. Laboratory analyses and documentation of archaeo-faunal assemblages from excavated sites. The laboratory analysis was conducted in two stages:
    (a) Preliminary analysis focused on identification and quantification of marine fauna assemblages and a basic analysis of any temporal changes;
    (b) Intensive analysis focused on detailed examination of all datasets using Optimal Foraging Theory (OFT) models and trophic level methods and collation of this information, to obtain an archipelago-wide picture of human subsistence patterns and potential impacts on local ecologies. This stage involved systematic application of deductive methods to data sets and recording of results.

Research Questions

The following questions are addressed:

1. Do the archaeo-faunal assemblages of the South Wellesley Islands reflect declining efficiencies in marine exploitation and human harvest pressure on resources?
2. As humans adapt their foraging strategies in response to major environmental/climatic events and internal social pressures through time, is there a corresponding change in the average trophic levels of the marine fauna represented in the archaeological assemblages examined for this case study?
3. Do the archaeo-fauna assemblages reflect any dysfunctional trophic cascades in the local marine ecosystem resulting from over-exploitation of particular marine resources?

Outcomes

My project has a number of specific objectives:

- Proposed Outcome A: Identify evidence of human subsistence strategies, focusing on the diversity of marine species types exploited (diet-breadth) and patterns of habitat (patch) exploitation through time.
- Proposed Outcome B: Characterise temporal changes in the biomass contribution and population structure of particular species through development of taxa size/age profiles. This approach will identify, for example, declining efficiencies in marine exploitation and human harvest pressure on resources (resource depression).
- Proposed Outcome C: Identify and assess changes in marine trophic levels exploited and explore potential evidence of trophic cascades in the local ecosystem(s) in order to determine anthropogenic impacts on local ecologies.
- The study will advance our knowledge of past Kaiadilt Aboriginal lifeways in the South

Wellesley Islands region, particularly in relation to cultural change in the recent past. It will also expand our understanding of the structure and chronology of the archaeological record of northern tropical Australia.

- The study will augment our understanding of historic patterns of marine subsistence in the South Wellesley Islands, extending the fisheries records by several thousand years.
- This archaeological research was undertaken in collaboration with the Kaiadilt Aboriginal community and will result in the recording of cultural places on their lands and provide traditional owners with information to help make management decisions about their lands and waters.

1.5 Thesis Structure

Part I of the thesis outlines the research and sets a context for the proposed aims of the study. Chapter 1 introduced the study and situated it in the context of global issues relating to our understanding of human foraging behaviours. This chapter presented the scope of this research and outlined aims and objectives of the study. Chapter 2 includes overviews of the physical environment and cultural setting of the South Wellesley Islands in order to provide background context for presentation of the research results. The physical environment section incorporates information about palaeoenvironment, geology, climate and hydrology. Details of flora and fauna contribute to our understanding of resource availability. A section reviewing the Aboriginal cultural setting informs our appreciation of Kaiadilt lifeways in the islands. Previous archaeological research in the region is also reviewed.

Part II explains the methodology that is used to approach the investigation. Chapter 3 situates the study in Australian anthropological debates and considers the impacts of depositional and post-depositional factors on the archaeological record. Chapters 4 and 5 present a comprehensive overview of the theoretical framework adopted for considering the research topic, enabling a more focused approach to dealing with the vast quantities of archaeological research materials. Regional and global case studies of similar research elsewhere are discussed that support the validity of using the theoretical concepts for addressing the topic. Chapter 6 outlines the methods of investigation adopted for the study. Attention is given to all technical aspects of the study discussing field and excavating procedures, laboratory protocols and units of measurement, implementation of models linked to the theory and statistical examinations.

Part III presents all materials and supporting data generated by the investigation. The research materials collected and analysed for this study come from eight archaeological sites situated in a variety of landforms across Bentinck Island, Sweers Island and Fowler Island in the South

Wellesley Archipelago. The project incorporated regular community meetings and working relationships with Kaiadilt people, which provided the research team with opportunities to approach landowners to seek permission to survey and excavate on people's lands. For each archaeological site case study the local environments and site descriptions and site chronologies are presented in Chapters 7 to 14.

Part IV synthesises the results of analyses undertaken using the chosen methodology. Chapter 15 combines the results of scientific analyses on materials introduced in Part III with background information introduced in Part I. Temporal and spatial variances in the archaeological record are explored to characterise faunal remains discard patterns. These data contribute to exploring issues of hunter-gatherer subsistence practices, evidence of intensified exploitation and any consequential pressures on resources. Finally Chapter 16 concludes the study with a brief overview of the main findings and consideration of the implications of research results for the Kaiadilt community and for better understanding local, regional and global issues in research relating to hunter-gatherer subsistence and anthropogenic impacts on the environment.

Chapter 2. The South Wellesley Islands: Physical Environment, Resource Availability and Cultural Setting

2.1 Introduction

The South Wellesley Archipelago, in the southern Gulf of Carpentaria, covers an area of c.1,500km^2 encompassing 10 islands along with reefs and sandy cays. This chapter outlines the physical environment and Aboriginal cultural setting of the islands, providing a context for the study area that includes Bentinck, Sweers and Fowler Islands. These three islands are the largest of the South Wellesley Group, which until 1948 were seasonally and/or permanently occupied by the Kaiadilt people.

The physical environment section incorporates an overview of the geology and environmental features of the study area, including climate, hydrology, flora and fauna, providing a background to regional landscape development and resource availability. The section reviewing the Aboriginal cultural setting includes information gathered from local ethnographies and oral histories informing our appreciation of Aboriginal lifeways, particularly in the study area, and to a lesser extent for the southern Gulf region. A review of previous archaeological research in the region confirms this study will add to an understanding of the late Holocene archaeological record of the Gulf of Carpentaria.

2.2 Physical Setting

Located in the southern Gulf of Carpentaria (Figure 2.1) the Wellesley Islands are divided geographically into the South and North Wellesleys (Figure 2.2). The South Wellesleys consist of Bentinck Island, which covers c.150km^2 along with Sweers, Fowler, Albinia, Margaret, Allen, Little Allen, Bessie, Douglas and Horseshoe Islands. Mornington is the largest in the North Wellesley group, covering c.966km^2 and is surrounded by smaller satellite islands. The shortest access to the North Wellesleys from the mainland at Bayley Point is via a series of smaller, inter-visible stepping-stone islands (Denham, Andrew, Forsyth, Pains and Bayley) with a maximum water crossing required between Mornington Island and the mainland of c.4.5km. In contrast, accessing the South Wellesleys require a minimum open water crossing of c.10km between Bessie and Horseshoe Islands with limited inter-visibility between Bentinck Island and the mainland.

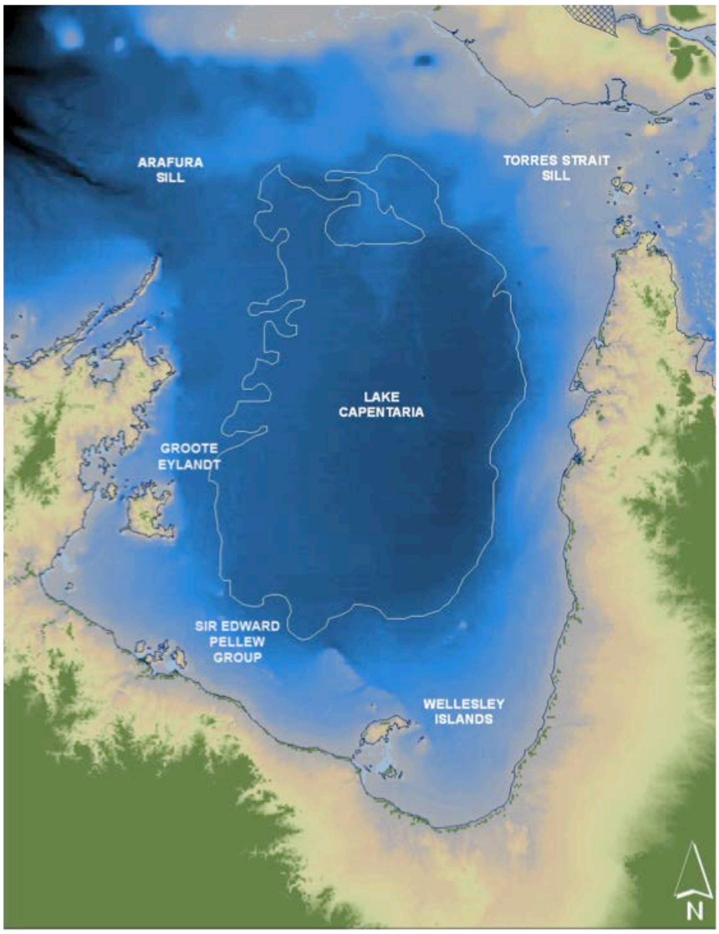


Figure 2.1: The Gulf of Carpentaria illustrating major island groups (data sourced from Geosciences Australia after Torgersen *et al.* 1985) (map prepared by Emma Hain).

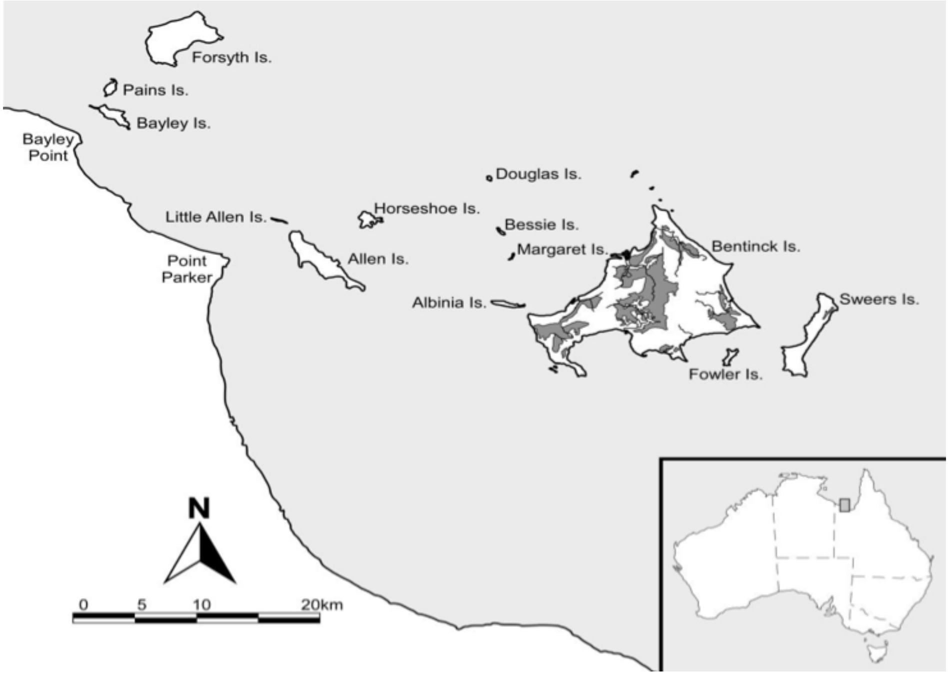


Figure: 2.2: The North and South Wellesley Islands, southern Gulf of Carpentaria (map prepared by Sean Ulm).

2.2.1 Palaeoenvironment and Environmental Change

Before progradation commencing in the region c.6,000 BP, the mainland coastline was up to 15km further south of its current position (Grimes 1979; Murray-Wallace and Belperio 1991; Rhodes *et al.* 1980). As such, the South Wellesley Islands would have been considerably further offshore than they are today with landform development and stabilisation occurring post-3,000 BP (Figure 2.3 and 2.4).

Four swamp cores collected from the Marralda Swamp on the southeast coastline of Bentinck Island provide a palaeoenvironmental record, offering insight into both wetland development and vegetation history of the island for the past c.2,400 years (Moss *et al.* 2015). The core AMS radiocarbon dates indicate that between 4,500-2,000 years ago Marralda Swamp was situated in a near-shore beach environment setting linked to higher sea levels up to c.2m above present mean sea-level (PMSL); this is confirmed by evidence from elsewhere in the Gulf of Carpentaria (Grimes 1979; Nakada and Lambeck 1989, Reeves *et al.* 2008; Lewis *et al.* 2013; Sloss *et al.* 2012) (Figure 2.4).

From c.2,400 years ago coastal dunes and northwest prograding beach ridge systems developed parallel to Marralda Swamp protecting it from wave action (Moss *et al.* 2015). Mangrove development related to falling sea-levels and a prograding coastal system followed around 500 years ago at this location and nearby Mirdirdingki Creek, forming in an environment protected from wave action with suitable silt substrates (Moss *et al.* 2015; see also Grindrod *et al.* 1999, 2002). The Marralda Swamp cores indicate mangrove forests dominated until the 1940s when it is proposed that cyclone activity altered the environment, particularly at Marralda where a barrier was established that blocked tidal seawater flows and allowed groundwater to freshen the site (Moss *et al.* 2015).

Moss *et al.* (2014) carried out palynological analysis of the Square B deposits at Thundiy, north coast of Bentinck Island, which reveals four pollen zones in the matrix that suggest major vegetation and landscape changes over the past 500 years. During the period 500-750 cal BP (21-30cm) the landscape is more open, suggestive of a coastal phase evidenced by higher values of chenopods. At 19cm there is a spike in charcoal values followed by an increase in arboreal taxa, particularly Pandanus. This suggests increased burning that correlates with evidence for increased human occupation. A radiocarbon date of c.510 cal BP is attributed to this zone. Between 250-500 cal BP (c.12-15cm), there is a decline in charcoal values and an increase in Casuarinaceae. Grass taxa increase and arboreal taxa decrease during the 0-250 cal BP (between 3-9cm). The overall proportion of mangroves declines over time and taxa change from a mixed Avicennia, Ceriops and Rhizophora forest to a contemporary fringe dominated by Rhizophora.

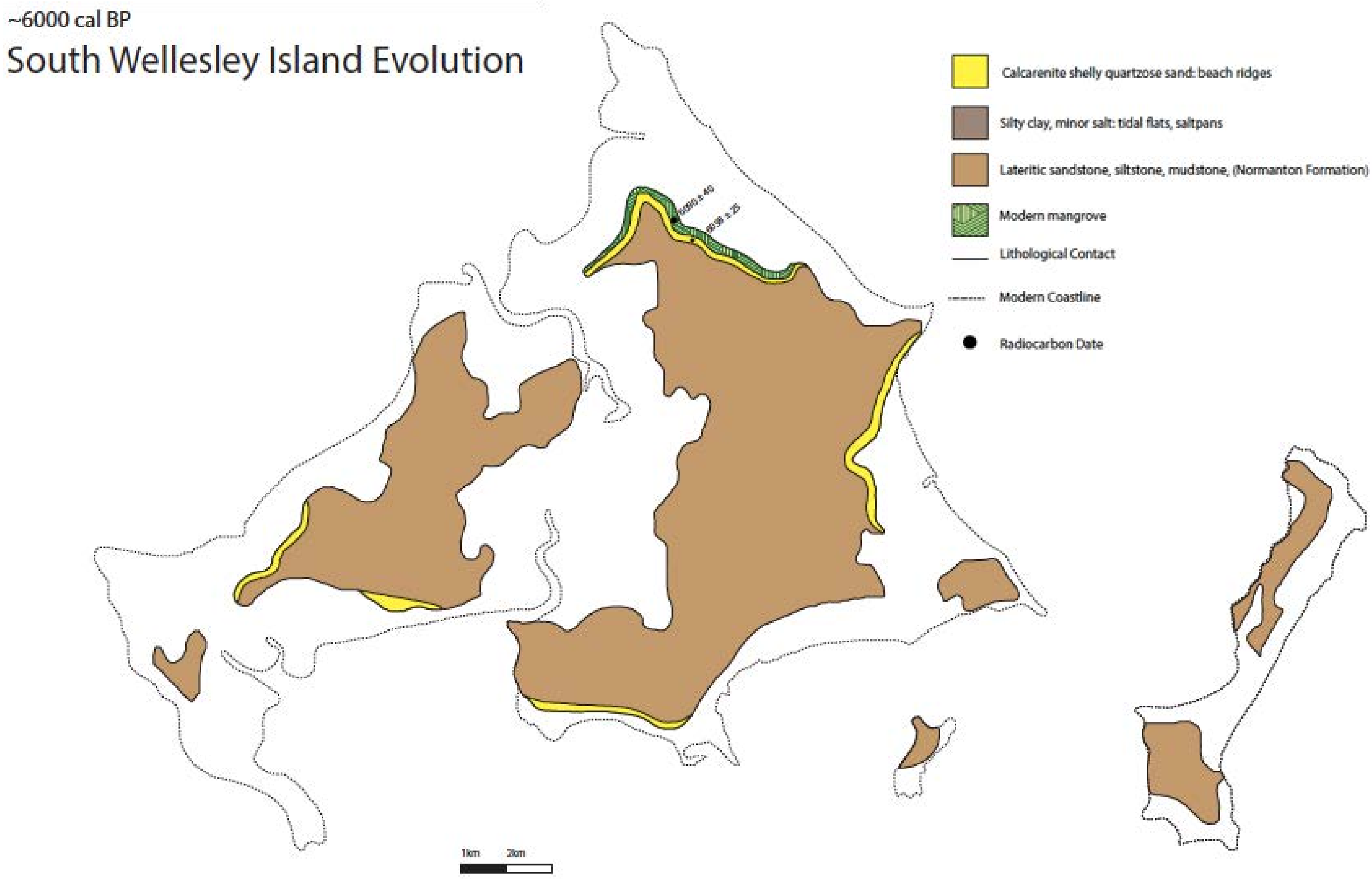


Figure 2.3: Inferred 6000 cal BP palaeo-coastlines of Bentinck, Sweers and Fowler Islands illustrating Holocene land surfaces formed post-marine transgression (i.e. saltpans, beach ridges etc) (map prepared by Alison Sternes).

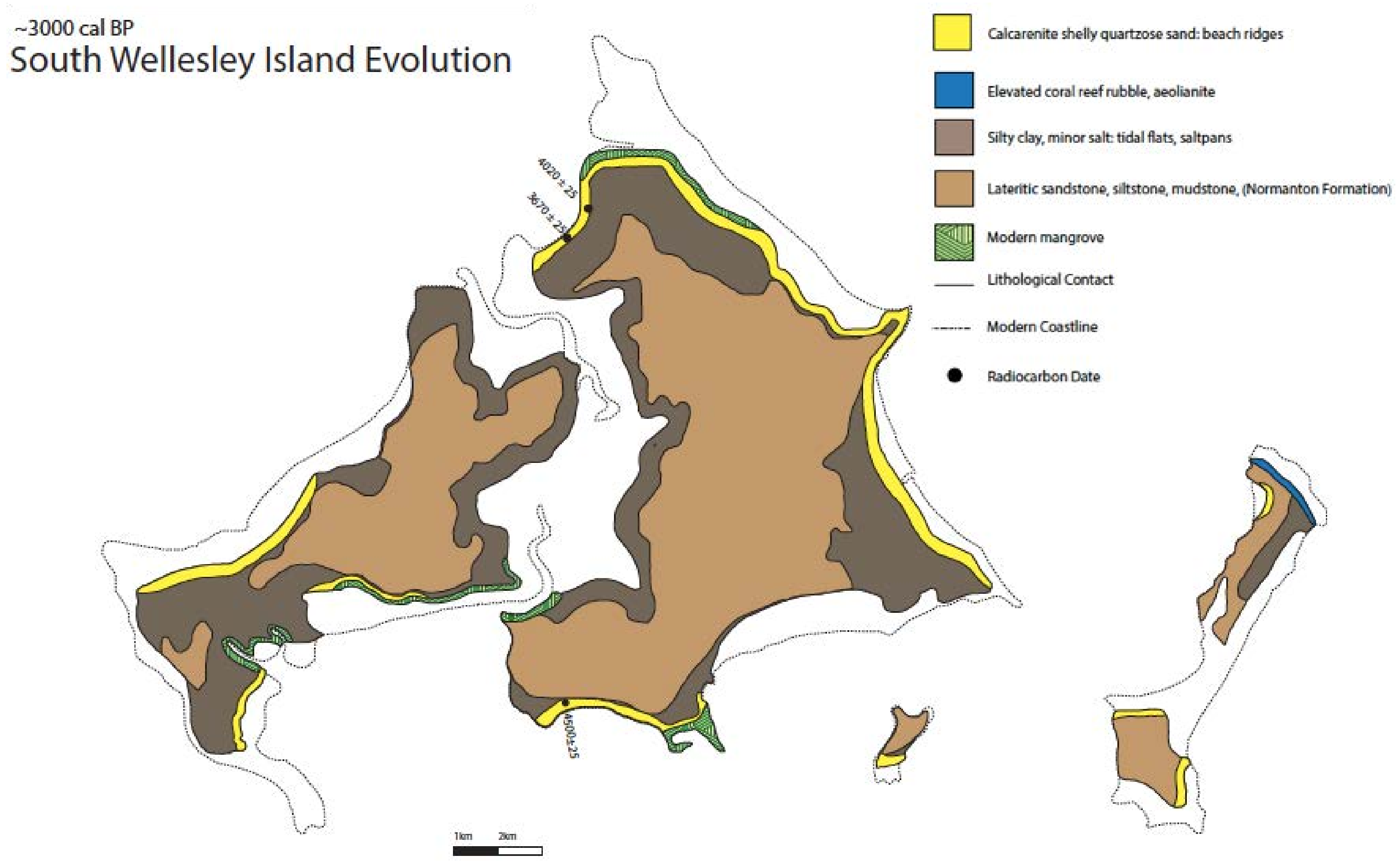


Figure 2.4: Inferred 3000 cal BP palaeo-coastlines of Bentinck, Sweers and Fowler Islands illustrating Holocene land surfaces formed post-marine transgression (i.e. saltpans, beach ridges etc) (map prepared by Alison Sternes).

2.2.2 Geology and Geomorphology

The Wellesley Islands are part of the Normanton lateritic formation with Bentinck, Sweers and Fowler Islands made up of a lateritic bedrock unit, termed the 'Mornington Plateau' (Grimes 1979). The lateritic plateau meets the shore in places in the form of low sea cliffs while the rest of the coastline landform features include beach ridges, cheniers, transgressive aeolian dunes, low-lying beaches, supra-tidal mudflats, hypersaline claypans or saltflats, mangrove forests, estuaries and swamps (Figure 2.5).

Soils are similar to those in much of western Cape York Peninsula and the southern Gulf, being well-drained, lateritic, light brown to grey coloured, and clay-rich with low nutrient levels (Grimes and Sweet 1979). Soil development occurs on the weathered Mornington bedrock plateau and ridges (Figure 2.6). The hypersaline claypans or saltflats are flat expanses of silty clay sediments that during the dry season are exposed and shaped by strong prevailing southeasterly winds that transport large amounts of sediment (Figure 2.7). During the wet season these areas experience seasonal inundation during king high tides combined with run-off. Numerous mounds and sandy residuals that dot the claypan surface project above the shallow waters and become refuges for wildlife (especially birds) during periods of inundation.

The dunes comprise fine aeolian sands above coarser wave-deposited sands and calcium carbonates such as weathered and fragmented shell material (Figure 2.8). Close to the coast the dunes and swales exhibit evidence of high-energy storm activity with coral and pumice deposited up to 100m inland in some locations.

Beach ridges and cheniers are ancient foredunes or storm deposits. These features have been formed through alternating wave and wind depositional processes that were later stranded inland through progradation of the shoreline in the last 2,500 years (Figure 2.9). These land systems are characterised by variable sandy substrata that ranges from fine red sands to a coarse shell grit/sandy matrix (in places up to 2m thick) anchored on a laterite palaeo-dune (Stock 2008). Swamps and soaks have formed in the low points in the terrain forming a humic/sandy soil surface horizon (Figure 2.10).

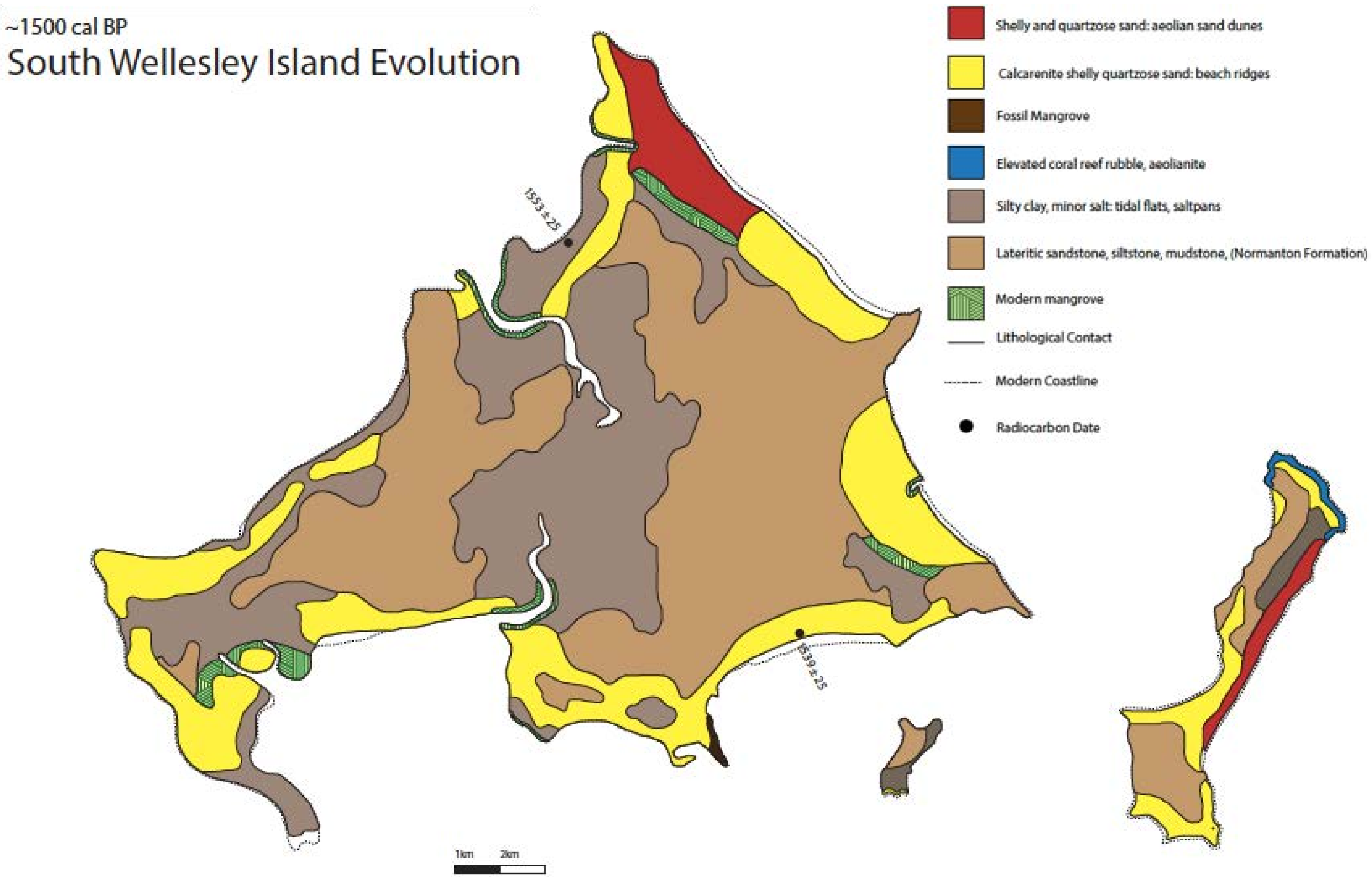


Figure 2.5: Geology of Bentinck, Sweer's and Fowler Islands c.1,500 cal BP to present (map prepared by Alison Sternes).

Figure 2.6: Low cliffs where the lateritic plateau meets low country salt claypans.

Figure 2.7: Hypersaline claypans or saltflats.

Figures 2.8a and 2.8b: Beach foredunes along Bentinck Island's east coastline.

Figure 2.9: Beach ridges, ancient foredunes.

Figure 2.10: Swamps and soaks.

Bentinck Island

Bentinck Island is a low-lying island measuring approximately 18km x 14km. The average elevation is below 5m above PMSL with the highest point around 22m above PMSL. Bentinck has two high lateritic plateau zones separated by two almost intersecting river channels oriented northwest-southeast and circumscribed by supra-tidal hypersaline claypans that dominate the interior (Figures 2.5 and 2.11). These rivers and claypans flood during the wet season effectively dividing the island in two, east from west. Vast stretches of intertidal sandy-mud flats surround the island perimeters (Bruinsma and Duncan 2000).

Figure 2.11: Aerial view of Bentinck Island.

Sweers Island

Sweers Island originated from two remnants of lateritic peneplain (north and south ends) to which calcareous sand dunes and terraces have been deposited to form a high central ridge running northeast-southwest (Figure 2.12). The island is 8.5km long x 3km at its widest point and most of the island is less than 13m above PMSL, except for the small area around Inspection Hill, which attains an elevation of 32m. Along the coastline mudstone cliffs up to 10m high are overlain in places with limestone. Some of the sea cliffs on the windward (eastern) side of the island exhibit caves and there are outcrops of beachrock and sandy beaches along the narrow coastal strip and shore platforms. The leeward side features low sand dunes, sandy beaches and salty claypans. Well-developed rocky and coral reefs fringe the island.

Figure 2.12: Aerial view of Sweers Island.

Fowler Island

Fowler Island is a low-lying small sandy island with terrain up to c.8m in elevation. From north to south the island's length is approximately 1.7km and from east to west it measures approximately 800m, not including the often-submerged broad reef platforms and mudflats (Figure 2.13). The island is composed of labile sandstone in the northwest; the east coast is a coral/rock platform while sandy beach ridges make up the remaining terrain. There is a small swamp in the centre.

Figure 2.13: Aerial view of Fowler Island.

2.2.3 Climate

Studies indicate that a lengthy dry period during the mid-Holocene was followed by an increasingly more variable climate pattern from 3700 to 2000 cal BP, associated with increased El Nino-Southern Oscillation (ENSO) strength and intensity (Donders *et al.* 2007; Gagan *et al.* 2004; Prebble *et al.* 2005; Reeves *et al.* 2013; Shulmeister 1999). Subsequently there is evidence of wetter conditions in northern Australia associated with strong extended La Nina-like conditions from 1500 to 1000 years ago (Shulmeister 1999; Markgraf and Diaz 2000; Moss *et al.* 2011; Williams *et al.* 2010). Williams *et al.* (2010) suggest that there was a reorganisation or disruption in Indigenous resource systems at this time resulting from the La Nina-like weather patterns. Then an extended El Nino-like phase brought significantly drier conditions from 700 to 500 years ago (Goodwin *et al.* 2004; Williams *et al.* 2010, Moss *et al.* 2011). Variable climatic and hydrological patterns, linked to changes in ENSO and the Interdecadal Pacific Oscillation (IPO), characterise the past 500 years (Brockwell *et al.* 2009; Hendy *et al.* 2002; Markgraf and Diaz 2000; Moss *et al.* 2011; Williams *et al.* 2010).

The Gulf of Carpentaria region experiences both a semi-arid and monsoonal climate characterised by cool dry winters (April to October) and hot wet summers (November to March). During the Austral summer the Inter-Tropical Convergence Zone (ITCZ) moves south bringing monsoonal rain and cyclones during which more than 97% of rainfall occurs. Weather records collected from the Mornington Island Station in 2014 indicate the mean annual maximum temperature is 30.1°C and minimum is 22.1°C, with a mean annual rainfall of 695mm (Bureau of Meteorology 2014a). However, annual rainfall figures recorded for 1901 (1289.7mm), 2002 (968.2mm) and 2011 (2393.5mm) suggest annual rainfall data are highly variable. Coastlines (particularly the southeast and east shores) are seasonally exposed to high-energy marine processes including storm surges, water spouts, intense tropical storms and cyclones (Gillieson 2005:207). These climatic episodes have been shown to have had short-term localised impact on ecosystems and have disrupted species availability (e.g. Moss *et al.* 2015).

2.2.4 Hydrology

Bentinck Island is the only island of the three to have a permanent freshwater lake (near the southeast coast). Water sources on Sweers and Fowler Islands are limited to springs, swamps and soaks. Tidal variation in the southern Gulf is more prominent than elsewhere in the Gulf as the combined effects of strong winds, shallow water depth, wet season run-off and atmospheric pressure can halt and/or reverse the typical clockwise flow, creating a counter-clockwise current (Forbes and Church 1983:21). A typical pattern is a daily diurnal tide (one high and low tide a day) but for one to three days in every fortnight the tide shifts to a semi-diurnal '6 hourly' tide. During a semi-diurnal tide there is relatively little water movement.

2.2.5 Flora and Fauna

To date no detailed systematic floral survey has been assembled for Bentinck Island. However, recent research by Moss *et al.* (2015) provides some insight into local vegetation histories for the island. Peter Saenger conducted vegetation surveys of Sweers Island during an expedition funded by the Royal Geographic Society of Queensland. The information presented in this section is based on the findings of Saenger (2005) and Moss *et al.* (2015) as well as personal observations during fieldwork, combined with information contained in the Queensland Government *Wildlife Online* database (www.qld.gov.au) and a scientific report submitted by J. Walker to the Queensland Environmental Protection Agency in 1991. Common and scientific names are confirmed through the *Atlas of Living Australia* database (www.ala.org.au).

Terrestrial Fauna

Bird fauna in the study area include brolgas (*Grus (Mathewsia) rubicunda*), curlews (*Numenius madagascariensis*), pied oystercatchers (*Haematopus longirostris*), sulphurcrested cockatoos (*Cacatua galerita*), black cockatoos (*Calyptorhynchus banksii*), eagles (e.g. *Aquila (Uroaetus) audax, Hieraaetus morphnoides*), kites (e.g. *Haliastur sphenurus, Milvus migrans*), hawks

(*Accipiter (Leucospiza) fasciatus*), falcons (*Falco* spp.) and the Australian Bustard (*Ardeotis australis)* (Atlas of Living Australia 2015). Terrestrial animals include goannas (*Varanus* spp.), rodents (*Planigale maculates*, *Coniurus penicilatus*), lizards (*Tiliqua scincoides*, *Cryptoblepharus* spp.), snakes (*Furina ornate*, *Pseudonaja textilis*) and frogs (*Litoria caerulea*), along with abundant termite ant mounds (Walker 1991:11).

Marine Fauna

The open water and rocky/coral fringing reefs surrounding the three islands offer rich biodiversity in both flora and fauna. Fishes, turtle (*Chelonia mydas*), dugong (*Dugong dugon*), crabs (*Scylla serrata, Portunus pelagicus*) and invertebrate molluscs are prevalent in the waters today. A brief overview of each fauna type follows below.

Dugong and Turtle: Dugong are large herbivorous marine mammals of the order Sirenia, which grow up to 3m in length and 450kg (Saalfeld and Marsh 2004). Dugong feed on seagrasses in shallow tidal and subtidal coastal marine environments (Saalford and Marsh 2004:96). Green turtles feed on seagrasses and the red algae that grow on rocky reefs (Limpus and Chatto 2004). Today dugong and turtle remain prized meats for Aboriginal people around the Wellesley Islands (Tindale 1977). While there are six species of turtle known from the region, based on ethnographic information the green turtle (*Chelonia mydas*) is the most often hunted.

Cartilaginous Fishes: Sharks and rays are cartilaginous fishes of the class Chondrichthyes, subclass Elasmobranchii (Larson *et al.* 2004). They inhabit marine waters across a wide depth range with 49 species of shark and 36 species of ray recorded for Gulf of Carpentaria waters, particularly the fringing rocky and coral reefs around the coast (Larson *et al.* 2004:59). Sharks are considered top predators in the trophic food chain and will take large bony fishes, dugong and turtles.

Bony Fishes: These are prevalent in the coastal waters surrounding the islands, inhabiting a range of marine environments. Demersal species reported for the study area that are associated with bottom formations or rocky and coral reefs include: groupers and cods (Serranidae), snappers (Lutjanidae) and emperors (Lethrinidae). These are carnivorous predators of fishes, crustaceans and molluscs (Heemstra and Randall 1993), ranging in maximum size from 20cm to 250cm (Johnson and Gill 2005; Malcolm 1998). They are slow-growing species that are potentially vulnerable to overexploitation (Williams *et al.* 2004). Barramundi (*Lates calcarifer*), trevally and queenfish (Carangidae), grunters (Haemulidae) bream (Sparidae), whiting (Sillaginidae) and catfish (Ariidae) frequent coastal waters and may also enter estuaries (Allen 1989; Collette 1999; Iwatsuki 2013; McKay 1992; Smith and McKay 1986). These fish also feed on crustacea, molluscs and some on small fishes. Mullet (Mugilidae) prefer inshore slow-moving coastal waters and feed on zooplankton, microalgae, insects and plant materials (Harrison and Senou 1997). Appendix 1 lists all fish species recorded from the South Wellesley Islands based on surveys undertaken by Malcolm (1998) and Johnson and Gill (2005).

Crustaceans: Crabs are a diverse group with 192 species recorded for the Gulf of Carpentaria waters. In the South Wellesley Islands people predominantly collect mud crab (*Scylla serrata*) and blue swimmer crabs (*Portunus pelagicus*) are sometimes speared as well. Mud crabs inhabit mangrove-lined coasts, living in deep burrows in soft-muddy substrates and around mangrove roots. Blue swimmers are found in intertidal coastal and estuary waters to depths of 60m (Smit *et al.* 2004:252).

Molluscs: Shellfish comprise the largest groups or classes (Gastropoda and Bivalvia) of marine taxa in the Gulf of Carpentaria. Some of the key species noted by Willan and Dredge (2004) as being collected for food and other cultural purposes include: longbum (*Telescopium telescopium*), mudshell (*Geloina erosa*), hiant venus clam (*Marcia hiantina*), rock oyster (*Saccostrea glomerata*), granular ark (*Tegillarca granosa*), black nerite (*Nerita balteata*), topshell (family Trochidae), balers (*Melo amphora*), trumpets (*Syrinx aruanus*), spiral melongena (*Pugilina cochlidium*), and pearl oyster (*Pinctada* sp.). Appendix 2 lists molluscan species recorded for the South Wellesley Islands based on archaeological records and personal observations.

Marine Flora

Acropora hyacithus dominates with 70% of coral cover, while other common coral taxa includes *Oulophyllia, Lobophyllia, Favia, Goiastrea, Favites, Turbinaria* and *Montipora*. Extensive seagrass beds also occur in the South Wellesley Group, particularly in the shallow waters between the three islands. Common species include *Halophila decipiens, H. spinulosa, Halodule uninervis, Cymodocea serrulata* and *Syringodium isoetifolium*. Rocky reefs are covered with algae mostly comprised of *Cystophyllum muricatum, Sargassum* spp., *Laurencia* spp., *Caulerpa raceosa, Asparagopsis taxiformis* and Spyridia filamentosa (Saenger 2005:17).

The three study islands, Bentinck, Sweers and Fowler, exhibit a range of landscape features common to northern Australia with a mosaic of eucalypt and melaleuca woodlands and shrublands, open grasslands, mangrove communities of varying sizes and a few hardy species that occupy the hypersaline claypans. Figure 2.14 shows the mosaic vegetation zones for the three islands.

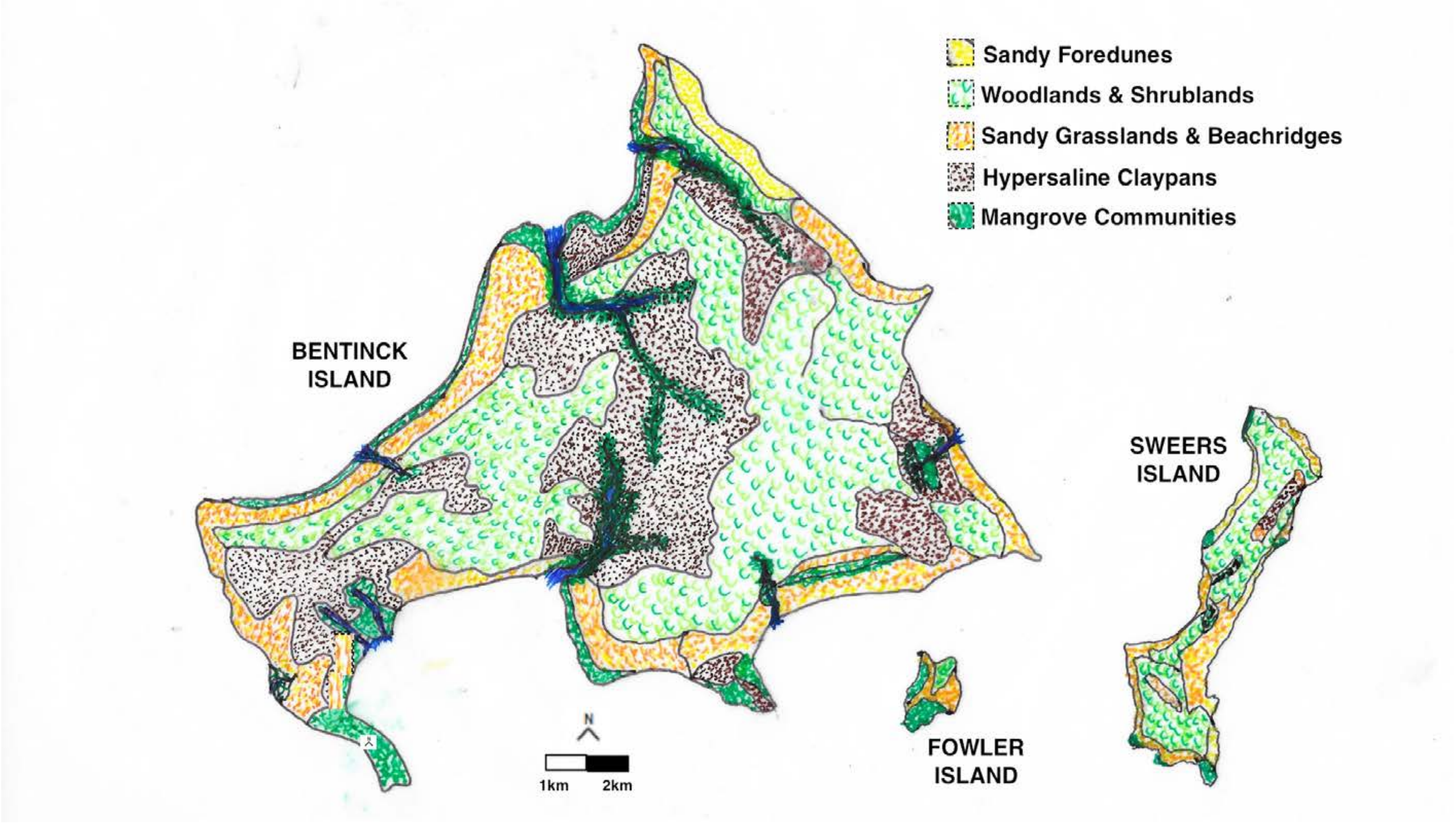


Figure 2.14: Map of vegetation types and areas on Bentinck, Sweers and Fowler Islands (after Saenger 2005 and Mackenzie in prep.)

Woodlands and Shrublands

The vegetation consists of dense to mid-dense stands of paperbark (*Melaleuca* spp.), ironbark (*Eucalyptus* spp.), bloodwoods (*Corymbia* spp.) and milkwood (*Excoecaria parvifolia*), while low-lying areas exhibit dense patches of coastal vine-thicket with scattered pandanus (*Pandanus spiralis*) and silky celtis (*Celtis paniculata*) (Saenger 2005:17).

Open Sandy Grasslands and Beachridges

Coast spinifex grasses (*Spinifex longifolius*) and thick tussock grasses (*Themeda australis*) dominate other grasses such as *Heteropogon contortus, Xerochloa imberbis, Chrysopogon elongates, Eragrostis concinna* and *Aristida holathera*. Areas of sparse mixed woodland of species described above intersperse the grasslands (Saenger 2005:17). On Sweers Island extensive sandy grasslands occur along the eastern shoreline and the centre of the island.

Hypersaline Claypans

Sparse vegetation consists of saltmarsh species including glasswort or beaded samphire (*Sarcocornia quinqueflra*), jellybean plant (*Suaeda arbusculoides*), halosarcia (*Halosarcia indica*), and grey samphire (*Tecticornia australasica*). Around the saltflat margins occasional shrubs are milky mangrove (*Excoecaria parvifolia*) and red dryandri (*Grevillea dryandri*) (Saenger 2005:19).

Mangrove Communities

The predominant species are *Rhizophora stylosa* (stilt-root mangrove) communities, found around the mouths of rivers and creeks, and *Avicennia marina* (grey mangrove) communities that dominate the open coastline (Bruinsma and Duncan 2000; Wightman *et al.* 2004; see also Saenger 2005). Other species noted during surveys in 1973 and 1990 include *Aegialatis annulata, A. corniculatum, Ceriops australis* and *Bruguiera exaristata* (Saenger 2005:19). Bentinck Island supports an extensive, thick mangrove forest on the southwest tip and other mangrove communities are established along the estuaries, rivers and creek channels. Today there are five small mangrove stands scattered around Sweers Island occurring in sheltered locations where silty-sand substrates are found. On Fowler Island dense mangrove forests are established on the south and west coasts and a small section of the north coast.

Foredune and Beach Ridge Areas

Coastal she-oak (*Casuarina equisetifolia*) and wattle (*Acacia* spp.) dominate vegetation along the foredunes. Coastal spinifex grasses (*Spinifex longifolius*), stands of pandanus (*Pandanus spiralis*) and cycad (*Cycas* sp.) are also present. Swamps and soaks have formed in the swales and low points in the dune terrain forming a humic/sandy soil surface horizon that has promoted a range of swamp vegetation including water lily (*Nymphae* sp.) and nut grass [penja] (*Eleocharis dulcis*) (Moss *et al.* 2015).

Results from analysis of four swamp cores collected from the Marralda Swamp and one from Mulla Island (Mirdirdingki Creek), on the southeast coastline of Bentinck Island, indicate that c.2400 years ago vegetation comprised wetland taxa, which persisted until c.500 years when it changed to mangrove taxa (Moss *et al.* 2015). Prior to c.500 years ago the presence of Asteraceae (Tubuliflorae) and monolete fern spores as well as pollen from melaleuca, eucalyptus, casuarina and callitris, suggest a wetland swamp environment. From c.500 years ago mangrove values increased (mainly *Rhizophora* spp. and *Avicennia marina*). After the 1940s the records show a decline in mangrove abundances with increased evidence for grasses (Poaceae and Typha) and a slightly increased representation of arboreal taxa (particularly pandanus, melalaeuca, eucalyptus and casuarinas). At this time there is also the largest number of pteridophyte taxa (Lycopodium and monolete fern spores) in the record (Moss *et al.* 2015). As indicated previously this major change in vegetation was due to the impacts of an unnamed cyclone, which crossed directly over Bentinck Island in 1948; Kaiadilt people described a storm surge estimated to be approximately 3.6m high covering all but the highest parts of the island, inundating water sources and campsites (Tindale 1962a; BOM 2014b). Elsewhere in northeast Australia studies clearly demonstrate the impacts that severe cyclones can have on coastal systems (Hopley 1974; Nott *et al.* 2013; Proske and Haberle 2012).

2.3 Cultural Setting

The Wellesley Islands exhibit a rich cultural landscape created by the Kaiadilt (who resided traditionally in the South Wellesleys) and the Lardil and Yangkaal (who occupy the North Wellesleys) with strong connections to Ganggalida on the adjacent mainland (Figure 2.15). Genetic research carried out in the 1960s illustrated differences in the populations of the North and South Wellesleys, with the Yangkaal and Lardil genetically indistinguishable from each other and displaying an ancestral link to the Ganggalida and Kaiadilt (Curtain *et al.* 1966, 1972; Simmons *et al.* 1962, 1964). An extensive oral history connects these people for purposes such as camping and hunting territories and indicates shared cultural seascapes. However, regional cross-cultural comparisons have been made, which highlight that each group has developed its own unique material culture and distinct language (Best 2012; Memmott 2010; Memmott *et al.* 2006; Trigger 1987). Linguistic analyses have proposed that the four language groups diverged at various stages from a linguistic ancestor tongue Proto-Tangkic (Evans 1985, 1995; Keen 1983; O'Grady *et al.* 1966). Lardil, retaining the most Proto-Tangkic elements, is proposed as having been the first language to diverge (Memmott *et al.* 2016).

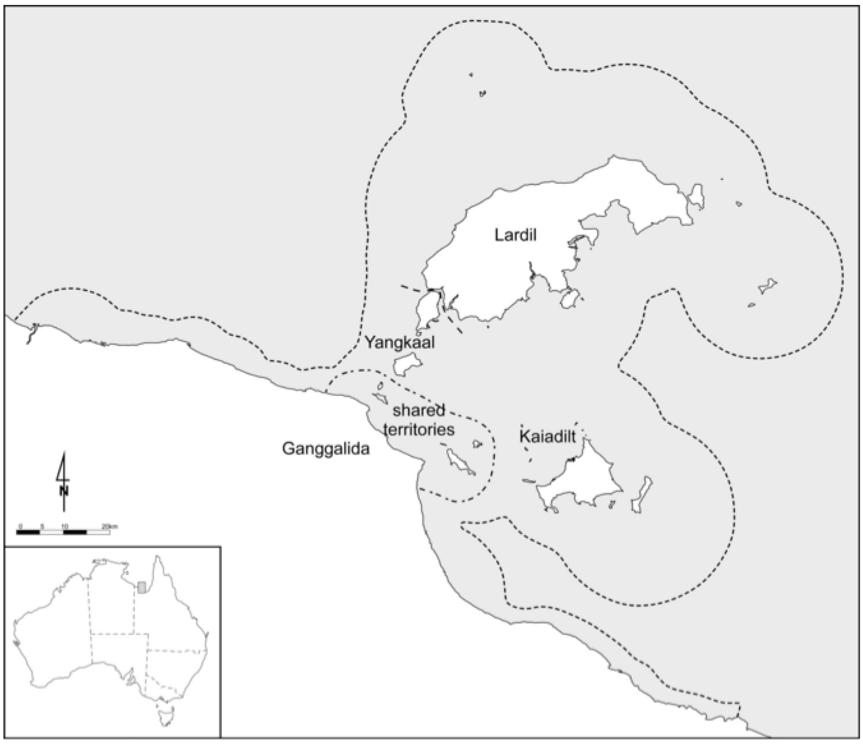


Figure 2.15: Cultural boundaries of the Wellesley Islands within area of sea claim (map reproduced with the kind permission of the National Native Title Tribunal). Available at www.nntt.gov.au accessed 3 December 2015.

2.3.1 Ethnographic Sources

The information in this section has been synthesised from a collection of ethnographic sources from anthropologists and linguists (e.g. Roth 1901, 1903; Tindale 1960, 1962a, 1962b; Evans 1985, 1995; Memmott 1982, 2010), as well as ethnohistoric and historical accounts from explorers, missionaries and pastoralists (Flinders 1814; McKnight 1979, 1986, 1995).

Tindale (1960, 1962a, 1962b, 1977) is the primary source of ethnographic information concerning the Kaiadilt people. Tindale spent a month on Mornington and Bentinck Islands in both 1960 and 1962 and his extensive research on cultural demography led to speculation regarding the long-term antiquity of Kaiadilt occupation and isolation on Bentinck Island (Tindale 1962a, 1962b). Tindale's research was mainly anthropological in nature, although he collected many material culture items, currently housed in the South Australian Museum. Roth (1901, 1903), in his capacity as Northern Protector of Aborigines visited the Wellesleys 60 years earlier, also collected material culture items, which are housed in the Australian Museum and the Queensland Museum. Roth rarely encountered people and so was unable to make many ethnographic observations.

Contemporary ethnographic research in the Wellesley Islands has focused on collecting present-day cultural information and exploring human-environment interactions and social landscapes. These studies have identified complex, dynamic social organisations of cultural identity tied to land, territorial boundaries and resource ownership across all groups (Dalley and Memmott 2010; Evans 1985; McKnight 1999; Memmott 1979, 2010; Memmott and Trigger 1998; Robins *et al.* 1998; Trigger 1987). Linguistic research by Evans (1985, 1995, 2005) in the Wellesleys has culminated with a well-recorded dataset from the Kaiadilt.

2.3.2 Kayardild Roots

Tindale's notion of long-term Kaiadilt isolation has been challenged by current archaeological, anthropological and linguistic research, which suggests a more recent linguistic divergence from Yangkaal and subsequent occupation of the South Wellesleys (Evans 1995, 2005; Memmott *et al.* 2016; Ulm *et al.* 2010). Evans (2005) demonstrated the rates of linguistic divergence evident for the Kaiadilt can occur within 1000 to 500 years with limited external interaction. A new hypothesis by Memmott *et al.* (2016) suggests the Kayardild language in its present form emerged within the past c.400-800 years.

Researchers now suggest that around c.2000 BP when sea-levels stabilised, proto-Tangkic speakers occupying Mornington Island made visits to the coastal mainland and the South Wellesley Islands, leading to colonisation in these areas thereby fissioning proto-Tangkic language into Northern and Southern Tangkic branches (Memmott *et al.* 2016). The Kayardild language then developed through a series of further fissioning and syncretism events that occurred through periods of isolation in the South Wellesleys alternating with proposed periods of interaction with the mainland and the North Wellesley Islands (cf. McNiven 1999). These events resulted from socio-environmental impacts (e.g. seeking refuge, conflict pressure between families, competition for resource harvesting) and periods of environmental instability (e.g. major tidal inundations), which caused people to travel and settle in the islands or on the mainland for longer periods (e.g. 10 years) than just temporary visits.

While anecdotally it is recounted that Kaiadilt men would rarely venture to the mainland, possibly only once in a lifetime, Evans (2005:18) suggests it was most likely more frequent, with accounts of Kaiadilt making the 12km crossing regularly and interacting with Ganggalida and Yangkaal via the intermediate Allen Island. The Kaiadilt population numbered 120 at the time of their removal in 1948, but was estimated at 270 based on detailed genealogical records (Evans 1998:2, 54).

2.3.3 Kaiadilt Identity

Bentinck, Sweers and Fowler Islands are the three largest islands in the South Wellesley group and were home to the Kaiadilt until 1948 when they were removed from their homeland to Mornington Island. They were the last group of coastal Aboriginal people in Australia to be indoctronated by European institutions. Flinders first recorded the Kaiadilt occupying their territory in 1802. In their Native Title Claim submission the Kaiadilt specify Bentinck, *Ringurrng* (Sweers), *Barthayi* (Fowler), *Dalwayi* (Albinia), *Nathayiwinda* (Douglas), *Karndingarrbayi, Duurathi, Jawari* and *Dararrbayi* Islands as their country, while Kaiadilt, Yangkaal and Gangalidda tribes share *Ngaarrkinab* (Allen) and *Dijirr* (Horseshoe) Islands. The Kaiadilt also hold that they 'have always had title to the *rarumbanda dulk* or *kayardilda dulk* (Kaiadilt country), under their own system of law' (Evans 1998:2). Kaiadilt country also includes all the littoral zones, taking in the fish-traps (*ngurruwarr*), reefs (*kamarr*), shoals (*kunthurld*), sandbanks (*ngakand*), seagrass areas where dugongs feed (*kurrngu*), and sea (*malaa*) as far as the eye can see (Evans 1998:1, 60). Tindale (1962b:304) examined ratios between areas of land and reef on Kaiadilt territory and the population size and proposed it to be one of the highest known densities for contemporary hunter-gatherers, where 'over 8 persons obtained their food on each square mile of reef'.

Evans (1998:2, 53) records that the sea country of the Kaiadilt is more important to them than their land because:

- The land, in contrast with the sea, is relatively impoverished;
- The sea is the focus of economic activity;
- The sea is a 'central organising theme' of Kaiadilt belief systems; and
- The sea abounds in sacred sites, both benign and dangerous.

Evans (2005) estimates that 90% of the food gathering activities of the Kaiadilt is oriented to the sea and shore (see also Tindale 1962b:300). Additionally, in Kaiadilt dietary laws and traditional beliefs, seafood is the basis of physical and spiritual health and provides the 'currency' for reinforcing family ties and allowing the practice of spiritual observance (Evans 1998:14.) The Kaiadilt consider hunting and gathering activities based on their seas as an opportunity to fulfil other cultural obligations including 'looking after country' and passing on knowledge, including knowledge of special sites, language and law to younger people (Evans 1998:15, 96-97).

The Kaiadilt have several ways of claiming an interest in or ownership of land and sea estates within the South Wellesley Islands, based on birth, conception, descent and bequest (Evans

1998, 2016). Because of the multiple ways of claiming connection with country the Kaiadilt estate- owning group is not a distinct 'clan-like unit' and a person may claim an interest in several estates. All members of an estate-owning group are termed *dulkuru dangkaa* and the question of which *dulmarra dangkaa* (senior person owning a country) has the final say on any issue is determined in practice by age and respect. Within his or her own 'country' a Kaiadilt person 'has full freedom to obtain resources' and may go anywhere without permission, with the exception of restricted dangerous sites or areas which have been closed after a death (Evans 1998:88, 94). Kaiadilt recognise the rights of *dulkuru dangkaa* and the obligation of others to seek permission to access someone else's country and/or take resources from another group's estate and also to share resources taken in another's country with the *dulmarra dangkaa* (Evans 1998:51-53, 79, 88). This is also relevant for marine resources evidenced by an important statement *ngurruwarrawanda yakuriya wungiinangku* 'fish from fishtraps must not be stolen' (Evans, pers. comm., 2009).

2.3.4 Kaiadilt Lifeways

Kaiadilt were highly mobile people shifting camps to shelter from the weather and to access seasonal resources. On Sweers and Bentinck Islands Flinders (1814:139) observed that huts were not found, but that dried grass was spread out around campfires; Roth (1908:560) likewise notes the use of "heaps of grass placed to windward of a depression in the ground, with a fire opposite". Tindale (20 May 1960) describes a cold season fire and the breakwind of cassytha vines rolled up which were the only winter shelter. 'Well trodden paths however were observd [sic] in almost every part of the Island walkd [sic] over - & some very recent fires & slight fences of straw near their fires where they no doubt sleep' (Robert Brown, 17 November 1802 in Vallance *et al.* 2001). Tindale (1977:249) reports that Kaiadilt placed their sleeping camps on sandy beaches above the high tide mark with day shelters in the half shade of the Casuarina trees:

> During the chill southerly storms of the southeast trade winds in July and August and the tropical cyclones they retreated to higher lands, as much as 10-15m above sea level, and to the somewhat higher stabilised, vegetation-covered sandhills, there to take refuge in leaf- and twig-lined pits, covered with whatever branches of timber and bark or grass they could find around them … In temperate weather, a roll of beach vines placed to windward was all that was necessary for sheltering their small night fires and themselves (Tindale 1977:250).

In the following passages Tindale (1962b:302) records Kaiadilt men and women attending to hunting and gathering activities. This is one of only a few recorded accounts from outsiders of daily life in the South Wellesley Islands, such was the elusiveness of Kaiadilt people (see also Flinders 1814; Vallance *et al.* 2001).

> Males explore the wider littoral, either walking up to their waists or chest in water or drifting over deeper reefs on their rafts of logs lashed together; at half tide either spearing fish trapped behind the walls of their stone fish traps or standing motionless for hours on the edge of outer reef channels waiting, in the hope of spearing a dugong, a turtle, or a shark. It is woman's work to repair fish trap walls and take the small fry among the fish trapped when the traps are almost dry. It is man's privilege to spear the larger fish cornered while the water is still deep. Among the Kaiadilt, women's work is closely tied to the aotic zone (in its sense of the strip of half-land between high and low water marks. At low tide they gather tjilangind (small rock oysters), kulpanda (Arca mud cockles), and the denizens of mud holes and rock pools, retreating only at high tide to their camps under the sheoak trees just above the tide mark or to inland areas of land to dig for roots and stems of "edible" trees and vines, to catch grasshoppers for food and to glean the few varieties of seeds and fruits which the sandy dune and salt-marsh environments yield to them. Wood for fires, armsful of dry grass for camps, and plant fibres for ropes and string are the chief products of the land essential to their well being (Tindale 1962b:302).

Men were the predominant hunters who had the privilege of spearing the large fish, marine turtle or dugong. Both dugong (*bijarrba*) and turtle (*bangaa*) yielded huge quantities of meat and everyone around the island was invited to share the feast. Such big animals were cooked in ground ovens (*walka*) dug in the sand, instead of on coals like small fish (Evans 1995:16).

Although most foods came from the sea and estuaries, terrestrial resources were also sought after. Birds and flying foxes, wild figs (*kirrika*), mangrove fruit (*thaminyirri*), wild tomatoes (*birrbari*), pandanus fruit (*kambuda*), water lily roots (*barrngkaa*) pounded into flour, bull rush heads (*nardaa*), wild yams (*thawalda*), and swam rush corms (*damuru* or *panja*) were all gathered (Evans 1995:17).

Due to the highly portable and perishable nature of materials used to construct their shelters, little archaeological evidence exists of camps today other than the shell midden remains from Kaiadilt meals. It also seems that even these can only provide a subset of all subsistence for Tindale (1960:142) reports that upon leaving their camp the *dulmarra dangkaa* 'cleaned country' by burning 'all remains of fish, bones and remnants of their camping'.

2.3.5 Material Culture

Best (2012) conducted a study of all material culture items from the Wellesley Islands and adjacent mainland (n=51) held in museum collections that were collected no later than 1916 and before substantial influences by European interactions. Best (2012:31) concludes that

> the material culture of Bentinck Island deals efficiently with intensification of marine resource exploitation, high population densities, access to restricted materials and a 'secular' social tradition.

Object categories recorded for the South Wellesley Islands include items used for containers, fire-making, fishing gear, tools and weapons; noticeably absent are items associated with ceremony, status and personal identity (Best 2012:29). The Kaiadilt specialised toolkit for marine subsistence includes:

The Raft (walbu) and Paddle (walbu bilirra) – used for transporting people and for hunting (Figures 2.16-2.18). Davidson (1935:139, 143-144) suggests that the raft found throughout the Wellesleys represents an older form of watercraft that was superseded by either bark or dugout canoes in other parts of Australia. One possible explanation of why the raft was retained is based on the lack of suitable materials in the islands for manufacturing other types of watercraft (Memmott 2010:91; Trigger 1987). The fan-shaped paddle was made by flattening a mangrove root (Roth 1901:9). A raft observed by Flinders was described as follows:

> The rafts consisted of several straight branches of mangrove, very much dried, and lashed together in two places with the largest ends one way, so as to form a broad part, and the smaller ends closing to a point. Near the broad end was a bunch of grass, where the man sits to paddle; but the raft, with his weight alone, must swim very deep ... Upon one of the rafts was a short net, which, from the size of the meshes, was probably intended to catch turtle; upon another was a young shark (Flinders 1814:137-138).

Figure 2.16: Walbu or raft of lashed-together poles. (Photo: Image 214a, Fryer Library Pictorial Collection, UQFL477, Fryer Library).

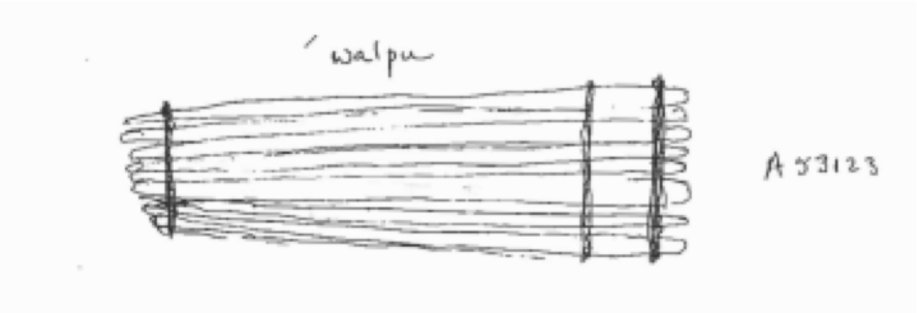


Figure 2.17: Walpu raft A53123 (drawn by Tindale 1960:141).

Figure 2.18: Fanned paddle, Bentinck Island (AM E13462) (Photo by Anne Best).

The Hammer Stone (jilanganda) – used as a tool to hammer oysters from rocks and smash them open to the flick the flesh into a baler shell dish using a wooden 'oyster pick' (*thawurra*). The stone is a fashioned 'semi-biface piece of rough quartzite-like rock' (Tindale 26 May 1960 1960:97). Millstones are used for a variety of other purposes such as pounding roots or smashing pandanus nuts (Figure 2.19).

Figure 2.19: Hammer stone (scale bar=1cm).

The Shell Knife (nara) – manufactured on baler shell (*Melo amphora*) (Figure 2.20). Tindale (1960:94) witnessed Kaiadilt men using a shell knife for cutting turtle, and it is reportedly used for butchering dugong and fish, as well as sharpening spears and fashioning paddles (Tindale 1960:172). Shell scrapers were made from (*tubalt)* mud shell (*Geloina erosa*) (Figure 2.21).

> A set of 5 broken shells of the baler shell of which the upper two in a nest of 5 (A53169-53173) were made into *nara* or baler shell knives and the lower three were dishes. The shell knives are used with the knife down towards the cutter … A piece of paperbark is folded over the shell knife and the bite takes place through this. Three were fashioned in the first instance and these, with sundry repairs and resharpenings completed the job … to use the knife the operator wrapped the handle end in paperpark and cut towards himself with firm stabbing cuts … one large blade was half buried in hot ashes and glowing coals, then re-sharpened by biting through paperbark, and the operation of cutting continued (Tindale 24 May 1960, 1960:93-95).

Figure 2.20: *Nara* baler shell knife A53168 (drawn by Tindale 1960:91)

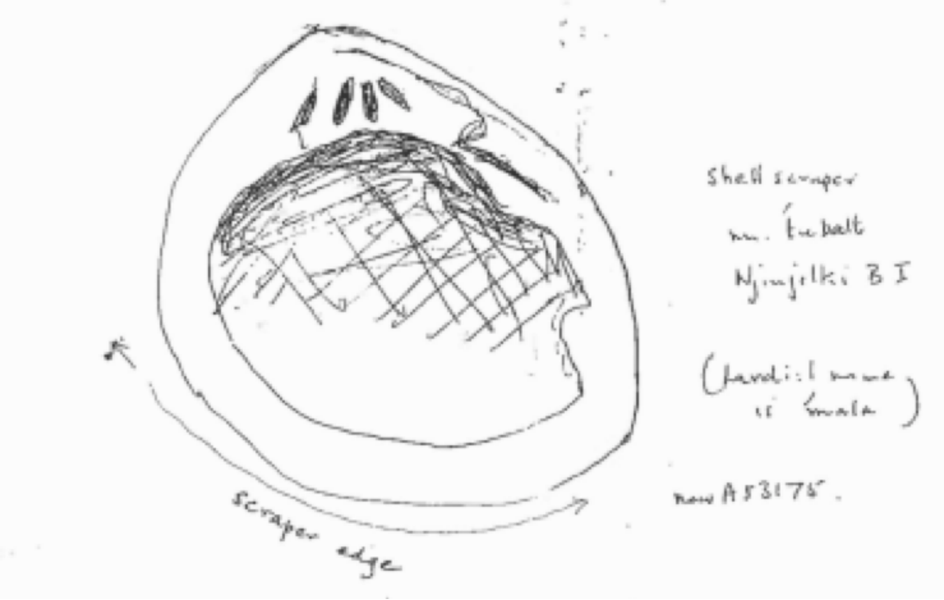


Figure 2.21: Tubalt mud shell scraper A53175 (drawn by Tindale 1960:105).

Shell containers – manufactured on trumpet shell (*Syrinx arianus*) and melon or baler shell (*Melo diadema amphora*) (Roth 1904:29). These are reportedly used for carrying water and frying fish (Figure 2.22).

> These are water carriers and have a hole punched in them for a finger grip. A baler shell similarly treated was brought in yesterday (Tindale 1962a:93). Baler shells were never used for boiling water but fat was used in baler shells for the frying of fish. The baler shell dish is called "'raw'lant (Tindale 1962a:142).

Figure 2.22: Shell container from Bentinck Island (AM E11822) (Photo by Anne Best).

Wooden Spears – Tindale (1960:150) notes there were several spears used on Bentinck, 'One was 'korombo, a three-pronged wooden spear and 'bingilt, a two-pronged one. The wooden prongs were simple and lashed on to the head with string'. Roth collected the spear shown below (figure 2.23).

> In pre-1948 days the hunting of dugong was by standing in water on a reef with a barbed spear and driving it well into the animal in hope of a kill. Dugong also could be cornered in fish traps, the big one on Baltae [Fowler Island] was good for dugong hunting. The dugong spear was kodjidji. In hunting for turtle a raft was used; one man swam holding the nose of the raft and gently pushed it backward while the other crouched on the raft with a kodjidji. The turtle was speared and one had to wait until it rose to breathe and was then caught by the swimmer (Tindale 1960:148-150).

Figure 2.23: Pronged spear, Bentinck Island (QM QE2492) (Photo by Anne Best).

Small Handheld Fishing Net – In the shallow estuaries fish were frightened, by clapping the water into folding nets (*mijilda*) (Figure 2.24) woven from grass twine (*malbaa*) (Evans 1995:16). These may have also been used for collecting small-fry fish in the fish traps. There are no large fishing nets and no hook and line technologies. According to Evans' informant Darwin Moodoonathi, although Kaiadilt men had observed the technology of dugong net manufacture at Allen Island they chose not to adopt it owing to the difficulty of its manufacture.

Figure 2.24: Hand-held knotted fishing net, Bentinck Island (AM E14979)
(Photo by Ann Best)

Fish Poison from Mangrove Bark (jurrkaa) – Creeks were blocked with grass and vine dams and the fish were stunned using fish poison, obtained by scraping the mangrove bark (*jurrkaa*) and swishing the poison in the water (Evans 1995:16). Scraping the poison is woman's work; they also push walls of grass and cassytha vine rolls through the water. Getting fish is man's work. Mullet and small species of fish are taken with poisons.

2.3.6 Kaiadilt Occupation Sites

Eating and sleeping camps – Ethnographic evidence suggests that occupation sites in the South Wellesley Islands were open shell matrix sites (Claassen 1998:11), located along coastlines and fringing the major estuarine waterways. Tindale (1977:249) reports that the overnight eating and sleeping camps that the majority of people used at most times of the year were placed on sandy beaches just above the high tide mark with day shelters in the half shade of the coastal fringe Casuarina trees (cf. Meehan 1982). Some occupation sites are more visible due to a prograding landscape preserving the archaeological record, however geomorphological processes (e.g. erosion), varied climate patterns and associated weather events (e.g. seasonal and long-term climate changes, storm surges and cyclones) have greatly impacted the Gulf of Carpentaria and the islands, thereby affecting the representation of archaeological materials (Rowland and Ulm 2012). A significant number of sites located on the shoreline have undoubtedly been destroyed. In contrast, sites that are located further inland, usually on high ground, are for the most part still *in situ* and display limited or little taphonomic disturbance. Based on Tindale's (1977:250) descriptions I interpret these sites to be central-place camps where foragers retreated to during times of refuge in inclement weather/wind conditions. At these central-place camps people brought back food to share and slept in 'twig-lined pits, covered with whatever branches of timber and bark or grass they could find' (Tindale 1977:250). A key characteristic of long-term residential base camps compared with one-off use dinnertime camps is the diversity of taxa targeted, with more varied taxa found in base-camp assemblages (Meehan 1982). Meehan (1982) also noted the small size of dinnertime camps (maximum of 15m x 10m) versus base camps (200m x 100m) and the presence of manufacturing and maintenance activities at base camps.

Constructed Stone-Walled Fishtraps – Evidence for intensive local exploitation of fish occurs in the form of extensive fishtraps found in the intertidal zone, where a variety of species could be efficiently caught within the trap at the receding tide (Memmott *et al.* 2008). Bentinck Island supports the highest density of fish traps in Australia per kilometre of coastline, attesting to the importance of marine-fauna resources for Kaiadilt people (Memmott *et al.* 2008; Rowland and Ulm 2011). Some of these traps are several acres in size, comprise >20 contiguous pens in a cluster and have rock walls up to 1m in height and breadth (Figure 2.25). Construction of these fishtraps (*ngurruwarra*) is attributed to Bujuku and Kaarrku, the mythical black crane seagull. But older Kaiadilt recall building and maintaining them (Evans 1995:16).

Figure 2.25a and 2.25b: Fishtraps on Sweers Island and north coast of Bentinck Island (Photo 1 by Daniel Rosendahl).

Use of fishtraps for increasing marine production during the late Holocene is linked to Aboriginal culture changes in Australia and elsewhere (Lourandos 1997). In the Gulf of Carpentaria region, fishtraps are common among the Wellesley Islands (Roth 1901; Memmott and Trigger, 1998; Trigger 1987) and throughout the Torres Strait Islands (Barham 2000; McNiven 2003). Researchers report fishtraps from around Australia (e.g. Barker 1992, Bird 1994; Dortch et al. 2006; Martin 1988; Ross 2009; Stockton 1982) and these structures are also found around the globe, for example, South Africa (Avery 1975; Hine et al. 2010); Hawaii (Titcomb 1972) and Alaska (White 2011). While use of fishtraps raises the probability of catching fish there is no guarantee of an increase in a group's food supply as this would depend on fish movements. In some places however, the use of fishtraps goes beyond harvesting of fish to also include sea-farming of some species. In Hawaii *loku koapa* or seawater ponds were used by to farm milkfish and mullet (Titcomb 1992). Likewise, Helitsuk people farmed salmon the central coast of British Columbia (White 2011). While it is possible that Kaiadilt people were able to keep fish alive for a time in some fishtraps that did not completely dry out, whether they carried out similar farming of fish has not been recorded ethnographically.

2.3.7 Contact History

In the mid-1940s, the Kaiadilt became the last group of coastal Aborigines in Australia to experience full contact with Europeans. Before establishment of the Mornington Island Mission in 1910, Kaiadilt, Lardil, Yangkaal and Ganggalida encountered occasional non-Aboriginal mariners in the 17th century when the Dutch (Abel Tasman and his crew) visited the Wellesley Islands on board the Limmenin 1644 (Emery 1973:33-34). On Sweers Island, Matthew Flinders found a tree bearing inscriptions of previous seafaring visitors, such as 'Lowry 1781'. Macassan fishermen and traders visited the Wellesley Islands, as part of widespread seasonal fishing across northern Australia (Memmott 1979; Oertle *et al.* 2014; Saenger 2005). Evidence in the South Wellesley Islands in form of pottery sherds (possibly from Sulawesi), tamarind trees, and the remains of smoking pits or stone lines used to process *beche de mere* further supports this idea (Oertle *et al.* 2014). It appears however that the degree of contact between Macassans and the occupants of the Wellesley Islands was minimal, indicated by a lack of loan words in the Kaiadilt and Lardil linguistic dataset (Evans 2005; Memmott 2010; Oertle *et al.* 2014).

In 1802, Matthew Flinders encountered some Kaiadilt people on Horseshoe Island and engaged in 'friendly intercourse' and some trading (Flinders 1814:137). This is not to say that the impacts of contact between Kaiadilt and external cultures before the 1940s were always friendly, in fact at times the contact appears confrontational. Reports infer that the Kaiadilt typically reacted to visitors by avoidance with occasional episodes of resistance. Flinders (1814:145) noted that the Kaiadilt 'were repeatedly seen upon both Bentinck's and Sweer's

Islands; but they always avoided us and sometimes disappeared in a manner which seemed extraordinary'. Later visitors to the islands were to experience similarly being avoided by the Kaiadilt. Landsborough and his exploration party traveled to Sweers Island in 1866 and established 'Carnarvon', a temporary township, port and quarantine facilities that existed from 1867-1880. Landsborough noted that during early encounters with Kaiadilt people they appeared 'suspicious and timid to Mr Phillips from whom they fled'.

After Carnarvon was abandoned pastoralists moved on to Sweers and Bentinck Islands. Within a few years, the Kaiadilt resumed their traditional occupation of Sweers Island, which was now stocked with large herds of cattle, sheep and goats. Walter E. Roth, Northern Protector of Aborigines, visited in 1901 and only had two encounters with the Kaiadilt – one day while exploring Bentinck Island he was halted by a long line of blazing fires. It is most likely the fires were simply lit to burn off grass or for hunting but Roth may have seen it as a threat. The next day Roth surprised a large group of 34 people at a freshly deserted beach camp, who swum to the outer reef to hide (Roth 1903).

Sometime between 1914 and 1917 a white man, John McKenzie, settled first on Bentinck Island, at the place known as Kurmbali in Kayardild (now McKenzie River) and then on Sweers Island until 1922. During this time he built and abandoned a hut on Bentinck Island and then built a house, kept goats and horses, and constructed a lime-kiln on Sweers Island. At some stage, McKenzie may have carried out a massacre of Kaiadilt people, and although there is no official report to testify to this event oral testimony of Kaiadilt people is damning. They tell of a white man riding across the island with dogs, shooting any Aboriginal people he saw. They also remember him abducting and raping young girls, who later gave birth to light-skinned babies (Kelly and Evans 1985). According to Belcher's (ms:71) exposition of events, '[t]he Kaiadilt used to spy on McKenzie from the cover of the sand dunes and, when he was absent at Burketown, killed and ate some of his goats. Such incidents provoked a deliberate campaign of retaliatory killing by McKenzie, in which eleven Kaiadilt died in 1917 (circa).'

In the meantime, a Presbyterian Mission had been established on Mornington Island. From the mid-1920s the Mission began attempting to make contact with Kaiadilt people through an intermediary, Yangkaal man Gully Peter. Although relationships were formed the Kaiadilt continued to live in relative isolation in their country in the South Wellesleys and it was not until the 1940s that their lifeways changed. For various reasons, people were gradually transferred off country with a few being removed to Aurukun Mission and the majority going to Mornington Mission. Between 1942 and 1945 a severe drought in the southern Gulf led to food shortages, famine and fighting amongst the Kaiadilt people. In February 1948, the last remaining Kaiadilt on Bentinck were evacuated after a cyclone caused widespread damage and salted up freshwater sources.

Tindale argues (1962b:299-300) that the following four primary factors led to a period of acute stress and population decline:
(a) population growth beyond the economic carrying capacity of their lands;
(b) the climatic effects of reduced rainfall in 1945-46, with the subsequent scarcity of vegetable foods and poor fishing;
(c) inter-horde conflict as a result of (b);
(d) two catastrophes – mass drownings, and a tidal surge that polluted many water sources with subsequent deaths.

The older Kaiadilt women built a stone-wall fishtrap on the edge of the channel on Mornington Island about a kilometre from their mission camp, in which to catch fish, turtle, dugong and crabs. Their reliance on these fishtraps in the South Wellesleys was far greater than that of the Lardil, and there was a practical necessity to recreate their technological means in their new homeland. But the effects of famine and stress took its toll on the relocated people whose lives changed immeasurably away from their country. Later generations assimilated into the township of Gununa, established on the former mission site, which provides residence to c.1,200 people, predominantly Lardil, Kaiadilt, Yangkaal and Ganggalida.

Although some Kaiadilt men accompanied Tindale to the South Wellesleys in 1962, most of the group did not see Bentinck Island again until the 1980s, when there was a growing move towards establishing outstations across northern Australia. The Kaiadilt had their traditional ownership recognised under Australian law for the first time in 1994 and by 1998 between 30 and 40 Kaiadilt people were permanently based on Bentinck Island (Evans 1998:50). Since then however, Kaiadilt people have moved back to Mornington Island due to a number of social, political and environmental problems (e.g. persuading families with school-age children to leave, the lack of economic opportunity on Bentinck, the feeling that tourist facilities on Sweers Island are an intrusion onto their land and sea, and potential ecological problems associated with proposed new mining and port developments on the adjacent mainland).

An influencing factor for Kaiadilt to join in the Wellesley Islands Sea Claim was their perception of ‘the effects on the local marine ecosystem of commercial prawning and fishing, as well as tourist fishing in what are Kaiadilt waters by their traditional law’ (Evans 1998:2). The Kaiadilt are also of the opinion that the loading of Century Mine ore at Karumba and in the Gulf has resulted in pollution of the Gulf waters and a decline in seagrass resources, which they say explains the recent poor condition of the turtle and dugong taken by traditional hunters

(Memmott and Channells 2004:28-29).

2.4 Previous Archaeological Research

Archaeological assemblages during the late Holocene are characterised by changing site densities and site and/or regional abandonments (Sim 1999; Sim and Wallis 2008; Williams et al. 2010). New site types, such as shell mounds, also emerge (e.g. Faulkner 2008; McNiven and Feldman 2003; Morrison 2003, 2010). There is a noticeable increase in the numbers of sites after 1,000 BP (Ulm 2006, 2011; Ulm and Reid 2000) except for some notable declines in site numbers between 1250-950 BP and 450-250 BP, which are correlated with changes in ENSO frequency and intensity (Williams et al. 2010). Climatic patterns in northern Australia are strongly influenced by the El Nino/Southern Oscillation (ENSO) cycle that brings periods of aridity alternating with high-intensity summer monsoons and increased rainfall (Bourke et al. 2007:92). ENSO events have been linked to mangrove forest defoliation during cyclones (Haberle 200:66). Conversely long periods of aridity can influence coastal processes such as progrodation by marine mud leading to colonisation by mangrove forests, especially where waterways are not flushed during reduced wet seasons (Bourke et al. 2007:93).

Archaeological projects in the region that incorporate focused studies of marine faunal assemblages, have been undertaken at Blue Mud Bay, Arnhem Land (Faulkner 2006, 2008), Groote Eylandt (Clarke 1994), Vanderlin Island, Sir Edward Pellew Archipelago (Sim 2002; Sim and Wallis 2008), Albatross Bay, Weipa (Morrison 2010; Bailey 1977) and a co-current project for the Wellesley Islands (Memmott *et al.* 2006, 2008, 2016; Robins *et al.* 1998; Ulm *et al.* 2010). Excavations reveal rapid and widespread changes in coastal site content, an increasingly diversified subsistence resource base and patterns of increase in site establishment and use (Rosendahl *et al.* 2014).

2.4.1 The Broad Trans-Gulf of Carpentaria

Blue Mud Bay, Arnhem Land

Faulkner (2006) recorded a total of 141 archaeological sites in the Blue Mud Bay study area. The exposed coast has a prevalence of lower-lying surface middens, with dates suggesting sporadic use from c.3,000-1,000 BP and more frequent use throughout last 800 to 1,000 years BP (Faulkner 2006:217). In contrast, large shell mounds dominate the wetland margin, which was intensively used c.2,500-500 BP. In general the shell mounds are older and contain fewer molluscan species than the surface middens, a pattern that Faulkner (2006:163) attributes to the 'differential availability of resources across the study area, reflecting the diversity of environmental conditions and the differential distribution of molluscan habitats.' Faulkner (2006:262) suggests the shell mounds are the result of concentrated, short-term exploitation strategies (see Section 4.4). The mass collection of *Tegillarca granosa* 'may have helped to buffer coastal populations against climatic instability', with the reliability of this species and related mudflat taxa underwriting reduced mobility (Faulkner 2006:262).

Groote Eylandt

Archaeological evidence from Groote Eylandt suggests increased intensity of coastal occupation around 900-1000 years ago, coupled with a decrease in the occupation of inland sandstone rockshelters after 1,500 BP (Clarke 1994:470). Clarke (1994:97) reports that in the period before Macassan contact people carried out a seasonal subsistence and settlement system. Her examination of shellfish assemblages from older sites indicates that people tended to move around selectively exploiting certain shellfish species (e.g. *Terebralia palustris, Marcia hiantina, Tegillarca granosa*). In contrast, during the period of Macassan contact (c.450 BP onwards), archaeological evidence points to greater use of sites with middens containing a diversity of species from sand/mud shellbeds in the immediate site environments. Clarke (1994:463) suggests this diversity is part of a strategy designed to provide for larger groups of people camped at the one location for longer periods of time. This strategy would entail collecting a variety of high-ranked and low-ranked prey species from one or more patches nearby to the site, rather than foragerers venturing long distances to find preferred prey species (for further information see Section 4.3).

Vanderlin Island, Sir Edward Pellew Group

Informed by their research on Vanderlin Island Sim and Wallis (2008:101) proposed a three-phase model for occupation, with dates ranging from pre-6,700 BP (before islandisation) to modern times. There are at least two hiatus periods of abandonment (6,700-4,200 BP and again from 2,500-1,700 BP), which Sim and Wallis (2008:103) argue were brought about by periods of climatic instability due to increasing intensity of ENSO events around these times (see Shulmeister 1999; Gagan et al. 2004). Climatic change affecting weather conditions would have likely hampered sea travel. Similar to elsewhere in the Gulf region, shell mounds cease to be created after c.600 BP. Shellfish assemblage compositions appear to reflect the environmental context within which they have situated rather than the phase of occupation. Sites located along the western side of the island, with its sheltered tidal embayments, are consistently dominated by *Tegillarca granosa* or *Marcia hiantina* or a combination of both. On the more environmentally diverse, exposed east coast sites contained both a greater range of species and *Terebralia palustris* was more prevalent, along with *Saccostrea* sp. (Sim and Wallis 2008:101).

Albatross Bay, Weipa

At Albatross Bay and Aurukun, western Cape York there are an estimated 600 mounds up to 14m in height and 200m long (although most are much smaller) dominated by the intertidal bivalve *Tegillarca granosa* (Bailey 1994, 1999; Morrison 2010). An additional 88 shell scatters and six shell middens were also identified during archaeological surveys (Morrison 2010:156). The majority of surface scatters are composed of *T. granosa* or *M. hiantina*, although a few consisted of *Geloina (Polymesoda) erosa* or *Telescopium telescopium*. Although none of the scatters appear to have been dated, based on location and composition Morrison (2010:297) argues the scatters are likely to be the result of 'production strategies and settlement patterns different to those associated with intensive mudflat exploitation'. Instead, it is the shell mounds of the region that Morrison (2010:54) notes 'reflect the long-term operation of socially constituted strategies of production and consumption'. A primary consideration is that as local and regional variations in coastal vegetation affect mollusc taxa present, the development and timing of mangrove environments serves as a precondition for the presence of particular mollusc habitats (Bailey 1975:10).

2.4.2 The Wellesley Islands

North Wellesley Group

For Mornington Island Memmott *et al.* (2006:49) reported an age estimate of 1,710 BP for Kanbaa and dates of c.5,000-5,500 BP from Wurdukanhan (Memmott *et al.* 2008:49), however the latter has since been proven to be a site of natural and not cultural origin (Rosendahl *et al.* 2015). On the mainland Robins *et al.* (1998) reported radiocarbon dates from three sites (Gunamula, Bayley Point and Old Doomadgee) dating between c.1,200 and 200 years ago.

Surveys and excavations at the Yiinkin Embayment, Mornington Island, identified a rich palaeoenvironmental and archaeological record (Rosendahl *et al.* 2014). The distribution of radiocarbon dates clustered into two groups, with natural bioherms dating between 7000 to 4000 cal BP and cultural deposits from 3,300 cal BP to the present, separated by a hiatus in dated archaeological and palaeoenvironmental deposits between 3,300 and 4,000 cal BP. The shellfish assemblage recovered from the excavations, and observed in surface shell scatters, indicate continuous exploitation of the whole range of ecological zones represented in the study area, including the offshore reef/rock platforms (Rosendahl 2012). While a range of taxa from the various ecological zones are present throughout the occupation of the embayment, the major focus is on the exploitation of intertidal mangrove habitats, with a prominent increase in the exploitation of the sandy-mudflat species, *Anadara antiquata* in the past millennia. The assemblages demonstrate concentrated exploitation of inter-to subtidal shellfish throughout the past 2,700 years due to increasing population demands (Rosendahl 2012:252). This suggests that the local shellfish populations were sustainable (i.e. not overfished during this time).

South Wellesley Group

During the 1960s Tindale conducted some archaeological surveys on Bentinck and Sweers. He identified dozens of archaeological sites and carried out a single undated excavation at Nyinyilki on the southeast corner of Bentinck Island. No further archaeological research was conducted in the South Wellesley Group until 1996 when Bird (1996) undertook a limited archaeological survey around a proposed Telecom tower site near the MacKenzie River area of Bentinck Island. No excavations were conducted and on the three observed shell midden sites, Bird (1996:8) states that 'it is quite likely that some Aboriginal shell middens located along the coastal margins have been re-worked by wave action during spring tides or storm surge. This would account for the presence of both edible and non-edible shell species within these deposits'. Kaiadilt representatives consulted during the survey noted that similar shell scatters are common on the island and these particular scatters have no special significance to them.

More recently Ulm *et al.* (2010:41) report three sites in the South Wellesleys with an initial chronology established dating from c.1600 BP, and evidence for continuous occupation post-1000 BP. The cultural data from these sites remained unexamined until the commencement of this project and the results from analysis of these materials are incorporated into this thesis.

2.5 Summary

This chapter provides a regional, palaeoecological, climatic and environmental context for the study area thereby informing the reader about South Wellesley Islands landscape development. The physical context of the islands enables an informed appreciation of the events and processes that are shaping and impacting the archaeological record. In understanding the broader patterns of environmental and ecological events, patterns of change identified in the archaeological record can be interpreted with greater resolution. Identifying the local post-depositional processes and landscape formations increases the opportunities for robust integration of the archaeological record and environmental record. This enables a confident reconstruction of human-environment interactions.

The cultural setting, described from the ethnographic datasets, demonstrates complex social systems for the Wellesley Islands. Evidence suggests however that while there are close connections between the four language groups of the islands and mainland territories, each group possesses certain traits that identify them as separate identity-conscious social groups. The South Wellesley areas under study (Bentinck, Sweers and Fowler Islands), exhibit a similar environment and range of resources to that of the North Wellesley Group, however, differences in material culture items between Kaiadilt people and Lardil people indicate the two groups approached resource exploitation in slightly different ways.

PART II: THEORY, METHODS AND TECHNICAL STUDIES

Chapter 3. The Study Situated in Northern Australian Anthropological Debates

3.1Introduction

In this review I summarise some of the key issues associated with archaeology of Indigenous coastal sites in northern Australia as identified in the literature. A range of depositional and post-depostional factors is considered and their effects on the archaeological record are discussed.

3.2 The Coastal Archaeological Record of Holocene Australia

Indigenous archaeological sites are located along the length of the Australian coastline, although very few date from the Pleistocene owing to the destructive impacts of sea-level changes during the late Pleistocene/early Holocene (Rowland and Ulm 2012:163). The coastal archaeological record of northern Queensland, in fact, exhibits few sites dating prior to c.2,000 BP (Ulm and Reid 2000; Williams *et al.* 2010) and a marked increase in the numbers of sites after 1,000 BP (Ulm 2006). The exact timing and magnitude of Holocene sea-level changes on the coast of Australia is still under review. In the Gulf of Carpentaria massive landscape changes resulted from the post-glacial marine transgression, where the shoreline moved landward by 1,000 km after rising sea-levels breached the Arafura Sill c.12,200 BP (Chivas *et al.* 2001; Reeves *et al.* 2007, 2008). Islands were created in the Gulf between 8,000 BP and 6,500 BP. Geophysical models indicate that the sea-level in the southern Gulf of Carpentaria was up to 2.5m higher that present mean sea-level (PMSL) during the culmination of the post-glacial marine transgressions (c.6,400 BP) before falling smoothly to the present sea-level over the past 1,000 years (Chappell *et al.* 1982; Rhodes 1982; Rhodes *et al.* 1980; Sloss *et al.* 2012). Littoral resources were further disrupted with the onset of modern El Niño-Southern Oscillation (ENSO) conditions around 5,500 years ago that rapidly altered climatic conditions in eastern and northern Australia (Shulmeister and Lees 1992; Wanner *et al.* 2008). Notable declines in archaeological site numbers between 1,300-900 BP and 550-250 BP are correlated with changes in ENSO frequency and intensity (Williams *et al.* 2010).

Ulm's (2013) recent synthesis argues that human responses to the changing natural and social environments of the mid-to-late Holocene are reflected in fundamental structural changes in the archaeological record which include: increased rates of site establishment and use; increased occupation of marginal landscapes including offshore islands; the appearance of new sites types (e.g. shell mounds and fishtraps); modified rock art styles and technologies (e.g. stone artefacts, shell fish hooks and watercraft); and intensive exploitation of new foods such as cereals and some marine resources (see Barker 2004; Beaton 1985; Bowdler 1981; Cosgrove *et al.* 2007; David 2002; Flood 1999; Haberle *et al.* 2010; Lourandos 1980, 1983, 1985, 1988, 1993, 1997; Lourandos and Ross 1994; Mulvaney 1969; Rowland and Ulm 2011; White and O'Connell 1982). Researchers have placed emphasis on various factors in explaining the wide range of changes in the archaeological record of the Holocene and these are discussed below.

3.2.1 Environmental Factors affecting Resource Productivity and Availability

Some researchers see these changes in the archaeological record as reflecting human responses to altered environments, specifically resource productivity and availability (e.g. Bailey 1983; Beaton 1985; Morwood 1987; Rowland 1983, 1989, 1999a; Walters 1989). Based on investigations at Princess Charlotte Bay, Beaton (1985:18) hypothesised a time-lag between sea-level stabilisation and coastal occupation resulting from a slow development of littoral resources not capable of feeding large human populations until at least 2,000 BP. However sites that demonstrate the use of coastal resources throughout the period of marine transgression (e.g. Walaemini Shelter, Cape York, Nara Inlet 1, Whitsundays and Alligator River system, NT) appear to invalidate the time-lag model (Barker 1991:107; Hiscock 2008:165). Walters, Hall and colleagues reported massive increases in coastal resource use during the past 1,200 years for the Moreton Bay area (see Hall 1982; Hall and Lilley 1987; Walters 1989, 1992). Walters proposed that increased capture rates of fish reflect changes to the marine ecosystem resulting in a greater fish biomass in the last millennium (Walters 1989), although Ulm (2002) found the increases posited for marine fish deposition rates in southeast Queensland to be unsustainable (see also Ulm and Vale 2006). Ulm (2006:253) suggests that reduced predictability of coastal resources during marine transgression and ENSO events may have led to an increased use of sub-coastal areas in preference to coastal areas. Researchers note that ENSO-related conditions also made the coast a hostile environment; most offshore islands were abandoned by Aboriginal people c.7,000 BP around the time they became islands and were not reoccupied until after 4,200 BP (Bowdler 1995; Rowland 2008; Sim and Wallis 2008).

3.2.2 Differential Site Preservation and Site Destruction

Other researchers place emphasis on variable site visibility and survivorship (e.g. Bird 1995; Bird and Frankel 1991; Rowland 1989, 1992; Rowland and Ulm 2012). Landscape change caused by erosion and progradation since sea-level stabilisation has affected vulnerable coastal landforms without major rock formations, such as low-lying mangrove flats, deltaic floodplains, chenier plains, back-beaches, beach-ridges and foredunes (Bird 1995; Fanning and Holdaway 2001; Holdaway *et al.* 2008, 2009; O'Connor and Sullivan 1994b; Rowland 1989, 1992). In most cases this had the effect of obliterating traces of coastal midden sites, however some erosional events of older coastlines can make older sites more visible (Rowland and Ulm 2012).

3.2.3 Changes in Social Structure with Trends Toward Socioeconomic Intensification

Lourandos focuses critical attention on issues of Holocene change in what became known as the 'Intensification Debate' (Lourandos and Ross 1994). Employing a socially oriented approach, Lourandos (1983, 1985, 1997) proposes that Aboriginal societies Australia-wide experienced similar trajectories in the late Holocene toward more intensive production and productivity. He argued that this was through more efficient management of resources, such as by 'regulating resource yields, managing the regeneration of resources and exploiting marginal areas and new resources' (Lourandos 1983:81). This efficiency benefited hunter-gatherers by enabling nomadic groups to become semi-sedentary. It also reduced the labour-time spent acquiring food thus allowing development of more complex social aspects of society. Lourandos' ideas of socioeconomic intensification, which he believed stimulated population growth, found favour with some researchers (see also Barker 1996; David 2002; David and Lourandos 1998, 1999; Lourandos and Ross 1994). However, critics challenged the late growth demographic model (Bird and Frankel 1991). Based on investigations at Nara Inlet 1 on Hook Island in the Whitsunday Group, Barker (1991:106) hypothesised that local foragers had initially exploited shore-based foods in the early Holocene and then in the late Holocene they became marine specialists with a greater emphasis on hunting and fishing using specialised technology in the open seas. Barker (1991:108) argues that this diversification of subsistence enabled long term occupation in the Whitsundays, evidence by the Nara Inlet 1 site that exhibits a significant increase in the rates of discard, greater variety and density of marine resources, increased hearth numbers and a new range of artefacts designed for marine procurement (see also Barker 1996, 2004). David *et al.* (2004:74) point out that territoriality associated with more intensive occupation of mainland areas is associated with 'sea-based expansions across much of north-eastern Australia' in the mid-Holocene. Lourandos extends and modifies the meaning of intensification – originally put forward by Boserup (1965) and Brookfield (1972) in the context of agricultural development – to incorporate modes of production practiced by hunter-gatherer populations. This will be further explored in Section 4.3.3 (Patch Choice and Time Allocation Models).

3.3 Local, Regional and Continental-Wide Narratives

Evidence of island use and exploitation of marine foods in west Kimberley region (O'Connor 1996a, 1996b, 1999a, 1999b; Veth et al. 2007, 2016) and the Whitsunday group (Barker 1991,

2004) demonstrates that foraging of coastal areas in northern Australia has occurred since at least the early Holocene. Ethnographic exploitation strategies and technologies however could not be more different – the only tools known from the west were simple wooden spears and basic rafts whereas specialised marine technologies (shell or bone fishhooks and harpoons) are reported from the Whitsunday's area (Barker 1991, 2004). Detailed investigations in many regions show extended periods of reduced occupation and abandonments during the late Holocene, including Ngarrabullgan in southeast Cape York Peninsula from c.600 BP (David and Wilson 1999) and the Curtis Coast in central Queensland from c.2000 to c.1000 BP (Ulm 2006). New oral traditions were created as people colonised recently created landscapes like Milingimbi in Arnhem Land (Jones 1990; Meehan 1982) or returned to use previously abandoned environments, such as Groote Eylandt in the Gulf of Carpentaria (Clarke 1994, 2002). As people adapted to new environments their cultural systems and patterns of land-use altered. Over the past two decades across northern tropical Australia – for example, the Aru Islands, Indonesia (O'Connor *et al.* 2005), Groote Eylandt (Shulmeister and Head 1993; Shulmeister and Lees 1992; Specht and McCarthy 2005), Sir Edward Pellew Islands (Bradley 1988; Sim and Wallis 2008), and the western Torres Strait (David and McNiven 2004; McNiven and Hitchcock 2004) – researchers report similar trajectories towards amplified settlement and use of islands by Aboriginal people in the late Holocene, evidenced by increased site densities and greater site numbers.

These findings run counter to accounts of a continental-wide narrative, and some emphasise the importance of local and subregional trajectories as a primary locus of change (e.g. Ulm 2013). Hiscock (2008:181) concludes 'Instead of a single economic trajectory the archaeological evidence documents diverse economic patterns during the Holocene as people adapted to changing local conditions by modifying their economic and social life'. Although Aboriginal foraging strategies are influenced by cultural transmission and a shared past, their responses must be based in local environmental and social contexts (Ulm 2013). A good illustration of this comes from recent research undertaken in the southern Gulf of Carpentaria, which investigated Aboriginal cultural patterns of two divergent island populations residing in similar physical environments (e.g. Evans 2005; Memmott *et al.* 2006; Ulm *et al.* 2010; van Holst Pellekaan *et al.* 2006). The findings demonstrate how the two groups with a shared ancestral language followed somewhat different trajectories, and despite sharing endogenous traits emerged as two different cultures with distinctive technologies and hunting strategies. Memmott and colleagues (2006:37) report that Lardil people in the North Wellesley Islands use a broader range of material culture (c.65 objects) than Kaiadilt people in the South Wellesley Islands (c.28 objects). Exclusively Lardil artefacts such as the dugong net and large fishing nets are absent from the South Wellesley Islands, while Kaiadilt people use larger-headed pronged spears with greater numbers of barbs. With researchers better appreciating the complexity of temporal and spatial diversity, more holistic approaches are being adopted that incorporate historical, archaeological and environmental histories at local and regional scales (e.g. Bird and Frankel 1991; Cosgrove *et al.* 2007; Fanning and Holdaway 2001; Holdaway *et al.* 1998, 2002; Sim and Wallis 2008; Ulm and Hall 1996).

3.4 Considering Factors of Deposition, Taphonomy, Sampling and Analysis

A combination of limited terrestrial food resources and the abundance of inshore marine resources in the South Wellesley Islands are reflected in a human subsistence base characterised by the extensive use of aquatic resources. Typically the archaeological sites are stratified accumulations of marine shells, animal bones (especially fish, marine mammals and marine reptiles) and other detritus reflecting human foraging choices and the shifting frequency and abundance of taxa in the local environment. However, the static spatial patterning of archaeological remains does not necessarily reflect the dynamic configuration of past human activities, as site formation and taphonomic processes transform culturally deposited materials (Schiffer 1972, 1983). Recent discussions suggest the high likelihood that assemblages excavated from open coastal sites in the Gulf of Carpentaria will have been subject to post-depositional factors that invariably impact the integrity of archaeological sites. Geomorphological processes (e.g. sea-level change, erosion, storm damage, progradation) have greatly impacted the Gulf of Carpentaria and undoubtedly have had enormous effects on the representation of archaeological materials (Rowland and Ulm 2012). It is therefore essential to develop a clear understanding of landscape formation processes for areas in which open coastal sites are located. Post-depositional processes such as trampling, weathering and soil chemistry will influence the survival of faunal remains (Ulm 2002:91) and therefore alter the composition of any excavated faunal assemblage (Claassen 1998:54; Stein 1992:150). The importance of knowing if weathering or degradation has occurred is paramount and additional analyses of deposit composition (e.g. pH, grain size distribution and organic matter content) can be used to identify post-depositional changes (Stein 1992). Faunal remains are also susceptible to differential preservation, which has been cited to explain under/over-representation of various taxa in archaeological assemblages (Claassen 1998; Lyman 1994b). Recovery depends on a number of factors and involves consideration of not only taphonomy, but also issues in sampling, identification and quantification (see Casteel 1976; Colley 1990; Nagaoka 2005b). These issues will be discussed in detail in Chapter 5.

3.5 What this Study Does to Contribute

Undertaking archaeological studies require recognition and acknowledgement of the complexities (outlined above) for interpreting the Australian archaeological record. Researchers examining coastal middens in northern Australia focus on questions regarding the antiquity of sites, the movement and social organisation of people and changes in patterns of resource exploitation (e.g. Bailey 1999; Barker 2004; Bourke 2000, 2005; Faulkner 2006; O'Connor 1999a, 1999b; Sim and Wallis 2008; Veth *et al.* 2007). A number of studies investigate key problems associated with human population growth and its effects on the environment (see Australian studies by Bird and Bliege Bird 1997; Faulkner 2006, 2009, 2011a; O'Connell and Hawkes 1984; Rowland 1999a). Few have paid particular attention to measuring potential long-term anthropogenic impacts on marine ecosystems (but see Faulkner 2006, 2009, 2011a).

This study benefits from using a robust theoretical framework that affords numerous models for not just identifying and interpreting the evidence of human-environment dynamics but also measuring the impacts of such interaction. Trophic level analysis derives from approaches used by ecologists for quantifying historic human impacts on fisheries (Pauly *et al.* 1998, 2000) and is incorporated into this investigation. While archaeologists have effectively applied trophic level analysis to investigations of prehistoric fisheries, none of these studies has taken place in Australia (e.g. Bourque *et al.* 2008; Quitmyer and Reitz 2006; Reitz 2004; Reitz *et al.* 2009; Wing 2001).

This will be the first study in Australia using the combination of optimal foraging models and trophic level analysis to investigate Aboriginal impacts on undisturbed Australian ecosystems against a backdrop of natural environmental change.

3.6 Summary

Changing sea-levels, ongoing marine processes and severe weather patterns have brought about continuous, dynamic landform evolution in the Gulf of Carpentaria (e.g. Chivas *et al.* 2001; De Deckker *et al.* 1988; Hope and Aplin 2005; Prebble *et al.* 2005; Reeves *et al.* 2006, 2007, 2008; Shulmeister and Lees 1992, 1995; Torgersen *et al.* 1983, 1985, 1988; Woodroffe and Chappell 1993; Woodroffe *et al.* 1988, 2000; Nott 1997, 2006; Nott *et al.* 2009; Specht and McCarthy 2005). These and other post-depositional factors must be considered when analysing the archaeological record. It is clearly evident from earlier discussion that interpreting archaeological evidence from coastal sites is hampered by uncertainties relating to site preservation (e.g. Bird 1995; O'Connor and Sullivan 1994a; Rowland 1992). The Holocene archaeological record reflects diverse economic patterns as people adapted to changes in their local environments.

Chapter 4. Optimal Foraging Theory: Subsistence Strategies

4.1 Introduction

This chapter outlines the evolutionary ecology theoretical framework that provides the contextual approach to be used for investigations in this study. Optimal Foraging Theory (OFT) and associated models are explained in detail and benefits in using this methodology for assessment of archaeological materials are discussed.

4.2 Background: Evolutionary Ecology as a Framework for Understanding and Predicting Foraging Behaviour

In attempts to better understand different behavioural decisions underlying foraging strategies, researchers adopted theory from evolutionary biology and microeconomics. Evolutionary ecology focuses on the role of ecological variables in the development of specific adaptations (Broughton and O'Connell 1999:153). By definition, it is 'the application of natural selection theory to the study of adaptation and biological design in an ecological setting' (Winterhalder and Smith 1992:5). In keeping with their Darwinian baseline, evolutionary ecologists consider that humans are 'designed by natural selection to respond to changing conditions in a way that yields the greatest possible benefit for the individual forager's survival and reproductive success' (Smith 1983:626). The costs and benefits of behaviour are best understood in terms of genetic fitness (Bettinger 1991:154). However, unlike with other Darwinian-style theoretical offshoots, such as selectionist archaeology (see Dunnell 1980, 1982, 1992) behaviour is not considered directly linked to an organism's genetic makeup; instead behaviours are a part of the variation of the phenotype expression and therefore still subject to natural selection (Krebs and Davies 1978, 1997; O'Connell and Hawkes 1984:504; Smith 1983). Bettinger (1991:154) explains that 'If behavioral variability (whatever its source, i.e., genetic or otherwise) results in differential genetic fitness and if such behaviors (again regardless of source) are transferable from one individual to another, then this transfer necessarily carries with it the implication of genetic fitness'.

Evolutionary ecologists regard the archaeological record as the primary source of information about how behaviour may have varied in the past (Broughton and O'Connell 1999:161), supported by anthropological studies and ethnoarchaeology that inform on the relationship between behaviour and its archaeological consequences (e.g. O'Connell and Hawkes 1984). Proponents employ ecologically-oriented mathematical models from Optimal Foraging Theory (OFT) that investigate the use of resources based on archaeological evidence (Smith and Winterhalder 1992; Winterhalder and Smith 2000). This is achieved by specifying the goals of an organism, a range of environmental factors likely to place constraints on its actions, a currency unit (such as calories captured per unit of foraging time) with which to measure the success of the organism, and a 'decision set', or range of options available in attempting to achieve a goal (Smith 1983:626; Winterhalder and Smith 2000:54). The models test hypotheses regarding the relative fitness of particular behaviours by replicating trade-offs between fitness gains and the costs and benefits associated with each strategy (Bettinger 1991; Boone and Smith 1998; Broughton and O'Connell 1999:153-154; Winterhalder and Smith 2000). The two types of costs incurred in performing an activity are opportunity costs (benefit forgone by choosing on activity over another); and resource costs (time, effort and materials expended) (Hames 1992:205). Optimisation logic does not imply that humans will always choose the best strategy; only that selection will tend to favour the better strategy among a defined set of alternatives (Broughton and O'Connell 1999:154; Nettle and Dunbar 1997). Because natural selection takes place at the level of an individual this makes each organism an agent, therefore evolutionary ecologists adhere to the concept of 'methodological individualism' where the properties of groups are viewed as being the outcome of the actions of their individual members (Boone and Smith 1998; Kelly 1995; Smith and Winterhalder 1992:39).

A growing number of archaeological studies demonstrate that OFT models are productive for understanding subsistence change over longer time-scales. We can model many of the subsistence decisions available to foragers of the past and thereby predict particular responses and coping strategies. For the most part, it seems these are aimed either at maximising energy returns under different constraints and/or minimising risks when environmental conditions are variable. These models offer a valuable tool for explaining subsistence change and they also elucidate the dynamic relationship between humans (predators) and their prey (Nagaoka 2002b).

4.3 OFT Models for Utility Increase

Archaeologists have found that localised human impacts on marine fisheries are generally evidenced by focused exploitation of specific resources and resource depression ((the decline in the encounter rates of prey resulting from human foraging practices (see Nagaoka 2002b:84)), and changes in the types of resources people used through time (Rick and Erlandson 2008:9). Utility increase models have successfully been used to identify and measure such evidence. These models examine ways in which agents (humans) faced with certain environmental constraints (e.g. the nature, abundance and structure of resources), can increase their rate of utility gain (measured as energy over time) while foraging for food or other resources (Mithen 1990:123).

4.3.1 Diet-Breadth and Prey Choice Models

Diet-breadth prey choice models are used to examine which resources should be chosen based on an assumption that foragers will generally seek to maximise utility returns for effort expended (Charnov 1976; Hawkes and O'Connell 1992; MacArthur and Pianka 1966). The model predicts that foragers will initially focus on the highest-ranked prey available (based on post-encounter caloric return rate), only turning to lower-ranked prey when the abundance of high-ranked prey declines (Kaplan and Hill 1992; Stephens and Krebs 1986). The reduced density of higher-ranked prey should result in foragers diversifying the diet breadth to include lower-ranked resources, which are introduced in order of diminishing returns only when higher-ranked resources are unavailable (Kaplan and Hill 1992:171). This becomes a fundamental trade-off between search costs and handling costs, which defines the optimal set of prey types for the foraging system (Smith 1983:628). Search time will decrease but the lower ranked resources will increase handling time (Figure 4.1).

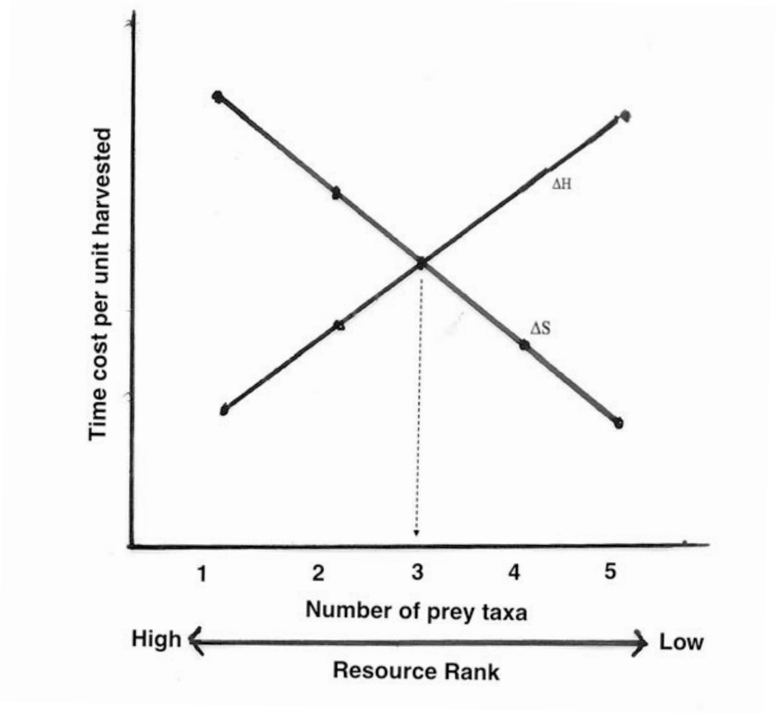


Figure 4.1: The MacArthur-Pianka diet-breadth model. Decreasing search costs ΔS (per unit) are plotted against increasing handling costs ΔH (per unit), as prey types are added to the diet in descending rank order of net return per unit. The optimal diet includes all prey types to the left of the arrow (MacArthur and Pianka 1966, after Winterhalder 1981).

Some studies demonstrate that for singly handled prey, post-encounter return rates are closely scaled to prey body size, which can be used as a proxy in the archaeological record (Broughton 1994a, 1994b, 1997; Hames and Vickers 1982; Hawkes *et al.* 1982). However, Stiner and her colleagues (Stiner and Munro 2002; Stiner *et al.* 1999, 2000) determine that use of size categories is flawed as it masks the significant impact that differences in pursuit, capture and processing costs can have on net energetic returns, due to differing mobility of similar sized prey (e.g. rabbits and tortoises). Furthermore, some ethnographic studies question the assumption that prey body size and prey rank are always positively correlated, as smaller prey may be easier to catch than larger prey thus increasing their post-encounter return rate (Bird *et al.* 2009; O'Connell *et al.* 1988; Smith 1991:230). Anomalies also occur through the use of mass-capture technologies or new processing techniques that can increase the yield of the resource per capture episode and elevate a low-ranked resource into the optimal set (Lupo and Schmitt 2002, 2005; Madsen and Schmitt 1998; Zeder 2012:10). Still, Broughton *et al.* (2011) contend that prey ranks can and have been established through empirical studies that incorporate measurements of pursuit and processing times and caloric returns of different prey (e.g. Bird and Bliege Bird 1997; Bird *et al.* 2002; Broughton 1994a, 1997).

4.3.2 Resource Depression

In the context of this study the term 'Resource depression' is best defined as the decline in the encounter rates of prey resulting from human foraging practices (Nagaoka 2002b:84), evidenced by the significant reduction in prey population numbers and sizes (where the prey demographic ratio profile trends toward more juvenile than mature specimens). Over the past decade archaeological researchers investigating marine resource intensification and depression using OFT models have focused on Pacific island contexts (e.g. Butler 2001; Fitzpatrick and Donaldson 2007; Jones 2007, 2009; Mannino and Thomas 2002; Morrison and Hunt 2007; Nagaoka 2001, 2002b; Thomas 2001, 2002, 2007a, 2007b) and along the western coastline of the Americas (Betts and Frieson 2004; Braje et al. 2007; Broughton 2002; Butler 2000; Butler and Campbell 2004; Erlandson and Rick 2008; Erlandson et al. 2005, 2008; Kennett and Kennett 2000; Roy et al. 2003). Faulkner (2006, 2009, 2011a) is one of the few researchers in Australia to investigate these issues through the study of coastal middens (cf. Bird et al. 2002, 2009; Codding et al. 2010). Faulkner (2006:259) proposes that environmental and climate changes altered the distribution and abundance of resources, which in turn affected patterns of settlement and resource exploitation strategies. By adopting an ecological approach he determines that the archaeological record reflects temporal and spatial variations in human group sizes, mobility and differential focus on resources (Faulkner 2006:286).

Analyses of trends in prehistoric foraging behaviour have made good use of quantitative indices, for example predictions of resource use intensification and/or resource depression can be tested using indices of diversity such as average prey size (Figure 4.2) (Butler 2001:93; Broughton 1997) richness (NTAXA) (Broughton and Grayson 1993; Grayson and Delpech

1998; Nagaoka 2001) and evenness (Shannon-Weaver Function) and by measuring taxonomic abundances and age/size mean and maximum for species (after Reitz and Wing 2008:235).

(a) ∑ MNI queenfish - large fish taxon / ∑ [MNI large fish taxa + MNI small fish taxa]
(b) ∑ MNI taxa from Patch A / ∑ [taxa from Patch A + taxa from Patch B]

Figure 4.2: (a) Index to track change in relative abundance of one high-ranked taxon against all taxa within each patch – values that approach 1.0 indicate high frequencies of queenfish, whereas values closer to 0.0 indicate few queenfish and more of other species; and (b) Index to study changes in patch use by comparing the proportion of taxa from one patch to another (modified from Broughton 1997; Butler 2001; Nagaoka 2002b).

These studies illustrate that where resource intensification (the focused exploitation of a class of taxa) of a fishery occurs we can expect to see a progressive decline in the average size and abundance of high-ranked resources accompanied by an increase in low-ranked resources (Butler 2001; Morrison and Hunt 2007; Nagaoka 2001, 2002a, 2002b, 2005a). It is important to note that archaeologists disagree about how to interpret variability in abundance index values; some suggest that high proportions of large prey remains represent higher overall foraging efficiency, while others argue the opposite. For example, Codding, Bird and Bliege Bird (2010:1) argue that variation in the proportional remains of large prey and small prey is best predicted by the success rate of large prey hunts compared with the time spent foraging small prey. This argument is valid as the overall energy return rate may be higher in the case of foraging low-ranked resources if more time and energy is spent hunting higher-ranked resources.

4.3.3 Patch Choice and Time Allocation Models

Patch choice and time allocation models specify which areas should be searched in order to obtain the maximum return when resources exhibit a 'patchy' distribution (i.e. similar resources are clumped together in a fine-grained manner in a range of distinct clumps or 'patches') (MacArthur and Pianka 1966; Smith 1983:631). Within each patch, resources are ranked from most to least efficient (Smith 1991:208). The Marginal Value Theorem (MVT) proposed by Charnov and Orians (1973) enhanced application of the model by considering two critical variables: (1) The forager must decide which set of patches to forage and when to leave one patch and move to another (Winterhalder and Kennett 2006:15-16); (2) It is assumed that exploitation in a patch will gradually deplete the resources resulting in exploitation depression, so foragers should periodically sample other patches, and leave the present patch whenever higher returns can be had elsewhere (Smith 1983:631). The model postulates that as higher-ranked patches become depleted, foragers should add patches to their itinerary in order of decreasing returns (Smith 1983:632). Using cost-benefit principles of marginal value three relationships between patch residence time and return rates can be modelled provided that prey is not significantly depleted: (1) energy acquired increases with patch residence time; (2) energy gain remains constant; and (3) foraging within a patch causes a progressive decline in energy return rate (Smith 1983; Charnov 1976; Charnov *et al.* 1976).

Boserup (1965) and Brookfield (1972) originally created the concept of resource intensification in the context of agricultural development. Resource intensification was defined as a process by which total productivity or yield per area of land is increased through the investment of more labour, time or skills in an effort to extract greater production output (Thakar 2011:2597). The archaeological concept of intensification has continued to develop and is now applied to modes of production by hunter-gatherer populations (e.g. Broughton 2004a; Braje 2007; Butler and Campbell 2004; Mannino and Thomas 2002; Zori and Brant 2012:3). In the hunter-gatherer production context evolutionary ecologists define intensification as the investment of labour in the exploitation of resources (Thakar 2011:2597). Some classes of lower-ranked marine resources subject to intensified or concentrated exploitation (e.g. molluscs) occur in dense concentrations at predictable locations and continued intensive exploitation of a patch can lead to depletion of the resource (Butler and Campbell 2004; Morrison 1994:112). In this respect, investigating intensification can benefit from using the patch choice/time allocation model. Strategies should be considered that reduce the risk of patch exploitation depression. Uncertainty about fluctuating resource abundance can be reduced through increased forager mobility by enabling sampling of a broader range of patches (Cashden 1992; Sobel and Bettles 2000). This may be evidenced in the archaeological record by the combined presence of prey species found in different patches (e.g. mud whelks are found only in mangrove muds and turban snails are found on rocky reefs). A territorial resource-defence strategy would benefit groups that compete with others for access to patches, provided that a lower degree of energetic cost is required for defending spatially-confined clumps as opposed to finding and accessing new patches (Kennett and Clifford 2004).

4.3.4 Central-Place Foraging and Field Processing Models

In most circumstances food items are not consumed at the location of acquisition, as many food items require processing before they can be ingested (e.g. cleaning and cooking fish). The camp or central-place is often where processing activities are carried out, food is shared and information about the location of resources is exchanged (Orians and Pearson 1979). Central-place foraging does impose travel costs, such as the cost of carrying a food item and limiting the forager's ability to handle other items while searching (Bettinger *et al.* 1997; Kaplan and Hill

1992; Orians and Pearson 1979). In stable/evenly dispersed environments foragers should be able to access a variety of resources within short foraging distances of any camp, so foragers should choose to disperse as small groups to exploit resources and frequently move the central camp over short distances as required (Cashden 1992; Smith 1983). To minimise round-trip time while foraging in patchy environments, foragers should consider the location of resource clumps when selecting a place to camp. Moving camp closer to one resource would simply put it further from others and no advantage would be offered in predicting the location of mobile-game (Cashdan 1992; Smith 1983). Metcalfe and Barlow (1992) derived a trade-off model (Figure 4.3) in order to predict whether foragers should process resources (remove bulky low-utility parts) at the point of procurement or transport them back to a central location (Bird *et al.* 2002:462). Others have since adopted the approach (e.g. Beck *et al.* 2002; Bettinger *et al.* 1997; Bird and Bliege Bird 1997; Jones and Madsen 1989). Intermediate resource distribution patterns should favour a similarly intermediate settlement pattern (Smith 1983:634). This model suggests a strategy that might help foragers cope with resource depression in a specific patch or location (Nagaoka 2002b). This model predicts that when closer patches become depressed, more use should be made of less-depleted patches further out from the central place; travel will remain worthwhile as long as a patch's return rate still falls above that of other patches (Broughton 2002:63). Foragers should relocate the central-place camp when foraging returns fall below those that can be obtained elsewhere (Kelly 1992:46; Sahlins 1972:33).

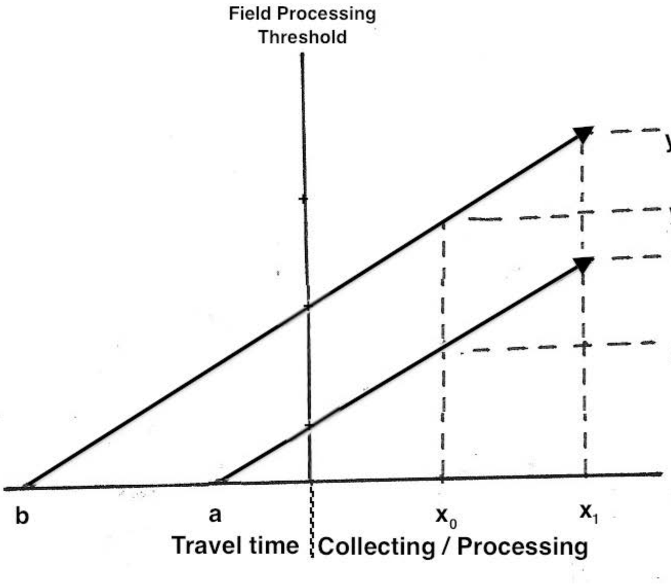


Figure 4.3: Central-Place Foraging Model showing the trade-off between resource transportation and procurement and processing costs. The model uses a linear utility/time function that shows the relationship between costs (X_0 collecting time and X_1 processing time) and benefits (Y_0 return from unprocessed and Y_1 return from processed resources). It predicts that resources should be transported without processing only if travel time is less than the field-processing threshold. Solid lines (a and b) represent different travel times to and from the central place (modified from Metcalfe and Barlow 1992 and Bird *et al.* 2002).

4.4 OFT Models for Risk Reduction

The concept of risk management incorporates strategies for preventing and mitigating losses caused by 'naturally occurring or human-induced process(es) or event(s)' (Smith 1996:5; see also Zori and Brant 2012:1). Evolutionary ecologists have begun to pay more attention to the role of 'uncertainty' as a factor in shaping alternative outcomes in foraging decisions (Smith 1983:638). Attempts have been made to incorporate risk as an explicit component of many OFT models, including diet breadth/prey choice, patch use/time allocation (e.g. Caraco 1979a, 1979b; Caraco *et al.* 1980; Smith 1983). Gremillion (1996) shows that diet breadth models will produce different dietary outcomes if the goal of energy maximisation is substituted for risk minimisation. Consideration of risk avoidance in modelling foraging strategies brings OFT principles into closer agreement with Flannery's (1986) Broad Spectrum Revolution update (Zeder 2012:11; see also Flannery 1969; Winterhalder and Kennett 2006, 2009). Zori and Brant (2012) discuss some additional coping strategies for risk-averse populations that can be modelled. These are outlined below.

4.4.1 Diversification

Diversification in the context of risk reduction can involve allocating more time to capturing and handling resources with a lower-value in terms of prey net energy yields, even when higher-ranked resources with greater energy yields are available (Clarkson 2004:60). Foraging groups may also benefit from using a combination of strategies, for example, among the Ache of Paraguay women typically target low-risk but predictable, low-ranked resources (prey with smaller body size), and men target high-ranked prey (larger body size) with unpredictable returns (Hawkes 1991; Hawkes and Bliege Bird 2002; Hawkes and O'Connell 1992).

4.4.2 Intensification

The concept of intensification (already discussed in Sections 3.2.3 and 4.3.3), has a number of different definitions as used by other researchers (e.g. Boserup 1965; Braje 2007; Broughton 2004a; Faulkner 2006; Lourandos 1983; Mannino and Thomas 2002; Morrison 2010; Rosendahl 2012). In this thesis 'intensification' or intensive harvesting is used in an evolutionary ecology context whereby more labour is invested in the exploitation of a specific resource or resource patch in order to increase yield (see Thakar 2011). While intensification is often described as a process whereby 'the total energy extracted per areal unit of land is increased at the expense of an overall decrease in foraging efficiency' (Broughton 1994b:501), this runs counter to the socioeconomic construct of intensification put forward by Lourandos (1983) and colleagues (Barker 1996; David and Lourandos 1989, 1999; Lourandos and Ross 1994). Moreover, it is also possible that intensification was also occuring in the South Wellesley

Islands through Kaiadilt people efficiently management of resources, such as by 'regulating resource yields, managing the regeneration of resources and exploiting marginal areas and new resources' (Lourandos 1983:81).

Intensification as a risk management strategy would require increasing production (harvesting, processing, and/or food storage) to the point that shortfalls of the resource are unlikely (Marston 2011:191). The longevity of such a strategy may be a problem unless the resource is resistant to intensive exploitation or productivity-enhancing methods (e.g. irrigation) are used (Zori and Brant 2012:3; see also Betts and Friesen 2004; Butler and Campbell 2004; Moss 2012). Alternatively, some patches may be abandoned either permanently or temporarily until resources have had time to recover.

4.4.3 Group Foraging

Group foraging and living arrangements also offer advantages through the division of labour, increasing the chances of locating prey, and sharing information about environmental conditions that can help reduce uncertainty about prey locations (Smith 1983:634; Sobel and Bettles 2000). Sharing yields among group members can also even out resource capture rates (Clarkson 2004:60). Risk pooling distributes losses over a larger unit than the individual or group 'so that losses can be more predictable and can be absorbed by the gains of other units' (Wiessner 1977:8). The principle of risk reduction can be extended beyond the foraging group to regional networks in the form of exchange and reciprocity arrangements (Weissner 1982).

4.4.4 Exchange

Risk transferring can be accomplished through non-reciprocal exchange, otherwise known as theft or raiding, although the costs associated with such a strategy can be high if theft escalates into open hostilities between parties (Zori and Brant 2012:4; Sobel and Bettles 2000). Territorial expansion, conquest and resource extraction are also strategies employed to cope with extended periods of drought (Arkush 2006, 2008; Kennett and Kennett 2000).

4.5 Discussion

Aside from social risks (e.g. population pressure and interpersonal and intergroup conflict), volatile natural environments and events also represent hazards for foraging groups (Zori and Brant 2012). The unpredictability of foraging environments, long-term climatic change, drought and floods can all produce adverse consequences for foragers (Allen 2004; Zori and Brant 2012; Smith 1983; Winterhalder *et al.* 1999). Regional and local biogeographic patterns and cycles of resource abundance must therefore be considered when explaining and interpreting faunal assemblages (Moss 2012:2; Erlandson and Rick 2010).

The availability of species (in particular shellfish) may be a reflection of changing local habitats (Moss 2012:8). For example, detailed palaeoenvironmental reconstructions available for the Alligator River system, Northern Territory (Woodroffe *et al.* 1986, 1988) confirm that widespread environmental changes along the northern Australia coastline resulted in redistributions of coastal and marine resource zones (Hiscock and Kershaw 1992; Schrire 1982; Woodroffe *et al.* 2000). The archaeological record indicates that foragers shifted camps and activities from the estuarine embayment to the coastal floodplains and shores in response to disappearing mangroves (c.4500 BP) and the creation of new beach ecosystems (Hiscock 2008:172, 1999). Patches of *Anadara* shell beds that thrived in this environment were heavily exploited. This is evidenced by large *Anadar*a shell midden mounds that were created by foragers on the northern Australia coastline from the Kimberley region c.3000 BP to Cape York Peninsula c.2500 BP (Bailey 1977, 1994, 1999; Bourke *et al.* 2007; Faulkner 2006; Faulkner and Clarke 2004; Hiscock and Faulkner 2006; O'Connor 1999b; Woodroffe *et al.* 1988). Faulkner (2009, 2011) determined that a decline in *Anadara* shell sizes from sites at Blue Mud Bay over time indicates exploitation depression. The end of *Anadara* sp. mound building in northwest Australia c.800-600 BP (see Bailey *et al.* 1994; Ulm 2011) coincided with further landscape evolution from shallow embayments and open beaches to mangrove-rich coasts and mud flats without abundant *Anadara* resources (Faulkner 2011a; Hiscock and Faulkner 2006).

4.6 Summary

This chapter has provided an overview of the evolutionary ecology theoretical framework utilised for approaching investigations in this study. Although ecologists initially used this framework to examine factors in animal prey-predator relationships, some archaeologists and anthropologists saw merit in the framework as a way to better understand human foraging behaviour. Theoretical models have been created that can be used to form hypotheses about expected signatures in the archaeological landscape that result from certain human foraging behaviours. The methodology has informed researchers' understandings and interpretations of human subsistence strategies in the past based on archaeological evidence.

Chapter 5. Trophic Analysis: Testing the Nature And Level of Human Impacts on Marine Ecosystems

5.1 Introduction

While OFT models can identify and measure episodes of resource intensification and depression, it is difficult to test ideas about the level of human impacts on marine ecosystems, partly due to poor visibility of the marine environment and partly because there are few archaeological methods by which to quantify long-term fishing impacts (Quitmyer and Reitz 2006:806). Pauly and his colleagues (1998, 2000) advocate a method that can assist in understanding marine ecosystems through assessing changes in marine trophic levels and trophic cascades. This approach, only recently applied to analyses of zooarchaeological data, has proven to be a useful quantitative heuristic for measuring long-term impacts on marine ecosystems (e.g. Erlandson *et al.* 2004, 2008; Morales and Rosello 2004; Quitmyer and Reitz 2006; Reitz 2004). It works through the basic premise of a food web, that because 'components of an ecosystem are inextricably linked … we should expect heavy human predation on a particular marine species to have a corresponding effect on the competitors, prey or predators that the depleted species strongly interacted with' (Rick and Erlandson 2008:11).

5.2 Background

5.2.1 Trophic Levels, Food Webs and Trophic Cascades

Drawing on Darwin's initial idea of a food web, Elton (1927) pioneered the concept of how food chains or food webs operate as functional aggregations of species that have the same predators and prey. Lindeman (1942) contributed the notion that trophic dynamics are based on the transfer of energy from one part of the ecosystem to another. Food webs depict the flow of energy via trophic linkages in linear feeding pathways that trace consumers from a base species (e.g. plants) up to the top consumer, which is usually a large predatory carnivore (e.g. tuna fish) (Thompson *et al.* 2007). An organism's trophic level is the position it occupies in an ecological community or food chain, with the broad levels being primary producers (plant organisms that do not feed on other organisms), herbivores, omnivores and carnivores. Small primary consumers at the base of a food chain can increase faster and are relatively abundant; larger secondary consumers grow at a slower rate while predators toward the top end are progressively fewer in number. The resulting arrangement of sizes and numbers of animals, commonly known as the Eltonian Pyramid, has since been modified to include trophic links (Figure 5.1).

As well as the direct trophic relations among species there are also indirect effects in a food-web that can alter the abundance, distribution or biomass in the trophic levels (Cohen *et al.* 1990). A trophic cascade is the net effect of these direct and indirect relationships. Trophic cascades are further separated into species-level and community-level cascades (Polis *et al.* 2000:473). Species-level cascades are where only a subset of organisms, at a given trophic level, are impacted by a change in population numbers and these do not usually explain habitat-wide changes in biomass distribution. In contrast, community-level cascades are where most or all of the organisms, which make up a given trophic level, experience a change in population numbers that has a dramatic effect on the entire food-web (Polis *et al.* 2000:473).

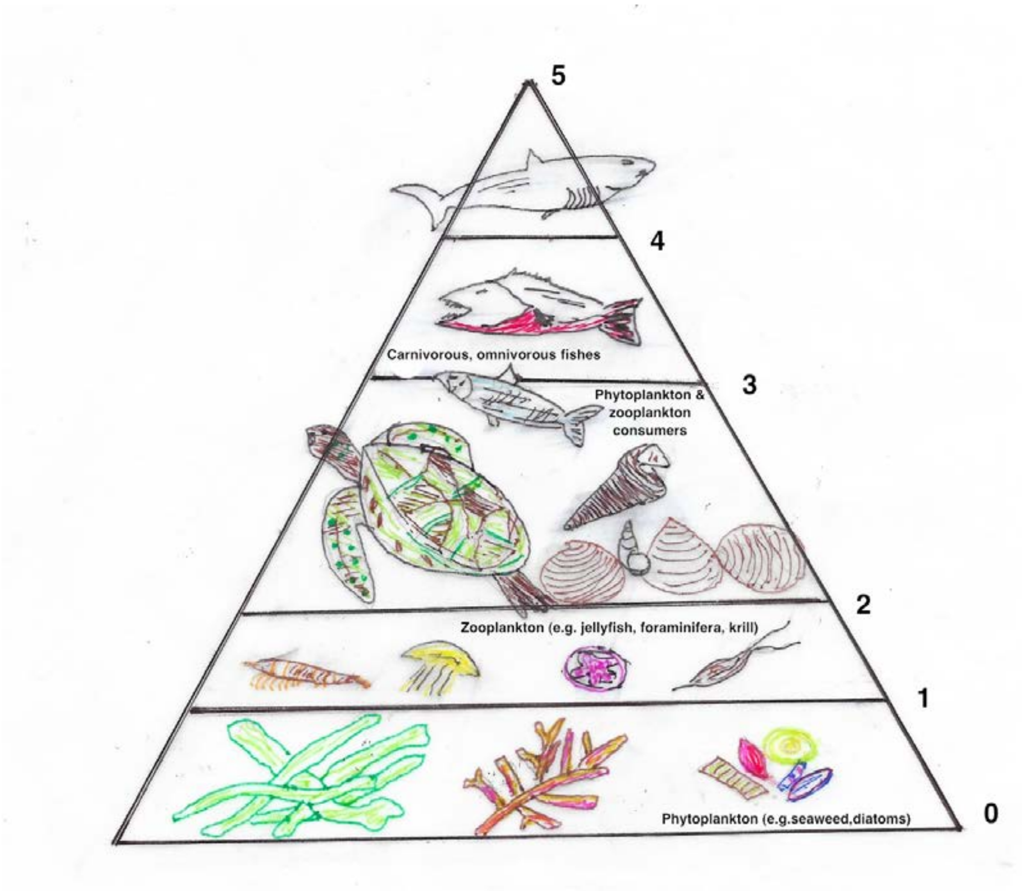


Figure 5.1: Marine trophic pyramid (after Elton 1927).

An example of trophic cascading is demonstrated by the near collapse of southern California kelp forest ecosystems. Kelp forests support herbivorous sea urchins and abalones; the sea urchins are in turn food for sea otters, lobsters and large fishes (Steneck *et al.* 2002; Tegner and Dayton 2000). Exploitation of these otters began about 8,000-10,000 BP followed much later by the fur trade, which eventually eliminated the mammals by the early 1800s (Erlandson *et al.*

2005; Ogden 1941). Removing just one of these predatory species did not have a detrimental effect on the ecosystem because other species of the same trophic level continued to regulate urchins. However, the intense exploitation and ecological extinction of spiny lobsters and abalone starting in the 1950s left sea urchins without predators and allowed them to devour the kelp forests (Dayton *et al.* 1998). Subsequent fishing of sea urchins in the 1970s and 1980s enabled kelp forests to return but the ecosystems in many areas now effectively lack trophic levels higher than that of primary producer – an organism that produces its own energy without consuming other organisms (Tegner and Dayton 1991). Similar events of kelp deforestation are reported from Alaska (Estes and Duggins 1995), the northwest Atlantic coastline of USA (Steneck et al. 2002), Australia (Andrew 1994) and New Zealand (Schiel 1990).

Of course trophic cascades can also result from environmental change not just human impacts, for example the impacts of El Nino/la Nina. In February 1992 the Mary River in southeast Queensland underwent two severe flood events that coincided with the decimation of 1000km^2 of seagrass meadows in Hervey Bay. This consequentially had a detrimental effect on dugong populations in the bay that feed on the seagrasses (see Rowland 1999b).

5.2.2 Applications, Limitations and Implications

Structural food web models, such as species composition, richness, biomass and ecosystem productivity, can be used to investigate the functioning of ecosystems (i.e. rules organising trophic interactions) (Belgrano *et al.* 2005) as well as responses of ecosystems to species loss (Dunne *et al.* 2002). Valuable insights have been gained about the effects of diversity, complexity, population stability and trophic cascades in an ecosystem (Cohen *et al.* 1990; Pace *et al.* 1999; Williams and Martinez 2008:512, 2000) (refer to Williams and Martinez (2008) for a comparative overview about the various models).

An early limitation of the trophic dynamic concept was the precision by which an organism could be allocated to a specific trophic level (Thompson *et al.* 2007). Assigning trophic levels in ecology was originally a simplistic scheme that involved placing organisms in predefined integral levels (see Elton 1927 and Lindeman 1942). Phytoplankton was allocated a 'Level 1'; zooplankton was 'Level 2'; fish consuming zooplankton were 'Level 3'; and fish consuming other fish would be 'Levels 4 and 5' (Thompson *et al.* 2007:612). This scheme did not take into account the fact that some zooplankton are carnivorous and thus should be assigned a trophic level higher than 'Level 2', which has a domino effect on the levels assigned to higher consumers (Rigler 1975). After decades of additional research, this limitation seems now to be mostly resolved. Essentially a more precise estimate of trophic level can be obtained by observing the diet of various organisms (Pauly *et al.* 2000:48). Based on the quantitative contribution of each prey item to the diet of the consumer, various models have been produced that use a 'flow-based' trophic position or value (e.g. Cohen *et al.* 1990; Williams and Martinez 2000; see also early work of Odum and Heald 1972). Today some critics still question whether trophic levels can accurately or usefully characterise real food webs, which they see as 'a tangled web of omnivores' above herbivore level (Thompson *et al.* 2007:612; Williams and Martinez 2000). In theory, there can also be wide biogeographic variation in the exact composition of diets as well as substantial shifts in diet during the life of most fishes. Still, Pauly and colleagues (2000:48) report that studies have found trophic level assignments generally fit more than 80% of global aquatic species.

The long-term research efforts of Pauly and colleagues have culminated in the production of a website, www.fishbase.org, an invaluable online research tool that lists trophic level values for almost all aquatic organisms. They were able to confirm the accuracy of these published values, by comparing them to trophic level data produced from isotopic analysis of fish biochemistry (Pauly *et al.* 2000:49). These studies measure nitrogen isotopes that are incorporated into the tissues of sea creatures, where it was found that the 'isotopic ratio shifts by a roughly constant amount from one trophic level to the next - no matter what species are involved' (Minagawa and Wada 1984; Pauly *et al.* 2000:49).

5.2.3 Overfishing (Resource Depression) and its Link to Trophic Cascades

The trophic level data compiled by Pauly *et al.* (2000) has since been used to analyse current and historic global fisheries. Their results cause concern as these indicate 'the average trophic level of catches has declined over the years' (Pauly *et al.* 2000:49). The emphasis has moved away from high trophic level piscivorous fish to low trophic level herbivorous fish and planktivorous invertebrates. They term this decline ''fishing down the food web' and argue that by competing with their prey for food at the lower trophic levels, people are impacting the entire marine ecosystem (Pauly *et al.* 1998:860, 2000). The continued depletion of fisheries is unsustainable and will contribute to the collapse of the ecosystem by triggering trophic cascades and lower biodiversity (Erlandson and Rick 2008:12-13).

In a subsequent paper, Jackson *et al.* (2001:32) argue that accelerated exploitation of coastal resources associated with human population growth and use of technological advancements has been the primary cause of collapsing marine ecosystems. Severe overfishing – defined as 'the reduction of a species well below the sustainable yield or to such low abundance that it may not recover even if fishing ceases' (Jackson *et al.* 2001:36) – they claim will cause ecological extinctions because the food web does not function properly (Jackson *et al.* 2001:29). Even low-level 'artisanal' fishing has been shown to have a dramatic effect on marine species populations (Pinnegar and Engelhard 2008:3; see also Jennings and Polunin 1996; Jennings *et al.* 1995). Archaeologists analysing faunal remains report that a reduction in average fish and shellfish sizes over time and even depletions of coastal resources can be linked to small-scale human foraging (e.g. Van Neer *et al.* 2002; Mannino and Thomas 2002; Reitz 2004; Wing 2001). Given that the archaeological record is a palimpsest, trophic collapses may reveal human impacts not directly recorded in the archaeological record. For example, ethnographic reports indicate dugong bones are disposed of in the sea, which account for their under-representation in middens; but an increase in the predation of dugong would mean lower grazing pressure on seagrass resulting in larger seagrass yields that support enlarged mollusc populations living in those environments.

Patterns of prehistoric 'fishing down the food web' (Pauly *et al.* 1998:860) are reported in several regions including Georgia and Florida region, USA (see Quitmyer and Reitz 2006; Reitz 2004; Reitz *et al.* 2009), Caribbean Islands (see Wing 2001) and Spain (Morales and Rosello 2004). Evidence from these investigations points to a decline in the mean trophic level of the species exploited associated with declines in the preferred species size and increases in species diversity or breadth. Wing (2001) attributed the decline in fish size as fishing pressure, which affected the age structure of target prey populations. Quitmyer and Reitz (2006) equated the increase in small-bodied prey to using more efficient mass-capture techniques (cf. Butler and Campbell 2004:336). Archaeological evidence from the California coastline is in stark contrast to this pattern. Here researchers report that the prehistoric Chumash people 'fished up the food web', focusing on low trophic level shellfish during the early and middle Holocene and then targeting finfish and pinnipeds during the late Holocene (e.g. Braje *et al.* 2007; Erlandson *et al.* 2004, 2005, 2008, 2009; Glassow and Wilcoxon 1988; Kennett 2005; Rick *et al.* 2005, 2008; Roy *et al.* 2003). The reversal coincided in part with the appearance of specialised maritime technologies (Erlandson *et al.* 2009:718; cf. Barker 2004).

5.2.4 Shifting Baseline

Erlandson, Rick and colleagues' research on California's northern Channel Islands and nearby mainland produced evidence of regional and local fisheries spanning the last 12,000 years. They attribute the foraging strategies of Chumash people and their predecessors as being more sustainable and having fewer ecological repercussions (Erlandson and Rick 2010:240). Jackson *et al.* (2001) agree that archaeological reconstructions of ancient fisheries can shed light on underlying causes and rates of ecological change. Most fishery assessments around the world have a limited perspective of recent observations within the last 50 years. Modelling studies and retrospective archaeological records from coastal ecosystems offer baselines that contrast with recent observations (Christensen *et al.* 2003; Jennings and Blanchard 2004; Pauly 1995; Sheppard 1995). The evidence suggests that many species could have been much more abundant in prehistory before humans impacted marine ecosystems, and this 'shifting baselines syndrome' (Pauly 1995:430) needs to be considered when setting future restoration targets for fisheries (Erlandson and Rick 2008:14).

5.3 Summary

This chapter has provided an overview of trophic level systems and how this concept can be used in analyses of temporal changes in ecosystems, thereby complementing processes of optimal foraging theory presented in the previous chapter. The premise works on identifying trophic cascades: the net effect of indirect changes in a food web or ecosystem caused by direct changes to one or more species that can alter the abundance, distribution or biomass in the trophic levels. The trophic level data compiled by Pauly *et al.* (2000) are used to analyse current and historic global fisheries and quantify long-term fishing impacts. This approach is proving to be useful quantitative heuristic for measuring long-term impacts on marine ecosystems.

Chapter 6. Methods of Investigation

6.1 Introduction

This chapter describes the scientific analytical procedures adopted for identifying, quantifying and understanding changes in the archaeological marine faunal remains assessed in this study.

6.2 Taphonomy, Sampling, Identification and Quantification: General Considerations

This section addresses general issues that affect the preservation of coastal archaeological sites, as well as specific taphonomic issues relating to the analysis and interpretation of archaeo-faunas.

6.2.1 Taphonomy

Faunal remains are susceptible to differential preservation, which has been cited to explain under/over-representation of various taxa in archaeological assemblages (Claassen 1998; Lyman 1994b). Recovery depends on a number of factors; for example, fish taxa with large, robust elements (e.g. carnivorous species) are more likely to be recovered than taxa with smaller diagnostic skeletal elements (Colley 1990:215; Nagaoka 2005b). O'Connell *et al.* (1988) established through ethnoarchaeology that differential bone transport has an effect on skeletal part representation. Many fish are small enough to be processed and eaten whole, which could also pose problems with determining the nature of deposits (Colley 1990). Other human foraging strategies can also have a detrimental effect on bone survivability; for example ethnographic studies indicate that after each meal Kaiadilt people placed all such remains in a fire in a cleaning ritual (Tindale, June 7 1960). It is apparent that any investigations aimed at reconstructing past subsistence patterns based on analysis of coastal assemblages may be challenging (Sullivan 1993:31-32). The alteration or differential loss of molluscan and other marine taxa will affect the accuracy of any dietary or subsistence reconstructions (Faulkner 2011a, 2011b; Jerradino and Navarro 2008). Variability in shell or bone fragmentation caused by differential robustness, physical degradation and/or chemical alteration in archaeological deposits will have consequences for relative abundance estimates (NISP, MNI and weight) (Mowat 1995; Szabó 2009:186). The effects of differential fragmentation have been highlighted in taxa size class studies aimed at investigating the potential impacts of human predation (Faulkner 2011b:118). Such degradation is also problematic for trying to differentiate cultural and natural processes of site formation (Grayson 1984; Mowat 1995; Stein 1992). Some authors advise that studying archaeological fish remains involves consideration of not only taphonomy but also issues in sampling, identification and quantification (see Casteel 1976; Colley 1990; Nagaoka 2005b).

6.2.2 Sampling

A study by Colley and Jones (1987) illustrates how the variability of inter/intra-site sampling can influence archaeological interpretations. Therefore, care needs to be taken when treating archaeological assemblages from a test-pit as representative of the whole site and region because different activities may have been carried out at different sites or even different parts of a site. Controlled screening experiments have demonstrated the significant biases that screen-mesh size can have in fishbone recovery (see Casteel 1972; Nagaoka 2005b). Vale and Gargett (2002) utilised 6mm, 3mm, and 1mm screens for their Arrawarra I Project, which resulted in a well-recovered fishbone assemblage, except that the bones retained in the 3mm and 1mm mesh were highly fragmented and difficult to identify (see also Ross and Duffy 2000). Ross and Tomkins (2011) noted that although fishbones collected in the <3mm mesh sieves were difficult to identify to family or species level they could still inform on overall estimations of fish contributions to the hunter-gatherers' diet.

6.2.3 Identification

In Pacific tropical waters, there is great diversity among hundreds of marine species, many endemic to single locations (Johnson and Gill 2005; Malcolm 1998). It is therefore paramount for the analyst to have access to a comprehensive fish osteological and reference collection containing disarticulated skeletons of a wide range of species and sizes of fish, as well as otoliths wherever possible (Casteel 1976; Colley 1990:210). Otoliths can provide good information regarding identification, size and age estimation, and season of death for fishes (Casteel 1976; Weisler 1993). Butler has expressed concern that identification bias may occur if only those fish families present in the reference collection are counted; some species represented in archaeological sites remain unidentified because the analysts do not recognise diagnostic characteristics of the element (Butler 1994). Analysing mollusca can be done through comparison with photographs and descriptions in several reference texts (Abbott and Dance 1998; Carpenter and Niem 1998; Lamprell and Healy 1998; Lamprell and Whitehead 1992). However, it is advisable to use a modern and archaeological shell reference collection as well. Nomenclature of taxa in this document is consistent with current names in the World Register of Marine Species available online. In some cases the names have been updated since previous archaeological and biological studies were published, so some taxa will have both names recorded initially so as to assimilate the reader with information previously published.

6.2.4 Quantification

Debate abounds regarding the best methods of quantifying archaeo-faunal materials, so it is important to consider strengths and limitations of counting methods in faunal analysis (e.g. Claassen 2000; Glassow 2000; Mason *et al.* 1998, 2000). Differences in the way that various investigators calculate a measurement can cause problems when making comparisons between sites (Ulm 2002). 'Specimen' can be defined as element or fragment or taxon, so archaeologists should specify criteria for meanings applied to NISP and MNI before interpreting (Lyman 1994:38).

The differential nature of fragmentation of shells based on robustness, meat extraction techniques and taphonomic processes inevitably affects the quality of NISP abundance measures (Szabó 2009:186). NISP can be a poor measure in cases where the assemblages are highly fragmented and can result in over- or under-representation of families. While MNI estimates can be used to counteract such distortions, there are considerable problems associated with their calculation and interpretation (Grayson 1984). In circumstances where identification and quantification is done based on more than one element, the problem of 'division in aggregates' that occurs when each excavation unit is treated as a stratigraphic unit (Grayson 1984:29-49) can cause an over-estimation of numbers, especially if one individual is scattered over several units (Grayson 1984:29). Side matching (left and right) for MNI has the effect of reducing MNI; alternatively unmatched parts have been shown to inflate figures (Lyman 1994). Shell weight has been beneficial for informing on the relative contributions of each taxon to shell densities per stratigraphic and excavation unit, however shell weight as a measure is problematic because some mollusca that have robust heavy shells may not have much meat, and conversely other mollusca may be meaty but have frail shells (Szabó 2009:187; see also Meehan 1982).

There is no simple method for quantifying the relative dietary contribution of fish from faunal remains although estimates of an individual's or aggregate's weight can be attempted (see Casteel 1976; Nichol and Wild 1984). Archaeological fish bone specimens can be compared with bones in an osteological reference collection that come from fish for which the metric size and weight is known. Published handbooks (e.g. Yearsley *et al.* 2001) also provide detailed information about the nutritional values (i.e. protein, carbohydrate and fat content) of Australian domestic seafood species.

6.3 Data Collection Strategy and Methods

6.3.1 Survey and Site Selection

The physical dataset comprises archaeological marine fauna assemblages sampled from eight archaeological sites in the South Wellesley Islands. These sites have been initially identified and recorded during pedestrian survey transects using standard archaeological survey techniques (i.e. random transects walked across various geographical areas of the islands structured by access restrictions (e.g. permissions by Traditional Owners, safety considerations etc). For each site a description is recorded in a field notebook, along with GPS coordinates for mapping and surface archaeological samples are collected for dating purposes. Some sites considered to contain stratigraphic deposits were then selected for excavation to obtain subsurface archaeological materials that can be analysed to provide more detailed evidence regarding past human occupation of the site. Site selection is based on a number of variables such as the site is representative of other sites in the area and the site exhibits the best evidence to hold in situ and relatively undisturbed archaeological deposits. Due to time and budgetary constraints only a small sample of the total archaeological sites discovered were excavated.

6.3.2 Archaeological Excavations

Standard archaeological 50cm x 50cm x c.60-90cm (deep) test pits were carefully hand-dug in thin excavation units of 2.5 – 3.0cm depths within stratigraphic units (SUs), which provide temporal (time) and spatial (space) controls over the recovered assemblage. All material was removed from each excavation unit and collected in a bucket that was weighed and then sieved through 2.3mm mesh to remove excess soil. The remaining archaeological materials retained in the sieve were then bagged and sequentially numbered. A sample of soil from each excavation unit was collected to provide micro-palaeoenvironmental samples (e.g. forams, pollen, phytoliths). Standard colorimetric pH tests, grain size and colour descriptions were recorded for every excavation unit. A detailed description is recorded of the site location, excavation methods and observed conditions for each excavation unit. All materials stored in bags were taken back to the laboratory for processing.

6.4 Radiocarbon Dating and Age/Depth Relationship Models

Chronological trends are of particular importance in this study and along with AMS radiocarbon dates obtained on specific site start and site termination samples, the site excavation units provide relative ages for assemblage materials. For the overall project of which this study forms a part, 29 AMS ages were undertaken at the ANTARES AMS facility at ANSTO and 159 samples were measured at the Waikato Radiocarbon Laboratory. The author assisted with the preparation of 15 marine shell samples at the AMS facility at ANSTO under the supervision of

Geraldine Jacobsen in May 2012. A variety of sample types were dated for the larger project including marine shell, foraminifera, fish otoliths, pollen concentrates, coral and charcoal. For all archaeological sites analysed marine shell samples and fish otoliths were used as the main reference ages, with other dates providing supporting background information. Radiocarbon ages were calibrated using OxCal 4.2 (Bronk Ramsey 2009) and the Marine13 dataset (Reimer *et al.* 2013), with a ΔR of -49±102 ^{14}C years for marine samples from the Gulf of Carpentaria (Ulm *et al.* in prep.). All calibrated ages are reported at the 95.4% probability range. Since the Gulf of Carpentaria has a maximum depth of <70m (Torgersen *et al.* 1983), marine organisms are assumed to have ^{14}C activities close to coeval surface waters indicating that dates should not be impacted by the marine reservoir effect (Broecker *et al.* 1984:339).

As I am particularly interested in potential changes through time, the assemblages from each site in Chapters 7-14 have been divided into temporal phases of 250-year periods for comparative purposes. Excavation units were assigned to chronological periods based on an age/depth model derived from the calibrated radiocarbon ages and stratigraphic observations, interpolating between individual data points. All calibrated radiocarbon ages for each site are displayed in tabular format along with depths from which the dates were obtained (See Chapters 7-14). The age/depth relationship graph for all radiocarbon ages obtained for each site is presented alongside a stratigraphic profile for the site. The method for deriving the age/depth linear relationship model or curve requires plotting the series of calibrated ages on an X-axis against the depth from which the dated shellfish specimen was collected on the Y-axis. The resulting trendline formula is then used (by inserting X=250, 500, 750 etc) to solve for Y=depth of the 250-year breaks and therefore assign the associated excavation units (XUs). In doing so I am then able to divide the contents of the assemblage for temporal comparisons. Even though time-averaging these open shell deposits only allows for identification of broad-scale trends and not subtle changes, it allows determination of variation in relative taxa abundance, indicative of taxa exploitation patterns and/or environmental changes affecting the distribution of taxa.

6.5 Laboratory Methods and Analyses

6.5.1 Laboratory Processing

In the laboratory for each excavation unit from each square, materials were reviewed individually to ensure materials are not contaminated. The materials were first separated into types (i.e. shell, bone, stone, flora, soil containing micro-palaeoenvironmental samples). The marine fauna assemblages, represented by invertebrate remains (shell) and vertebrate remains (bone), made up the primary data to be analysed for this project. The remainder of materials was distributed to other scientific specialists involved in the overall ARC Discovery Project who conducted their own analyses and supplied supporting information to assist my understanding and interpreting results of the current project.

6.5.2 Non-Quantitative Data Collection

The non-quantitative part of primary data collection includes taxonomic identification and determining skeletal element representation for all marine fauna present in assemblage(s). The identification and analysis of faunal remains classically follow standard zooarchaeological procedures as set out in Reitz and Wing (2008). This step begins with a preliminary classification of fauna into classes (i.e. Mammalia, Aves, Amphibia, Reptilia, Chondrichthyes, Osteichthyes, Gastropoda, Bivalvia etc) within each provenance (excavation unit/site). Use of reference manuals and comparative collections of modern remains is vital to the next steps that involve identifying the remains to the lowest taxonomic level (i.e. Family, Genus, species) and also identifying each specific element (e.g. right or left valve for Bivalvia; apex or aperture for Gastropoda; and skeletal element – otolith, dentary etc – for Osteichthyes and other classes). The JCU Tropical Archaeology Research Laboratory (TARL) houses two comprehensive marine fauna reference collections that are used for comparison of the faunal remains recovered in the archaeological assemblages. The author and colleagues specifically collected these materials to provide reference materials for studies focusing on the analysis of marine faunal materials from the South Wellesley Islands. Table 6.1 lists the taxa included in the fish skeletal reference collection (n=52). The collection contains more than one skeleton for some species, as different sized specimens are included to facilitate age/size determinations of archaeological specimens. Table 6.2 lists the taxa included in the molluscan fauna collection (n=68). The majority of specimens in the collections were obtained during periods of fieldwork in the South Wellesley Islands by the author and colleagues involved in this research project.

Table 6.1 TARL Fish Reference Collection.

Ref. No.	TAXON	FAMILY	COMMON NAME
1	*Scomberoides commersonnianus*	Carangidae	Talang Queenfish
2	*Scomberoides commersonnianus*	Carangidae	Talang Queenfish
3	*Carcharhinus limbatus*	Carcharhinidae	Blacktip Shark
4	*Acanthopagrus latus*	Sparidae	Western Yellowfin Bream
5	*Liza vaigiensis*	Mugilidae	Diamond Scale Mullet
6	*Liza vaigiensis*	Mugilidae	Diamond Scale Mullet
7	*Caranx papuensis*	Carangidae	Brassy Trevally
8	*Lethrinus laticuadis*	Lethrinidae	Grass Emperor, snapper bream
9	*Lutjanus carponotatus*	Lutjanidae	Stripey, Chalk Fish
10	*Platycephalus arenarius*	Platycephalidae	Northern sand flathead

Ref. No.	TAXON	FAMILY	COMMON NAME
11	*Pomadasys kaakan*	Haemulidae	Spotted grunter bream, Javelin Fish
12	*Lethrinus laticaudis*	Lethrinidae	Grass Emperor, snapper bream
13	*Lethrinus laticaudis*	Lethrinidae	Grass Emperor, snapper bream
14	*Carcharhinus amblyrhynchos*	Carcharhinidae	Long nosed grey Shark
15	*Lutjanus johnii*	Lutjanidae	Fingermark
16	*Lutjanus sebae*	Lutjanidae	Red Emperor
17	*Epinephelus coiodes*	Serranidae	Estuary Rockcod (small)
18	*Epinephelus coiodes*	Serranidae	Estuary Rockcod
19	*Polydactylus sheridani*	Polynemidae	King Threadfin Salmon
20	*Scomberoides commersonnianus*	Carangidae	Talang Queenfish
21	*Lutjanus johnii*	Lutjanidae	Fingermark
22	*Arius graeffei*	Ariidae	Catfish
23	*Acanthopagrus berda*	Sparidae	Black Bream
24	*Amniataba caudovittatus*	Terapontidae	Yellow Tail Trumpeter
25	*Arrhamphus sclerolpsis*	Hemiramphidae	Snubnosed garfish
26	*Elops hawaiiensis*	Elopidae	Giant Herring
27	*Plectropomus leopardus*	Serranidae	Coral Trout
28	*Lutjanus johnii*	Lutjanidae	Fingermark
29	*Choerodon cyanodus*	Labridae	Blue tuskfish
30	*Lutjanus carponotatus*	Lutjanidae	Stripey, Chalk Fish
31	*Epinephelus coiodes*	Serranidae	Estuary Rockcod
32	*Lutjanus carponotatus*	Lutjanidae	Stripey, Chalk Fish
33	*Plectropomus leopardus*	Serranidae	Coral Trout
34	*Sphyraena barracuda*	Sphyraenidae	Barracuda
35	*Caranx ignobilis*	Carangidae	Giant Trevally
36	*Scombeeromorus commerson*	Scombridae	Narrow-barred Spanish Mackeral
37	*Lates calcarifer*	Latidae	Barramundi
38	*Lutjanus russellii*	Lutjanidae	Moses Perch
39	*Mugil cephalus*	Mugilidae	Sea Mullet
40	*Gerres subfasciatus*	Gerridae	Silver Biddy
41	*Gerres subfasciatus*	Gerridae	Silver Biddy
42	*Sillago maculata*	Sillaginidae	Whiting
43	*Sillago maculata*	Sillaginidae	Whiting
44	*Rachycentron canadum*	Rachycentridae	Cobia Black Kingfish
45	*Tylosurus gavialoides*	Belonidae	Longtom
46	*Tylosurus gavialoides*	Belonidae	Longtom
47	*Epinephelus coiodes*	Serranidae	Goldspotted Rockcod

Ref. No.	TAXON	FAMILY	COMMON NAME
48	*Epinephelus malabaricus*	Serranidae	Blackspotted Rockcod
49	*Choerodon schoenleinii*	Labridae	Black-spot Tuskfish
50	*Pomadasys kaakan*	Haemulidae	Spotted grunter bream, Javelin Fish
51	*Plectropomus maculatus*	Serranidae	Barcheek Coral Trout
52	*Caranx bucculentus*	Carangidae	Bluespotted Trevally

Table 6.2 TARL Molluscan Fauna Reference Collection.

Ref. No.	TAXON	FAMILY	COMMON NAME
1	*Acrosterigma reeveanum*	Cardiidae	Pacific cockle
2	*Anadara antiquata*	Arcidae	Antique ark
3	*Anadara rufescens*	Arcidae	Red-tinged ark
4	*Arca* sp.	Arcidae	Ark shell
5	*Asaphis violascens*	Psammobidae	Pacific asaphis
6	*Barbatia* sp.	Arcidae	Decussate ark
7	*Beguina semiobiculata*	Carditidae	Halfround cardita
8	*Calliostoma* sp.	Calliostomatidae	Top snails
9	Cardiidae	Cardiidae	Cockle
10	*Cerithidea cingulata*	Potamididae	Girdled horn shell
11	*Cerithidea largillierti*	Potamididae	Horn snail
12	Cerithidea sp.	Potamididae	Ceriths
13	*Cerithium coralium*	Cerithiidae	Coral cerith
14	*Chama sp.*	Chamidae	Jewel box shells
15	*Circe scripta*	Veneridae	Script venus
16	*Clypeomorus* sp.	Cerithiidae	Necklace cerith
17	*Codakia tigerina*	Lucinidae	Pacific tiger lucine
18	*Corbula fortisulcata*	Corbulidae	Basket shell
19	*Cypraea* sp.	Cypraeaidae	Cowrie shell
20	*Ellobium* sp.	Ellobiidae	Cassidula
21	*Euchelus atratus*	Chilodontidae	Black margarite
22	*Gafrarium pectinatum*	Veneridae	Comb / tumid venus
23	*Geloina erosa*	Corbiculidae	Mudshell
24	*Glauconome virens*	Glauconomidae	Green mangrove mussel
25	*Irus sp.*	Veneridae	Irus venus
26	*Isognomon isognomon*	Isognomonidae	Tree oysters
27	*Littoraria scabra*	Littorinidae	Periwinkle
28	*Lunulicardia hemicardium*	Cardiidae	Pacific half cockle
29	*Lunella cinerea*	Turbinidae	Smooth moon turban
30	*Mactra* sp.	Mactridae	Trough shells
31	*Mactra dissimilis*	Mactridae	Dissimilar trough shell

Ref. No.	TAXON	FAMILY	COMMON NAME
32	*Marcia hiantina*	Veneridae	Hiant venus shell
33	*Melo amphora*	Volutidae	Baler shell
34	*Mitra* sp.	Mitridae	Miter shell
35	*Mitrella scripta*	Collumbellidae	Dotted dove shell
36	Mytilidae	Mytilidae	Sea mussels
37	*Nassarius coronatus*	Nassariidae	Coronate dog whelk
38	*Nassarius* sp.	Nassariidae	Dog whelk snails
39	*Natica gualteriana*	Naticidae	Gualteri's moon snail
40	*Neotrapezium sublaevigatum*	Trapezidae	Trapezium cardita
41	*Nerita balteata*	Neritidae	Black nerite
42	*Nerita planospira*	Neritidae	Flat-spired nerite
43	*Nerita* sp.	Neritidae	Nerite snails
44	*Nerita undata*	Neritidae	Waved nerite
45	*Oliva lignaria*	Olivadae	Olive shell
46	Patellidae	Patellidae	Limpit
47	*Pinctada sp.*	Pteridae	Pearl oyster
48	*Pinnidae*	Pinnidae	Pen shell
49	*Pitar pellucidus*	Veneridae	Pellucid venus clam
50	*Placamen retroversum*	Veneridae	Tiar venus clam
51	*Placuna placenta*	Placunidae	Wndowpane oyster
52	*Planaxis sulcatus*	Planaxidae	Furrowed clusterwinkle
53	*Polinices sp.*	Naticidae	Moon snail
54	*Saccostrea glomerata*	Ostreidae	Rock oyster
55	*Pyrene* sp.	Collumbellidae	Dove shell
56	*Rhinoclavis* sp.	Cerithidae	Vertagus
56	*Semele sinensis*	Semelidae	Semele shell
57	*Solen* sp.	Solenidae	Razor clam
58	*Strombus* sp.	Strombidae	Stromb shell
59	*Tegillarca granosa*	Arcidae	Granulated ark
60	*Telescopium telescopium*	Potamididae	Longbum
61	*Tellina* sp.	Tellinidae	Tellin
62	*Terebralia palustris*	Potamididae	Mud creeper
63	*Terebralia sulcata*	Potamididae	Sulcate swamp cerith
64	*Trisidos tortuosa*	Arcidae	Tortured ark
65	*Trochus* sp.	Trochidae	Top shell
66	*Turbo* sp.	Turbinidae	Turban snail
67	*Turitella terebra*	Turitellidae	Turret shell
68	*Volegalea cochlidium*	Melongenidae	Spiral melongena

For every species/biological class present in the assemblage the author has determined its patch or known preferred habitat (e.g. coral reefs, pelagic, estuarine for fishes and rocky reefs, mangroves and upper tidal muds, inshore sand-mud flats for molluscs) and its marine trophic level, based on published scientific data (e.g. Pauly *et al.* 1998, 2000). Appendices 1 and 2 include information about taxa preferred habitat environments. More details about the fish skeletal remains collection has also been published by Tomkins *et al.* (2013). All data are recorded in Excel worksheets along with primary quantitative data discussed below.

6.5.3 Quantitative Data Collection

Measuring relative abundance is a principle objective of this project. Primary quantitative data to be recorded include standard zooarchaeological metrics:

- NISP – Number of Identified Specimens (count of each archaeological specimen identified in assemblage that can be matched to a taxon);
- MNI – Minimum Number of Individuals (estimate of smallest number of individuals that could account for the skeletal elements in the assemblage. Calculated using elements that only occur once in an individual); and
- Weights – g/kg are recorded for each taxon or biological classification in each excavation unit.

In order to determine size changes through time of the dominant shell taxon, metric length (mm) measurements of intact *Marcia hiantina* bivalve specimens are carried out using conventions established by other researchers (Bailey and Craighead 2003:187; Claassen 1998:108; Peacock 2000:189; Spenneman 1987:85). Figure 6.1 shows the dimensions that are consistently measured and recorded for each specimen using a set of digital callipers. Length (mm) measurements are also taken of each intact skeletal element used for the vertebrate MNI determinations. These measurements are then compared with the sizes of similar samples from the TARL Fish Reference Collection in order to estimate body weight of the archaeological fish specimen. The estimates are made using allometric formulas (see Tables 6.3 and 6.4 below) derived from the known measurements (length-weight) of the reference samples.

Analysis of primary data values will then be undertaken using statistical measures and ecological models (see Tables 6.3 and 6.4). This secondary stage quantitative data will focus on addressing proposed aims and outcomes of this project in order to answer research questions. These data will come directly from field survey results and will be displayed in the form of a GIS-generated map with accompanying site descriptions.

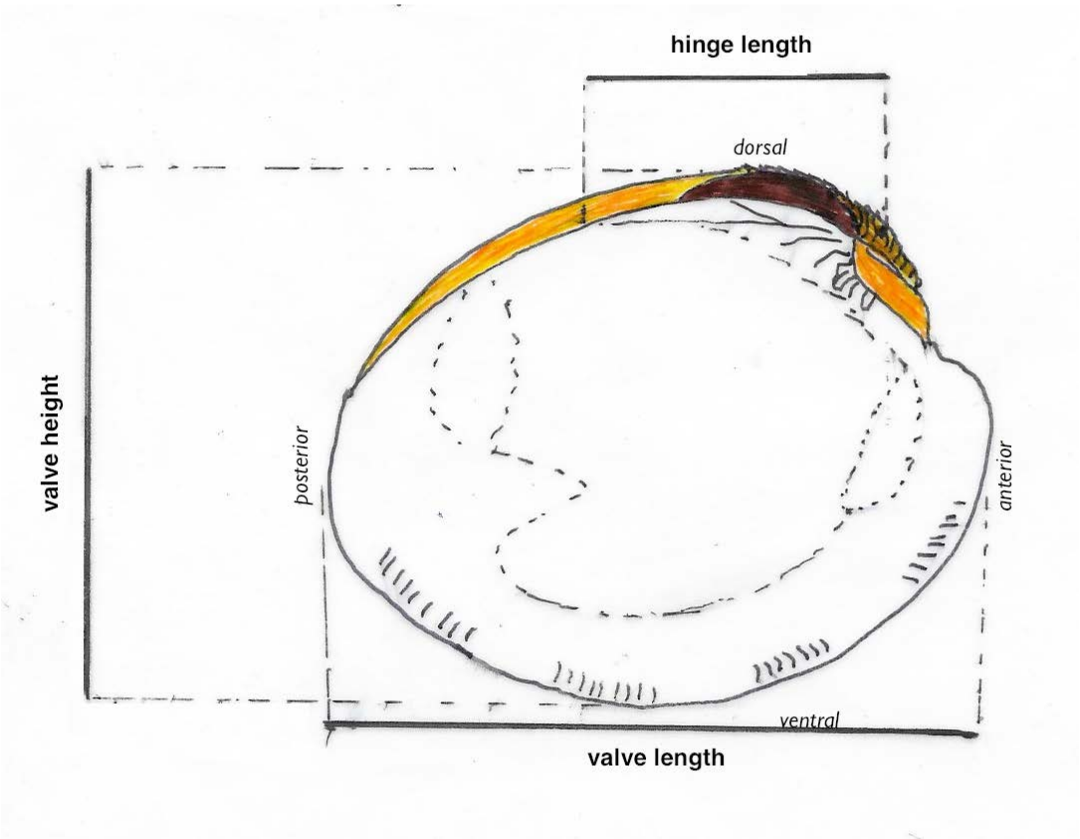


Figure 6.1 ***Marcia hiantina*** **standard valve measurements.**

Aim 1: Identify and document Aboriginal archaeological sites in the study area in order to increase the regional archaeological knowledge and provide insights into late Holocene cultural changes in tropical Australia.

Aim 2: Employ a suite of models informed by an underlying ecological theoretical basis in order to assess the effects of past human interaction with marine ecosystems as evidenced in the archaeological record. Analysis of the archaeological deposits will provide evidence of human diet, in particular, prey selection choices and habitat exploitation patterns through time.

Proposed Outcome A: Identify evidence of human subsistence strategies, in particular, the diversity of marine species types exploited (diet-breadth) and patterns of habitat (patch) exploitation through time.

Established foraging theory models (as discussed in literature review) can be used to generate predictions about human subsistence change in response to different variables. These models are covered in Chapter 4. Predictions lead to hypotheses generation, which can be tested using standard statistical analysis methods (see Tables 6.3 and 6.4).

Table 6.3 Analytical tools for measuring diversity in diet breadth, patterns of patch exploitation and foraging efficiency.

Evidence to Measure	Analytical Tool	Expected Result	Other Tests (if required)
Diet breadth (marine species diversity)	Shannon Weaver function $H' = -\sum_{i-1}^{R} p_i \log p_i$ where: H' = information content of the sample (can be biomass, MNI) p_i = the relative abundance of the i^{th} taxon within the sample Log p_i = the logarithm of p_i - this can be to the base 2, e, or 10. expressed as $e^{H'}$ Shannon entropy values: 0.1 = only one species 1/R = all species equal 5 = very high diversity	If diet breadth is increasing we should see higher $e^{H'}$ values. If few species are targeted we should see low values (e.g. Nagaoka 2002b, 2001; Butler 2001).	Correlation test for 1. abundance to stratum; 2. abundance to sample size Spearman's rho test* $\rho = 1 - (6\ \Sigma d_i^2 / n(n^2-1))$ null hypothesis H_0 = no association between taxa diversity and excavation unit *Spearman's rho is used as MNI, and relative abundance values derived from them, are best treated as ordinal scale measures (Grayson 1984). Excavation units arbitrarily assigned values 1-n where 1 is upper (youngest) zone and n is deepest (oldest) zone.
Diet breadth (marine species diversity)	Regression correlation or relationship between richness (NTAXA) and sample size (MNI) Slope & intercept of the regression line reflect rate at which taxa are added as sample size increases. Variance in these values can be compared.	If diet breadth is increasing, we expect regression coefficients describing the relationships between NTAXA and MNI to increase significantly (e.g. Grayson and Delpech 1998).	Correlation test for 1. abundance to stratum; 2. abundance to sample size Spearman's rho test* $\rho = 1 - (6\ \Sigma d_i^2 / n(n^2-1))$ null hypothesis H_0 = there is no association between the two variables (ie. taxa richness and excavation unit)

Foraging Efficiency	Resource Use Index: Σ Large shell taxon / (Σ Large shell taxon + Σ Small shell taxon) values: 1=all high-ranked taxon 0=all low-ranked taxon Also determined within a taxon by estimating specimen biomass using allometric measures (see Table 5.2 below)	A decline in foraging efficiency is seen as a decline in large-bodied taxa relative to small-bodied taxa plotted across site strata (excavation units) ie. reduced index values over time. (e.g. Broughton 1997; Broughton *et al.* 2011; Cannon 2000)	Spearman's rho test* $\rho = 1 - (6\ \Sigma d_i^2 / n(n^2-1))$ null hypothesis H_0 = there is no association between the two variables (ie. taxa size and excavation unit)
Foraging Efficiency	Patch Use Index: Σ taxon from Patch A / (Σ taxon Patch A + Σ taxon Patch B) values: 1 = all Patch A taxon 0 = all Patch B taxon	A decline in index indicates a shift from Patch A taxon to Patch B taxon that can reflect an overall decline in foraging efficiency, as well as a shift in time allocation across patches (e.g. Nagaoka 2002b).	Spearman's rho test* $\rho = 1 - (6\ \Sigma d_i^2 / n(n^2-1))$ null hypothesis H_0 = there is no association between the two variables (ie. patch selection and excavation unit)

Aim 3: Utilise marine trophic level analysis, a technique not previously applied in the Australian archaeology arena, in order to understand the human impacts on local ecologies.

Proposed Outcome B: Characterise temporal changes in the biomass contribution and population structure of one particular species through the development of taxa size/age profiles.

Proposed Outcome C: Identify and assess changes in marine trophic levels exploited and potential evidence of trophic cascades in the local ecosystem(s) in order to determine anthropogenic effects on local ecologies.

Sample biomass refers to the estimated total body weight of an organism represented by the archaeological specimen (Reitz *et al.* 1987; Reitz and Wing 2008). Sample biomass estimates are calculated using specimen weights and the regression formula described in Table 6.4 below.

Table 6.4 Analytical tools for calculating biomass and mean trophic level of biomass.

Evidence to measure	Analytical Tool	Expected Result
Biomass (calculation 1) contribution represented by individual archaeological specimen	Straight line regression equation based on allometric form $Y=a(X^b)$ (Schmidt-Nielsen 1984) where: Y = estimated body weight X = measurement of element a = the Y - intercept of linear regression line b = slope of regression line transformed using a common log $\log Y=\log a+b\ (\log X)$	Allometric constants are used to estimate body weight or standard lengths (Wing 2001). Generally the relationship between fish length and otolith length is linear (Harvey *et al.* 2000:3). Usable meat weight (MTWT) is assumed to represent 70% of mean body weight per fish taxon, following White (1953).
Biomass (calculation 2) for whole species catch	Value of biomass calculation 1 x MNI for species and summing total for each patch $\Sigma\ (Y^*MNI)$	Estimate of biomass of the catch for each species. Done by multiplying the average estimated weight of the individuals in each species by MNI (e.g. Wing 2001).
Mean Trophic Level of Biomass	Mean trophic level (TL) formula: $TL_i = \Sigma_{ij}\ TL_{ij}\ Y_{ij} / \Sigma\ Y_{ij}$ where: TL_i = mean trophic level for time period i Y_i = landings by trophic levels of individual species groups j mean trophic level index (available at http://www.fishbase.org) (Pauly *et al.* 1998, 2000).	If mean TL calculated for early stage of occupation is greater than mean TL determined for later stage of occupation, then this indicates 'fishing down food web' and reverse suggests 'fishing up food web' (e.g. Erlandson *et al.* 2009; Pauly *et al.* 1998; Wing 2001)

Estimating the weight of the catch is the first step in calculating its mean trophic level. In archaeological deposits, this is based on surviving remains, estimated sizes of animals in the sample and the species composition. Where the biomass value is known for a specific taxon, this should be used. General class values can be used in cases where values for specific taxa are not available (e.g. see Reitz and Wing 2008:68; Wing 2001). Total body weight of an animal can be estimated by using allometry, a method based on the log–log relationship that exists between total body weight and the dimensions of supportive tissue (Reitz *et al.* 1987; Reitz and Wing 2008). These are all established routine methods in the zooarchaeological literature.

To demonstrate how the above procedures can be implemented, using the prey-choice model we can predict that high-ranked prey will be preferable over low-ranked prey, so they are particularly susceptible to resource depression. Foraging efforts concentrated on high-ranked taxa will result in a high foraging efficiency (the net return rate per unit time) (Smith 1991). As encounter rates with high-ranked resources decline, these taxa will contribute proportionally less to the diet, causing foraging efficiency to decline. If the mean foraging return rate drops to the point where it is beneficial to add lower-ranked taxa to the diet, then diet breadth (the number of species incorporated in the diet) may increase (Nagaoka 2002b:86). Archaeological studies illustrate that where resource intensification of a fishery occurs we can expect to see a progressive decline in the average size and abundance of high-ranked resources accompanied by an increase in low-ranked resources (Butler 2001; Morrison and Hunt 2007; Nagaoka 2001, 2002b, 2005b). Researchers (e.g. Broughton 2007; Hames & Vickers 1982; Hawkes *et al.* 1982) show that prey body size is a proxy measure of prey rank or profitability. Temporal changes in the frequency of large and small-bodied fishes should reflect general changes in fish resource use as a whole. Exploitation depression can also be measured directly through a study of the demographic structure of prey populations.

6.6 Summary

The methods and procedures discussed in this chapter have been applied consistently for collecting, handling, measuring and quantifying the faunal material data presented in Part III of this thesis. Analytical tools outlined in Tables 6.3 and 6.4 explain the process for investigating the faunal material data in Part IV to address the main aims and outcome of this research as outlined above.

PART III: SITES AND SITE ASSEMBLAGES

Chapter 7. Dangkankuruwuru, Bentinck Island

7.1 Introduction

This chapter reports on archaeological investigations at Dangkankuruwuru, an Aboriginal occupation site located on a high ridge along the southwest coastline of Bentinck Island. Findings are consistent with the projected trajectory of island settlement, showing repeated deposition of cultural materials from around 1,500 years ago until c.100 years ago.

7.2 Site Description and Setting

Dangkankuruwuru (also Dankonarupai, Tindale 1962a) is a large, stratified shell midden deposit intermittently exposed across the surface of the northwest end of a high beach ridge, which runs roughly parallel to the modern coastline (NNE-SSW) along the southwest corner of Bentinck Island (Figures 7.1 -7.2). The site covers a minimum area of c.10,500m^2 (150m long x 70m wide). The site is situated c.700m from the present-day shoreline (Latitude: 17.10729E; Longitude: 139.42189S). Several dunes and swales lie between the beach ridge and the shoreline on which the Dangkankuruwuru site is located (Figure 7.3).

The ridge is over 9m in elevation and is made up of shelly and quartz sands held together by spinifex grasses (Figures 7.4-7.7). Local vegetation includes occasional pandanus trees on the highest part of the ridge, with well-established eucalypts, melaleuca and acacia trees on its margins. An extensive low-lying salt claypan abuts the inland margin of the beach ridge. On the northeastern side of the beach ridge is a small unnamed tidal creek, rich with mangrove vegetation. The shoreline has a dense mangrove fringe that forms a barrier to the sea, comprising red stilt-root mangrove (*Rhizophora stylosa*), yellow mangrove (*Ceriops togal*) orange mangroves (*Bruguiera* spp.) and grey mangroves (*Avicennia marina*) (Wightman *et al.* 2004).

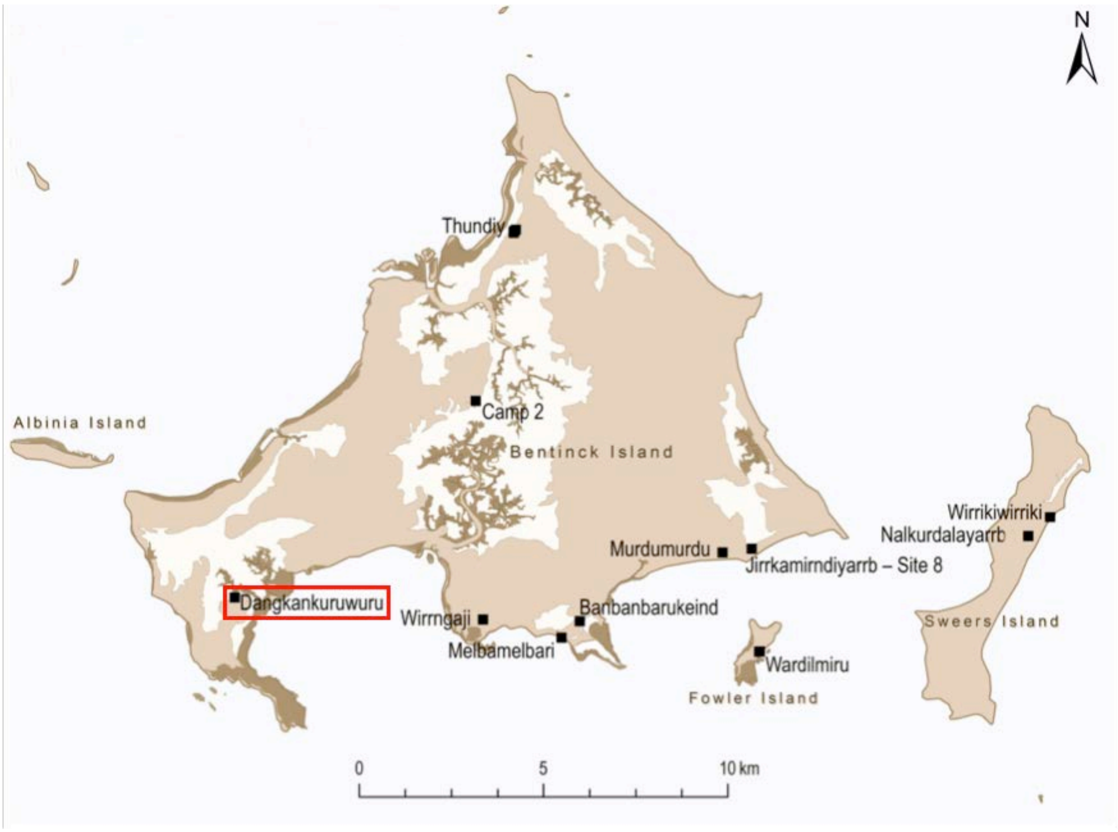


Figure 7.1: Map of South Wellesley Islands showing Dangkankuruwuru site location (map prepared by Lincoln Steinberger and Sean Ulm).

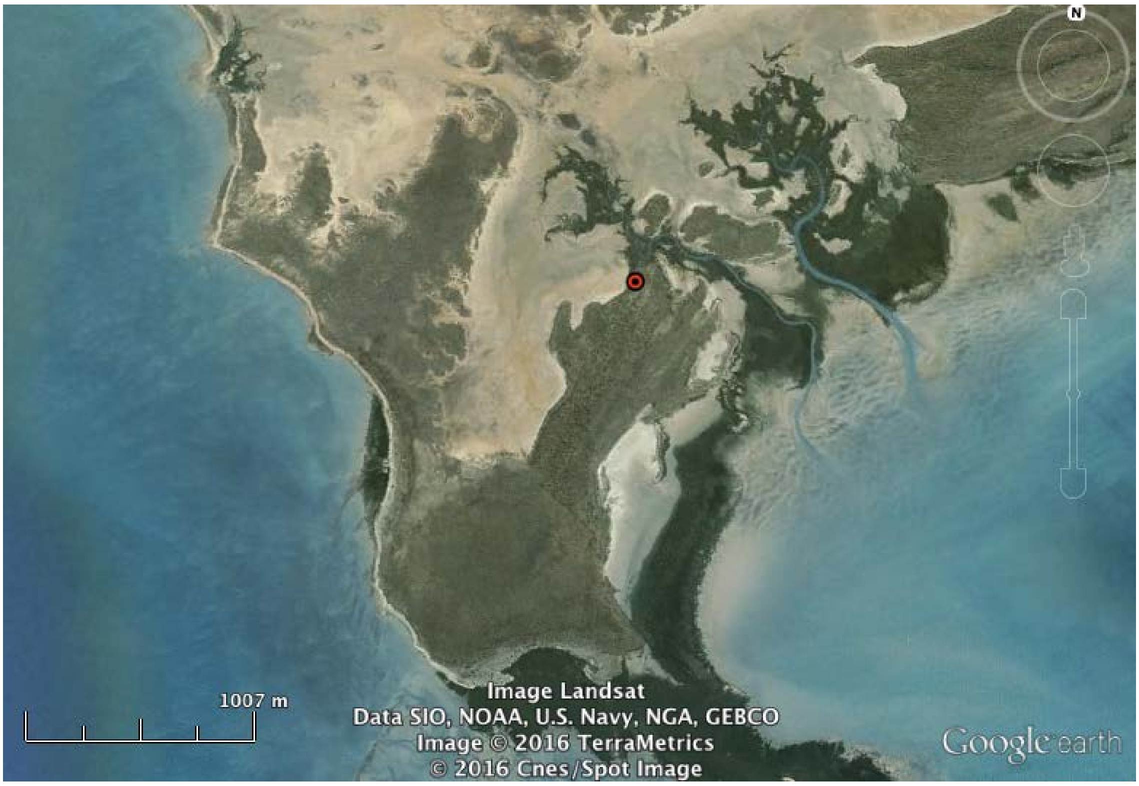


Figure 7.2: Aerial view map showing Dangkankuruwuru site location (after Google Earth).

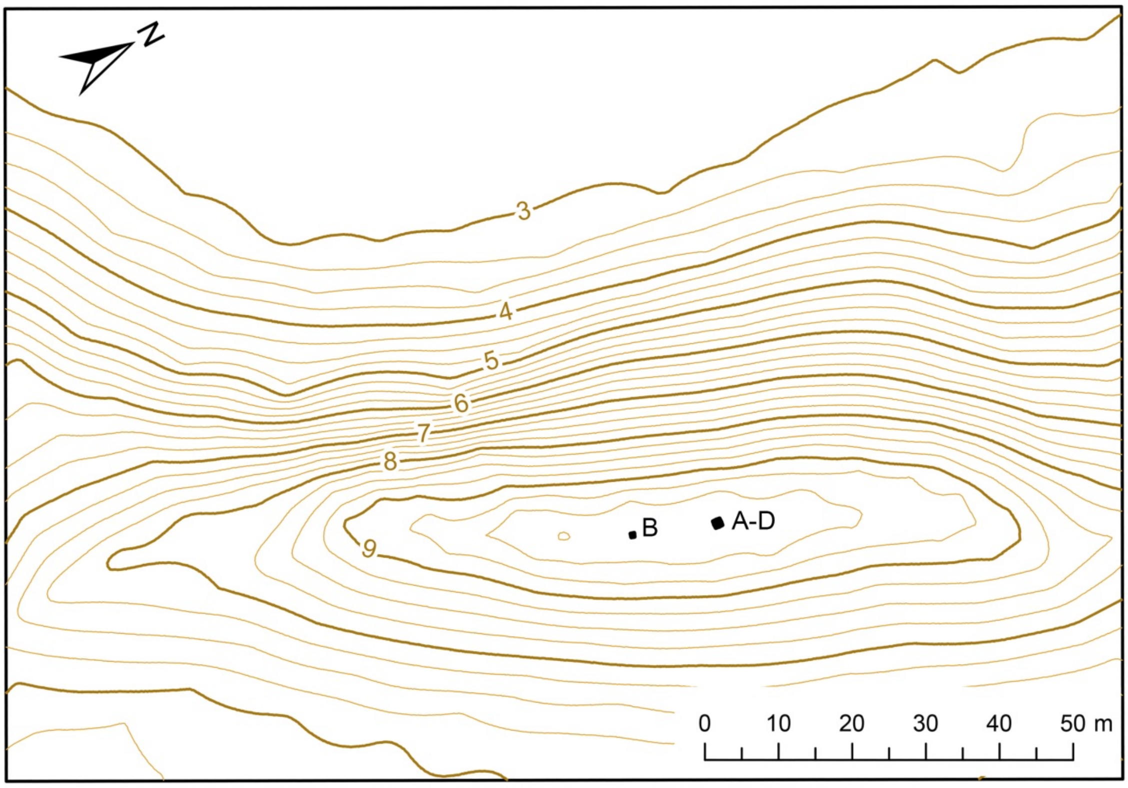


Figure 7.3: Topographical profile map of Dangkankuruwuru (map prepared by Lincoln Steinberger and Sean Ulm).

Figure 7.4: Dangkankuruwuru view north.

Figure 7.5: Dangkankuruwuru view northwest.

Figure 7.6: Dangkankuruwuru view west.

Figure 7.7: Dangankuruwuru view southwest (Photo by Daniel Rosendahl).

The nearby coastline comprises intertidal and subtidal sandy to muddy flats, rocky reefs, claypan saltflats, seagrass beds, coral reefs and mangrove communities (Figure 7.8). The rocky foreshores support clumps of oysters (*Saccostrea glomerata*) and small top snails (*Calliostoma* sp.), long bums or telescope mud whelks (*Telescopium telescopium*) and sulcate swamp ceriths (*Terebralia sulcata*) are common amongst rearward mangroves. The intertidal sandy-mudflats along the front shoreline support hiant venus clams (*Marcia hiantina*).

Archaeological shell is found in high-density patches (up to 100 shell fragments per m^2) across the top of the ridge with the densest exposures occurring on the highest part of the ridge, closest to a clump of pandanus trees. Surface shell material is dominated by *M. hiantina*, *S. glomerata* and *Glauconome virens* with occasional *T. telescopium* and *T. sulcata.*

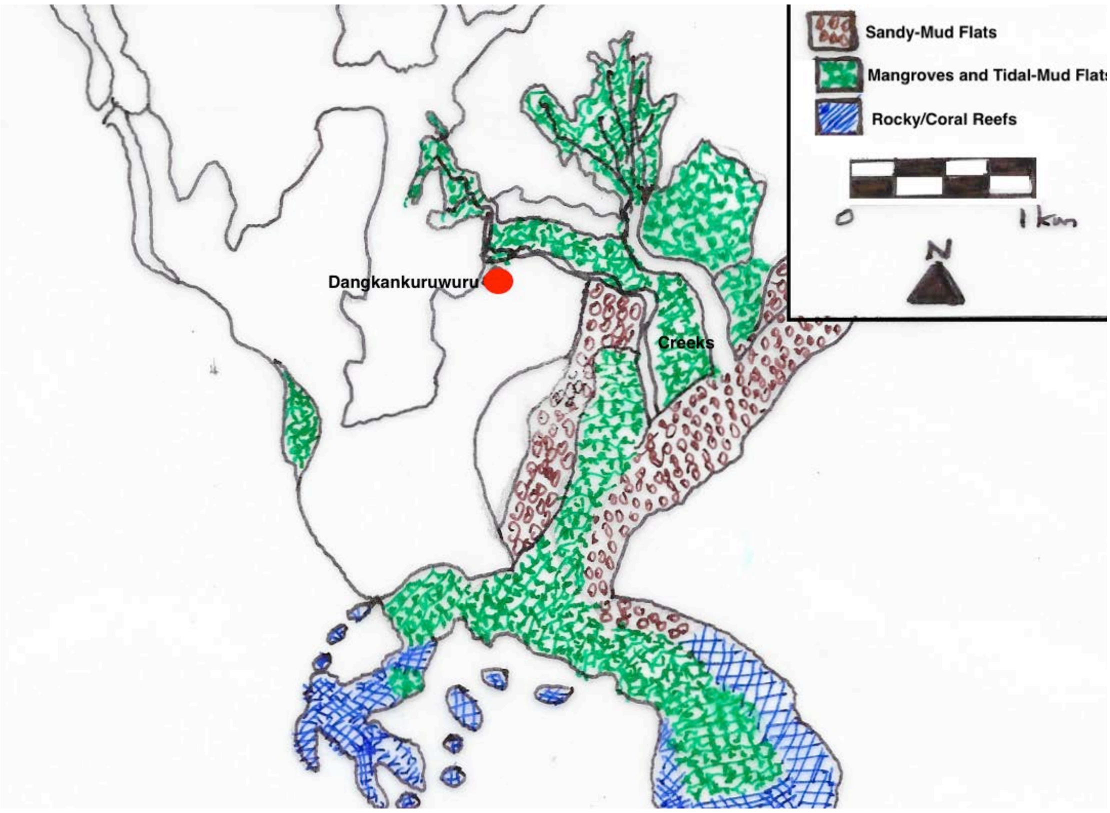


Figure 7.8: Resource habitat communities near Dangkankuruwuru

7.3 Excavation Methods

During the 2013 field season, a detailed pedestrian survey of the southwest corner of Bentinck Island identified varying quantities of shell and occasional stone artefacts along the edges of the clay saltpan and on high sand ridges. Dangkankuruwuru was selected for test excavation owing to the high density of surface cultural material and its location on the highest sand ridge away from tidal and storm surge influence.

Two 50cm x 50cm test pits (Square A and Square B) were initially excavated at a 12m interval along an NNE-SSW transect placed in the approximate centre of the visible surface shell exposure (Figure 7.3). The test pits were placed to determine patterns of variation in subsurface deposits. Excavation proceeded in shallow excavation units (XUs) averaging 2.6cm in depth and 10kg in weight. Cultural deposits continued to a depth of approximately 63cm in Square B and excavation was discontinued at 72.5cm. Square A was still producing dense midden materials at 65cm, and the pit was expanded to a 1m x 1m square to allow access to deeper deposits. Additional 50cm x 50cm squares B1 (so named to avoid confusion with Square B), C and D, were excavated abutting Square A, and excavation in the four squares ceased at a maximum depth of c.97cm below ground surface (Figure 7.9). A total of 1467kg from 148 XUs was removed from the 1m x 1m square (37 XUs per square A, B1, C and D); an additional 235kg came from Square B (Figure 7.10). All excavated sediments were dry sieved on site through 2.3mm mesh screens and bagged for later sorting and identification in the laboratory.

Figure 7.9: Dangkankuruwuru Squares A-D, 1m x 1m excavation (photo by Sean Ulm).

Figure 7.10: Dangkankuruwuru Square B, 50cm x 50cm excavations (photo by Sean Ulm).

7.4 Cultural Deposit and Stratigraphy

Excavations revealed an extensive, c.60cm thick, high-density cultural sequence with shell, bone, stone artefacts and charcoal resting on coarse sands and degrading beach rock. The deposit can be divided into three stratigraphic units (SUs) based on sediment colour and texture (Figure 7.11and Table 7.1). SU1 includes materials located between XU1 to XU5 that appear to be cultural materials that were rapidly deposited in a short space of time (c.250 years). The brown to yellowish-brown sediments of the upper shell deposit are likely to derive from wind-blown sediments trapped by an exposed shell surface and SUII includes dense materials (also from cultural sources) located between XU6-27 deposited over a longer time span (c.1250 years), with subsequent percolation of sediments down the shell profile. SUIII contains less cultural materials in upper layers overlying a coarse sand base.

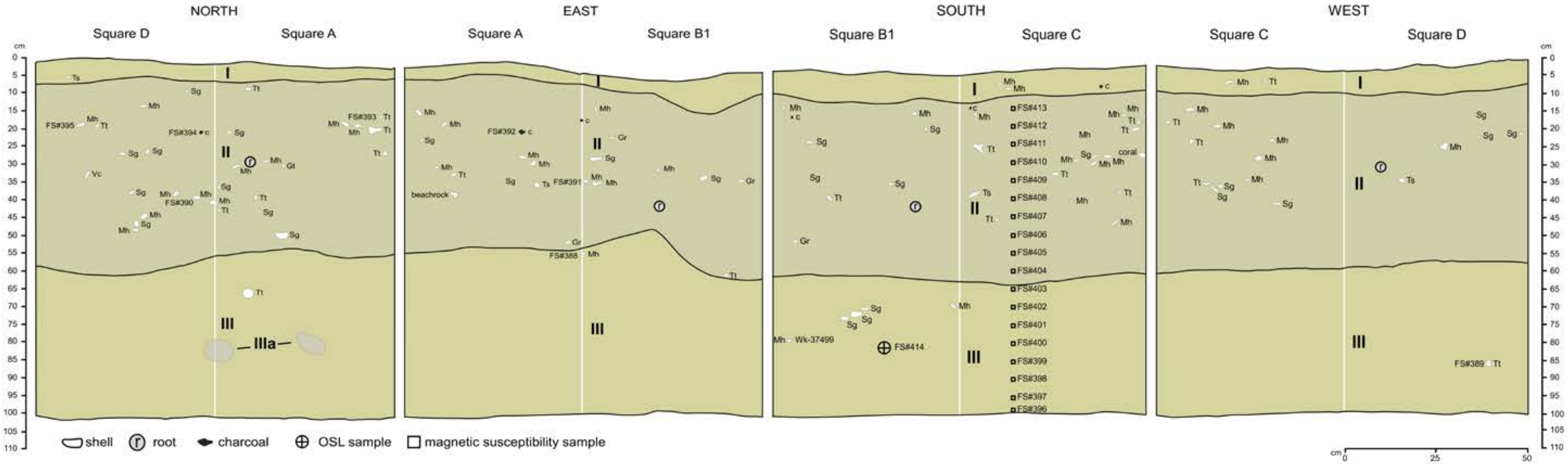


Figure 7.11a: Stratigraphic section drawing, Dangkankurwuru Squares A-D (drawing by Michelle Langley and Sean Ulm).

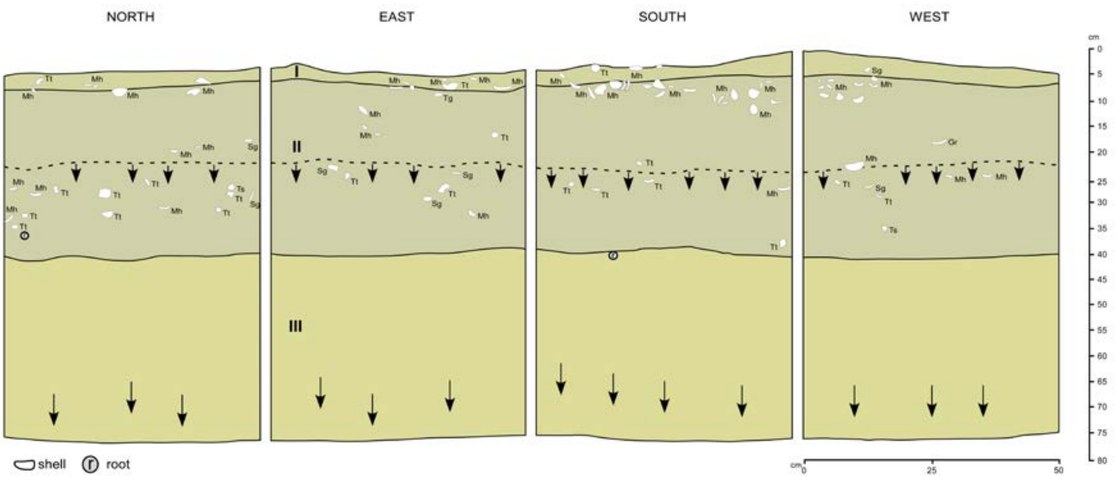


Figure 7.11b: Stratigraphic section drawing, Dangkankuruwuru Square B (drawing by Michelle Langley and Sean Ulm).

Table 7.1: Stratigraphic Unit (SU) descriptions for combined Squares A-D and Square B.

SU	Description
I	SUI extends across the entire Square A-D and Square B with depths ranging between 5cm to 10cm below ground surface. The unit comprises angular to subangular dry and loosely consolidated sands that become more consolidated with depth. These sediments are brown (7.5YR-4/3 to 7.5YR-5/4) to dark yellowish brown (10YR-4/4) in colour, and there is coarse shell grit interspersed throughout the SU. This SU contains occasional grass roots. Cultural materials include charcoal fragments, whole and fragmented molluscs (venus clams, oysters and telescope snails), crab fragments, fish bones and otoliths. pH values are somewhat acidic (6.0-7.5). Shell and bone materials appear to have reasonable preservation levels.
II	Transitional unit grading from dark yellowish brown (10YR-4/4) to brown (7.5YR-4/3) to light brown (7.5YR-6/4 to 10YR-6/3). This unit spans 45-55cm in Squares A-D and 40cm in Square B. The matrix consists of less consolidated sands with numerous beach rock and gravel inclusions throughout. Large quantities of whole and fragmented shells (venus clams, oysters, longbums and sulcate swamp ceriths, nerites and mangrove-mud mussels) are present throughout as are occasional small and blocky fragments of charcoal. pH values are highly alkaline (8.5-10.0). Insect burrows suggest there is evidence for the minor disturbance of materials from insects.
III	There is a distinct change in sediment colour between SUII and SUIII from yellow and brown hues to pink (7.5YR-7/4) coarse sands and shell grit. Larger shell fragments are still present but in much lower quantities than before. Beach rock is also encountered. The basal XUs (lowest 5-10cm) appear to be culturally sterile. pH values are acidic (5.5).

7.5 Radiocarbon Dating and Chronology

Five radiocarbon determinations were obtained for the deposits at Dangkankuruwuru indicating that the site has been used for at least 1500 years (Table 7.2). As we are particularly interested in potential changes through time, the assemblages have been divided into temporal phase blocks of 250-year periods for comparative purposes. Excavation units were assigned to chronological periods based on an age-depth model derived from the calibrated radiocarbon ages and stratigraphic observations (Figure 7.12 and Table 7.3). Even though time-averaging these open shell deposits only allows for identification of broad-scale trends and fails to record subtle changes, it allows for determination of variation in relative taxa abundance, indicative of taxa exploitation patterns and/or environmental changes affecting the distribution of taxa.

Table 7.2: Radiocarbon ages on marine shell for Dangkankuruwuru. Calibrations undertaken using OxCal v.4.2 (Bronk Ramsey 2009) and Marine13 calibration dataset (Reimer *et al.* 2013). For marine samples a ΔR of −49±102 as recommended by Ulm *et al.* (in prep.) is employed.

Sq	XU	Lab. Code	Depth (cm)	Conventional Radiocarbon Age (CRA)	Calibrated Age BP (95.4%)	Calibrated Age BP Median
A	1	Wk-38692	0-1.6	399±24	0*-271	115
B1	5	Wk-39328	9.38	360±25	0*-253	99
B1	11	Wk-39329	24.3-27.4	1502±25	895-1301	1104
B1	20	Wk-39330	47.58-50.1	1569±25	940-1362	1168
B1	29	Wk-37499	74.6	1927±25	1306-1782	1537

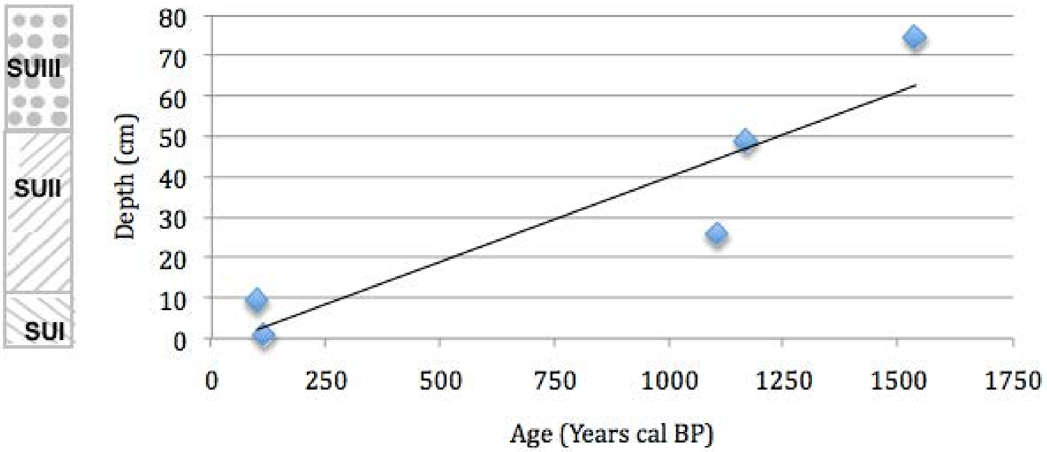


Figure 7.12: Age depth relationship of all radiocarbon determinations obtained for Dangkankuruwuru.

Table 7.3: Temporal phases of 250-year periods, showing allocation of XUs.

Temporal phase	0-250	250-500	500-750	750-1000	1000-1250	1250-1500	1500-1750	1750-2000
Sq A-D XU	1-5	6-7	8	9-10	11-20	21-27	29-34	35-37
Sq B XU	1-5	6-7	8	9-10	11-20	21-25		

7.6 Site Integrity and Taphonomy

Evidence suggests that the deposit exhibits reasonable stratigraphic integrity. There is a predictable shell decay profile with highly weathered tiny gastropod and bivalve specimens recovered from the base of the deposit and relatively well-preserved specimens from the upper deposit. Degradation of fish bone materials is greatest in lower XUs with fewer bone fragments being collected and those that are found are generally unidentifiable. There is evidence of some minor disturbance within the matrix in the form of ant nests and some other insect burrows.

7.7 Laboratory Methods

The molluscan and fishbone assemblages from Squares A, B1, C and D are combined for analysis and are reported in Section 7.8 below. Based on radiocarbon determinations combined with analysis of stratigraphy the excavated materials have been divided into assemblages that correlate with the 250-year units in Table 7.3 for OFT analysis. Although there are no secure dates for Square B the square is located 12m apart from Square A-D. As both squares exhibit very similar stratigraphic profiles, the same radiocarbon ages have been applied to the Square B assemblages. See Chapter 6 for a discussion of the standard laboratory methods employed.

7.8 Cultural Materials

17,436.1g (1%) from the sediment and materials excavated from the 1m x 1m square (Square A-D) were retained in the 2.3mm mesh screen and 3,138g (1%) were retained from Square B. Tables 7.4 and 7.5 show the overall summary results of the retained materials. Molluscan shell makes up 52% (9,128.7g) of the Squares A-D assemblage and 76% (2,636.4g) of Square B. Remains of other marine fauna (e.g. fish, crab) are associated with the shell deposit. Bone contributes 0.1% (21.26g) for Squares A-D and 0.1% (3.22) for Square B. Small quantities of crustacea (44g) were recovered from both squares combined, represented by mud crab (*Scylla* spp.) (32.5g) and goose barnacle (Pedunculata) (11.5g). Beach rock, coral and pisolith stones contribute 37.1% of Squares A-D and 12.9% of Square B. A few small, flaked stone artefacts manufactured on silcrete are also present in some XUs (Clair Davey pers. comm. 2015). The higher proportion of these materials recovered from Squares A-D reflects the greater depth of excavation into the culturally-sterile lower SUIII deposits. Organics make up the rest of the Squares A-D and Square B assemblages.

Table 7.4: Summary excavation data and retained materials from Dangkankuruwuru Squares A, B1, C and D.

XU	Depth Below Surface (cm)	Mean Thickness (cm)	Weight (kg)	Vol cm^3	pH	Stone Artefacts (g)	Marine Shell (g)	Bone (g)	Barnacle (g)	Crab (g)	Charcoal (g)	Other Organic (g)	Rock Rubble Coral (g)	Total Retained Materials (g)	Retained % of Total Midden
1	3.20	3.2	12.1	8000	6	0	394.63	2.31	0.03	0.00	13.68	401.93	172.60	985.18	8.14%
2	5.74	2.54	6.7	6350	6	0	382.62	2.12	7.03	0.14	14.24	57.07	93.12	556.34	8.30%
3	8.20	2.46	10.8	6150	6	0	403.57	3.62	0.29	0.68	57.15	63.30	145.44	674.05	6.24%
4	11.34	3.14	9.4	7850	6	0	532.08	3.88	0.37	0.57	65.77	76.37	169/16	679.04	7.22%
5	13.82	2.48	7.7	6200	6	0	526.55	3.14	0.07	0.00	48.29	49.86	180.64	808.55	10.50%
6	16.20	2.38	5.7	5950	7.5	0	352.79	1.50	0	0.20	44.80	44.59	205.40	649.28	11.39%
7	18.74	2.54	12	6350	7.5	4.06	469.9	2.04	0.45	0.86	9.40	53.68	433.92	974.31	8.12%
8	21.30	2.56	9.3	6400	7.5	0	471.9	0.50	0.06	0.49	3.74	35.42	249.73	761.84	8.19%
9	23.56	2.26	8.2	5650	7.5	0	501.54	0.27	0.06	0.19	3.00	44.04	253.25	802.37	9.79%
10	26.06	2.5	8.2	6250	7.5	0	473.13	0.64	0.3	2.41	2.30	37.13	210.40	726.31	8.86%
11	29.04	2.98	10.5	7450	8	0	710.67	0.21	0.31	1.78	1.05	46.30	299.92	1060.24	10.10%
12	31.26	2.22	8.8	5550	8	0	549.78	0.04	0.22	1.45	0.69	33.69	497.64	1083.51	12.31%
13	33.80	2.54	8.8	6350	6	3.26	476.65	0.11	0.17	0.44	0.57	34.60	531.33	1047.13	11.90%
14	36.22	2.42	8.4	6050	8.5	0	420.24	0.07	0.16	0.09	1.39	26.94	355.79	804.68	9.58%
15	39.30	3.08	10.9	7700	8	0	459.9	0.07	0.28	1.00	0.88	32.92	145.56	640.61	5.88%
16	41.70	2.4	6.3	6000	8	0	284.04	0.10	0.21	4.37	0.13	43.99	122.04	454.88	7.22%
17	44.42	2.72	11.1	6800	7.5	0	346.95	0.01	0.03	3.10	0.26	29.38	109.36	489.09	4.41%
18	46.90	2.48	8.9	6200	8.5	0	190.99	0.13	0.03	0.80	0.03	21.98	131.64	345.6	3.88%

XU	Depth Below Surface (cm)	Mean Thickness (cm)	Weight (kg)	Vol cm^3	pH	Stone Artefacts (g)	Marine Shell (g)	Bone (g)	Barnacle (g)	Crab (g)	Charcoal (g)	Other Organic (g)	Rock Rubble Coral (g)	Total Retained Materials (g)	Retained % of Total Midden
19	49.26	2.36	9	5900	8	0	157.11	0.06	0.03	0.00	0.15	26.74	114.84	298.93	3.32%
20	51.56	2.3	9.9	5750	8	0	119.04	0.05	0	10.09	0.07	24.18	114.42	267.85	2.71%
21	54.36	2.8	11.9	7000	8	0	165.01	0.00	0	0.00	0.22	22.48	117.76	305.47	2.57%
22	57.34	2.98	11.7	7450	8.5	0	161.77	0.22	0.39	0.00	0.07	26.73	115.04	304.22	2.60%
23	60.34	3	11.8	7500	9	0	167.64	0.02	0	2.48	0.03	27.23	122.23	319.53	2.71%
24	62.82	2.48	11.8	6200	9	0	93.54	0.11	0.05	1.10	0.05	24.04	94.71	213.6	1.81%
25	65.48	2.66	11.2	6650	8.5	0	54.66	0.00	0.03	0.03	0.06	15.69	69.20	139.67	1.25%
26	69.44	3.96	8.5	9900	8.5	0	78.85	0.04	0	0.13	0.11	29.93	114.56	223.62	2.63%
27	71.88	2.44	8.5	6100	8.5	0	23.06	0.00	0	0.00	0.05	20.43	64.80	108.34	1.27%
28	74.26	2.38	8.7	5950	8.5	0	14.35	0.00	0	0.00	0.08	13.51	38.60	66.54	0.76%
29	76.92	2.66	10	6650	8.5	0	26.9	0.00	0	0.03	0.05	13.77	44.48	85.23	0.85%
30	79.46	2.54	11	6350	8.5	0	13.3	0.00	0	0.00	0.00	16.46	85.96	115.72	1.05%
31	81.86	2.4	9.5	6000	8.5	0	16.26	0.00	0	0.00	0.03	15.03	145.60	176.92	1.86%
32	84.14	2.28	9.5	5700	8.5	0	30.71	0.00	0.05	0.00	0.19	14.98	198.97	244.9	2.58%
33	86.68	2.54	10.3	6350	8.5	0	11.65	0.00	0	0.00	0.10	20.61	206.78	239.04	2.32%
34	89.24	2.56	9.3	6400	8.5	0	12.04	0.00	0	0.01	0.08	9.12	169.80	190.97	2.05%
35	91.98	2.74	10.8	6850	8.5	0	11.68	0.00	0	0.00	0.01	13.75	164.89	190.32	1.76%
36	94.30	2.32	4	5800	8.5	0	7.63	0.00	0	0.00	0.00	8.11	188.16	203.9	5.10%
37	96.78	2.48	9.7	6200	8.5	0	15.57	0.00	0.09	0.00	0.00	13.24	169.48	198.38	2.05%
Total:	-	96.78	350.9	35090	-	7.32	9128.70	21.26	10.7	32.4	268.7	1489.2	6477.7	17436.1	4.97%

Table 7.5: Summary excavation data and retained materials from Dangkankuruwuru Square B.

XU	Depth Below Surface (cm)	Mean Thickness (cm)	Weight (kg)	Vol cm^3	pH	Stone Artefacts (g)	Marine Shell (g)	Bone (g)	Barnacle (g)	Crab (g)	Charcoal (g)	Other Organic (g)	Rock Rubble Coral (g)	Retained Materials Total (g)	Retained % of Total Midden
1	1.92	1.92	6	4800	5.5	0	436.16	0.07	0.02	0	0.05	12.79	10.28	459.37	7.66%
2	5.04	3.12	3.5	7800	7	0	1013.4	1.41	0.00	0	0.72	2.98	14.64	1033.15	29.52%
3	7.58	2.54	8	6350	7	0	88.1	0.02	0.00	0.01	0.02	1.10	12.92	102.17	1.28%
4	10.28	2.7	5.5	6750	6	0	56.32	0.17	0.01	0	0.11	2.42	20.89	79.92	1.45%
5	14.96	4.68	11.9	11700	7	0	77.84	0	0.06	0	0.10	4.93	38.17	121.10	1.02%
6	19.00	4.04	10.9	10100	7.5	0	107.67	0.01	0.01	0.01	0.06	4.14	34.63	146.53	1.34%
7	21.56	2.56	9	6400	6	0	137.97	0.67	0.01	0.05	0.02	4.01	31.66	174.39	1.94%
8	24.12	2.56	8.9	6400	8	0	160.64	0.53	0.00	0	0.00	4.44	32.72	198.33	2.23%
9	26.60	2.48	9	6200	8.5	0	155.92	0.27	0.24	0	0.29	4.33	46.40	207.45	2.31%
10	29.62	3.02	12.4	7550	8.5	0	137.99	0.07	0.00	0	0.06	4.90	69.26	212.28	1.71%
11	32.28	2.66	8.5	6650	8	0	117.09	0	0.35	0	0.39	3.25	33.62	154.70	1.82%
12	34.52	2.24	8.4	5600	8.5	0	44.72	0	0.00	0	0.01	5.51	9.77	60.01	0.71%
13	37.14	2.62	9.5	6550	8	0	30.32	0	0.00	0	0.00	9.02	11.55	50.89	0.54%
14	39.70	2.56	9.7	6400	7	0	5.63	0	0.00	0	0.00	2.51	4.72	12.86	0.13%

XU	Depth Below Surface (cm)	Mean Thickness (cm)	Weight (kg)	Vol cm^3	pH	Stone Artefacts (g)	Marine Shell (g)	Bone (g)	Barnacle (g)	Crab (g)	Charcoal (g)	Other Organic (g)	Rock Rubble Coral (g)	Retained Materials Total (g)	Retained % of Total Midden
15	42.34	2.64	9	6600	6	0	3.93	0	0.00	0	0.00	3.07	5.24	12.24	0.14%
16	44.82	2.48	9.9	6200	8	0	10.22	0	0.00	0	0.00	2.36	4.80	17.38	0.18%
17	47.12	2.3	8.3	5750	8	0	10.13	0	0.00	0	0.00	1.67	4.77	16.57	0.20%
18	49.64	2.52	8.8	6300	8.5	0	6.22	0	0.00	0	0.00	1.57	2.98	10.77	0.12%
19	52.20	2.56	9.6	6400	8.5	0	8.54	0	0.00	0	0.00	1.96	2.55	13.05	0.14%
20	54.66	2.46	8.9	6150	8.5	0	3.96	0	0.00	0	0.00	1.23	1.54	6.73	0.08%
21	57.38	2.72	8.5	6800	8.5	0	4.65	0	0.09	0	0.00	2.62	2.49	9.85	0.12%
22	60.60	3.22	13	8050	8.5	0	7.37	0	0.00	0	0.00	2.75	2.28	12.40	0.10%
23	64.52	3.92	12	9800	8.5	0	8.88	0	0.00	0	0.00	2.85	3.65	15.38	0.13%
24	69.30	4.78	14.5	11950	8.5	0	1.81	0	0.00	0	0.00	2.90	1.32	6.03	0.04%
25	72.54	3.24	11.8	8100	8	0	0.89	0	0.00	0	0.00	1.73	1.89	4.51	0.04%
Total:	-	72.54	235.5	181350	-	0	2636.37	3.22	0.79	0.07	1.83	91.04	404.74	3138.06	1.33%

7.8.1 Invertebrate Mollusc Remains

Squares A, B1, C and D

In total 9.1kg of shell was recovered from Squares A-D. 86% of all shell by weight was identified to family, genus or species level. The remaining 14% of shell based on weight could not be identified beyond Mollusca due to the generally small size of these specimens and the lack of diagnostic attributes that prevented identification to taxon; this unidentified portion of the mollusc assemblage is not included in analyses presented below. The identified assemblage comprised 36 molluscan taxa (with an MNI=1430) consisting of 19 marine bivalve taxa and 17 marine gastropod taxa (Figures 7.13-7.14). The shell assemblage is dominated by *M. hiantina* with an MNI of 437 or 31% of the assemblage, *S. glomerata* (17%), *Glauconome virens* (11%) and *Telescopium telescopium* (8%). Small cerith gastropods contribute 9% of the assemblage. The remaining 31 taxa are relatively rare, each contributing less than 1% of the shell assemblage by weight. MNI and weight data are presented in Tables 7.6 and 7.7.

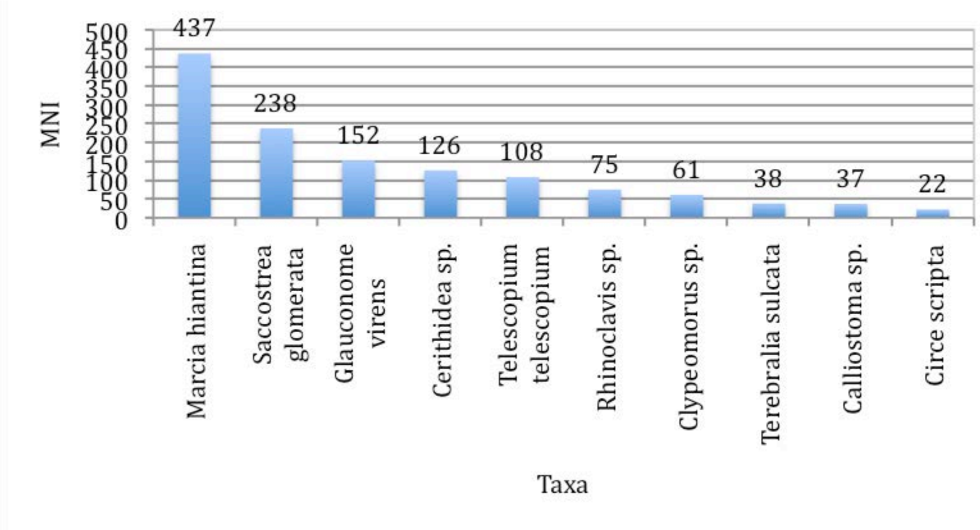


Figure 7.13: Dangkankuruwuru Squares A-D, top 10 mollusc taxa by MNI.

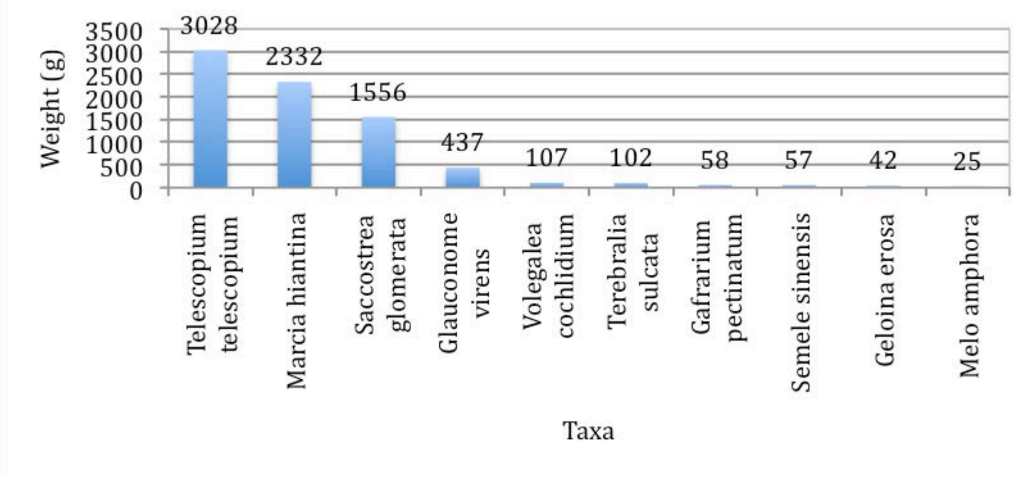


Figure 7.14: Dangkankuruwuru Squares A-D, top 10 mollusc taxa by weight.

Table 7.6: Dangkankuruwuru Squares A-D molluscan assemblage taxa MNIs.

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
MARINE BIVALVIA																				
Asaphis violascens				1																
Barbatia sp.																				
Cardiidae																	1			
Chama sp.											1				1					
Circe scripta	2					1		1	2		1	1			1	1	1			
Corbula fortisulcata	1				1		1							2	1					
Gafrarium pectinatum			2	2				1	1		2				1					
Geloina erosa							1													
Glauconome virens	2	5	8	3	3	3	7	6	19	19	17	9	10	5	2	6	4	4	5	5
Irus sp.								1												
Isognomon isognomon																			1	
Lunulicardia hemicardium										1										
Mactra sp.	1		2	2	1									2	1	1				1
Marcia hiantina	33	24	32	38	46	17	28	12	19	15	15	21	16	17	17	16	11	9	6	3
Mytilidae											1									
Placamen retroversum																				
Saccostrea glomerata	10	7	6	9	8	9	14	13	10	19	21	14	12	17	12	7	7	6	4	6
Semele sinensis	1		3	2	4	1	2			1										
Tellina sp.									1	1										
MARINE GASTROPODA																				
Calliostoma sp.		3	1	2	1		3	2	1	2	1	1		1	3	2	1			1
Cerithidea cingulata			2			2	1		1	2	1		1		1	2	1			1
Cerithidea sp.	9	7	10	6	6	4	8	1	8	1	6	5	5	5		2	5	2		
Cerithium coralium					1	2												1	1	1
Clypeomorus sp.	5				5	2	3	4	3	3		2	1		1			2		2
Ellobiidae							1													
Lunella cinerea						2						1						1		

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Melo amphora													1							
Mitra sp.																				
Mitrella scripta							1													
Nerita balteata							1													
Nerita spp.		2		1	1									1		1				
Patellidae																				
Planaxis sulcatus	1					1	1		1		1			2						1
Rhinoclavis sp.		4	1	2			2	5	8			2	3	8	4	2		2	3	4
Telescopium telescopium	5		3	4	2	5	5	9	6	7	10	8	7	8	7	3	4	2		2
Terebralia sulcata	2	1	1	3	3		4	3	2	1	4	1	1		3	1	1		2	1
Turbo sp.																			1	
Volegalea cochlidium		2		1	1				1	2	1			1			2			
XU Totals	**72**	**55**	**71**	**76**	**83**	**49**	**83**	**58**	**83**	**74**	**82**	**65**	**57**	**69**	**55**	**44**	**38**	**29**	**23**	**28**

Table 7.6: Dangkankuruwuru Squares A-D molluscan assemblage taxa MNIs (cont).

Taxon XU	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**Totals**
MARINE BIVALVIA																		
Asaphis violascens																		**1**
Barbatia sp.												1						**1**
Cardiidae																		**1**
Chama sp.																		**2**
Circe scripta			1		1	1		1		2	1	2	1			1		**22**
Corbula fortisulcata								1									1	**8**
Gafrarium pectinatum								1				1						**11**
Geloina erosa																		**1**
Glauconome virens	4	3	1	1		1												**152**
Irus sp.																		**1**
Isognomon isognomon																		**1**
Lunulicardia hemicardium												1						**2**

Taxon XU	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**Totals**
Mactra sp.		1				1												**13**
Marcia hiantina	8	9	8	6	1	3	1			1	1	1	1		1		1	**437**
Mytilidae									1									**2**
Placamen retroversum													1					**1**
Saccostrea glomerata	5	6	4	2	3	2	2		1			1		1				**238**
Semele sinensis																		**14**
Tellina sp.							1	1										**4**
MARINE GASTROPODA																		
Calliostoma sp.	1					2				1	1	2	1	1			1	**37**
Cerithidea cingulata						1				1			1		1			**19**
Cerithidea sp.		2		2	1			2	2	4		2	7	7	7	1	1	**126**
Cerithium coralium						1												**7**
Clypeomorus sp.	1	1	1		1	1	2	2	2		2	4	4	1	3		2	**61**
Ellobiidae																		**1**
Lunella cinerea		1	1															**6**
Melo amphora																		**1**
Mitra sp.					1													**1**
Mitrella scripta								2	2								1	**4**
Nerita balteata																		**1**
Nerita spp.																		**6**
Patellidae										1								**1**
Planaxis sulcatus												1		1				**12**
Rhinoclavis sp.	1	3	1			1	1	1	1	1	1		2	4	2	1	2	**75**
Telescopium telescopium	1	4	2	1		1				1							1	**108**
Terebralia sulcata	1			1		1										1		**38**
Turbo sp.	1																	**2**
Volegalea cochlidium												1						**12**
XU Totals	**23**	**30**	**19**	**13**	**8**	**16**	**7**	**11**	**11**	**7**	**12**	**22**	**17**	**14**	**4**	**9**	**13**	**1430**

Table 7.7: Dangkankuruwuru Squares A-D molluscan assemblage taxa weights (g).

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
MARINE BIVALVIA													
Asaphis violascens	0	0	0	5.7	0	0	0	0	0	0	0	0.69	0
Barbatia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Cardiidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Chama sp.	0	0	0	0	0	0	0	0	0	0	0.12	0	0
Circe scripta	0.1	0	0	0	0	0.16	0	0.19	0.48	0	0.49	0.12	0
Corbula fortisulcata	0.58	0	0	0	0.23	0	0.25	0	0	0	0	0	0
Gafrarium pectinatum	0	0.88	6.66	10.57	2.19	0	0.58	0.54	11.28	0.68	11.83	0.54	0
Geloina erosa	0	0	0	4.95	0	0	23.76	0	0	0	13.06	0	0
Glauconome virens	7.21	2.41	4.86	7.8	6.11	6.18	17.23	13.99	64.64	70.25	60.08	30.89	35.96
Irus sp.	0	0	0	0	0	0	0	0.05	0	0	0	0	0
Isognomon isognomon	0	0	0.05	0	0	0	0	0	0	0	0	0	0
Lunulicardia hemicardium	0	0	0	0	0	0	0	0	0	0.15	0	0	0
Mactra sp.	1.44	0.55	1.55	5.19	4.31	0.18	1.02	0.08	2.1	0	0.19	0	0.37
Marcia hiantina	183.57	138.66	137.24	268.16	282.3	87.03	113.42	91.52	85.66	76.15	97.28	119.09	83.92
Mytilidae	0	0	0	0	0	0	0.02	0	0	0	0.05	0	0
Placamen retroversum	0	0	0	0	0	0	0	0	0	0	0	0	0
Saccostrea glomerata	65.5	79.94	51.79	56.29	53	67.72	79.67	85.69	71.76	86.13	166.93	105.03	72.09
Semele sinensis	4.35	0.61	8.03	3.65	11.42	5.5	11.71	0.34	1.05	2.14	2.57	1.4	0
Tellina sp.	0	0	0	0	0	0	0	0	0.21	0.04	0	0	0
MARINE GASTROPODA													
Calliostoma sp.	0	0.13	0.05	0.18	0.01	0	0.5	0.16	0.35	0.09	0.17	0.01	0.06
Cerithidea cingulata	0	0	0.27	0	0	0.36	0.03	0	0.14	0.005	0.12	0	0.28
Cerithidea sp.	0.62	0.33	0.3	0.49	0.16	1.15	0.55	0.13	0.68	0.08	0.73	0.18	0.38
Cerithium coralium	0	0	0	0	0.48	0.24	0	0	0	0	0	0	0
Clypeomorus sp.	0.92	0	0	0	0.67	0.32	0.97	0.7	0.42	0.48	0	0.42	0.18
Ellobiidae	0	0	0	0	0	0	0.04	0	0	0	0	0	0

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Lunella cinerea	0	0	0	0	0	7.5	0	0	0	0	0	3.85	0
Melo amphora	0	0	1.92	0.67	0	0	8.05	0	0	0	2.07	11.21	0.37
Mitra sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Mitrella scripta	0	0	0	0	0	0	0.43	0	0	0	0	0	0
Nerita balteata	0	0	0	0	0	0	7.5	0	0	0	0	0	0
Nerita spp.	0	0.59	0	0.08	0.43	0	0	0	0	0.5	0	0	1.14
Patellidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Planaxis sulcatus	0.09	0	0	0	0	0.04	0.04	0	0.12	0	0.04	0.22	0
Rhinoclavis sp.	0	0.2	0.06	0.23	0	0	0.41	0.45	0.38	0	0	0.1	0.2
Telescopium telescopium	80.58	81.03	109.79	78.52	79.28	121.41	131.62	207.52	187.48	174.41	264.09	207.73	211.94
Terebralia sulcata	0.75	1.62	0.63	8.68	8.57	0.09	3.38	8.91	3.91	1.96	13.47	6.89	3.7
Turbo sp.	0.65	0	0	0.57	0	0	0	0	0.31	0	0	0	0.31
Volegalea cochlidium	0	36.94	2.34	6.76	11.01	0	1.72	1.45	1.51	4.73	1.33	0	0
Unidentified Shell	48.27	38.73	78.03	73.59	66.38	54.91	67.00	60.16	69.06	55.33	76.05	61.41	65.75
XU Totals	**394.63**	**382.62**	**403.57**	**532.08**	**526.55**	**352.79**	**469.90**	**471.90**	**501.54**	**473.13**	**710.67**	**549.78**	**476.65**

Table 7.7: Dangkankuruwuru Squares A-D molluscan assemblage taxa weights (g) (cont).

Taxon XU	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
MARINE BIVALVIA													
Asaphis violascens	0.65	0	0.47	0	0	0	0.1	0	0.53	0	0.17	0	0
Barbatia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Cardiidae	0	0	0	0.24	0	0	0.08	0	0	0	0.04	0	0
Chama sp.	0	0.09	0	0	0	0	0	0	0	0	0	0	0
Circe scripta	0	0.85	0.29	0.06	0	0	0	0	0	0.09	0	0.52	0.38
Corbula fortisulcata	0.42	0.15	0	0	0	0	0	0	0	0	0	0	0
Gafrarium pectinatum	0.15	1.44	1.05	0	0	0.22	1.03	0	0	3.15	1.47	0.54	0.16
Geloina erosa	0	0	0	0	0	0	0	0	0	0	0	0	0
Glauconome virens	14.69	6.77	11.44	11.42	16.73	5.08	9.16	6.45	8.92	6.71	1.92	1.76	3.39

Taxon XU	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
Irus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Isognomon isognomon	0	0	0	0	0	0.31	0	0	0.09	0	0	0	0
Lunulicardia hemicardium	0	0	0	0	0	0	0	0	0	0	0	0	0
Mactra sp.	4.13	0.22	0.18	0.01	0	0	0.5	0	0.39	0	0	0	0.09
Marcia hiantina	77.34	88.39	75.61	61.88	39.88	34.9	24.38	43.37	30.88	27.05	26.99	7.83	12.99
Mytilidae	0	0.04	0	0	0	0	0	0	0	0	0	0	0
Placamen retroversum	0	0	0	0	0	0	0	0	0	0	0	0	0
Saccostrea glomerata	85.35	86.22	49.6	78.96	21.43	27.94	21.54	26.46	28.26	38.7	11.64	17.2	10.38
Semele sinensis	2.45	0.13	0.99	0	0.65	0	0	0	0	0.11	0	0	0
Tellina sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
MARINE GASTROPODA													
Calliostoma sp.	0.77	0.07	0.65	0.05	0	0	0.16	0.01	0	0	0	0	0.3
Cerithidea cingulata	0	0.05	0.38	0.1	0	0	0.11	0	0	0	0	0	0.13
Cerithidea sp.	0.61	0	0.14	0.38	0.06	0	0	0	0.09	0	0.28	0.07	0
Cerithium coralium	0	0	0	0	0.18	0.1	0.05	0	0	0	0	0	0.19
Clypeomorus sp.	0	0.17	0	0	0.33	0	0.28	0.09	0.13	0.14	0	0.17	0.1
Ellobiidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Lunella cinerea	0	0	0	0	1.92	0	0	0	1.54	3.13	0	0	0
Melo amphora	0.74	0	0	0	0	0	0	0	0	0	0	0	0
Mitra sp.	0	0	0	0	0	0	0	0	0	0	0	0.1	0
Mitrella scripta	0	0	0	0	0	0	0	0	0	0	0	0	0
Nerita balteata	0	0	0	0	0	0	0	0	0	0	0	0	0
Nerita spp.	1.05	0.02	2.58	0	0	0	0	0	0	0	0	0	0
Patellidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Planaxis sulcatus	0.68	0	0	0	0	0	0.06	0	0	0	0	0	0
Rhinoclavis sp.	0.83	0.33	0.26	0	0.14	0.26	0.44	0.04	0.16	0.1	0	0	0.18
Telescopium telescopium	165.48	213.45	97.41	130.81	73.31	49.87	38.45	48.32	70.24	66.23	35.58	18.38	36.69
Terebralia sulcata	3.23	4.14	4.48	1.29	0	1.48	0.66	20.03	0.34	1.21	0.77	0	0.95
Turbo sp.	0	0.61	0	0.39	0	1.41	0	0.11	0	0	0	0	0
Volegalea cochlidium	5.24	5.54	0.25	24.2	1.34	0	0	0	0	0	0	0.34	0

Taxon XU	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
Unidentified Shell	56.43	51.22	38.26	37.16	35.02	35.54	22.04	20.13	20.20	21.02	14.68	7.75	12.92
XU Totals	**420.24**	**459.90**	**284.04**	**346.95**	**190.99**	**157.11**	**119.04**	**165.01**	**161.77**	**167.64**	**93.54**	**54.66**	**78.85**

Table 7.7: Dangkankuruwuru Squares A-D molluscan assemblage taxa weights (g) (cont).

Taxon XU	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**Totals**
MARINE BIVALVIA												
Asaphis violascens	0	0	0	0	0.1	0	0	0	0	0	0	**8.41**
Barbatia sp.	0	0	0	0	0	0.08	0	0	0	0	0	**0.08**
Cardiidae	0	0	0	0	0	0	0	0	0	0	0	**0.36**
Chama sp.	0	0	0	0	0	0	0	0	0	0	0	**0.21**
Circe scripta	0	0.18	0	0.17	0.29	1.31	0.18	0	0	0.02	0	**5.88**
Corbula fortisulcata	0	0.18	0	0	0	0	0	0	0	0	0.55	**2.36**
Gafrarium pectinatum	0.22	1.17	0	0	0	0.58	0.64	0.68	0	0	0	**58.25**
Geloina erosa	0	0	0	0	0	0	0	0	0	0	0	**41.77**
Glauconome virens	0.8	0	1.15	0.41	1.23	0.62	0	0.55	0	0	0.55	**437.36**
Irus sp.	0	0	0	0	0	0	0	0	0	0	0	**0.05**
Isognomon isognomon	0	0	0	0	0	0	0	0	0	0	0	**0.45**
Lunulicardia hemicardium	0	0	0	0	0	0.4	0	0	0	0	0	**0.55**
Mactra sp.	0	0	0	0.04	0	0	0	0.23	0	0	0	**22.77**
Marcia hiantina	4.53	0.64	1.35	0.78	0.88	4.81	0.6	0.2	1.08	0	1.19	**2331.55**
Mytilidae	0	0	0.01	0	0	0	0	0	0	0	0	**0.12**
Placamen retroversum	0	0	0	0	0	0	0.54	0	0	0	0	**0.54**
Saccostrea glomerata	4.08	0.11	0.84	0.26	0.5	2.96	0.31	0.58	0.57	0	0.46	**1555.89**
Semele sinensis	0	0	0	0	0	0	0	0	0	0	0	**57.1**
Tellina sp.	0.01	0.26	0	0	0	0	0	0	0	0	0	**0.52**
MARINE GASTROPODA												
Calliostoma sp.	0	0	0.03	0.2	0.35	0.04	0.01	0	0	0.21	0.17	**4.73**
Cerithidea cingulata	0	0	0.25	0	0	0.21	0	0.42	0	0	0	**2.85**

Taxon XU	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**Totals**
Cerithidea sp.	0	0.09	0.43	0	0.39	0.99	1.08	0.89	0.22	0.14	0	**11.64**
Cerithium coralium	0	0	0	0	0	0	0	0	0	0	0	**1.24**
Clypeomorus sp.	0.26	0.28	0	0.48	0.67	0.78	0.18	0.78	0	0.56	0.38	**10.86**
Ellobiidae	0	0	0	0	0	0	0	0	0	0	0	**0.04**
Lunella cinerea	0	0	0	0	0	0	0	0	0	0	0	**17.94**
Melo amphora	0	0	0	0	0	0	0	0	0	0	0	**25.03**
Mitra sp.	0	0	0	0	0	0	0	0	0	0	0	**0.1**
Mitrella scripta	0	0.2	0	0	0	0	0	0	0	0.14	0	**0.77**
Nerita balteata	0	0	0	0	0	0	0	0	0	0	0	**7.5**
Nerita spp.	0	0	0	0	0	0	0	0	0	0	0	**6.39**
Patellidae	0	0	0.06	0	0	0	0	0	0	0	0	**0.06**
Planaxis sulcatus	0	0	0	0	0.06	0	0.1	0	0	0	0.15	**1.6**
Rhinoclavis sp.	0.23	0.02	0.1	0.18	0	0.22	0.44	0.21	0.11	0.31	0.4	**6.99**
Telescopium telescopium	4.85	3.25	15.1	3.94	4.14	11.22	0.56	1.73	0.67	0.85	1.66	**3027.59**
Terebralia sulcata	0.24	0	0.19	0	0	0	0	0	0.11	0	0	**101.68**
Turbo sp.	0	0	0	0	0	0.08	0	0	0	0	1.39	**5.83**
Volegalea cochlidium	0.3	0	0	0.49	0.72	0.58	0	0	0	0	0	**106.79**
Unidentified Shell	7.54	7.97	7.39	6.35	6.93	5.83	7.01	5.77	8.92	5.40	8.67	**1264.82**
XU Totals	**23.06**	**14.35**	**26.90**	**13.30**	**16.26**	**30.71**	**11.65**	**12.04**	**11.68**	**7.63**	**15.57**	**9128.69**

Concentrated shell deposition between 1000-1250 cal BP accounts for 34% of the identified mollusc assemblage based on MNI, suggesting a significant use of the site around this time with substantial deposition occurring in a relatively short space of time (Figure 7.15). Further intensive site use occurred between 250 years ago to present, accounting for 25% of the assemblage based on MNI. At other times midden creation occured much more slowly. There may even be a hiatus or limited use period between 500-750 cal BP where taxa quantities are at their lowest. The assemblage exhibits reasonably high diversity in every period with a calculated Shannon-Weaver Evenness Index between 0.54-0.64, while 65% of the assemblage comprises four species. The presence of hiant venus clams, long bums, sea-green mangrove mussels and oyster, suggest foraging strategies focused on the mangrove fringe and adjacent intertidal and sub-tidal sand and mudflats with evidence for rocky reefs also being accessed (see Figure 7.8).

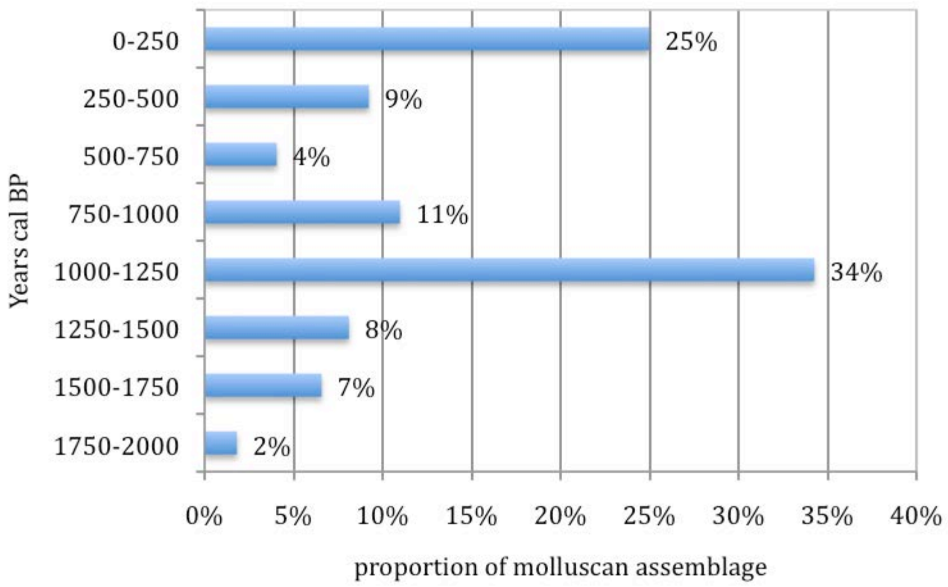


Figure 7.15: Proportion of Squares A-D total mollusc assemblage MNI per 250-year period.

Square B

In total 2.6kg of shell was recovered from Square B. 91% of all shell by weight was identified to family, genus or species level. The remaining 9% of shell based on weight could not be identified beyond Mollusca due to the generally small size of these specimens and the lack of diagnostic attributes that prevented identification to taxon; this unidentified portion of the mollusc assemblage is not included in analyses presented below. The identified assemblage comprised 23 molluscan taxa (with an MNI=455) consisting of 13 marine bivalve taxa and 10 marine gastropod taxa (Figures 7.16 and 7.17).

The shell assemblage is dominated by *M. hiantina* with an MNI of 306 or 67% of the assemblage, *Saccostrea glomerata* (15%), *Telescopium telescopium* (5%), *Terebralia sulcata* (2%) and *Calliostoma* sp. (1%). Small cerith gastropods (*Cerithidea* sp. and *Rhinoclavis* sp.) contribute 7% of the assemblage, but these specimens are not thought to have been collected for food. The remaining 16 taxa are relatively rare in the deposit, each contributing less than 1% of the shell assemblage by weight. MNI and weight data are presented in Tables 7.8 and 7.9.

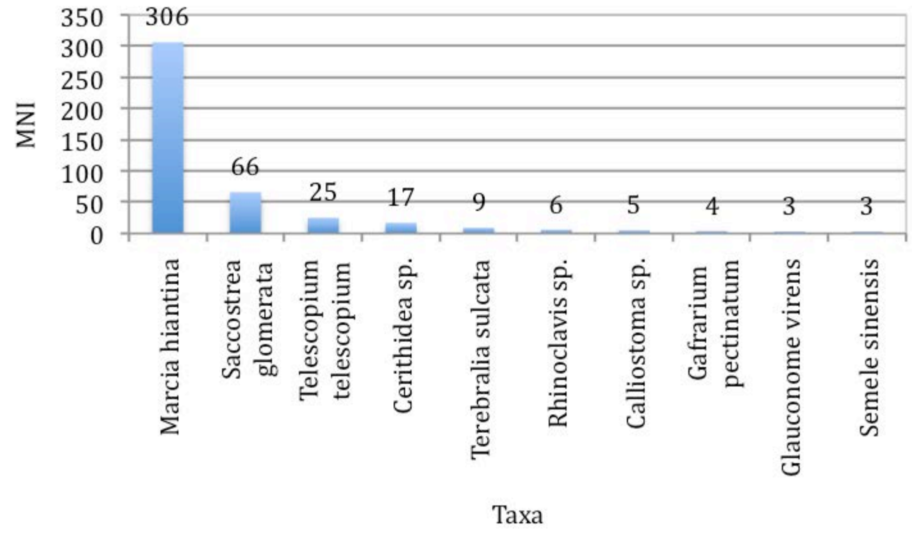


Figure 7.16: Dangkankuruwuru Square B, top 10 mollusc taxa by MNI.

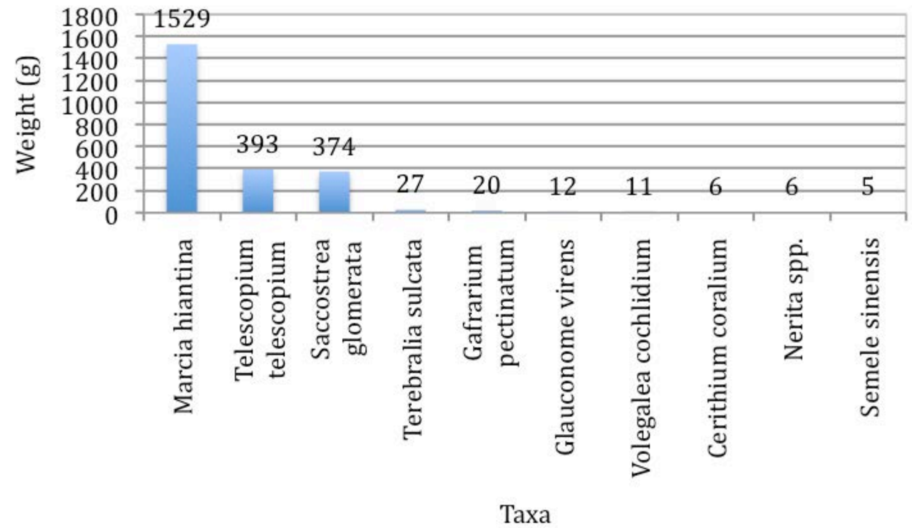


Figure 7.17: Dangkankuruwuru Square B, top 10 mollusc taxa by weight.

Table 7.8: Dangkankuruwuru Square B molluscan assemblage taxa MNIs.

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**Total**
MARINE BIVALVIA																										
Barbatia sp.										1																**1**
Circe scripta	1																									**1**
Corbula fortisulcata											1															**1**
Gafrarium pectinatum	1	1				1	1																			**4**
Glauconome virens	1					1		1																		**3**
Lunulicardia													1													**1**
Marcia hiantina	66	19	16	5	1	2	3	4	4	3	3	1	3							1			1			**306**
Placamen retroversum		1										1														**2**
Saccostrea glomerata	6	1		1	3	6	9	15	10	7	3	2					1	1	1							**66**
Semele sinensis		1								1		1														**3**
MARINE GASTROPODA																										
Calliostoma sp.										1				2	1				1							**5**
Cerithidea sp.		1	3		4	1	2	2					2		1	1										**17**
Melo amphora				1																						**1**
Nerita spp.	1																									**1**
Patellidae																						1				**1**
Rhinoclavis sp.			1		1			1			2											1				**6**
Telescopium telescopium	1	1	2		1	3	3	4	1	3	1	3			1			1								**25**
Terebralia sulcata	1							1	1	2	2		1							1						**9**
Volegalea cochlidium		1							1																	**2**
XU Totals	**7**	**20**	**22**	**7**	**10**	**14**	**18**	**28**	**17**	**18**	**12**	**8**	**7**	**2**	**3**	**1**	**1**	**2**	**2**	**2**	**0**	**2**	**1**	**0**	**0**	**455**

Table 7.9: Dangkankuruwuru Square B molluscan assemblage taxa weights (g).

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
MARINE BIVALVIA													
Asaphis violascens						0.56							
Barbatia sp.										0.26			
Chama sp.	0.51												
Circe scripta	0.11												
Corbula fortisulcata											0.16		
Gafrarium pectinatum	3.17	3.44				3.42	1.06	0.23	2.55	0.40	0.48	4.19	
Glauconome virens	0.47				0.40	4.99	0.84	2.47	2.59				
Lunulicardia hemicardium													0.01
Marcia hiantina	337.96	957.53	70.51	15.54	21.55	18.05	13.06	18.10	24.41	12.87	18.15	5.27	10.25
Mytilidae			0.01					0.02					
Placamen retroversum		3.32	0.32									0.06	
Saccostrea glomerata	16.56	3.69	2.28	12.91	15.39	41.22	51.08	68.15	61.49	37.02	38.93	7.54	5.02
Semele sinensis		1.24				0.74				0.31		2.59	
MARINE GASTROPODA													
Calliostoma sp.										0.35			
Cerithidea sp.		0.17	0.18	0.01	0.55	0.15	0.10	0.33					0.05
Cerithium coralium													6.42
Melo amphora				1.47									
Nerita spp.	6.02												
Patellidae													
Rhinoclavis sp.			0.02		0.20			0.07			0.07		
Telescopium telescopium	45.72	22.78	7.03	11.98	22.95	19.19	43.30	50.13	44.44	43.34	32.54	20.91	
Terebralia sulcata	1.37			0.30		0.80	0.70	0.52	0.61	9.82	9.27		2.45

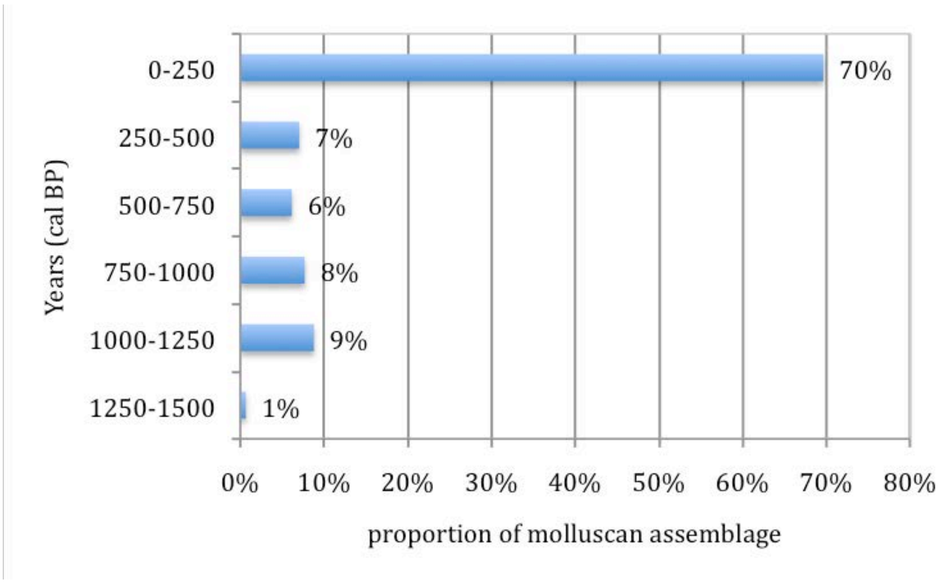
Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Volegalea cochlidium	0.83	4.82	0.92		0.92		1.16		2.29				
Unidentified Shell	23.44	16.41	6.83	14.11	15.88	18.55	26.67	20.62	17.54	33.62	17.49	4.16	6.12
XU Totals	**436.16**	**1013.40**	**88.10**	**56.32**	**77.84**	**107.67**	**137.97**	**160.64**	**155.92**	**137.99**	**117.09**	**44.72**	**30.32**

Table 7.9: Dangkankuruwuru Square B molluscan assemblage taxa weights (g) (cont).

Taxon XU	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**Totals**
MARINE BIVALVIA													
Asaphis violascens													**0.56**
Barbatia sp.													**0.26**
Chama sp.													**0.51**
Circe scripta													**0.11**
Corbula fortisulcata													**0.16**
Gafrarium pectinatum						0.91		0.11		0.34			**20.30**
Glauconome virens													**11.76**
Lunulicardia hemicardium													**0.01**
Marcia hiantina	1.19		1.07				1.04	0.75	0.45	1.31			**1529.06**
Mytilidae			0.01			0.04							**0.08**
Placamen retroversum													**3.70**
Saccostrea glomerata	0.62	0.41	0.29	3.54	1.09	3.42	0.18	0.88	1.16	1.32			**374.19**
Semele sinensis													**4.88**
MARINE GASTROPODA													
Calliostoma sp.	0.05	0.10				0.09							**0.59**
Cerithidea sp.		0.04	0.07										**1.65**
Cerithium coralium													**6.42**
Melo amphora													**1.47**
Nerita spp.													**6.02**
Patellidae									0.10				**0.10**

Taxon XU	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**Totals**
Rhinoclavis sp.									0.23				**0.59**
Telescopium telescopium	0.95	1.45	6.67	4.59	3.38	1.88	1.11	1.62	2.95	4.03	0.05	0.24	**393.23**
Terebralia sulcata							0.11	0.02	0.30	0.54	0.46		**27.27**
Volegalea cochlidium													**10.94**
Unidentified Shell	2.82	1.93	2.11	2.00	1.75	2.20	1.52	1.27	2.18	1.34	1.30	0.65	**242.51**
XU Totals	**5.63**	**3.93**	**10.22**	**10.13**	**6.22**	**8.54**	**3.96**	**4.65**	**7.37**	**8.88**	**1.81**	**0.89**	**2636.37**

Concentrated shell deposition between 0-250 cal BP accounts for 70% of the identified mollusc assemblage based on MNI, suggesting a significant use of the site around this time with substantial deposition occurring in a relatively short space of time (Figure 7.18). At other times midden creation occurs much more slowly. 90% of the assemblage comprises four species. The presence of hiant venus clams, oyster, long bums and lesser long bums, suggest foraging strategies focused on the mangrove fringe and adjacent intertidal and sub-tidal sand and mudflats with evidence for rocky reefs also being accessed (see Figure 7.8). This is consistent with taxa finds in Square A-D.



7.18: Proportion of Square B total mollusc assemblage MNI per 250-year period.

7.8.2 Vertebrate Remains

Squares A, B1, C and D

Fishbone is present in the combined Squares A-D cultural deposit, totaling 21.26g and consisting of 913 pieces of bone (Table 7.10). Reviewing site taphonomy, it seems that degradation of fish bone materials is greatest in lower XUs. 882 pieces of bone weighing 18.92g could not be assigned to a fish skeletal element, due to the generally small size of these specimens and the lack of diagnostic attributes that prevented identification to a taxon. The MNI figures have been calculated by summing the MNIs for each 250-year temporal phase, which suggest at least 23 individual fish are in the assemblage. Identified taxa include catfish (Ariidae), wrasse (Labridae), diamond-scale mullet (*Liza vaigiensis*), sea mullet (*Mugil cephalus*), longtom (*Tylosurus gavialoides*), stripey (*Lutjanus carponatus*), Moses perch (*Lutjanus russellii*), shark (Carcharhinidae), bream (*Acanthopagrus* sp.), garfish (Hemiramphidae), whiting (*Sillago burrus*), rockcod (Serranidae) and yellowtail grunter (*Amniataba caudovittata*).

Table 7.10: Fishbone remains at Dangkankuruwuru Squares A-D.

XU	Square	Taxon	Element	MNI	NISP	Weight (g)
1	D	Osteichthyes	unidentified		26	0.5657
1	C	Osteichthyes	unidentified		20	0.267
1	A	Osteichthyes	unidentified		28	0.544
1	C	Osteichthyes	unidentified		1	0.0527
1	A	Ariidae	otolith	1	1	0.2162
1	D	Labridae	left dentary	1	1	0.2732
1	D	*Liza vaigiensis*	right otolith	1	1	0.0181
1	A	*Tylosurus gavialoides*	left otolith	1	1	0.0214
1	D	*Lutjanus carponatus*	right otolith	1	1	0.2273
1	D	*Lutjanus russellii*	right otolith	1	1	0.0586
1	A	Carcharhinidae	vertebrae		2	0.0642
2	D	Osteichthyes	unidentified		27	1.0161
2	B1	Osteichthyes	unidentified		3	0.0984
2	C	Osteichthyes	unidentified		27	0.3528
2	A	Osteichthyes	unidentified		15	0.5418
2	A	Carcharhinidae	vertebrae		3	0.1067
3	D	Osteichthyes	unidentified		52	0.8295
3	B1	Osteichthyes	unidentified		64	1.3590
3	C	Osteichthyes	unidentified		34	0.2868
3	A	Osteichthyes	unidentified		39	1.0646
3	C	*Mugil cephalus*	left otolith	1	1	0.0434
3	A	Carcharhinidae	tooth	1	2	0.034
4	B1	*Acanthopagrus* sp.	epihyal		1	0.0608
4	B1	*Acanthopagrus* sp.	left dentary	1	1	0.0619
4	B1	*Acanthopagrus* sp.	posttemporal		1	0.0303
4	D	Osteichthyes	unidentified		24	0.4043
4	B1	Osteichthyes	unidentified		73	1.446
4	C	Osteichthyes	unidentified		35	0.4758
4	A	Osteichthyes	unidentified		54	1.1848
4	C	Labridae	right articular	1	1	0.0399
4	C	*Liza vaigiensis*	right otolith	1	1	0.048
4	C	*Liza vaigiensis*	left otolith		1	0.0376
4	D	*Lutjanus carponatus*	left preopercle	1	1	0.0944
5	D	*Acanthopagrus* sp.	ceratohyal		1	0.0432

XU	Square	Taxon	Element	MNI	NISP	Weight (g)
5	B1	*Acanthopagrus* sp.	left premax		1	0.0462
5	D	Osteichthyes	unidentified		21	0.3057
5	B1	Osteichthyes	unidentified		60	1.8764
5	C	Osteichthyes	unidentified		20	0.2381
5	A	Osteichthyes	unidentified		28	0.4118
5	A	Ariidae	otolith	1	1	0.2092
5	A	*Tylosurus gavialoides*	left otolith	1	1	0.0106
			0-250 cal BP	**14**	**676**	**15.0665**
6	D	Osteichthyes	unidentified		12	0.2353
6	B1	Osteichthyes	unidentified		28	0.4328
6	C	Osteichthyes	unidentified		12	0.1627
6	A	Osteichthyes	unidentified		14	0.5544
6	B1	*Sillago burrus*	left otolith	1	1	0.0152
6	D	*cf. Sillago burrus*	left otolith	1	1	0.0397
6	A	*Amniataba caudovittata*	opercular	1	1	0.0633
7	D	Osteichthyes	unidentified		12	0.4621
7	B1	Osteichthyes	unidentified		9	0.0924
7	C	Osteichthyes	unidentified		9	0.1794
7	A	Osteichthyes	vertebra		1	0.8717
7	A	Osteichthyes	unidentified		23	0.4363
			250-500 cal BP	**3**	**123**	**3.15453**
8	D	Osteichthyes	unidentified		6	0.1272
8	B1	Osteichthyes	unidentified		5	0.1143
8	C	Osteichthyes	unidentified		6	0.1453
8	A	Osteichthyes	unidentified		7	0.077
8	A	Hemiramphidae	right otolith	1	1	0.0359
			500-750 cal BP	**1**	**25**	**0.4997**
9	B1	Osteichthyes	unidentified		3	0.0196
9	C	Osteichthyes	unidentified		6	0.0443
9	A	Osteichthyes	unidentified		2	0.0174
9	A	Ariidae	otolith	1	1	0.1752
9	A	Serranidae	left otolith	1	1	0.0142
10	D	Osteichthyes	unidentified		6	0.0857
10	C	Osteichthyes	unidentified		7	0.4259
10	A	Osteichthyes	unidentified		12	0.1301
			750-1000 cal BP	**2**	**38**	**0.9124**

XU	Square	Taxon	Element	MNI	NISP	Weight (g)
11	D	Osteichthyes	unidentified		1	0.0149
11	B1	Osteichthyes	unidentified		1	0.0243
11	C	Osteichthyes	unidentified		2	0.0169
11	C	Labridae	pharyngeal	1	2	0.1551
12	D	Osteichthyes	unidentified		2	0.0151
12	B1	Osteichthyes	unidentified		2	0.0154
12	A	Osteichthyes	unidentified		1	0.005
13	A	Osteichthyes	unidentified		6	0.1137
14	D	Osteichthyes	unidentified		2	0.0169
14	B1	Osteichthyes	unidentified		1	0.0332
14	C	Osteichthyes	unidentified		1	0.0198
15	B1	Osteichthyes	unidentified		3	0.0548
15	A	Osteichthyes	unidentified		1	0.0124
16	B1	Osteichthyes	unidentified		1	0.0062
16	C	Osteichthyes	unidentified		2	0.0517
16	A	Osteichthyes	unidentified		1	0.0422
17	D	Osteichthyes	unidentified		1	0.0102
18	B1	Osteichthyes	unidentified		4	0.0761
18	B1	*Sillago burrus*	right otolith	1	1	0.0494
19	B1	Osteichthyes	unidentified		1	0.0477
20	D	Osteichthyes	unidentified		2	0.0368
20	B1	Osteichthyes	unidentified		1	0.0263
			1000-1250 cal BP	**2**	**39**	**0.8441**
22	B1	Osteichthyes	unidentified		2	0.0579
22	C	Osteichthyes	unidentified		2	0.1668
23	C	Osteichthyes	unidentified		1	0.0147
24	B1	Osteichthyes	unidentified		2	0.0369
24	C	Osteichthyes	unidentified		2	0.0303
24	B1	*Lutjanus carponatus*	right otolith	1	1	0.035
26	A	Osteichthyes	unidentified		1	0.0441
27	D	Osteichthyes	unidentified		1	0.0049
			1250-1500 cal BP	**1**	**12**	**0.3906**

Square B

Fishbone is present in the Square B cultural deposit, totaling 3.22g and consisting of 15 pieces of bone (Table 7.11). Reviewing site taphonomy, degradation of fish bone materials is greatest in lower XUs. 11 pieces of bone weighing 2.30g in total could not be assigned to a fish skeletal element, due to the generally small size of these specimens and the lack of diagnostic attributes that prevented identification to a taxon. The MNI figures have been calculated by summing the MNIs for each XU, which suggest at least three individual fish are in the assemblage. The only taxon that could be identified was blue catfish (*Neoarius graeffei*).

Table 7.11: Fishbone abundance at Dangkankuruwuru, Square B.

XU	Square	Taxon	Element	MNI	NISP	Weight
1	Sq B	Osteichthyes	vertebra		1	0.07
2	Sq B	Osteichthyes	unidentified		2	1.41
3	Sq B	Osteichthyes	unidentified		1	0.02
4	Sq B	Ariidae	otolith	1	3	0.17
6	Sq B	Ariidae	otolith	1	3	0.01
7	Sq B	Ariidae	otolith	1	1	0.67
8	Sq B	Osteichthyes	unidentified		1	0.53
9	Sq B	Osteichthyes	unidentified		1	0.03
9	Sq B	Osteichthyes	unidentified		1	0.24
10	Sq B	Osteichthyes	unidentified		1	0.07
			Fish-bone Totals	**3**	**15**	**3.22**

7.9 Application of Models

7.9.1 Diet-Breadth/Prey Choice

Broad patterns in the breadth and diversity of molluscan exploitation at Dangkankuruwuru can be identified using species richness and abundance measures. The species richness graphs show the number of species collected from each habitat per 250-year period (Figure 7.19). Three habitats (Rocky/Coral Reefs, Sandy-Mudflats and Mangroves and Tidal-Mudflats) were consistently exploited, however the level of species richness by habitat varies between chronological periods. This variation is not considered statistically significant (X^2=4.87, d.f=10, p>0.5). Figures 7.20 shows that the top five species were consistently exploited over time in generally the same ratios for each period, except for the last 250 years where there is a spike in hiant venus clam (*M. hiantina*) numbers. These results suggest that for the most part the same species were being foraged from the local area, and also that the diet breadth was quite broad.

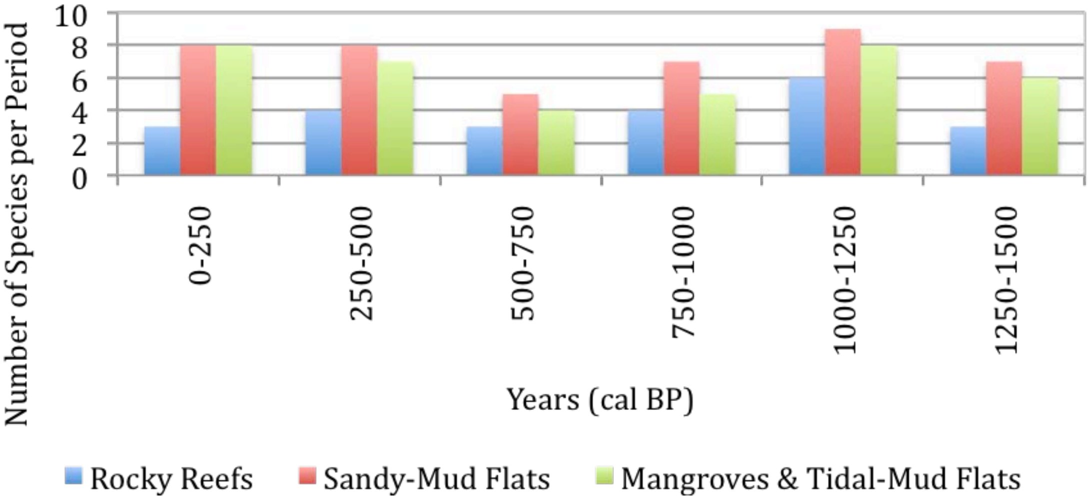


Figure 7.19: Dangkankurwuru Squares A-D, species richness per habitat per 250-year period.

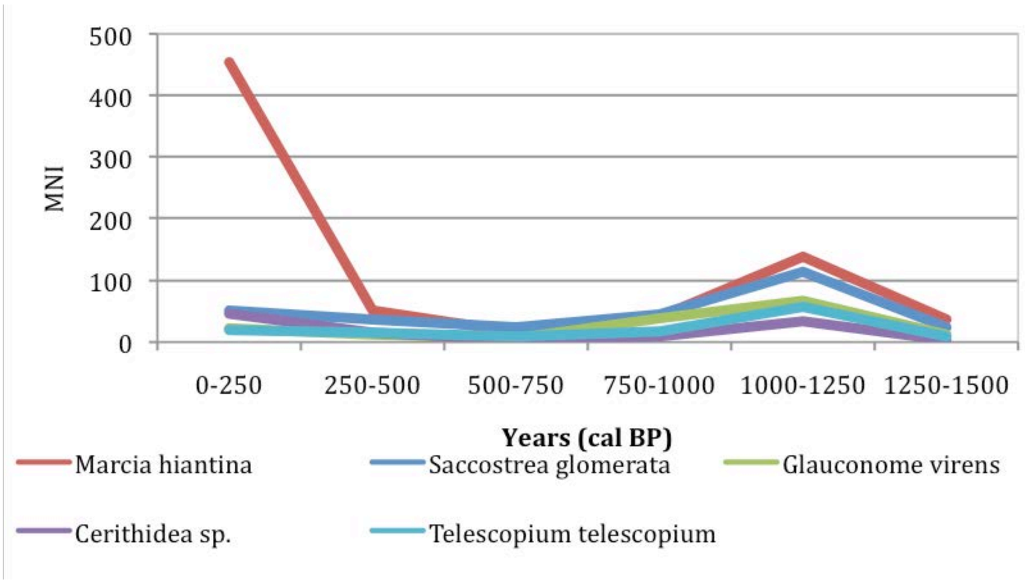


Figure 7.20: Dangkankuruwuru Squares A-D top five mollusc taxa MNI per 250-year period.

7.9.2 Habitats/Patch Choice

Figure 7.21 shows the proportion of MNI collected by habitat. As already noted, the Dangkankuruwuru mollusc assemblage includes taxa from three patches or habitats, however there is temporal variance in the quantities of taxa taken from each patch. Chi-square results indicate that this variance is statistically significant (X^2=242.93, d.f.=10, p<0.001). The Sandy-Mud Flats patch is the dominant focus of resource exploitation during 1250-1500 cal BP contributing almost half the assemblage for that period. Mangrove-dwelling species are at their highest (40%) between 750-1000 cal BP however only a limited range of taxa is being targeted. In contrast, Sandy-Mud Flats species contribute only 32% of the assemblage at this time even though there is higher species richness. The Sandy-Mud Flats patch is again heavily exploited in the last 250 years.

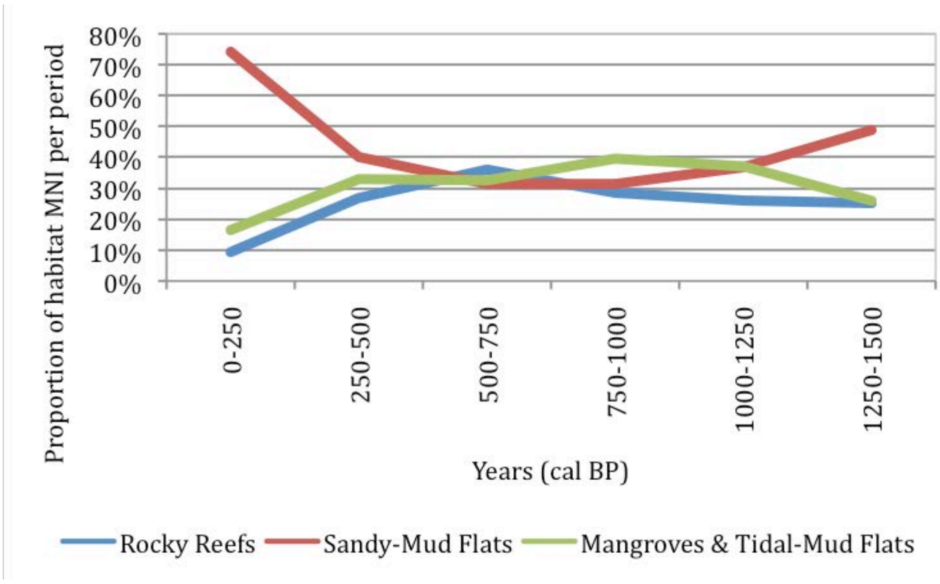


Figure 7.21: Percentage of species MNI collected from each patch by 250-year period, Dangkankuruwur Squares A-D.

Changes in patch use between the Sandy-Mud Flats and Mangroves and Tidal-Mud Flats patches can be tracked through the use of an index (Figure 7.22). The decline in the index indicates that foragers' preference is switching from mangrove taxa to Sandy-Mud flats taxa through time. The chi-square result (X^2=150.79, d.f.=5, p<0.001) indicates that the decline in mangrove species is significantly correlated with the increase in Sandy-Mud Flats species.

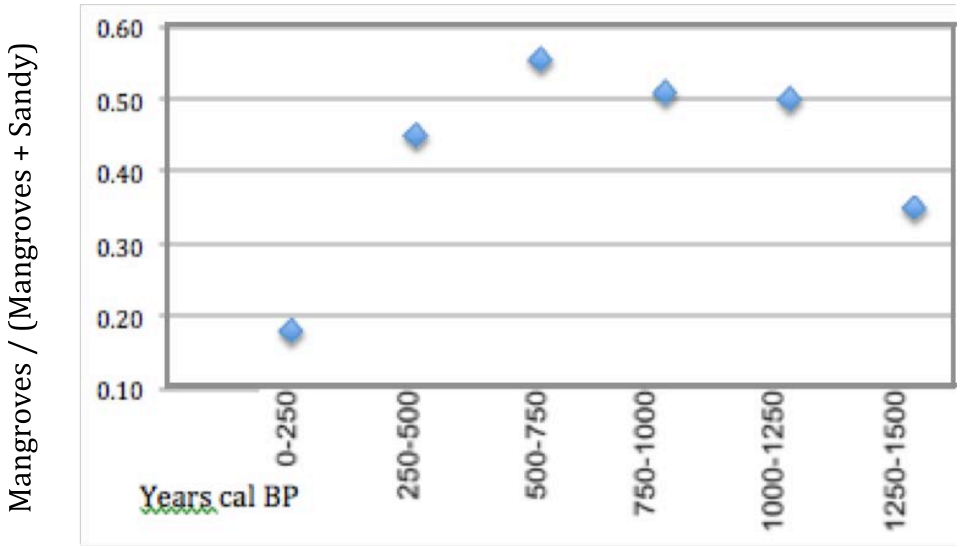


Figure 7.22: Change in patch use indicated by Mangroves-Sandy-Mud Flats Patch Index for Dangkankurwuru Squares A-D.

In terms of the top five species, *M. hiantina*, a Sandy-Mud Flats species is more intensively exploited than the other three species (*Glauconome virens* and *Telescopium telescopium*, all mangrove species, and *Saccostrea glomerata*, a rocky reef species), particularly in the last 500 years. (note that *Cerithidea* sp. is considered to be a non-economic species that was not deliberately collected). Not shown on the graph, but of some relevance is the fact that other Sandy patch species not previously collected in earnest before, are being exploited in greater numbers at this time too, for example, *Gafrarium pectinatum*, *Semele sinensis* and *Mactra* sp. From this information, we can suggest that either there was a changing distribution or decline of mangrove habitats or foragers chose to intensify exploitation of the Sandy-Mudflats patch for socio-cultural reasons.

7.9.3 Central-Place Foraging Model

Based on the site's location, relatively large size and number of taxa present, Dangkankuruwuru appears to have been a central-place for occupation where foragers brought food back to share. Central-place foraging does impose travel costs, such as the energetic cost of carrying a food item from its procurement source back to camp. Rocky Reef species make up a lower proportion of the assemblage throughout all periods, perhaps because of higher associated capture costs. The location of rocky reefs out past the tide line (Figure 7.8) would make it (1) harder to access the resource habitat, and (2) further to transport the oysters back to the central-place camp. It may also be harder to extract the molluscs from the rocks therefore consumption of these molluscs was likely to be occurring at the rocks.

7.9.4 Resource Intensification and Foraging Efficiency

At Dangkankuruwuru, *M. hiantina* is the most prevalent taxon in the assemblage and it is documented throughout the entire period of occupation. Based on the prey choice model, it stands to reason that as the dominant taxon the hiant venus clam would be classed as a high-ranked taxon. At this site, very low values of high-ranked taxa occur before 1500 cal BP, suggesting there may have been a low-level cultural occupation prior to this time. Greater abundances of high-ranked taxa occur for periods 1000-1250 cal BP and 250 cal BP to present, indicating these periods saw more intensive site use. When reviewing the relationship between *M. hiantina* MNI and mean valve sizes for each excavation unit (see Tables 7.12 and 7.13), there is no significant change for Dangkankurwuru (Spearman's r_s=-0.2113, p>0.05, n=20). However, when examined per 250-year period, there are corresponding changes such that MNI increases are followed by a reduction in mean valve length (Figure 7.23) as predicted in resource depression models.

Table 7.12: Metrical data for *M. hiantina* valves from Dangkankuruwuru, Squares A-D.

XU	Mean (mm)	Median (mm)	S.D. (mm)	Min (mm)	Max (mm)	Range (mm)	No.
1	34.80	35.66	3.15	29.36	39.08	9.72	16
2	34.92	35.45	3.4	29.09	40.24	11.15	12
3	35.52	35.55	3.5	26.68	40.92	14.24	25
4	33.7	33.68	3.66	26.12	41.87	15.75	39
5	34.75	35.32	3.62	27.64	40.62	12.98	26
6	37.78	38.12	2.3	34.83	40.04	5.21	4
7	34.43	33.13	2.99	31.01	38.54	7.53	8
8	34.46	33.96	4.66	28.76	44.07	15.31	9
9	33.47	32.8	2.49	28.75	37.98	9.23	12
10	33.82	33.57	1.26	32.44	35.67	3.23	6
11	35.68	35.68	1.85	32.91	38.44	5.53	6
12	34.45	35.06	1.62	31.37	36.43	5.06	13
13	35.3	34.44	2.38	32.36	37.95	5.59	5
14	34.39	34.63	4.69	25.13	42.22	17.09	10
15	34.95	34.72	2.08	31.52	39.3	7.78	11
16	34.95	35.11	3.00	31.66	40.58	8.92	11
17	33.04	31.89	3.67	29.52	38.45	8.93	6
18	31.86	31.86	0	31.86	31.86	0	1
19	31.91	32.65	6.70	23.83	42.21	18.38	7
20	36.01	36.01	0.71	35.51	36.52	1.01	2

Table 7.13: Metrical data for *M. hiantina* valves from Dangkankuruwuru, Square B.

XU	Mean (mm)	Median (mm)	S.D. (mm)	Min (mm)	Max (mm)	Range (mm)	No.
1	33.02	32.10	2.07	29.9	36.6	6.7	21
2	33.64	33.50	2.32	26.7	40.5	13.8	120
3	31.81	30.30	3.24	28.0	36.20	8.2	9
4	31.10	31.1	0	31.1	31.1	0	1
5	32.30	33.2	2.99	29.0	33.8	4.8	3
6	32.37	32.50	2.68	29.5	35.0	5.5	4
7	33.50	33.50	0	33.50	33.50	0	1
8	32.10	32.10	4.38	29.0	35.20	6.2	2
9	34.20	34.60	3.01	31.0	37.0	6	3
10	35.20	35.20	0	35.20	35.20	0	1
11	33.20	33.20	0	33.20	33.20	0	1
12	32.50	32.50	0	32.50	32.50	0	1
13	37.60	37.60	0	37.60	37.60	0	1

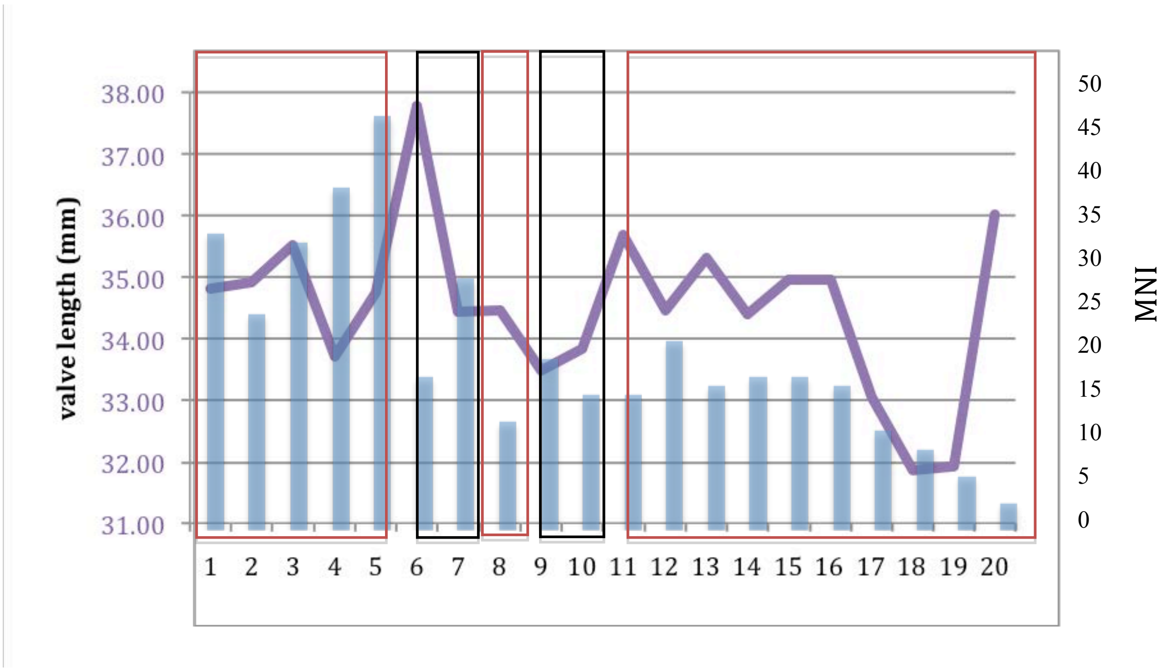


Figure 7.23: Relationship between *M. hiantina* MNI (columns) and mean valve length (mm) per 250-year period for Squares A-D and Square B.

This suggests that the hiant venus clam could be a subject of resource depression, and/or foraging efficiency (the amount of time foragers spend in the patch when compared with the energy return rate from prey collected) could be declining in the Sandy-Mud Flats patch. It appears that resource intensification of *M. hiantina* in some periods may have resulted in reducing specimen sizes, although this does not seem to be a lasting effect when predation pressure eases. However, if exploitation of this species continued without abatement, we could likely see the long-term effects of resource depression that would eventually deplete the clam population.

Of the identified vertebrate taxa rockcods, wrasses and stripeys inhabit shallow coastal waters around rocky/coral reefs. Longtoms, garfish, diamond-scale mullet, whiting, catfish, bream and yellowtail grunter have been caught on the reefs and in the creeks and estuaries. Trevally and Russell's perch are often found cruising deeper waters; however these species have also been caught off the beach at Sweers Island. Reef sharks frequent the shallow inshore waters of the South Wellesley Islands in search of fish prey. Although these fish are generally found in different coastal waters habitats, it is entirely feasible that all of these taxa could have navigated into nearshore waters, perhaps chasing prey or getting caught in tides and currents. It would therefore definitely be possible to spear and or net fish in the fishtraps, in creeks and estuaries, off the beach and in the shallow nearshore waters. Table 7.14 shows the lengths of the fish otoliths collected from the Dangkankuruwuru midden as well as the lengths of comparative fish otoliths in the TARL fish reference collection (Tomkins *et al.* 2013). It is estimated that in total these fish weighed over 7.7kg, providing approximately 5488 calories of energy. The other fish (trevally, shark, bream) that were identified from other diagnostic elements in the absence of otoliths could feasibly have contributed an additional 2-5kg to the diet (1400-3500 calories) based on the weights of live collected specimens for the TARL fish reference collection.

Table 7.14: Estimated weights of fishes based on otolith lengths of archaeological specimens compared with reference collection specimens.

Taxon	XU	Comparative otolith length (mm)	Comparative taxon weight (g)	Length of archaeological otolith (mm)	Estimated weight (g) / energy return* of archaeological fish (kcal/hr)
Squares A, B1, C, D.					
Ariidae	1	9.5	300	8.5	268 / 187
Liza vaigiensis	1	7.1	480	6.5	439 / 307
Tylosurus gavialoides	1	7.0	550	6.25	726 / 508
Lutjanus carponatus	1	10-11.2	300-600	18.35	801 / 560
Lutjanus russellii	1	14.8	1385	7.0	655 / 455
Mugil cephalus	3	10	725	6.0	435 / 304
Liza vaigiensis	4	7.1	480	9.5	642 / 449
Ariidae	5	9.5	300	9.25	292 / 204
Tylosurus gavialoides	5	7.0	550	5.5	432 / 302
Sillago burrus	6	10.2-11.2	380-430	7.0	265 / 185
Hemiramphidae	8	5.5	50	6	54 / 37
Ariidae	9	9.5	300	8	252 / 176
Serranidae	9	10-16.5	1000-3850	6.5	1098 / 768
Sillago burrus	18	10.2-11.2	380-430	5.5	210 / 147
Lutjanus carponatus	24	10-11.2	300-600	7.25	308 / 215
Square B.					
Ariidae	8	9.5	300	13	410 / 287
Ariidae	9	9.5	300	10	316 / 221
Ariidae	10	9.5	300	8	252 / 176

* It is estimated that 70% of a fishes weight will be meat and on average 1g = 1 calorie (Smith 2011).

7.10 Discussion

Dangkankuruwuru exhibits evidence for very limited occupation prior to 1500 cal BP and possibly a hiatus between 750-500 cal BP. Two phases of intensive occupation occur between 1250-1000 cal BP and between 250 cal BP to present, where mollusc MNI numbers are at their highest. There is also evidence that foragers diversified their diet breadth at these times with the highest species richness recorded for the Sandy-Mudflats and Mangrove and Tidal-Mudflats habitats. Intensified exploitation of the hiant venus clam corresponds with a slight reduction in the targeting of high-ranked species from other habitats (mangroves and rocky reefs) such as oyster, sea-green mussels and longbums.

Other archaeological research in the Gulf of Carpentaria at Groote Eylandt and Mornington Island provides evidence for more intensive use of sites post-500 cal BP with middens containing diverse species from sand-mud shellbeds in the immediate vicinity. Rosendahl *et al.* (2014) and Clarke (1994) suggest this diversifcation is the result of a strategy designed to provision larger groups of people camped at one location for longer periods of time.

On the basis of available information, I suggest that intensified exploitation of hiant venus clams along with diversified diet breadth in all local habitats at certain times, likely indicates increased demand for existing resources to provision increasing foraging populations at Dangkankuruwuru. Based on the reduction in the mean size of specimens that correspond with increases in MNI, I suggest that intensive focus on *M. hiantina* affected the population structure of this species, which would eventually have led to declining foraging efficiency and likely resource depression if exploitation continued in earnest for extensive lengths of time.

7.11 Summary

Excavation at Dangkankuruwuru revealed a relatively deep, high-density shell deposit consistent with observations of the material exposed across the dune surface. The marine fauna assemblage is consistent with the site being a central-place camp that was mainly utilized during the last 250 years with a period of high use also occurring 1000-1250 cal BP. Here occupants shared resources hunted in the clear nearshore waters and gathered from Sandy-Mud Flats and Rocky Reefs habitats. Mangrove and Tidal-Mud Flats shellfish species are still being collected at these times, although species from the other two habitats are present in greater numbers. There is also a significant increase in fish numbers present for the period 0-250 cal BP. These results at Dangkankuruwuru, where foragers at first diversified their collection pattern to incorporate taxa from different patches and then gradually focused on one taxon at the expense of others, are indicative of hunter-gatherer foraging choices, rather than a reflection of short-term environmental changes impacting resources.

Chapter 8. Thundiy, Bentinck Island

8.1 Introduction

Archaeological investigations at the site of Thundiy on the north coast of Bentinck Island revealed a large, stratified shell midden deposit dating from c.800 cal BP to the present. Cultural materials are widely exposed across the ground surface and extend to c.50cm below ground surface.

8.2 Site Description and Setting

During the 2009 field season, a detailed pedestrian survey of the northern coastline of Bentinck Island revealed widespread quantities of shell and occasional stone artefacts along the surface of a mid-Holocene beach ridge extending between the mouths of Rukathi Creek and the Makarrki River (Figures8.1-8.2). The beach ridge is approximately 4km long (SW-NE) and up to 150m wide (SE-NW), c.6.25-6.5m above sea-level sitting on a partially consolidated beachrock (Figure 8.2). A large low-lying salt-clay pan runs parallel to the site along the northwestern edge of the beach ridge and extends c.220m toward the sea where a dense mangrove forest (c.100m wide) fringes the shoreline (Figures 8.3-8.5). Tindale (1962a:285) records a dense concentration of named campsites along this ridge, which he calls a 'wooded plateau' further describing the landscape between the Makarrki River and Rukathi Creek as 'a quarter-mile wide belt of normally dry claypan and sand [that] lies behind the mangrove fringe'.

Thundiy is a large, stratified midden covering a minimum area of c.600,000m^2. Excavations were undertaken at the approximate centre of the site at Latitude: 17.018360S; Longitude: 139.49390E. Shell is found in high-density patches across much of the ground surface and is dominated by *Marcia hiantina*, *Tegillarca (Anadara) granosa*, *Saccostrea glomerata*, *Volegalea cochlidium* and *Telescopium telescopium*, with lesser quantities of *Gafrarium pectinatum*, *Semele sinensis* and *Placuna placenta*. A few species of small gastropods are also prolific throughout the site including *Cerithidea* spp., *Clypeomorus* sp. and *Rhinoclavis* sp. Stone artefacts manufactured on silcrete are commonly associated with the shell deposit. The remains of other marine fauna (e.g. fish bone and turtle bone) are also present.

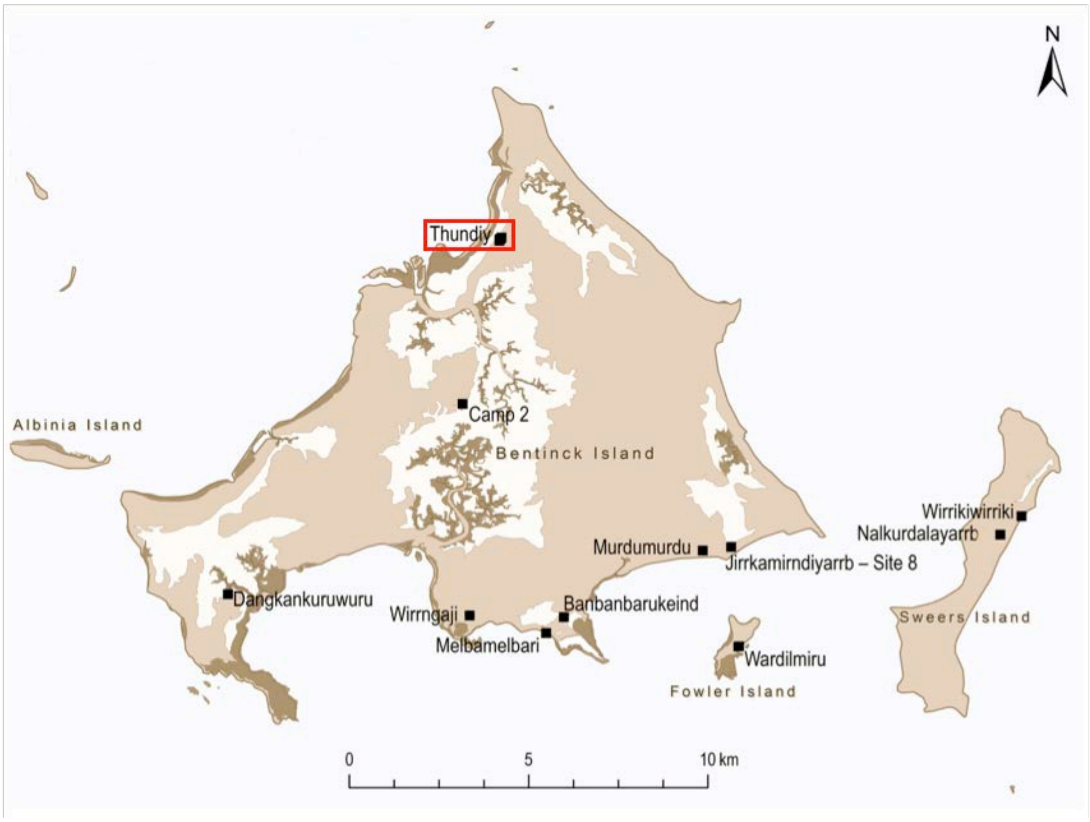


Figure 8.1: Map of South Wellesley Islands showing Thundiy site location (prepared by Lincoln Steinberger and Sean Ulm).

Figure 8.2: Aerial view map showing Thundiy site location (after Google Earth).

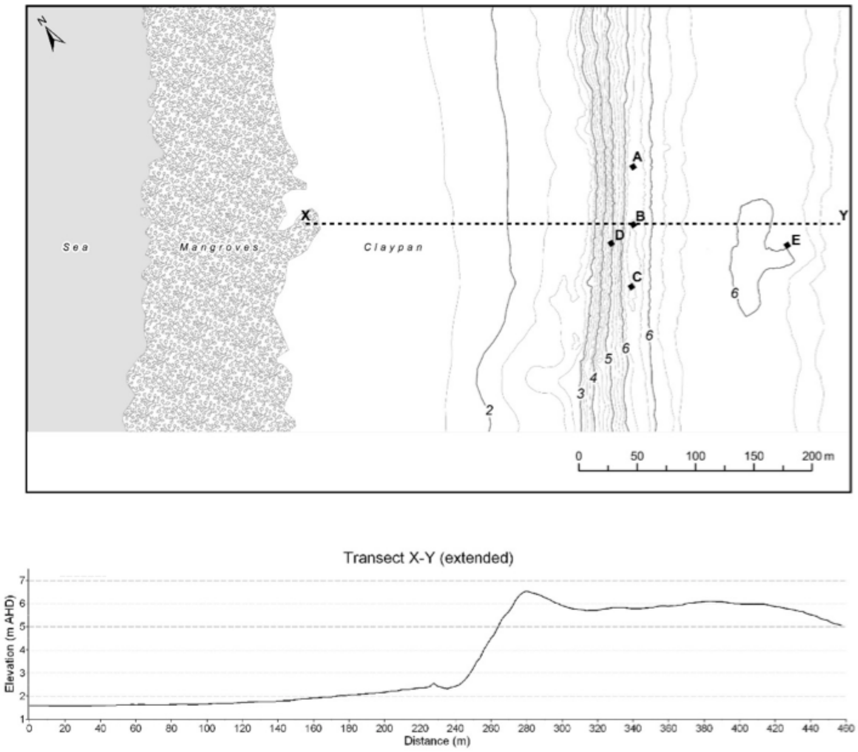


Figure 8.3: Topographic map of the central area of Thundiy showing the location of excavation squares A-E. (D) Cross-section X-Y (as shown on C). Elevations relative to Australian Height Datum (AHD) (prepared by Lincoln Steinberger and Sean Ulm).

Figure 8.4: Western slope at Thundiy showing tall mangrove forest in the mouth of the Makarrki River in the background (facing west) (Photo by Daniel Rosendahl).

Figure 8.5: General view of Thundiy surface in vicinity of Square C. Large bivalves are *Placuna placenta* (facing northwest).

The beach ridge is vegetated with pandanus, spinifex grasses (*Triodia* spp.), eucalypts, grevilleas, casuarinas and acacia trees. Mangrove vegetation includes the red stilt-root mangrove (*Rizophora stylosa*), yellow mangrove (*Ceriops togal*), orange mangroves (*Bruguiera* spp.) and grey mangroves (*Avicennia marina*) (Wightman *et al.* 2004). During the wet season, this salt claypan is inundated. A large tidal waterway (Rukathi Creek) can be found at a distance of approximately 1.5km to the northeast of the site and located c.2km to the west-southwest is the Makarrki River estuary. Both these waterways are rich with estuarine marine resources.

The coastline adjacent to Thundiy comprises extensive intertidal and subtidal sandy-mud flats, rocky bommies, claypan salt flats and mangrove communities (Figure 8.6). The rocky outcrops support clumps of oysters (*S. glomerata*) and *Calliostoma* sp. Telescope mud whelks (*T. telescopium*) are common amongst rearward mangroves. The intertidal sandy-mud flats along the front shoreline support hiant venus clams (*M. hiantina*) and tumid venus clams (*G. pectinatum*). Low stone-walled intertidal fishtraps have been observed on the seaward side of the dense mangrove fringe.

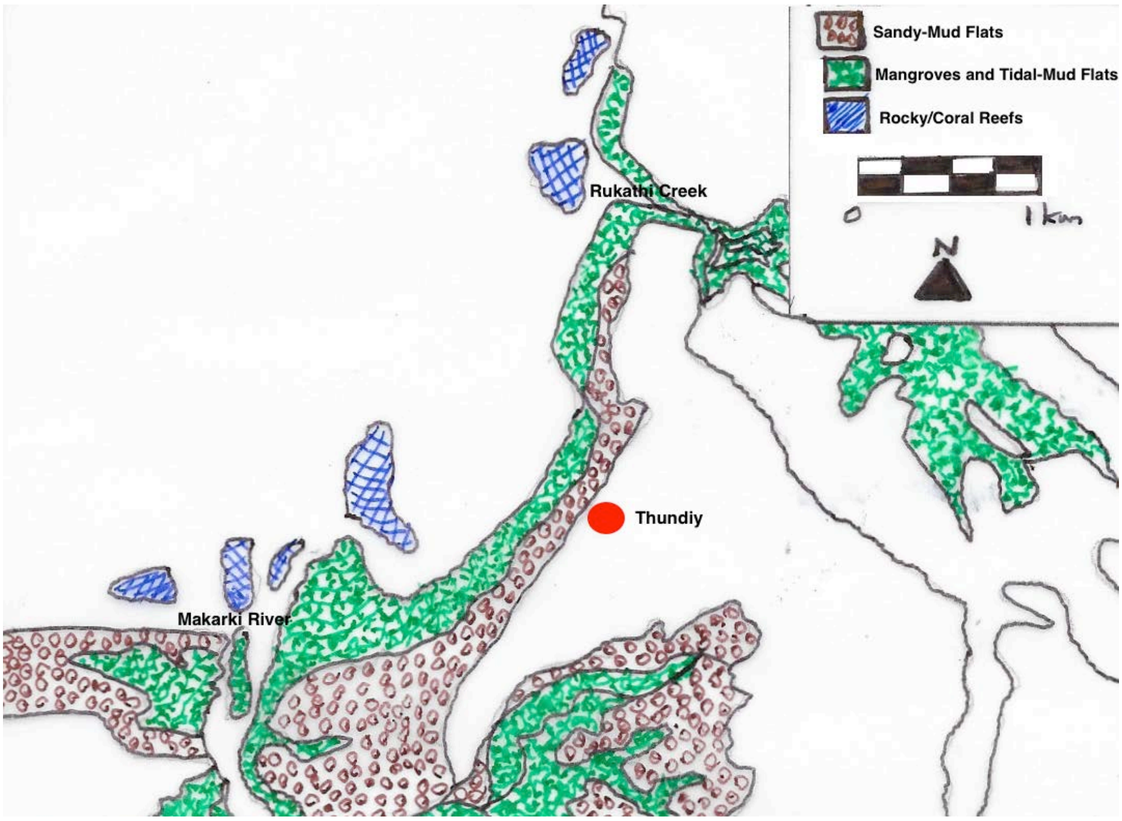


Figure 8.6: Resource habitat communities near Thundiy

8.3 Excavation Methods

Thundiy was selected for test excavation for three reasons. First, the site appeared to be potentially one of the most extensive coastal archaeological sites documented for the Australian tropical zone. Second, the site held significance for Kaiadilt people today who recalled their ancestors were camped at this location. Third, it was located on the north coast behind a thick mangrove fringe protecting the deposits from the prevailing direction of winds and cyclones from the southeast. Three 50cm x 50cm squares were excavated at 50m intervals along a transect line established in the approximate middle of the site along the highest part of the beach ridge (Figure 8.2). The excavation squares were placed to determine patterns of variation in subsurface deposits. Excavations proceeded in shallow, arbitrary excavation units averaging 2.5cm in depth and c.11kg in weight. Excavations ceased at c.60cm below ground surface in the three squares. All excavated materials were dry sieved through 2.3mm mesh on site and materials retained in the sieve were bagged for sorting and identification in the laboratory (see Chapter 5 for a detailed discussion of the standard excavation and laboratory methods employed at all sites). A further two squares (D and E, see Figure 8.2) were excavated in 2014 to investigate geophysical anomalies and will be reported elsewhere (see Kenady in prep.).

8.4 Cultural Deposit and Stratigraphy

Excavations revealed an extensive, high-density cultural sequence with shell, bone, stone artefacts and charcoal concentrated in all squares. The stratigraphic profile in all squares is characterised by dense cultural shell deposits to a depth of c.40cm overlying c.20cm of shelly beach ridge material overlying partially consolidated beachrock (Figures 8.7-8.9).

Figure 8.7: Square A 50cm x 50cm excavation pit profile (facing north) (photo by Sean Ulm).

Figure 8.8: Square B 50cm x 50cm excavation pit surface (facing north) (photo by Sean Ulm).

Figure 8.9: Square C 50cm x 50cm excavation pit profile (facing north) (photo by Sean Ulm).

The majority of shell was recovered in Square A from between XU1-12 (c.0cm-36cm depth), in Square B from XU1-12 (c.0cm-37cm) and in Square C from XU1-10 (c.0cm-30cm). The deposit can be divided into four stratigraphic units (SUs) – from the top, SUI is dense shell matrix in dark brown humic (7.5YR-3/2), sandy sediment. SUIIa is a layer of dark brown humic (7.5YR-3/2), sandy sediments with lesser quantities of shell. SUIIb contains brown to light brown (7.5YR-6/4) coarse sands with small pisolith gravels and numerous small (<10mm) gastropods. SUIII is the beach ridge surface containing light brown (7.5YR-6/4) shell grit with pebbles and corals, which appears to be culturally sterile (Table 8.1; Figures 8.10-8.12).

Table 8.1: Stratigraphic Unit (SU) descriptions, Thundiy Squares A, B and C.

SU	Description
I	Extends across all squares with depths below ground surface averaging 15cm in Square A, 35cm in Square B and 27cm in Square C. The unit comprises angular to subangular loosely-consolidated sands with numerous spinifex grass rootlets. These sediments are dark brown (7.5YR-3/2) in colour. Some evidence of insect disturbance with small burrow voids present. Dense matrix of cultural materials includes charcoal fragments, whole and fragmented venus clams (*Marcia hiantina*), ark clams (*Tegillarca granosa*), windowpane oysters (*Placuna placenta*) and rock oysters (*Saccostrea glomerata*). pH values are highly alkaline (9.5-10.0). Shell materials appear to be reasonably well-preserved.
IIa	SUII is a transitional unit between SUI and SUIII that ranges in thickness from c.5cm in Square B to 8cm in Square C and 15cm in Square A. The upper layers of the unit are described as SUIIa and feature dark brown (7.5YR-3/2) humic sediments, fewer spinifex grass rootlets and shell grit inclusions. The thick matrix of cultural materials reduces in density with depth as large shells lessen in number while small gastropods increase in number. pH values are highly alkaline (9.5-10.0).
IIb	The lower layers of the SUII transitional unit are described as SUIIb and feature brown (7.5YR-5/3) to light brown (7.5YR-6/4) loosely-consolidated coarse sands and increasing small (<10mm) gastropods and shell grit inclusions ranging in thickness from 8cm in Square B to 12cm in Square C and 15cm in Square A. The unit contains water-rounded pebbles, corals and ironstone pisoliths. This unit appears to be culturally sterile apart from occasional weathered shells that have likely filtered down the matrix through taphonomic processes. pH values are highly alkaline (9.5-10.0).
III	Very loosely consolidated coarse sands containing abundant shell grit, small gastropods commonly found in natural beach ridge deposits, water-worn pebbles and large pieces of coral. SUIII in Square A ranges in colour from light brown (7.5YR-6/4) to brown (7.5YR-5/4). In Square B and Square C the sediments are light brown (7.5YR-6/4) in colour. A continuous layer of partially consolidated beach rock forms the base of this unit at c.60cm below the surface. SUIII is culturally sterile. pH values remain highly alkaline (9.5-10.0).

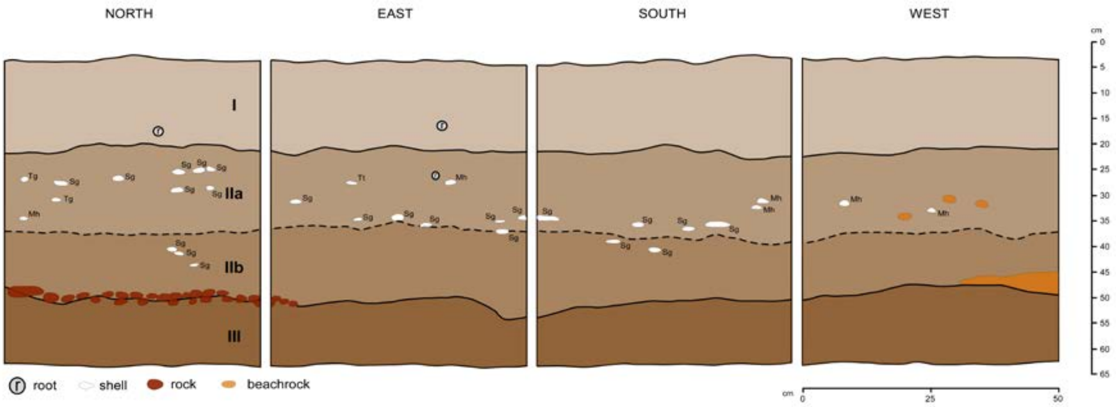


Figure 8.10: Stratigraphic section drawing, Thundiy Square A (prepared by Michelle Langley and Sean Ulm).

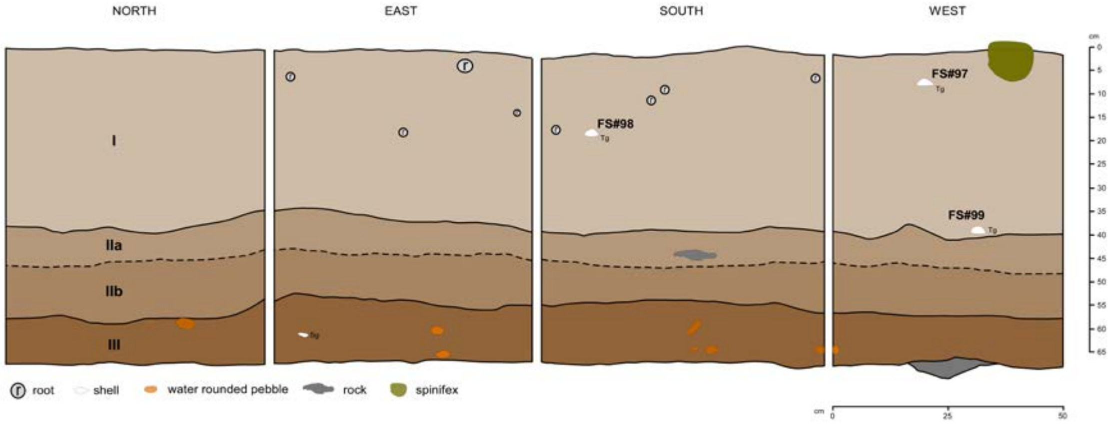


Figure 8.11: Stratigraphic section drawing, Thundiy Square B (prepared by Michelle Langley and Sean Ulm).

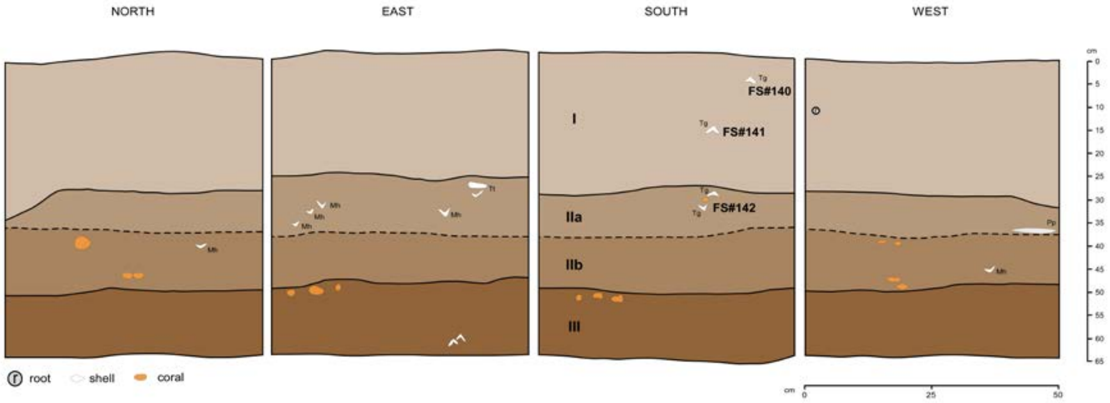


Figure 8.12: Stratigraphic section drawing, Thundiy Square C (prepared by Michelle Langley and Sean Ulm).

8.5 Site Integrity and Taphonomy

The deposit exhibits reasonable stratigraphic integrity. Although there is some evidence of minor disturbance in the form of insect burrows and spinifex grass roots towards the surface the impact of these appears to be minimal. The sequence of radiocarbon dates is in order with a regular age-depth relationship (see Section 8.6). Identification of vertebrate remains has been hampered due to bones being heavily fragmented throughout all units. There is also a predictable shell decay profile with highly weathered tiny gastropod specimens recovered from the base of the deposit and relatively well-preserved specimens from the upper deposit. At different times since the early 1980s, a 4WD track has been in use along the top of the ridge, which may have contributed to surface shell fragmentation.

8.6 Radiocarbon Dating and Chronology

Eighteen radiocarbon determinations were obtained for the deposits at Thundiy that indicate cultural occupation since c.800 cal BP occurring some 3000 years after the formation of the underlying natural shelly-beach ridge (Nagel *et al.* 2016). This cultural matrix is characterised by a dense layer of cultural shell that overlies natural beach ridge material and basal beachrock ridge. Table 8.2 shows these dates.

Nine dates are <1000 cal BP from the cultural deposits on cultural materials (*Tegillarca granosa*, *Marcia hiantina*, *Gafrarium pectinatum*) and were used to investigate age-depth relationships (Figure 8.13). These radiocarbon ages date site occupation to between 104 and 793 cal BP with a sharp chronostratigraphic disjunction to the lower beach ridge dating between 4717 and 5039 cal BP. The sandy beach ridge deposits overlie beachrock dated on a *G. pectinatum* concreted into its surface to 5334 cal BP (Table 8.2).

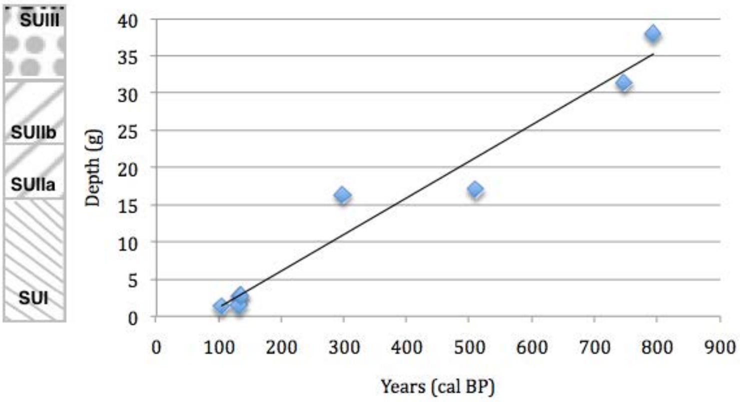


Figure 8.13: Age-depth relationship of cultural radiocarbon determinations for Thundiy Squares A-C. Note that some of the dates are not visible on the graph as they overlap at the surface.

Table 8.2: Radiocarbon ages on marine shell for Thundiy, Squares A-C. Shaded laboratory code cells indicate dates on natural deposits. Calibrations undertaken using OxCal v.4.2 (Bronk Ramsey 2009) and Marine13 calibration dataset (Reimer *et al.* 2013). For samples a ΔR of −49±102 as recommended by Ulm *et al.* (in prep.) is employed.

Sq	XU	Depth (cm)	Sample (species)	Lab. Code	$\delta^{13}C$	CRA	Calibrated Age BP (95.4%)	Calibrated Age BP Median
A	1	0-2.7	*Tegillarca granosa*	Wk-32135	-1.6±0.2	428±36	0*-301	132
A	1	0-2.7	*Marcia hiantina*	OZP-186	-2.7±0.1	430±35	0*-302	133
A	6	14.5-18.0	*Tegillarca granosa*	Wk-32136	-1.8±0.2	611±34	0*-490	298
B	1	0-2.5	*Marcia hiantina*	OZP-197	-3.3±0.1	370±30	0*-258	104
B	6	15.4-18.6	*Marcia hiantina*	Wk-34772	0±0.2	851±25	309-661	510
B	11	30.3-33.4	*Tegillarca granosa*	Wk-28560	-1.6±0.2	868±30	314-675	525
B	13	36.7-39.4	*Marcia hiantina*	Wk-37498	-2±0.2	1192±22	611-1007	793
B	20	57.5-60.4	*Marcia hiantina*	Wk-36175	1±0.2	4716±28	4795-5305	5039
C	1	0-2.7	*Marcia hiantina*	OZP-187	-1.6±0	435±30	0*-303	135
C	11	31.4	*Tegillarca granosa*	Wk-28561	-1.3±0.2	1139±30	548-934	747
C	15	41.7-44.7	*Marcia hiantina*	Wk-36176	0.3±0.2	4484±29	4421-4985	4717
C	20	56.5-59.6	*Gafrarium tumidum*	Wk-36177	2±0.2	4682±28	4724-5292	4997
B	4	9.34-12.34	*Elphidium* sp.	Wk-39331	1.7±0.2	5375±46	5568-6065	595
B	9	24.5-27.5	*Elphidium* sp.	Wk-39332	1.7±0.2	5284±46	5461-5933	5706
B	13	36.7-39.4	*Elphidium* sp.	OZQ-662	1.7±0.2	6165±50	6394-6931	6659
B	13	36.7-39.4	*Elphidium* sp.	OZQ-538	1.7±0.2	6460±80	6700-7290	7009
B	20	57.5-60.4	*Elphidium* sp.	OZQ-663	1.7±0.2	5615±40	5827-6301	6067
B	2	57.5-60.4	*Elphidium* sp.	OZQ-539	1.7±0.2	5890±60	6105-6639	6362
D	13	35	*Gafrarium tumidum*	Wk-40103	-	4942±21	5036-5571	5334

Assemblages were divided into periods spanning 250 years based on analysis of the age-depth relationship of radiocarbon dates and the matrix stratigraphy. Table 8.3 displays how the excavation unit materials were allocated to each period.

Table 8.3: Temporal phases of 250-year periods, showing allocation of XUs.

Temporal phase	0-250	250-500	500-750	750-1000	c.4750-5000
Square A XUs	1-3	4-7	8-11	12	13-20
Square B XUs	1-3	4-7	8-12	13	14-20
Square C XUs	1-3	4-7	8-11	12	13-20

8.7 Laboratory Methods

The molluscan and fishbone assemblages from Squares A, B and C were analysed for this project. Two additional squares (D and E) were excavated during the 2014 field season; however, details of the materials from these squares are not included here. Based on radiocarbon determinations combined with analysis of stratigraphic units the excavated materials have been divided into two groups for each square (see Table 8.4). Only the cultural assemblage from each square will be discussed in detail here as the non-cultural, natural beach ridge assemblage does not contribute to resolving questions relating to optimal foraging. The lowest probable cultural materials comprised charcoal fragments recovered from XU16 in Square B, but these are likely to derive from upper cultural deposits.

Table 8.4: Division of excavated materials between cultural and non-cultural portions.

Square	Cultural (max. depth)	Natural Beach Ridge
A	XU1-12 (c.36cm)	XU13-20
B	XU1-13 (c.39cm)	XU14-20
C	XU1-12 (c.36cm)	XU13-20

8.8 Cultural Materials

Square A (XUs 1-12)

28,227.67g (21% of the total sediment and materials excavated from XU1-12) were retained in the 2.3mm sieve residue for analysis. Table 8.5 shows the overall summary results of the retained materials. Molluscan shell makes up 81.76% (22,931.63g) of the total assemblage and marine vertebrate bone (fish and possibly turtle) contributes 0.01% (6.74g). Small quantities of crustacea (20.23g) were recovered from XU1-12, represented by mud crab (*Scylla* spp.) (11.83g) and goose barnacle (Pedunculata) (8.98g). The assemblage contains 28 flaked silcrete stone artefacts weighing a total of 22.38g. Other non-artefactual stone (including beachrock and pisoliths) contribute 17.09%, coral accounts for 0.25% and organics make up the rest of the assemblage.

Square B (XUs 1-13)

39,763.71g (28% of the total sediment and materials excavated from XU1-13) were retained in the 2.3mm sieve residue for analysis. Table 8.6 shows the overall summary results of the retained materials. Molluscan shell makes up 85.39% (33,960.59g) of the total assemblage. Fishbone contributes 0.01% (6.96g) and other marine fauna bone (possibly turtle) contributes 0.02% (10.97g). Small quantities of crustacea (123.16g) were recovered from XU1-12, represented by mud crab (*Scylla serrata*) (64.92g) and goose barnacle (Pedunculata) (58.24g).

The assemblage contains 19 flaked silcrete stone artefacts weighing a total of 6.86g. Other non-artefactual stone (including beachrock and pisoliths) contribute 12.92%, coral accounts for 0.30% and organics make up the rest of the assemblage.

Square C, (XUs 1-12)

35,150.52g (27.5% of the total sediment and materials excavated from XU1-12) were retained in the 2.3mm sieve residue for analysis. Table 8.7 shows the overall summary results of the retained materials. Molluscan shell makes up 87.89% (30,894.65g) of the total assemblage. Fishbone contributes 0.03% (12.23g) and other marine fauna bone (possibly turtle) contributes 0.01% (5.33g). Small quantities of crustacea (43.64g) were recovered from XU1-12, represented by mud crab (*Scylla serrata*) (17.75g) and goose barnacle (Pedunculata) (12.05g). The assemblage contains 39 flaked silcrete stone artefacts weighing a total of 7.02g. Other non-artefactual stone (including beachrock and pisoliths) contribute 11.21%, coral accounts for 0.42% and organics make up the rest of the assemblage.

Table 8.5: Summary excavation data and retained materials from Thundiy Square A (XUs 1-12). *Note mollusc remains were not quantified for non-cultural units (XUs 13-20).

XU	Depth Below Surface (cm)	Mean Thickness (cm)	Weight (kg)	Vol cm^3	pH	Stone Artefacts (g)	Marine Shell (g)	Bone (g)	Barnacle (g)	Crab (g)	Charcoal (g)	Other Organic (g)	Rock Rubble Coral (g)	Retained Materials Total (g)	% of Total Midden
1	2.7	2.7	8.4	6750	9.0	0	2210.15	0	0.18	0.5	0.82	95.62	66.05	2373.32	28.25%
2	5.76	3.06	10.8	7650	9.0	0.38	3497.23	0	1.29	0.32	0.36	4.71	98.68	3602.97	33.36%
3	8.6	2.84	12.2	7100	9.5	0	3420.45	0	0.87	0.13	0.85	11.04	148.92	3582.26	29.36%
4	11.6	3	10	7500	9.5	0.2	3035.89	0	0.51	0.16	0.9	7.57	184.38	3229.61	32.30%
5	14.52	2.92	12.6	7300	9.5	2.3	3326.97	0	0.71	0.04	0.84	38.92	296.11	3665.89	29.09%
6	17.98	3.46	12	8650	9.5	0.63	2342.74	0	0.66	0.78	0.41	16.17	372.69	2734.08	22.78%
7	20.54	2.56	9.9	6400	9.5	0.02	851.96	0.74	0.26	6.44	0	4.46	498.58	1362.46	13.76%
8	23.64	3.1	11.4	7750	9.5	11.76	1140.66	5.37	0.06	0.93	0.19	4.03	545.77	1708.77	14.99%
9	26.58	2.94	9.7	7350	9.5	0.79	811.94	0.16	4.01	0	0.53	3.66	580.37	1401.46	14.45%
10	29.8	3.22	12.2	8050	9.5	0.35	869.65	0.37	0.14	0.44	0.03	3.85	854.9	1729.73	14.18%
11	32.64	2.84	10.5	7100	9.5	0	973.06	0.1	0	0	0	1.79	580.5	1555.45	14.81%
12	35.72	3.08	10.4	7700	10.0	5.95	450.93	0	0.29	2.1	0	2.12	836.34	1297.73	12.48%
13	38.6	2.88	11.4	7200	10.0	0	*	0	0	0	0.48	1.86	996.93	1007.44	8.84%
14	41.7	3.1	12.2	7750	10.0	0	*	0	0	0	0.76	2.28	1484.84	1489.9	12.21%
15	45.08	3.38	14.4	8450	8.5	0	*	0	0	0	0	0	4737.52	4737.52	32.90%
16	47.74	2.66	10.7	6650	10.0	0	*	0	0	0	0	0	4372.8	4372.8	40.87%
17	50.64	2.9	13.4	7250	10.0	0	*	0	0	0	0	0	4242.94	4242.94	31.66%
18	53.76	3.12	13.7	7800	10.0	0	*	0	0	0	0	0	3444.24	3444.24	25.14%
19	56.66	2.9	10.3	7250	10.0	0	*	0	0	0	0	0	1563.89	1563.89	15.18%
20	59.7	3.04	12.7	7600	10.0	0	*	0	0	0	0	0	877.7	877.7	6.91%
Total:	-	59.70	228.90	149250	-	22.38	22931.63	6.74	8.98	11.83	6.17	198.08	26784.15	49980.16	21.83%

Table 8.6: Summary excavation data and retained materials from Square B (XUs 1-13). *Note mollusc remains were not quantified for non-cultural units (XUs 14-20).

XU	Depth Below Surface (cm)	Mean Thickness (cm)	Weight (kg)	Vol cm^3	pH	Stone Artefacts (g)	Marine Shell (g)	Bone (g)	Barnacles (g)	Crab (g)	Charcoal (g)	Other Organic (g)	Rock Rubble Coral (g)	Retained Materials Total (g)	% of Total Midden
1	2.46	2.46	7.6	6150	9.5	0	2037.69	0	8.45	0.98	0.76	89.81	102.63	2240.32	29.48%
2	5.4	2.94	10.3	7350	9.5	0	3031.63	0	3.27	3.88	1.91	153.73	339.1	3533.52	34.31%
3	9.34	3.94	13.1	9850	9.5	0.26	3658.38	0	1.27	0	3.06	4.44	230.05	3897.46	29.75%
4	12.34	3	10.3	7500	9.5	0	3092.07	0	1.39	1.53	1.42	49.18	204.35	3349.94	32.52%
5	15.44	3.1	12	7750	9.5	3.89	3885	0	2.45	4	1.28	41.3	414.63	4352.55	36.27%
6	18.58	3.14	10.7	7850	9.5	2.23	3496.64	0	5.85	10.41	3.66	8.41	637.76	4164.96	38.92%
7	21.4	2.82	10.2	7050	9.5	0.18	3483.25	12.37	8.95	0	2.31	7.9	374.72	3889.68	38.13%
8	24.5	3.1	11	7750	9.5	0	3500.88	0	4.87	5.38	2.84	1.98	394.4	3910.35	35.55%
9	27.5	3	11.9	7500	9.5	0.28	1618.39	0.49	3.96	8.24	4.82	4.97	361.41	2002.56	16.83%
10	30.34	2.84	10.1	7100	9.5	0	2627.81	0.89	3.87	13.48	4.86	3.98	359.84	3014.73	29.85%
11	33.32	2.98	11.1	7450	9.5	0	2166.7	0	9.64	12.76	6.93	2.43	453.25	2651.71	23.89%
12	36.7	3.38	11.1	8450	9.5	0.02	1112	4.18	3.07	2.6	3.36	2.08	606.12	1733.43	15.62%
13	39.42	2.72	10.2	6800	9.5	0	250.14	0	1.16	1.66	0.64	1.74	746.14	1001.48	9.82%
14	42.42	3	10.8	7500	9.5	0	*	0	0.21	0.89	0.16	2.82	899.51	903.59	8.37%
15	45.48	3.06	11.7	7650	9.5	0	*	0	1.06	0	0.01	2.58	1300.64	1304.29	11.15%
16	48.64	3.16	12	7900	9.5	0	*	0	2.08	0.01	0.08	3.37	1485.96	1491.5	12.43%
17	51.64	3	11.4	7500	9.5	0	*	0	1.98	0.08	0	1.4	1772.95	1776.41	15.58%
18	54.52	2.88	11.4	7200	9.5	0	*	0	1.34	0	0	3.84	2453.65	2458.83	21.57%
19	57.46	2.94	13	7350	9.5	0	*	0	10.02	0.5	0	10.1	3521.04	3541.66	27.24%
20	60.44	2.98	12.7	7450	9.5	0	*	0	0	0	0	0.71	3098.73	3099.44	24.41%
Total:		60.44	222.60	151100		6.86	33960.58	17.93	74.89	66.40	38.10	396.77	19756.88	54318.41	24.40%

Table 8.7: Summary excavation data and retained materials from Square C (XUs 1-12). *Note mollusc remains were not quantified for non-cultural units (XUs 13-20).

XU	Depth Below Surface (cm)	Mean Thickness (cm)	Weight (kg)	Vol cm^3	pH	Stone Artefacts (g)	Marine Shell (g)	Bone (g)	Barnacles (g)	Crab (g)	Charcoal (g)	Other Organic (g)	Rock Rubble Coral (g)	Retained Materials Total (g)	% of Total Midden
1	2.68	2.68	8.8	6700	9.5	0	2328.1	2.22	1.76	0.05	2.25	42.7	49.62	2426.7	27.58%
2	5.82	3.14	10.8	7850	9.5	0	2687.54	2.1	2.79	0.95	1.67	4.36	68.39	2767.8	25.63%
3	8.6	2.78	10.1	6950	9.5	0.04	2479.59	1.23	1.58	0.15	0.8	4.55	92.81	2580.71	25.55%
4	11.68	3.08	11.6	7700	9.5	0.16	3518.01	0.87	4.07	1.13	0.46	16.52	109.98	3651.04	31.47%
5	14.72	3.04	12.1	7600	9.5	0.63	4400.22	1.03	3.74	0.34	0.63	3.78	136.93	4546.67	37.58%
6	17.74	3.02	11.3	7550	9.5	0	3052.82	0.5	1.92	3.83	0.43	1.48	221.39	3282.37	29.05%
7	20.76	3.02	11.3	7550	9.5	0.89	3931.49	0.82	1.25	2.09	0.82	2.8	341.57	4280.84	37.88%
8	23.66	2.9	10.5	7250	9.5	0.87	3319.25	6.53	3.91	2.48	2.05	1.05	393.05	3728.32	35.51%
9	26.78	3.12	10.9	7800	9.5	2.73	2600.08	0.52	1.81	2.2	1.76	2.95	560.67	3169.99	29.08%
10	29.76	2.98	10.3	7450	9.5	1.30	1480.66	1.11	0.91	3.68	2.1	0.94	757.38	2246.78	21.81%
11	32.74	2.98	9.6	7450	9.5	0.30	633.7	0.11	0.47	0.17	0.74	1.36	635.36	1271.91	13.25%
12	35.64	2.9	10.3	7250	9.5	0.10	463.13	0.5	0.63	0.49	0.75	1.95	718.17	1185.62	11.51%
13	38.9	3.26	13	8150	9.5	0	*	0	1.05	0.64	0.28	4.55	1400.57	1407.09	10.82%
14	41.68	2.78	10.1	6950	9.5	0	*	0	0.71	0.13	0.07	2.11	1267	1270.02	12.57%
15	44.68	3	12.5	7500	9.5	0	*	0	0	0	0	2.4	2347.81	2350.21	18.80%
16	47.54	2.86	10.4	7150	9.5	0	*	0	0.4	0	0	3.03	2101.34	2104.77	20.24%
17	50.68	3.14	15.1	7850	9.5	0	*	0	0	0	0	4.17	3169.15	3173.32	21.02%
18	53.64	2.96	12.3	7400	9.5	0	*	0	2.08	0	0	5.33	3199.71	3207.12	26.07%
19	56.52	2.88	12.4	7200	9.5	0	*	0	0.5	0.91	0.52	5.07	2471.95	2478.95	19.99%
20	59.62	3.1	13.7	7750	9.5	0	*	0	5.91	0.17	0.07	12.5	1699.57	1718.22	12.54%
Total:	-	59.62	227.10	149050	-	7.02	30894.59	17.54	35.49	19.41	15.40	123.60	21742.42	52848.45	23.27%

8.8.1 Invertebrate Mollusc Remains

Square A

Molluscs make up 81.76% of the Square A cultural assemblage (found between XU1-12) based on weight, contributing over 22.9kg of material. In total 90.3% of all shell from the excavation units containing cultural materials was identified to family, genus or species level (MNI=3404). This comprised a minimum of 46 molluscan taxa consisting of 22 marine bivalve taxa and 24 identified marine gastropod taxa (Tables 8.8 -8.9; Figures 8.14-8.15).

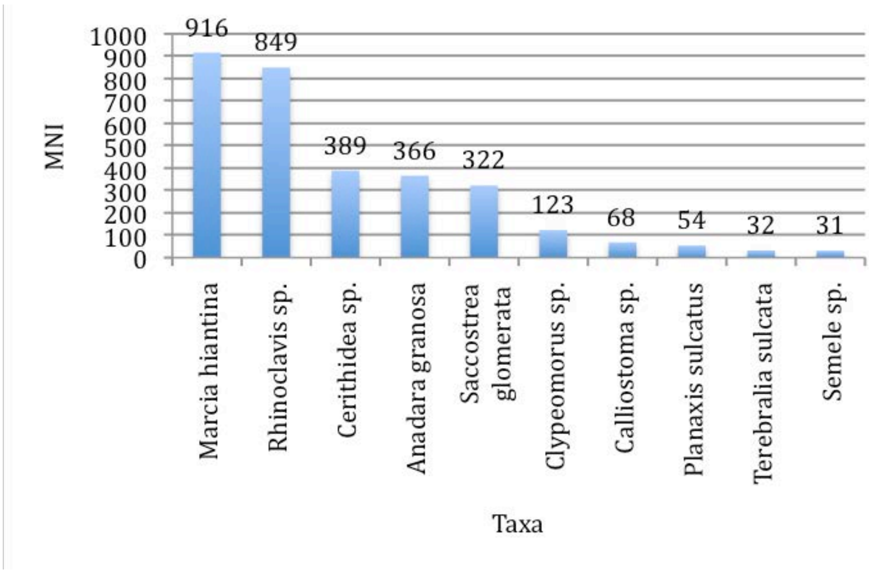


Figure 8.14: Thundiy Square A, top 10 mollusc taxa by MNI.

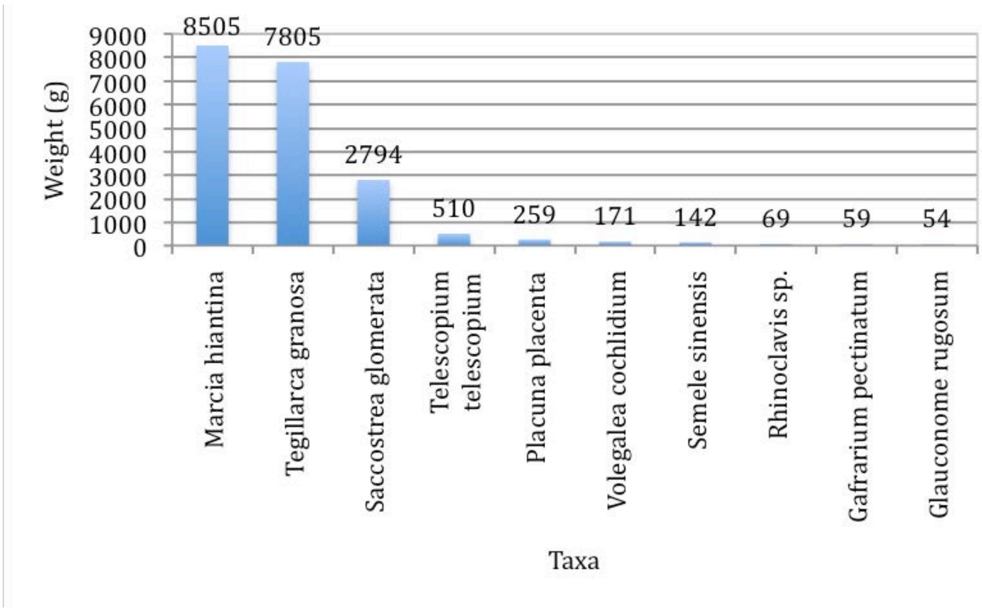


Figure 8.15: Thundiy Square A, top 10 mollusc taxa by weight.

Based on MNI the shell assemblage is dominated by *Marcia hiantina* with an MNI of 916 or 27% of the assemblage, *Tegillarca granosa* (MNI=366, 11%) and *Saccostrea glomerata* (MNI=322, 9%). Small *cerith* gastropods (*Cerithidea* sp. and *Rhinoclavis* sp.) have a combined MNI of 1397 thereby contributing 41% of the assemblage. The remaining taxa are relatively rare in the deposit, each contributing 0-2% of the shell assemblage by MNI. The assemblage exhibits reasonable diversity with a calculated Shannon-Weaver Function (H') of 2.18 on a scale of 0-5.

The majority of shell was recovered from XU1 to XU6. Concentrated shell deposition between 250-750 cal BP accounts for 66% of the identified mollusc assemblage based on MNI, suggesting significant use of the site around this time with substantial deposition occurring in a relatively short space of time (Figure 8.16). Further intensive site use occurred between 250 years ago to present, accounting for 21% of the assemblage based on MNI. The high percentage of taxa identified in the 50 years between 750-800 cal BP is largely attributed to *Rhinoclavis* sp., which is a small mollusc (<10mm) and is unlikely to be cultural. It probable that this taxon entered the site through natural processes (e.g. wind or wave deposition) and therefore forms part of the beach ridge. The presence of hiant venus clams, ark clams and oyster, suggest foraging strategies focused on the mangrove fringe and adjacent intertidal and sub-tidal sand and mudflats with evidence for rocky reefs also being accessed (see Figure 8.6).

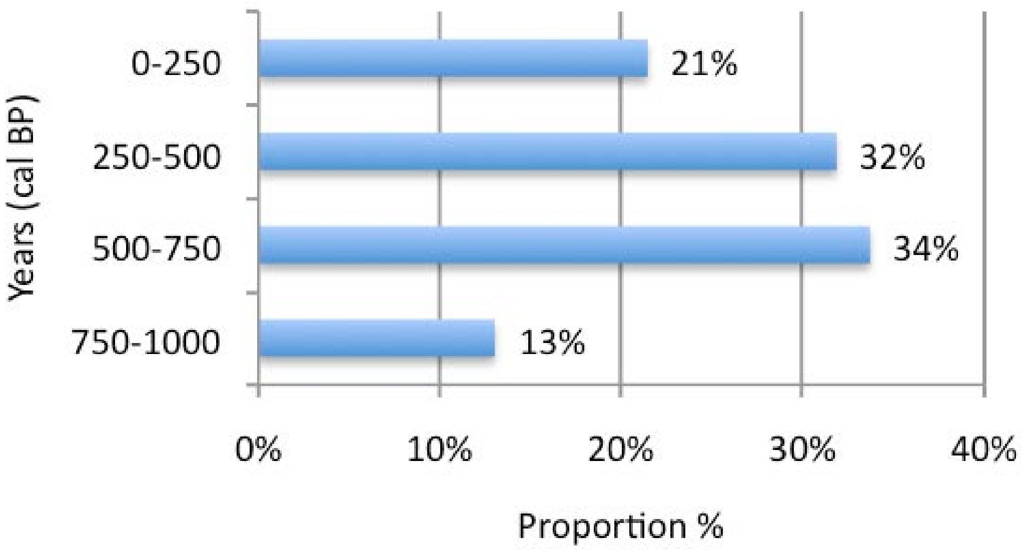


Figure 8.16: Proportion of total Square A mollusc assemblage MNI per 250-year period.

Table 8.8: Thundiy Square A molluscan assemblage taxa MNIs.

Taxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Totals**
MARINE BIVALVIA													
Asaphis violascens										1		1	**2**
Barbatia sp.									1	1		2	**4**
Beguina semiorbiculata		1			1							2	**4**
Chama sp.								1			1	2	**4**
Circe scripta								2		2	5	16	**25**
Codakia tigerina			1	1		1		1					**4**
Corbula fortisulcata			2	1		1	2	1	2	5	1	3	**18**
Gafrarium pectinatum			1	1		1	1	4	1	5	2		**16**
Geloina erosa													**0**
Glauconome virens	2	1	6	1	3	6	1						**20**
Isognomon sp.		1		1						1	2		**5**
Lunulicardia hemicardium	1				1				1		1	4	**8**
Mactra sp.			1							1		2	**4**
Marcia hiantina	79	112	122	143	203	172	43	11	6	7	5	13	**916**
Placamen retroversum										3	2	3	**8**
Placuna placenta	2	1	2	1	2	4	1						**13**
Saccostrea glomerata	3	2	10	15	22	18	19	71	36	30	64	32	**322**
Semele sinensis	1	1	6	11	5	3	1	1	1		1		**31**
Tegillarca granosa	61	102	118	49	21	13	2						**366**
Tellina sp.				1				1	2	1	1	2	**8**
Neotrapezium sublaevigatum			1										**1**
Trisidos tortuosa				1									**1**
MARINE GASTROPODA													
Calliostoma sp.		1	2	2	3	2	2	4	9	9	7	27	**68**
Cerithidea cingulata			3	2		3	3	2	5	4	1		**23**
Cerithidea sp.	5	6	14	8	50	45	17	14	18	87	45	80	**389**
Cerithium coralium									4	9			**13**
Clypeomorus batillariaeformis			7		4	2	17	5	19	21	24	24	**123**

Taxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Totals**
Mitrella scripta					1			1	2	2		4	**10**
Nassarius sp.		1					1		1	2		1	**6**
Nerita balteata										1		2	**3**
Nerita planospira					1								**1**
Nerita spp.		1		1	1						2		**5**
Planaxis sulcatus		3	1	2	7	3	5	2	6	8	5	12	**54**
Rhinoclavis sp.	5	7	15	7	6	9	83	75	112	174	156	200	**849**
Patellidae			1						1			2	**4**
Telescopium telescopium	2	1	1	1	2	1	2	4	4		2		**20**
Terebralia sulcata	2	2	5	3		4	1	2	2	2	4	5	**32**
Turbo cinereus												1	**1**
Turbo sp.	1				1						1	2	**5**
Volegalea cochlidium		1	3	2	3	2	2	2	1		1	1	**18**
XU Totals	**164**	**244**	**322**	**254**	**337**	**290**	**203**	**204**	**234**	**376**	**333**	**443**	**3404**

Table 8.9: Thundiy Square A molluscan assemblage taxa weights (g).

Taxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Totals**
MARINE BIVALVIA													
Asaphis violascens										0.49		0.37	**0.86**
Barbatia sp.				0.17					0.06	0.03		0.12	**0.38**
Beguina semiorbiculata		0.05	0.05		1.66							0.27	**2.02**
Chama sp.								0.97			0.95	2.28	**4.20**
Circe scripta								0.50		1.43	1.56	7.65	**11.14**
Codakia tigerina			0.08	0.06		0.06		0.18					**0.37**
Corbula fortisulcata		0.48	0.41			0.44	0.62	0.96	0.90	1.40	0.94	0.81	**6.96**
Gafrarium pectinatum			0.69	2.83	0.14	0.21	7.59	23.89	8.61	5.65	4.04	5.29	**58.93**
Glauconome virens	0.55	0.79	26.67	0.51	4.06	10.38	10.26	0.85					**54.06**
Isognomon sp.		0.03	0.19	0.10		0.31			0.07	0.01	0.84	0.37	**1.93**
Lunulicardia hemicardium	0.03				0.11				0.19	2.10	1.27	1.80	**5.50**
Mactra sp.			0.08	0.17					0.19	1.36	2.32	5.35	**9.47**
Marcia hiantina	511.65	854.20	1116.41	1478.81	2228.92	1507.66	416.06	168.76	126.88	63.82	15.33	16.91	**8505.41**
Neotrapezium sublaevigatum			0.66										**0.66**
Placamen retroversum		0.12								0.53	1.37	2.27	**4.29**
Placuna placenta	28.73	38.03	44.89	20.28	66.14	41.84	16.30	2.71					**258.92**
Saccostrea glomerata	20.69	21.34	122.53	137.51	198.92	80.78	155.35	575.19	367.56	431.36	624.24	58.78	**2794.25**
Semele sinensis	8.43	12.46	60.64	0.97	30.72	16.53	7.73	2.06	0.51		1.57		**141.62**
Tegillarca granosa	1386.94	2419.14	1773.96	1195.05	525.27	462.77	38.21	3.60		0.31			**7805.25**
Tellina sp.				0.43				0.05	0.88	0.61	1.13	1.57	**4.67**
Trisidos tortuosa				11.55	1.14								**12.69**
MARINE GASTROPODA													
Calliostoma sp.		0.05		0.33	0.24	0.31	0.33	0.70	0.87	1.37	0.83	2.28	**7.32**
Cerithidea cingulata			0.65	0.39		0.58	0.41	0.63	1.38	0.93	0.69		**5.67**
Cerithidea sp.	0.11	1.00	0.54	2.20	4.72	4.66	0.67	1.30	0.84	5.66	2.87	4.55	**29.13**
Cerithium coralium									0.79	1.02			**1.81**
Taxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Totals**

Clypeomorus batillariaeformis			1.36		1.04	0.53	2.43	1.46	4.40	4.94	5.46	5.53	**27.15**
Melo amphora		5.23			7.40		8.95	5.21	1.20			4.73	**32.72**
Mitrella scripta					0.21		5.02	0.20	0.15	0.22		0.84	**6.64**
Nassarius coronatus							0.21						**0.21**
Nassarius sp.		0.24							0.16	0.49		0.03	**0.92**
Nerita balteata										4.89		18.82	**23.71**
Nerita planospira					0.19								**0.19**
Nerita spp.	2.20	1.12		0.59	0.07				1.60		5.02		**10.60**
Nerita undata							1.43	8.60					**10.03**
Planaxis sulcatus		0.13	0.18	0.25	0.84	0.41		0.28	0.31	0.92	0.99	1.68	**5.99**
Polinices sp.							0.44						**0.44**
Rhinoclavis sp.	0.51	0.51	0.90	0.49	0.47	0.75		5.11	9.41	13.91	17.45	19.13	**68.63**
Patellidae			0.00				4.27		0.01	0.05		0.06	**4.39**
Telescopium telescopium	93.84	27.04	12.96	6.91	45.48	13.56		125.63	105.59	19.79	34.22	24.82	**509.84**
Terebralia sulcata	0.64	3.74	17.60	11.62		15.39	37.62	5.75	3.32	1.84	6.83	2.47	**106.82**
Trochus sp.							1.98					0.08	**2.06**
Turbo cinerea												0.21	**0.21**
Turbo sp.	0.85				0.10			0.09		1.49	0.56	0.35	**3.44**
Volegalea cochlidium		8.49	34.06	14.07	26.12	18.25		27.81	14.89	17.93	8.07	1.04	**170.72**
Unidentified Shell	154.97	103.05	204.93	150.62	183.02	167.34	136.08	178.17	161.17	285.10	234.51	260.47	**2219.43**
XU Totals	**2210.15**	**3497.23**	**3420.45**	**3035.89**	**3326.97**	**2342.74**	**851.96**	**1140.66**	**811.94**	**869.65**	**973.06**	**450.93**	**22931.63**

Square B

Molluscs contribute 85.39% of the Square B cultural assemblage (found between XU1-13) based on weight, contributing over 33.9 kg of material. 87.5% of all shell from the excavated square was identified to family, genus or species level (with an MNI=5380). This comprised 49 molluscan taxa consisting of 25 marine bivalve taxa and 24 marine gastropod taxa (Tables 8.10-8.11; Figures 8.17-8.18).

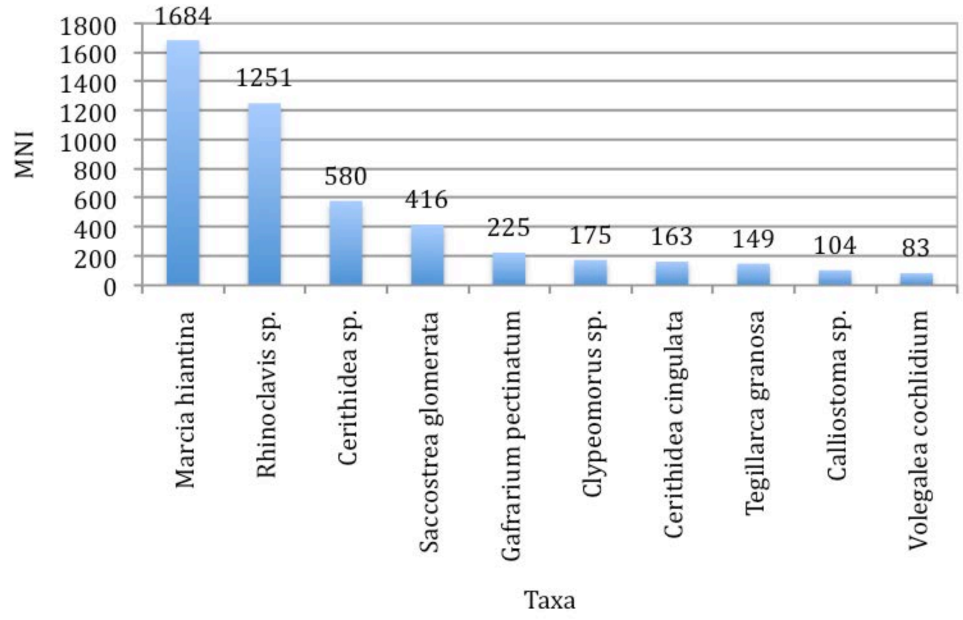


Figure 8.17: Thundiy Square B, top 10 mollusc taxa by MNI.

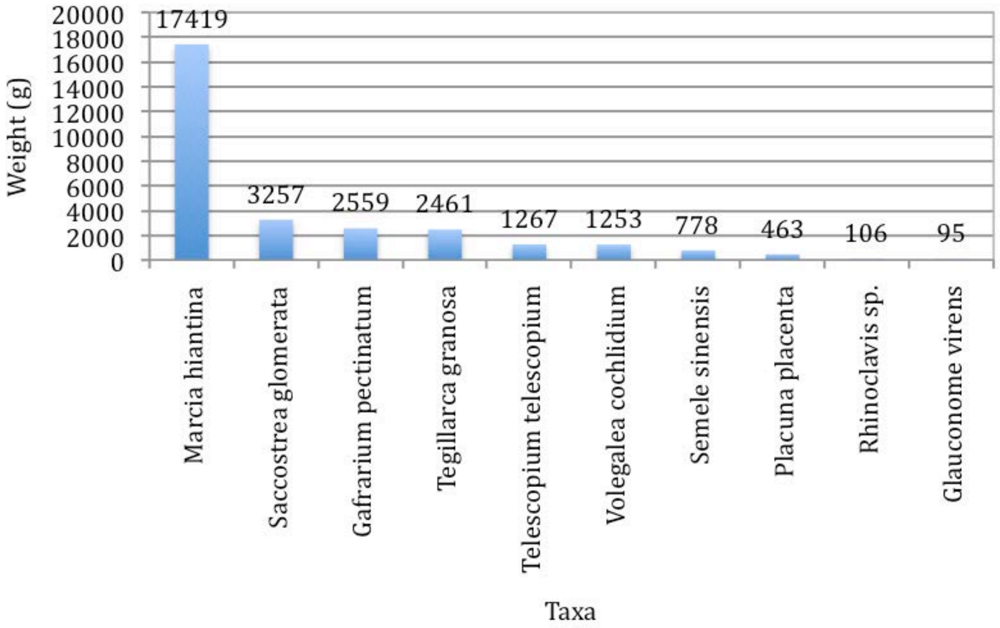


Figure 8.18: Thundiy Square B, top 10 mollusc taxa by weight.

The shell assemblage is dominated by hiant venus clams (*Marcia hiantina*) with an MNI of 1684 or 31% of the assemblage, *Tegillarca granosa* (MNI=149, 3%), *Gafrarium pectinatum* (MNI=225, 4%), *Saccostrea glomerata* (MNI=416, 8%), *Calliostoma* sp. (MNI=104, 2%) and *Volegalea cochlidium* (MNI=83, 2%). Small *cerith* gastropods (*Cerithidea* sp. and *Rhinoclavis* sp.) contribute MNI=1831, 34% of the assemblage. The remaining 43 taxa are relatively rare in the deposit, each contributing less than 1% of the shell assemblage by weight.

The majority of shell was recovered from XU2 to XU8. Concentrated shell deposition between 250-750 cal BP accounts for 78% of the identified mollusc assemblage based on MNI, suggesting significant use of the site around this time with substantial deposition occurring in a relatively short space of time (Figure 8.19). Further site use occurred between 250 years ago to present, accounting for 14% of the assemblage based on MNI. The majority of taxa identified in the between 750-1000 cal BP is largely cerith species (*Rhinoclavis* sp. and *Cerithidea* sp.), which are unlikely to be cultural and more likely to be a part of the natural beach ridge. The presence of venus clams, ark clams and oyster, suggest foraging strategies focused on the mangrove fringe and adjacent intertidal and sub-tidal sand and mudflats with evidence for rocky reefs also being accessed (see Figure 8.6).

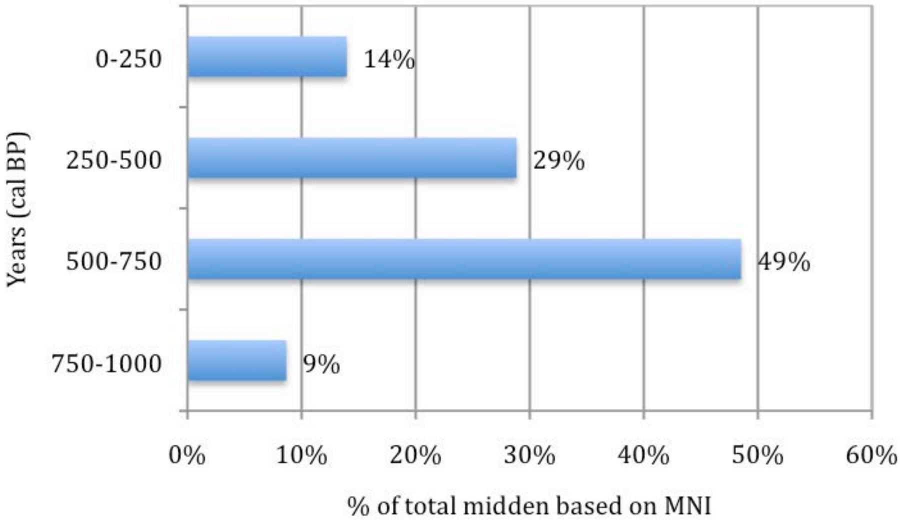


Figure 8.19: Proportion of total Square B mollusc assemblage MNI per 250-year period.

Table 8.10: Thundiy Square B molluscan assemblage taxa MNIs.

Taxon	1	2	3	4	5	6	7	8	9	10	11	12	13	Taxa Totals
MARINE BIVALVIA														
Arciidae													4	**4**
Asaphis violascens										1				**1**
Barbatia sp.						2		3			1	2		**8**
Beguina semiorbiculata									1				1	**2**
Cardidae								2						**2**
Circe scripta				1	5	4	2	3		4	7	6	6	**38**
Codakia tigerina	1					1	3	10	2	4	4	4	15	**44**
Corbula fortisulcata			1	1	3	3	3	2		1	2	3	6	**25**
Gafrarium pectinatum	1	3	5	6	23	26	28	34	39	34	17	8	1	**225**
Glauconome virens	1	2	8	4	5	1	1							**22**
Isognomon sp.						1							1	**2**
Lunulicardia hemicardium								3		1	2		5	**11**
Mactra sp.								2	1		1		1	**5**
Marcia hiantina	104	149	208	178	207	141	149	147	140	117	96	36	12	**1684**
Pitar pellucidus						21								**21**
Placamen retroversum						2								**2**
Placuna placenta	3	1	3	4	1	2	1	2						**17**
Saccostrea glomerata	1	3	16	23	39	71	74	68	33	35	29	24		**416**
Semele sinensis	2	9	9	7	13	10	6	9	6	1	1	2	1	**76**
Tegillarca granosa	26	56	20	20	8	7	3	6	1	1		1		**149**
Tellina sp.				1			1			2			2	**6**
Trisidos tortuosa	1													**1**
MARINE GASTROPODA														
Calliostoma sp.	1		2		2	12	1	5		10	16	17	38	**104**
Cerithidea largillierti		1					1	1						**3**
Cerithidea cingulata		1	5	5	9	3	3	4	13		96	11	13	**163**
Taxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Taxa Totals**

Cerithidea sp.	6	4	15	19	37	32	26	86	172		19	126	38	**580**
Cerithium coralium		1		1	4	9	4	2				15	30	**66**
Clypeomorus batillariaeformis		2	3	4	9	8	11	13	33	11	8	38	35	**175**
Ellobiidae													1	**1**
Euchelus atratus		2	1										2	**5**
Mitrella scripta						1	2	2	5		2	2	3	**17**
Nassarius coronatus						1								**1**
Nassarius sp.			2		4	1	1	2		1	1	4	4	**20**
Nerita undata		4	4											**8**
Nerita spp.	2			2	1			1					2	**8**
Patellidae													9	**9**
Planaxis sulcatus				3				2	3	6	4	5	11	**34**
Rhinoclavis sp.	17	6	16	27	28	68	50	167	121	162	73	308	208	**1251**
Telescopium telescopium		1	1	1	2	1	4	8	3	2	6	2	1	**32**
Terebralia sulcata		5	2	1		1	2	3	2		2		10	**25**
Trochus sp.					2				7					**9**
Turbo sp.	2					3		2	11				4	**22**
Volegalea cochlidium	1	1	10	4	12	11	7	12	7	8	7	1	2	**83**
XU Totals	**169**	**251**	**331**	**312**	**414**	**443**	**383**	**601**	**600**	**401**	**394**	**615**	**466**	5380

Table 8.11: Thundiy Square B molluscan assemblage taxa weights (g).

Taxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Totals**
MARINE BIVALVIA														
Arciidae													0.16	**0.16**
Asaphis violascens										24.44				**24.44**
Barbatia sp.						0.08		0.38			0.05	0.07		**0.59**
Beguina semiorbiculata									0.22				0.02	**0.24**
Cardidae								0.57						**0.57**
Chama sp.					4.59									**4.59**
Circe scripta				0.17	0.70	0.72	1.27	0.85	0.40	1.77	1.66	0.81	3.44	**11.79**
Codakia tigerina	0.02					0.03	0.67	1.03	1.05	1.15	2.26	1.64	3.64	**11.48**
Corbula fortisulcata			0.22	0.08	0.92	1.00	1.18	0.50	0.36	0.30	1.29	1.30	2.24	**9.39**
Gafrarium tumidum	2.49	18.08	62.49	60.30	223.20	312.93	345.68	415.76	463.2	388.99	202.7	56.66	4.17	**2556.74**
Geloina erosa					7.02									**7.02**
Glauconome virens	1.36	2.49	46.25	15.80	19.65	7.58	0.34			0.11		0.90	0.49	**94.97**
Isognomon sp.			0.08			0.08							0.37	**0.53**
Lunulicardia hemicardium								0.32	0.07	0.03	0.17		1.08	**1.68**
Mactra sp.								0.23	0.92		0.35		1.80	**3.29**
Marcia hiantina	1233.7	1855.7	1955.7	1902.6	2281.4	1942.6	1970.1	1699.0	1.74	1283.5	926.5	314.2	44.9	**17412.0**
Mytilidae						0.05				0.26				**0.31**
Pitar pellucidus						1.04								**1.04**
Placamen retroversum						0.47								**0.47**
Placuna placenta	80.27	44.99	89.47	96.80	37.52	13.36	21.27	55.37	18.27	4.71	1.07	0.33		**463.43**
Saccostrea glomerata	9.70	38.30	129.68	135.26	305.70	383.40	712.44	453.00	328.9	344.59	245.8	118.1	30.0	**3235.10**
Semele sinensis	56.16	41.42	122.90	113.75	138.32	139.96	53.16	37.30	36.13	19.03	7.46	7.28	4.14	**777.01**
Tegillarca granosa	457.07	589.80	453.60	465.18	180.30	127.56	40.59	72.62	16.75	21.63	13.41	21.41	0.46	**2460.38**
Tellina sp.				0.13			0.19			0.34			0.10	**0.76**
Trisidos tortuosa	1.00			0.33	1.84	9.96	5.85	2.44	1.40	7.03				**29.85**
Taxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Totals**

MARINE GASTROPODA													
Calliostoma sp.	0.01		0.07	0.36	0.29	0.26	0.47	0.37		0.77	0.83	1.13	1.42	**5.98**
Cerithidea largillierti		0.59					0.15	0.44						**1.17**
Cerithidea cingulata	0.13	0.19	0.70	0.86	1.38	0.86	1.01	0.80	2.84		12.04	2.04	2.65	**25.50**
Cerithidea sp.	1.28	0.42	0.50	0.93	1.49	1.62	1.40	4.25	8.72		2.45	4.37	3.35	**30.78**
Cerithium coralium		0.15		0.07	0.68	1.64	1.01	0.39				2.08	3.96	**9.97**
Clypeomorus		0.54	0.59	0.92	1.59	2.55	3.34	2.79	5.20	2.71	2.47	7.58	6.32	**36.60**
Cypraea sp.				0.17										**0.17**
Ellobiidae													0.04	**0.04**
Euchelus atratus		0.04	0.19										0.06	**0.28**
Melo amphora		1.53	2.74	3.50	2.33	2.59	1.61	4.58	4.54	9.99	4.60	1.55		**39.56**
Mitrella scripta	0.04					0.01	0.33	0.24	0.73		0.22	0.68	0.73	**2.98**
Nassarius coronatus						0.07								**0.07**
Nassarius sp.			0.12		0.40	0.06	0.02	0.64		0.00	0.27	0.46	0.89	**2.86**
Nerita undata		11.69	10.44											**22.13**
Nerita spp.	1.89			2.63	0.80			0.18	0.25	1.94		0.23	0.36	**8.28**
Patellidae											0.13		0.21	**0.34**
Planaxis sulcatus				0.20				0.19	0.24	0.21	0.28	0.40	0.98	**2.50**
Rhinoclavis sp.	0.67	0.32	0.94	1.91	1.85	5.08	9.41	13.08	6.70	11.02	3.33	20.94	15.7	**90.99**
Telescopium telescopium	2.36	19.38	35.19	17.35	51.12	91.11	110.24	236.13	162.3	152.53	235.0	118.3	31.4	**1262.52**
Terebralia spp.								0.76						**0.76**
Terebralia sulcata	0.47	17.04	6.43	2.65		1.87	4.52		1.42		2.50		2.15	**39.05**
Trochus sp.					0.28				6.22					**6.49**
Turbo sp.	0.09					0.22		0.33	0.30				0.46	**1.39**
Volegalea cochlidium	5.13	11.50	116.54	43.82	133.43	156.01	159.49	170.90	171.0	105.67	111.7	46.92	20.4	**1252.54**
Unidentified Shell	183.84	377.46	623.55	226.27	488.21	291.83	37.49	325.44	378.3	245.01	387.9	382.5	61.8	**4009.80**
XU Totals	**2037.6**	**3031.6**	**3658.3**	**3092.0**	**3885.0**	**3496.6**	**3483.2**	**3500.8**	**1618.3**	**2627.8**	**2166.7**	**1112.0**	**250.1**	**33960.5**

Square C

Molluscs make up 87.89% by weight of the Square C cultural assemblage (found between XU1-12), contributing over 30.8 kg of material. In total 89.9% of all shell from the excavation units containing cultural materials was identified to family, genus or species level. This comprised 44 molluscan taxa (with an MNI=4171) consisting of 20 marine bivalve taxa and 24 marine gastropod taxa (Tables 8.12-8.13; Figures 8.20-8.21).

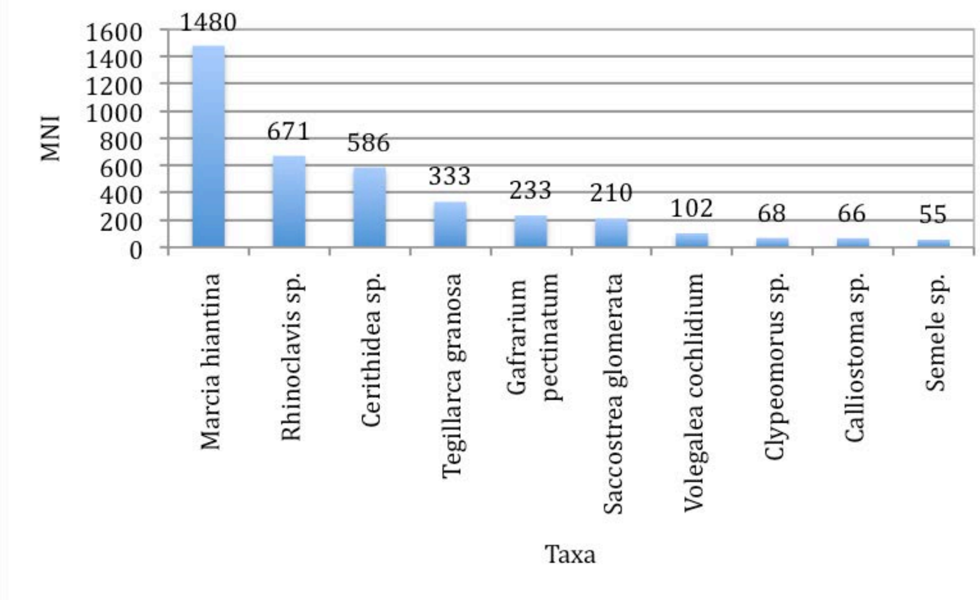


Figure 8.20: Thundiy Square C, top 10 mollusc taxa by MNI.

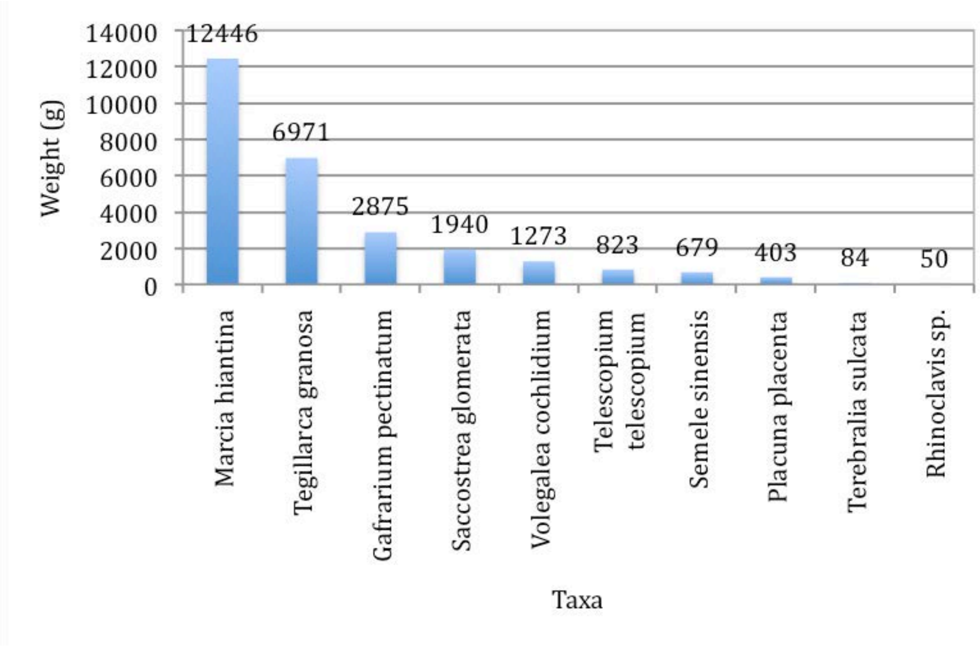


Figure 8.21: Thundiy Square C, top 10 mollusc taxa by weight.

Based on MNI the shell assemblage is dominated by *M. hiantina* with an MNI of 1480 or 35% of the assemblage, *Tegillarca granosa* (MNI=333, 8%), *Gafrarium pectinatum* (MNI=233, 5%) *Saccostrea glomerata* (MNI=210, 5%) and *Volegalea cochlidium* (MNI=102, 2%). Small *cerith* gastropods (*Cerithidea* sp. and *Rhinoclavis* sp.) have a combined MNI of 1257 thereby contributing 30% of the assemblage. The remaining taxa are relatively rare in the deposit, each contributing 0-2% of the shell assemblage by MNI. The assemblage exhibits medium diversity with a calculated Shannon-Weaver Function (H') of 2.20 on a scale of 0-5.

The majority of shell was recovered from XU1 to XU10. Concentrated shell deposition between 250-750 cal BP accounts for 76% of the identified mollusc assemblage based on MNI, suggesting significant use of the site around this time with substantial deposition occurring in a relatively short space of time (Figure 8.22). Further site use occurred between 250 years ago to present, accounting for 14% of the assemblage based on MNI. The majority of taxa identified in the between 750-1000 cal BP is largely made up of cerith species (*Rhinoclavis* sp. and *Cerithidea* sp.), which are unlikely to be cultural and more likely to be a part of the natural beach ridge. The presence of venus clams, ark clams and oyster, suggest foraging strategies focused on the mangrove fringe and adjacent intertidal and sub-tidal sand and mudflats with evidence for rocky reefs also being accessed (see Figure 8.6).

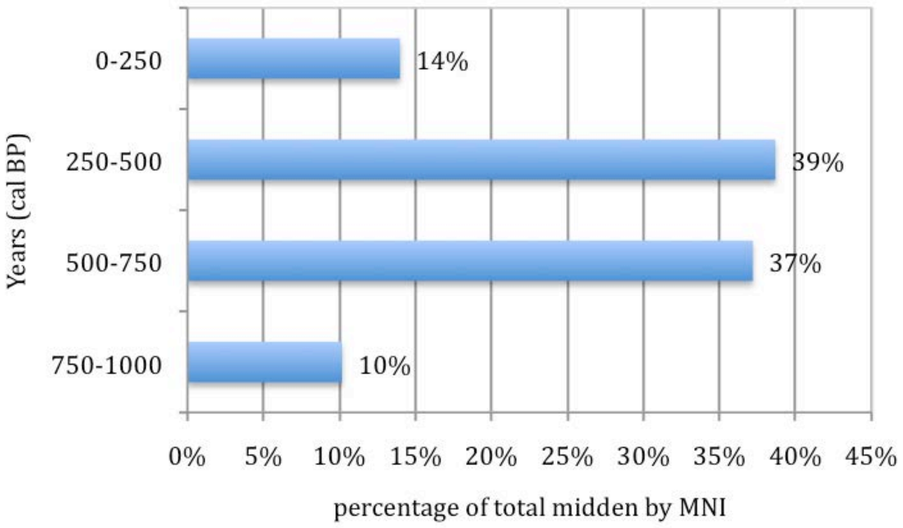


Figure 8.22: Proportion of total Square C mollusc assemblage MNI per 250-year period.

Table 8.12 Thundiy Square C molluscan assemblage taxa MNIs.

Taxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Taxa Totals**
BIVALVIA													
Arca sp.												1	1
Barbatia sp.								1	3		2	2	8
Circe scripta						1		3	2		3	3	12
Codakia tigerina	1			1	1			4	5		8	8	28
Corbula fortisulcata		1					2		1	3	1	3	11
Gafrarium pectinatum	1	1	2	6	21	49	65	43	21	21	2	1	233
Glauconome virens	1		1	2	3	2	1			1			11
Isognomon sp.	1					1	1			1			4
Lunilcardia hemicardium					1	2	1		2				6
Mactra sp.						2			1			2	5
Marcia hiantina	48	101	147	185	267	222	176	140	120	52	16	6	1480
Mytilidae												1	1
Pitar pellucidus				2									2
Placuna placenta	4	5	1	2	3	4		2					21
Saccostrea glomerata	1	1	3	12	13	21	49	37	31	24	10	8	210
Semele sinensis	3		2	6	20	11	9	-	1	1		2	55
Tegillarca granosa	70	77	27	71	56	16	2	2	6	6			333
Tellina sp.									1		2	2	5
Trisidos tortuosa								1					1
GASTROPODA													
Calliostoma sp.	2			1	4	6	3	5	9	10	13	13	66
Cerithidea largillierti							3	3		1			7
Cerithidea cingulata			1	2	7	2	1	3	3	5	11	1	36
Cerithidea sp.	11	4	17	7	20	7	21	41	105	61	124	168	586
Cerithium coralium								2		5	3		10
Clypeomorus batillariaeformis				1	10	3	4	3	12	13	12	10	68
Cypraea sp.												1	1

Taxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Taxa Totals**
Ellobium sp.									2			1	3
Euchelus atratus				1			2	2	4	5	9	11	34
Littoraria scabra									1				1
Melo amphora	1												1
Mitrella scripta				1	1		1		3	2	1	6	15
Nassarius sp.				2	1		1	4	1	1	1	3	14
Nerita sp.		2		1				-		2			5
Patellidae											4	1	5
Planaxis sulcatus	1	1	1		4	2	3	5	9	3	10	8	47
Polinices sp.												1	1
Rhinoclavis sp.	6	19	8	18	16	19	34	83	70	108	133	157	671
Telescopium telescopium			1	2	3	4	3	3	4	7	2	1	30
Terebralia sulcata		3	2	9	7			5	1	2	1	1	31
Trochus sp.							1				6		7
Turbo sp.		1		1				1					3
Volegalea cochlidium	1	1	1	5	9	36	15	14	10	3	5	2	102
XU Totals	**152**	**217**	**214**	**338**	**467**	**410**	**398**	**407**	**428**	**337**	**379**	**424**	**4171**

Table 8.13: Thundiy Square C molluscan assemblage taxa weights (g).

Taxon	1	2	3	4	5	6	7	8	9	10	11	12	Totals
BIVALVIA													
Arca sp.									0.63			0.08	**0.71**
Barbatia sp.		0.03						0.08	0.20		0.80	0.28	**1.39**
Chama sp.									0.53				**0.53**
Circe scripta						0.03		1.37	0.85	0.50	1.29	2.63	**6.67**
Codakia tigerina	0.11			0.37	0.09			0.63	0.86		2.72	3.35	**8.13**
Corbula fortisulcata		0.19	0.20		0.01		0.95	0.25	1.23	1.11	0.59	0.95	**5.48**
Gafrarium pectinatum	9.92	11.25	16.06	79.75	258.25	559.23	810.22	530.75	251.00	309.33	32.56	6.95	**2875.28**
Glauconome virens	3.38		0.49	4.60	9.15	9.95	0.12			0.04			**27.73**
Isognomon sp.	0.03	0.13			0.01	0.74	0.94			0.62		0.68	**3.15**
Lunulicardia					0.03	0.24	0.97	0.10	0.81		0.11	0.20	**2.46**
Mactra sp.						0.53		1.50	0.47		1.13	0.51	**4.15**
Marcia hiantina	449.65	1004.3	1382.0	1590.4	1943.1	766.47	2008.9	1535.0	1185.0	392.57	145.11	43.82	**12446.4**
Mytilidae												0.17	**0.17**
Pitar pellucidus				0.12									**0.12**
Placuna placenta	59.28	86.06	22.20	16.86	62.58	70.91	10.89	32.29	26.42		15.97		**403.46**
Saccostrea glomerata	22.20	15.23	43.68	166.32	105.07	272.12	513.40	289.99	282.00	133.03	43.86	53.60	**1940.50**
Semele sinensis	9.32		11.02	88.30	310.05	129.00	86.76	31.50	8.97	0.22		3.37	**678.51**
Tegillarca granosa	1522.1	1560.5	729.53	1208.9	1087.5	316.20	104.42	107.60	190.00	111.69	23.53	8.87	**6970.98**
Tellina sp.							0.05		0.94	0.20	0.35	1.13	**2.68**
Trisidos tortuosa					2.41		2.08	3.07	0.26				**9.77**
GASTROPODA													
Calliostoma sp.	0.52	0.05		0.66	0.04	0.49	0.49	1.37	0.74	0.75	0.99	1.50	**7.61**
Cerithidea largillierti							1.16	2.98		0.11			**4.25**
Cerithidea cingulata			0.32	0.33	0.84	0.20	0.55	0.88	0.91	1.01	1.75	0.12	**6.93**

Taxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Taxa**
Cerithidea sp.	0.73	0.20	1.67	0.74	1.48	0.77	1.89	3.99	9.12	4.76	4.49	11.33	**41.16**
Cerithium coralium								0.39		0.69	0.47		**1.55**
Clypeomorus				0.26	2.42	1.10	1.31	1.09	3.57	3.51	3.25	3.82	**20.33**
Cypraea sp.												0.25	**0.25**
Ellobium sp.									0.13			0.02	**0.15**
Euchelus atratus				0.01			0.20	0.30	0.26	0.30	0.35	0.48	**1.90**
Littoraria scabra									0.30				**0.30**
Melo amphora	0.30						23.87		7.28	1.06	1.05		**33.56**
Mitrella scripta				0.23	0.11		0.06		0.48	0.40	0.28	0.77	**2.33**
Nassarius sp.				0.15	0.27		0.06	0.41	0.30	0.02	0.27	0.37	**1.85**
Nerita sp.		0.81		0.43				0.23	0.90	0.17			**2.53**
Patellidae		0.01									0.26		**0.27**
Planaxis sulcatus	0.05	0.12	0.05		0.25	0.29	0.22	1.07	0.39	0.84	0.88	0.59	**4.75**
Polinices sp.												0.06	**0.06**
Rhinoclavis sp.	0.36	1.50	0.25	0.91	0.91	1.42	2.55	6.94	4.81	9.25	9.16	12.26	**50.32**
Telescopium	0.33		4.79	16.45	38.24	67.73	106.67	185.33	182.00	129.66	62.13	29.89	**823.22**
Terebralia sulcata	0.40	2.19	4.17	42.02	31.70	1.14	0.19	5.57	0.18	1.98	0.84	0.91	**91.28**
Trochus sp.							0.14	0.33			0.46		**0.93**
Turbo sp.		0.17	0.07	0.04	0.02		0.42	3.05	0.18	0.25			**4.20**
Volegalea cochlidium	0.87	2.36	20.19	58.08	121.63	398.75	200.87	191.23	165.00	56.69	36.19	21.51	**1273.36**
Unidentified Shell	248.49	2.39	242.89	242.04	424.03	453.55	51.15	379.96	273.40	319.89	242.86	252.64	**3133.30**
XU Totals	**2328.1**	**2687.5**	**2479.5**	**3518.0**	**4400.2**	**3052.8**	**3931.4**	**3319.2**	**2600.0**	**1480.6**	**633.7**	**463.1**	**30894.6**

8.8.2 Vertebrate Remains

Fishbone is present throughout the cultural deposits totaling 20.55g and consisting of 590 pieces of bone (Table 8.14). There are also 18 unidentified bone fragments (21.68g) that could be turtle. None of the fish bone in the Square A cultural deposit could be identified beyond Osteichthyes (1.37g). The small size of these specimens and the lack of diagnostic attributes prevented identification to taxon. Similarly in Square B most of the bone could not be assigned to a fish skeletal element, and therefore was labelled Osteichthyes. However, there were three catfish otoliths (0.96g) present in addition to 2 catfish cranium fragments (0.06g). The Square C cultural deposit contained the highest quantity of identified fish bone at Thundiy. A catfish otolith (0.33g), a grass emperor otolith (0.10g) and a wrasse grinding plate (1.01g), two whiting otoliths (0.10g), a scarid dentary (0.01g), a javelin grunter otolith (0.54g) and two shark vertebrae (0.04g) are present. The remaining bone (10.1g) could not be identified beyond Osteichthyes.

Table 8.14: Fishbone and non-fishbone abundances, Thundiy Squares A, B and C.

Sq	XU	Taxon	Element	MNI	NISP	Weight
A	7	Osteichthyes	unidentified		12	0.7387
A	9	Osteichthyes	unidentified		8	0.1630
A	10	Osteichthyes	unidentified		2	0.3737
A	11	Osteichthyes	unidentified		1	0.1014
B	7	Osteichthyes	unidentified		39	0.9845
B	7	Ariidae	otolith	1	1	0.3387
B	7	Ariidae	cranium frags		2	0.0663
B	9	Ariidae	otolith		1	0.4856
B	10	Osteichthyes	unidentified		35	0.7570
B	10	Ariidae	otolith		1	0.1431
B	12	Osteichthyes	unidentified		102	4.1797
C	1	Osteichthyes	unidentified		75	1.1337
C	1	Ariidae	cranium frags		5	1.0868
C	2	Osteichthyes	unidentified		52	1.1872
C	2	Ariidae	cranium frags		2	0.1239
C	2	Ariidae	otolith	1	1	0.7920
C	3	Osteichthyes	unidentified		53	1.2357
C	4	Osteichthyes	unidentified		56	0.8680
C	5	Osteichthyes	unidentified		38	0.9283
C	5	Labridae	right maxilla	1	1	0.0196
C	5	*Sillago burrus*	right otolith	1	1	0.0806
C	6	Osteichthyes	unidentified		20	0.4577
C	6	Ariidae	cranium frags		1	0.0394
C	7	Osteichthyes	unidentified		15	0.8181
C	8	Osteichthyes	unidentified		28	1.1820
C	8	Scaridae	right dentary	1	1	0.0162
Sq	**XU**	**Taxon**	**Element**	**MNI**	**NISP**	**Weight**

C	9	Osteichthyes	unidentified		13	0.4554
C	9	Ariidae	cranium frags		3	0.0502
C	9	*Sillago burrus*	left otolith		1	0.0261
C	10	Osteichthyes	unidentified		10	0.5278
C	10	*Pomadasys kaakan*	left otolith	1	1	0.5396
C	10	Carchihinidae	vertebrae	1	2	0.0472
C	11	Osteicthyes	unidentified		3	0.1054
C	12	Osteichthyes	unidentified		4	0.5028
Totals				7	590	20.5554
A	8	cf. *Chelonia mydas*	unidentified		12	5.3703
B	7	cf. *Chelonia mydas*	unidentified		5	10.9794
C	8	cf. *Chelonia mydas*	unidentified		1	5.3376
Totals					18	21.6873

8.9 Application of Models

8.9.1 Diet-Breadth/Prey Choice

Patterns of the breadth and diversity of molluscan exploitation at Thundiy can be identified using species richness and abundance measures. The species richness graphs show the number of species collected from each habitat per chronological period (Figures 8.23-8.25). The level of species richness by habitat varies between chronological periods. However this variation is not considered statistically significant. Chi-squared statistics for Square A (X^2 = 5.8012, d.f.=6, p>0.5), Square B (X^2 = 1.8939, d.f.=6, p>0.5) and Square C (X^2 = 2.51, d.f.=6, p>0.5).

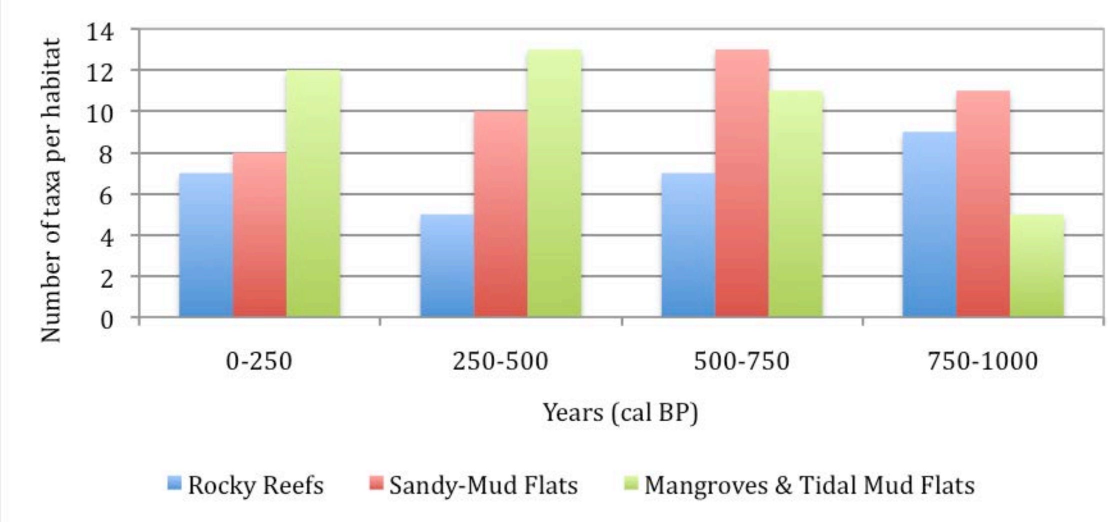


Figure 8.23: Thundiy Square A, species richness per habitat per 250-year period.

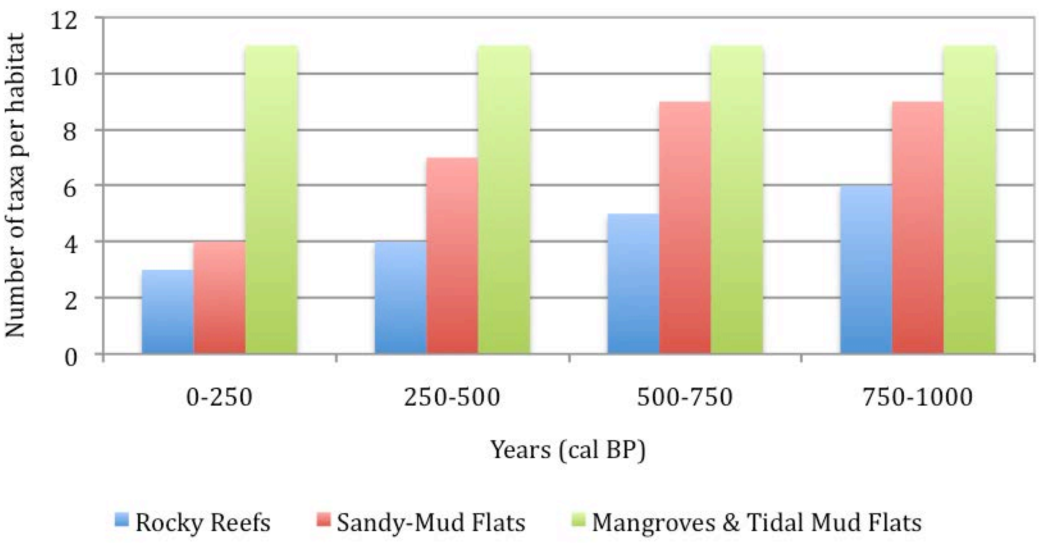


Figure 8.24: Thundiy Square B, species richness per habitat per 250-year period.

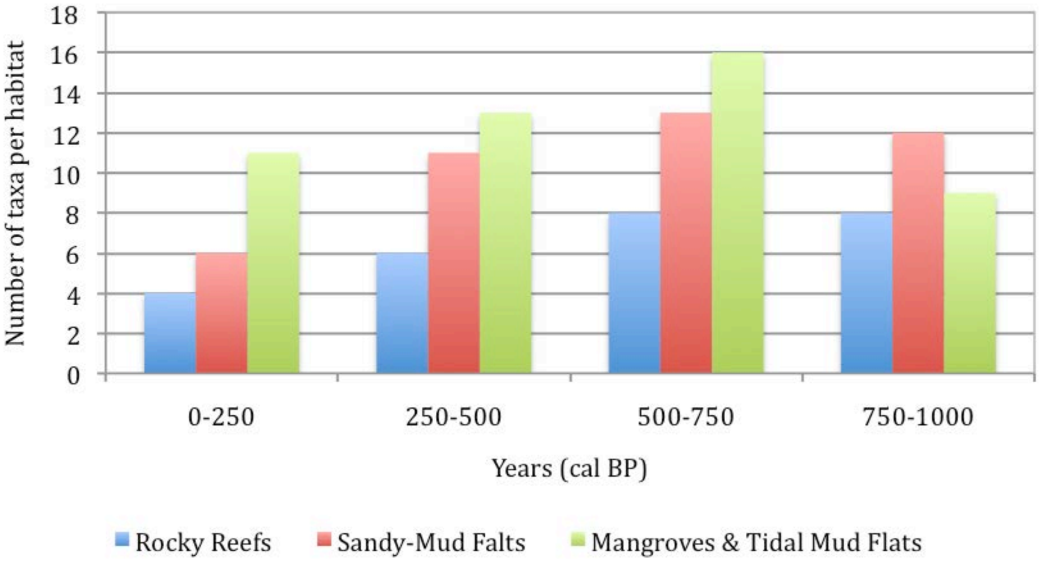


Figure 8.25: Thundiy Square C, species richness per habitat per 250-year period.

The top five species were consistently exploited over time however there is noticeable variance in each species' contribution to the total midden for each period (Figures 8.26-8.28). These results suggest that for the most part, while the same species were foraged from the local area, the emphasis on individual species varied.

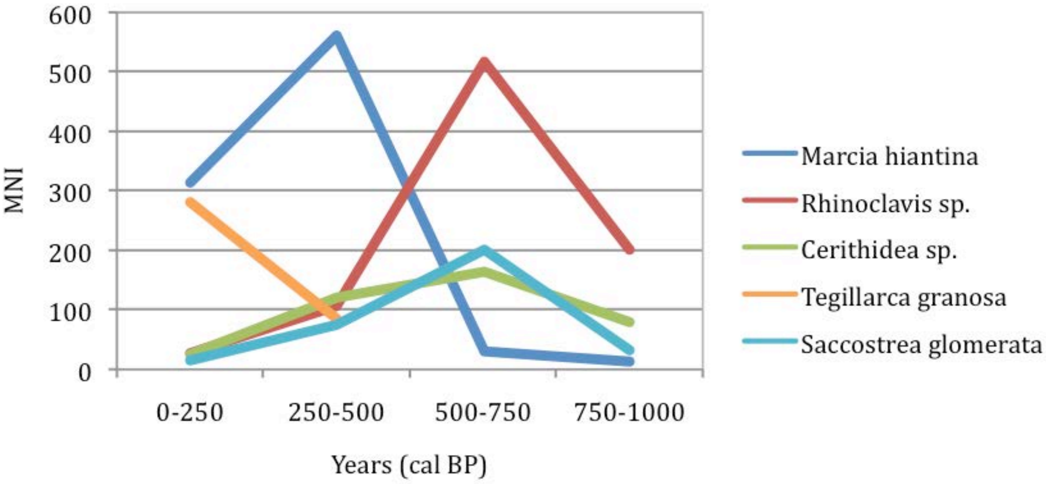


Figure 8.26: Thundiy Square A, top five mollusc taxa MNI per 250-year period.

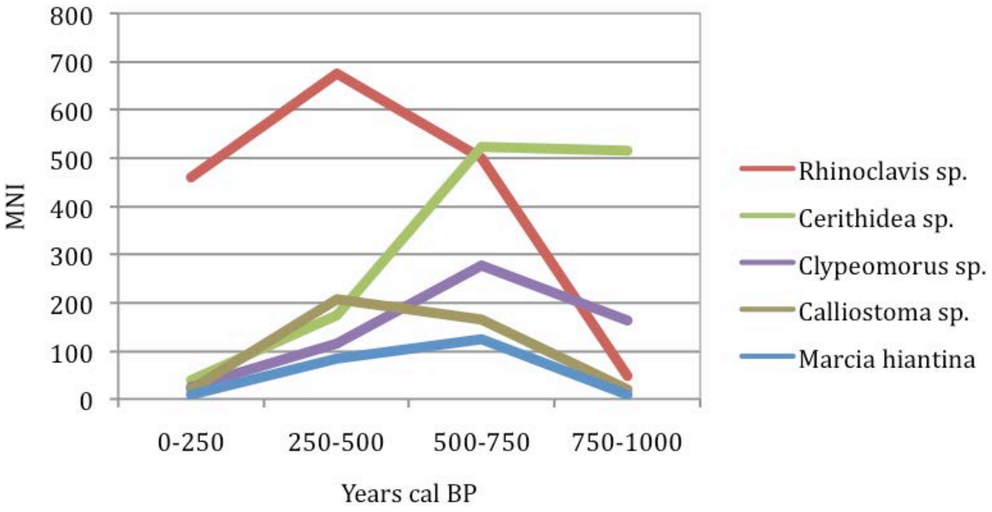


Figure 8.27: Thundiy Square B, top five mollusc taxa MNI per 250-year period.

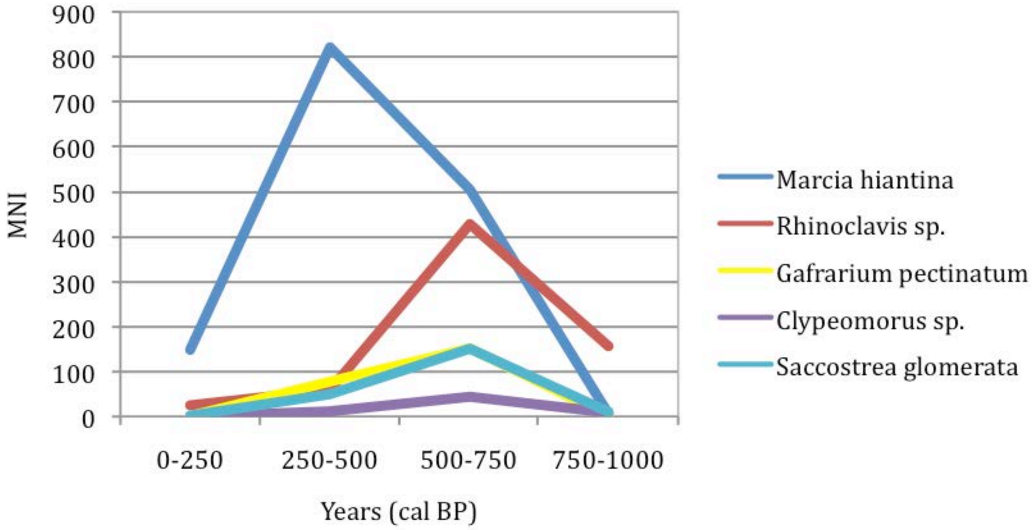


Figure 8.28: Thundiy Square C, top five mollusk taxa MNI per 250-year period.

8.9.2 Habitats/Patch Choice

Figures 8.29-8.32 show the proportion of MNI collected by habitat. The Thundiy mollusc assemblage includes taxa that come from all three patches or habitats, however there is temporal variance in the quantities of taxa taken from each patch. The chi-squared results indicate that this variance is statistically significant: Square A (X^2=560.06, d.f.=6, p<0.0001), Square B (X^2=626.37, d.f.=6, p<0.0001) and Square C (X^2=452.65, d.f.=6, p<0.0001).

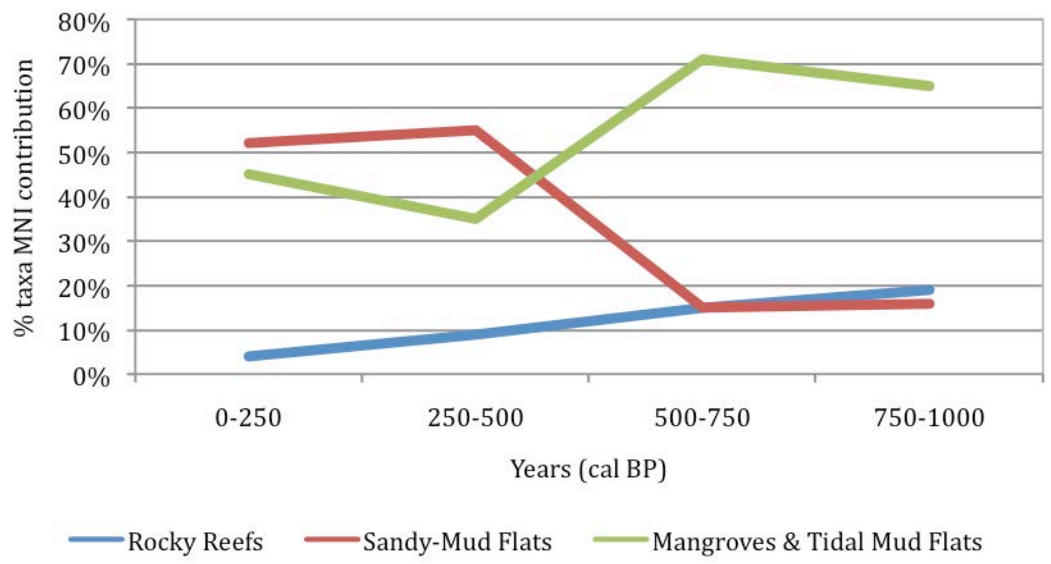


Figure 8.29: Thundiy Square A, percentage of mollusc taxa MNI collected from each patch by 250-year period.

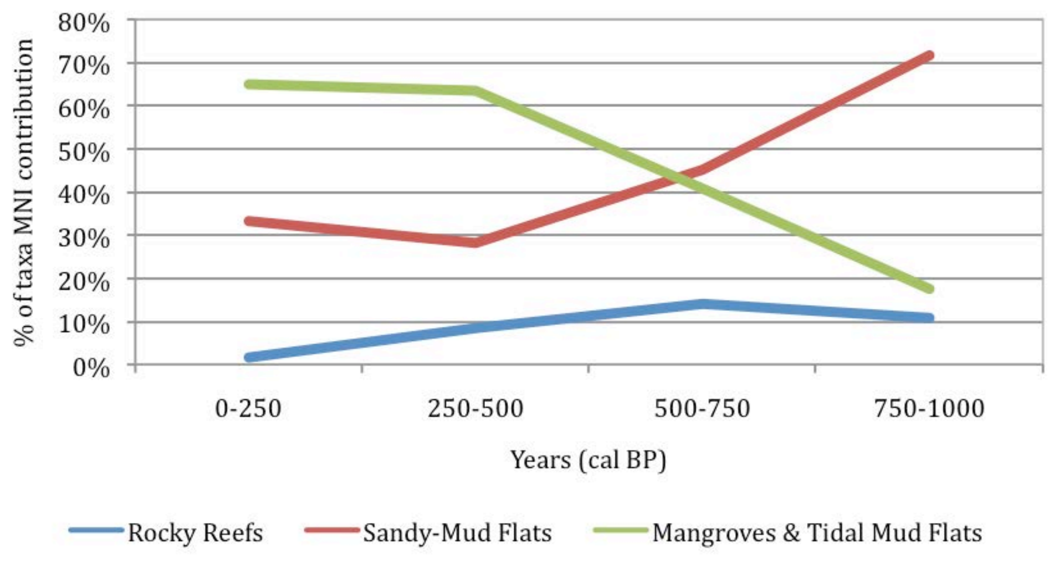


Figure 8.30: Thundiy Square B, percentage of mollusc taxa MNI collected from each patch by 250-year period.

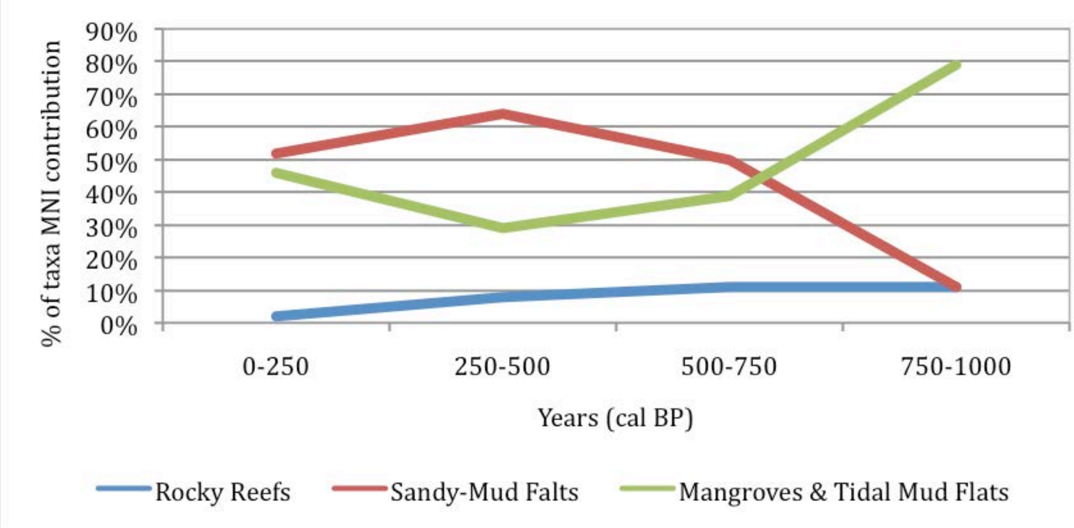


Figure 8.31: Thundiy Square C, percentage of mollusc taxa MNI collected from each patch by 250-year period.

The Mangrove Patch is the dominant focus of resource exploitation during 750-1000 years cal BP contributing over 60% of the combined total assemblage for that period (Figure 8.32) however the overall proportion of the Mangrove Patch assemblage drops to around 40% in the next period and then continues to remain through time. Rocky Reef species are at their highest (14%) between 250-500 cal BP but their overall contribution to total midden MNI drops down to only 4% between the 0-250 year period. In contrast, sandy-mud species contribute only 16% of the assemblage in the beginning but then dominate overall percentage contribution for the remainder of the time. The Sandy-Mud Flats patch is again heavily exploited in the last 250 years. Rocky Reef species make up a lesser proportion of the assemblage throughout all periods, perhaps because of higher associated capture costs, such as it may be more difficult to access the habitat; it may also be harder to extract the molluscs from the rocks, therefore consumption of some of the oysters might likely be occurring at the rocks.

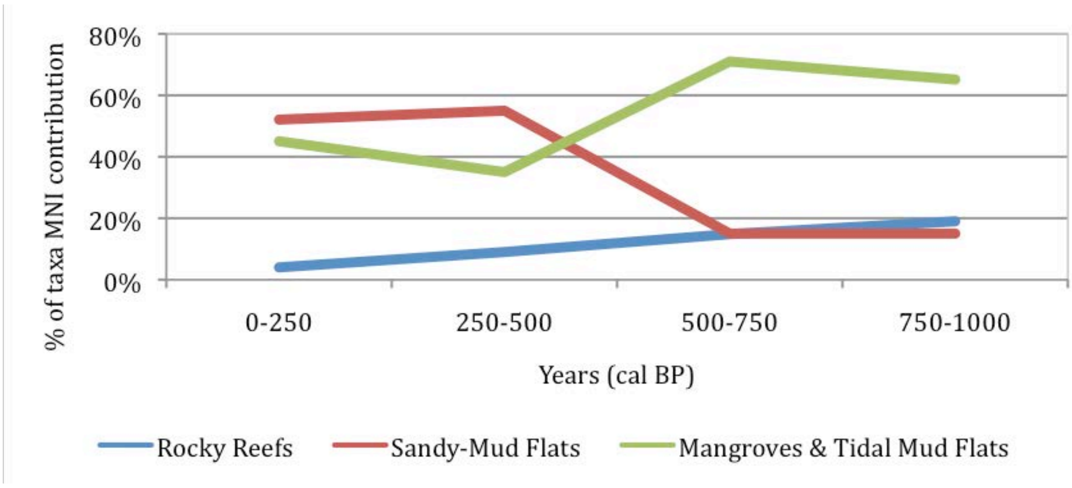


Figure 8.32: Thundiy combined squares, percentage of mollusc taxa MNI collected from each patch by 250-year period.

The data demonstrate that changes in patch use are such that the initial focus of foraging for Mangroves patch species (c.750-1000 cal BP) switches to the Sandy Patch in the next period. Patch exploitation remains consistent for the next 500 years and then Sandy Patch species increase at the expense of Rocky Reef species. These changes can be tracked through the use of two indexes. The decline in the Mangrove–Sandy-Mud Flats Patch Index indicates that foragers' preference is switching from Mangrove taxa to Sandy-Mud Flats taxa through time (Figure 8.33). The decline in the RockyCoral Reef–Sandy-Mud Falts Patch Index indicates that foragers' preference is also switching from Rocky Reef taxa to Sandy-mud Flats taxa through time (Figure 8.34). The chi-squared results indicate that the reduction of Mangrove species and Rocky Reef species are both significantly correlated with the increase in Sandy-Mud Flats patch species ($X^2 = 627.85$, d.f.=3, $p<0.0001$; $X^2 = 248.97$, d.f.=3, $p<0.0001$).

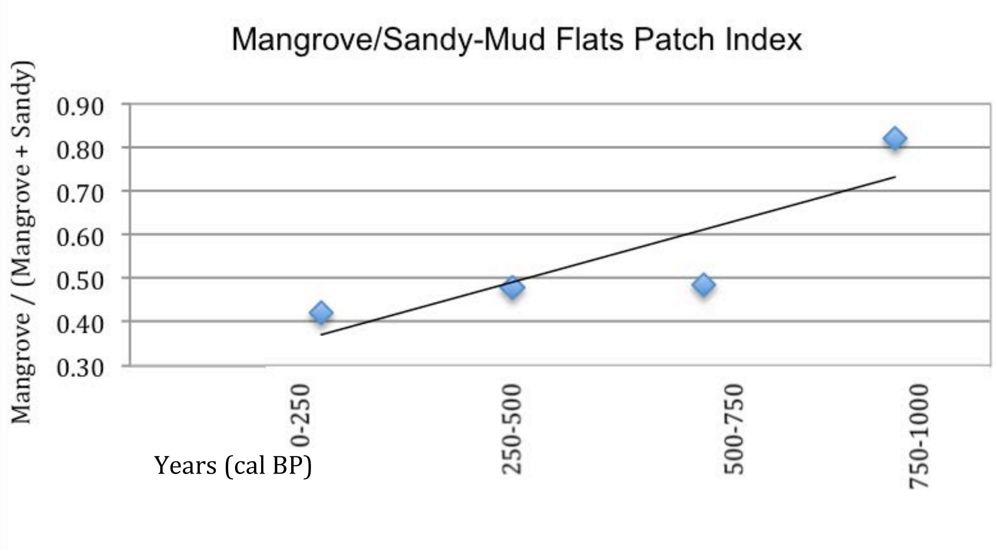


Figure 8.33: Change in patch indicated by Mangroves-Sandy-Mud Flats Patch Index.

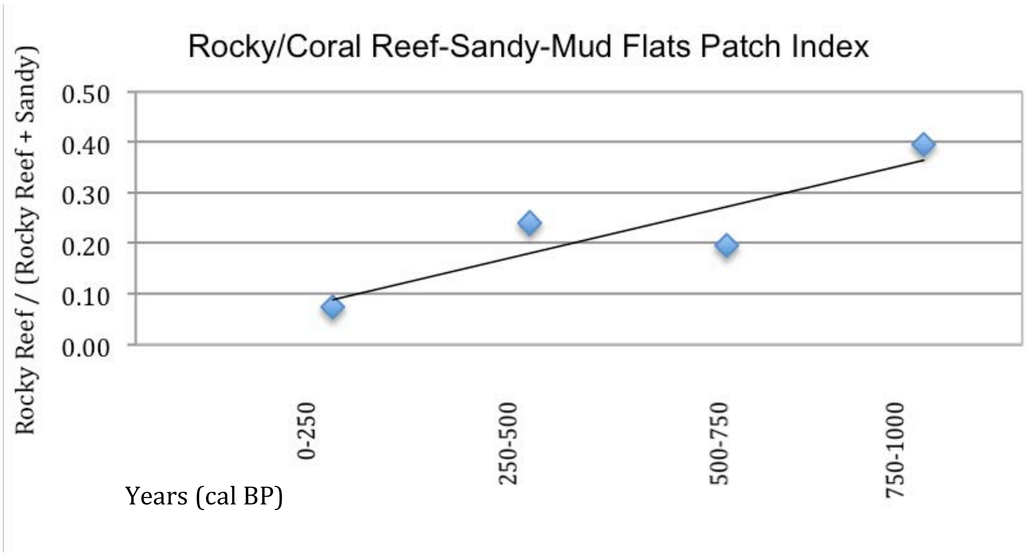


Figure 8.34: Change in patch use indicated by Rocky Reef-Sandy-Mud Flats Patch Index.

8.9.3 Resource Intensification and Foraging Efficiency

At Thundiy, we see that the hiant venus clam is the most prevalent taxon in the assemblage and it is documented throughout the entire period of occupation. When we review the top five species again, we can see that *M. hiantina* clam, a Sandy-Mud Flats species, is actually experiencing declining numbers through time even though its percentage contribution to the overall assemblage is increasing (Figure 8.26-8.28). Not shown on the graph, but of some relevance is the fact that other Sandy patch species, for example, *Gafrarium pectinatum* and *Lunulicardia hemicardium* are also declining in numbers through time. Possible explanations for this could be related to foragers' choices and/or environmental changes impacting on habitats. In attempts to determine the best explanation, it is also useful to review the relationship between the hiant venus clam MNI and specimen sizes for each period (Table 8.15; Figure 8.36).

Table 8.15: Metrical data for intact *M. hiantina* valves from Thundiy, Squares A-C.

XU	Mean (mm)	Median (mm)	S.D. (mm)	Min (mm)	Max (mm)	Range (mm)	No.
1	39.22	39.67	2.31	35.31	42.05	6.74	8
2	36.74	37.60	3.04	30.60	40.60	10.00	30
3	36.51	36.70	2.76	25.60	42.44	16.84	93
4	37.02	37.21	2.84	31.67	41.97	10.30	48
5	37.04	37.05	3.20	29.40	43.70	14.30	48
6	36.53	36.92	2.93	27.01	44.45	17.44	90
7	36.19	36.40	3.07	26.20	43.70	17.50	135
8	36.99	37.22	3.55	28.07	43.47	15.40	83
9	36.44	36.41	2.89	30.30	43.90	13.60	122
10	34.99	34.61	3.15	27.20	41.80	14.60	110
11	35.57	35.30	3.64	28.20	48.60	20.40	51
12	36.00	36.15	2.69	30.30	41.40	11.10	22

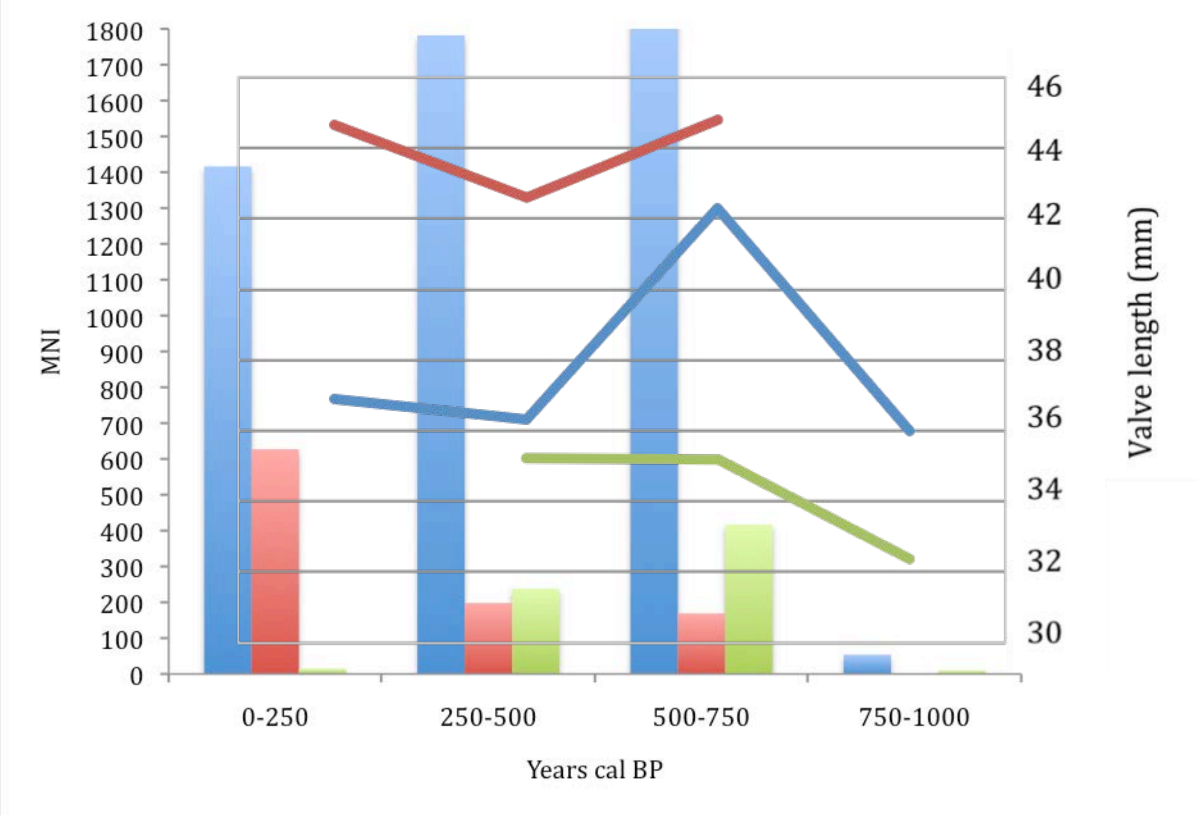


Figure 8.35: Relationship between *M. hiantina* (blue), *G. pectinatum* (green) and *T. granosa* (red) MNI (columns) and mean valve length (mm) per 250-year period (lines).

From the graph (Figure 8.35) we can see that there are subtle corresponding changes such that MNI increases are followed by a slight reduction in mean valve length. Also of interest is that numbers of *Gafrarium pectinatum* (another Sandy-Mud Flats patch species) have significantly dropped in the most recent 250-year period. In contrast the numbers have increased for exploitation of *Tegillarca granosa* (a Mangrove Mud-Flats patch species). This suggests that foraging efficiency could be declining in the Sandy-Mud Flats patch.

To confirm this we can track foraging efficiency through use of an index that compares abundance changes in a high-ranked taxon with a lower-ranked taxon within the patch, given that as the high-ranked taxa are depleted low-ranked taxa will be added to the diet breadth. In this case *M. hiantina* is matched up against *Clypeomorus* sp., a low-ranked gastropod found in the Sandy-Mud Flats Patch (Figure 8.36). The increase in this index suggests that foraging efficiency is not declining in this patch therefore human exploitation of M. hiantina is not greatly impacting the mollusc's population. The change is considered significant with a chi-square test.

The low numbers of identified vertebrate remains make it difficult to form an assessment of foraging efficiency for this class of taxa. Of the identified taxa, wrasses and parrotfishes inhabit shallow coastal waters around rocky/coral reefs. Whiting, catfish and javelin fish have been caught on the reefs and in the creeks and estuaries. Reef sharks frequent the shallow inshore waters of the South Wellesley Islands in search of fish prey. Although these fish are generally found in different coastal waters habitats, it is feasible that all of these taxa could have navigated into nearshore waters, perhaps chasing prey or getting caught in tides and currents. It would therefore be possible to spear and or net fish in the fish traps, in creeks and estuaries, off the beach and in the shallow nearshore waters.

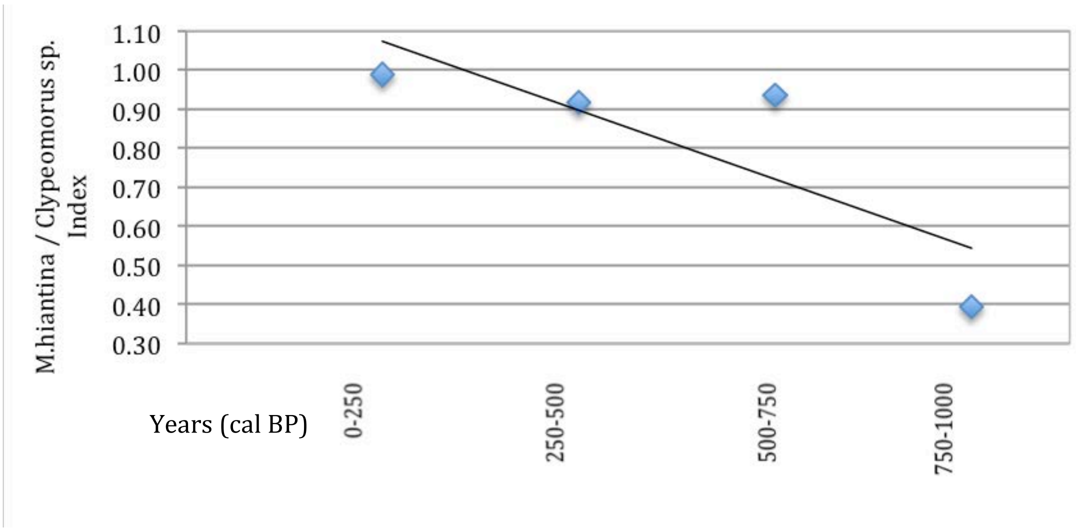


Figure 8.36: High-ranked taxon (*M. hiantina*) to low-ranked taxon (*Clypeomorus* sp.) index to track foraging efficiency.

8.10 Discussion

Radiocarbon dates from the basal layers of cultural deposits in Thundiy suggest the site was used for at least 800 years. The deposits are densely-packed with marine-shell that contributes over 80% of the materials recovered. Molluscs were foraged from three main habitats (Sandy-Mud Flats, Mangroves and Tidal-Mud Flats and Rocky Reefs) in varying quantities and proportions over the time the site was occupied. The recovered cultural materials were divided into chronological period parcels of 250 years, to determine temporal changes at the site. This also facilitates comparison with other sites being reviewed for the purpose of establishing spatial and temporal patterns across the study area.

Regarding midden contents, the initial 250 years (750-1000 cal BP) of occupation exhibits the lowest proportion (10%) of taxa numbers across the combined assemblage based on MNI (Figures 8.16, 8.19, 8.22). Further the low values of high-ranked taxa (e.g. *Marcia hiantina* and *Tegillarca granosa*) before 750 cal BP, suggests there may have been a very low-level cultural occupation before this time (see Figure 8.26-8.28). At this time the majority of shellfish (>70%) in the assemblage came from Mangrove and Mud-Flats habitats. The two middle periods (500-

750 cal BP and 250-500 cal BP) appear to reflect the greatest level of site use based on mollusc MNI numbers, with approximately equal quantities recorded for both periods. From this time 47.8kg of shell, representing at least 10,806 mollusc specimens, were identified. Fairly even proportions of shellfish were collected from both Mangrove and Mud Flats and Sandy-Mud Flats habitats. Only 10-12% came from Rocky Reef habitats. Figures 8.16, 8.19 and 8.22 reflect a reduction in site use for the most recent 250 years. At this time the majority of taxa were selected from Sandy-Mud Flats habitats (53%), with 40% collected from Mangrove and Mud-Flats habitats and 5% from Rocky Reefs.

Figures 8.29-8.32 reflect temporal changes in patch choice across the four 250 year chronological time frames. From these data, we can suggest that the Sandy-Mud Flats habitat greatly increased in value over time as a supply zone for dietary resources. In fact, *M. hiantina* as a proportion of the overall mollusc assemblage for the most recent 750 years has increased from 33% (500-750 cal BP) to 53% (0-250 cal BP). Resource intensification of *M. hiantina* in some periods did result in reducing specimen sizes; although this effect does not seem to be as significant at Thundiy as at other sites across the archipelago (see Chapter 15 for a summary of all sites). This is most likely because people did not overexploit the Sandy-Mud Flat species, instead choosing to diversify their diet with other species e.g. *Tegillarca granosa* (24% of the 0-250 cal BP period) from the same or different habitat zones.

Palynological analysis of the Square B deposits at Thundiy has revealed four pollen zones in the matrix that are suggestive of major vegetation and landscape changes over the past 500 years (Moss *et al.* 2014). During the period 500-750 cal BP (21-30cm) the landscape was more open and suggestive of a coastal phase evidenced by higher values of chenopods and Convolvulaceae. At 19cm there is a spike in charcoal values followed by an increase in arboreal taxa, particularly Pandanus and Asteraceae. A radiocarbon date of c.510 cal BP is attributed to this zone. Between 250-500 cal BP (c.12-15cm) there was a decline in charcoal values and an increase in Casuarinaceae. Grass and herbaceous taxa increased and arboreal taxa decreased during the 0-250 cal BP (between 3-9cm). The overall proportion of mangroves declined over time and taxa change from a mixed Avicennia, Ceriops and Rhizophora forest to a contemporary fringe dominated by Rhizophora. This may explain the general decline through time of taxa collected from Mangrove and Mud-Flats habitats and Rocky Reef habitats, in favour of species from Sandy-Mud Flats. Foragers may also have chosen to intensify their exploitation of the Sandy-Mud Flats patch and increase diet breadth for socio-economic reasons such as increasing population numbers.

Table 8.16 shows the lengths of the fish otoliths collected from the Thundiy midden as well as the lengths of comparative fish otoliths in the TARL fish reference collection (Tomkins *et al.* 2013). An independent investigation of using vertebral lengths to estimate fish size confirms the catfish weights below (Aird and Fitzpatrick 2013). It is estimated that in total these fish weighed over 1.2kg, providing approximately 5488 calories of energy. The other fish (shark, wrasse, parrotfish) that were identified from other diagnostic elements in the absence of otoliths could feasibly have contributed an additional 2-5kg to the diet (1400-3500 calories) based on the weights of live collected specimens for the TARL fish reference collection.

Table 8.16: Estimated weights of fishes based on otolith lengths of archaeological specimens compared with reference collection specimens.

Taxon	Sq/ XU	Comparative otolith length (mm)	Comparative taxon weight (g)	Length of archaeological otoliths (mm)	Estimated weight (g) / energy return* of archaeological fish (kcal/hr)
Ariidae	B7	9.5	300	14	c.442 / 575
Ariidae	C2	9.5	300	10	c.315/ 410
Sillago burrus	C5	10.2-11.2	380-430	7	c.220 / 220
Pomadasys kaakan	C10	14.5	310	13.5	c.290 / 320

8.11 Summary

Excavation at Thundiy revealed a relatively deep, high-density shell deposit consistent with observations of the material exposed across the dune surface. Based on the site's location, relatively large size and the presence of a large range of taxa, Thundiy is consistent with being a central-place camp that was mainly utilised during the periods 250-750 years with an episode of high use also occurring 0-250 cal BP. Here occupants shared resources hunted in the nearshore waters of the north coast, Makarrki River and Rukathi Creek and gathered from Sandy-Mud Flats, Mangroves and Tidal-Mud Flats and Rocky Reefs habitats. Therer is a general decline through time of taxa collected from Mangrove and Mud-Flats habitats and Rocky Reef habitats, in favour of species from Sandy-Mud Flats. Bourke et al. (2007) and Faulkner (2008, 2011a) suggest this pattern reflects long-term coastline alteration. A decrease in mangrove and rocky reef species is also reported from Myaoola Bay, which Faoulkner (2011a) ascribes to environmental impacts (e.g. cyclones, storm surges) related to ENSO events that affected species availability. The results at Thundiy may reflect a combination of hunter-gatherer foraging choices based on socio-economic reasons (e.g. growing population numbers) and environmental changes impacting resources.

Chapter 9. Wirrngaji, Bentinck Island

9.1 Introduction

This chapter reports archaeological investigations at Wirrngaji, located on the central south coast of Bentinck Island. Excavation at Wirrngaji revealed a thick upper layer of shell (c.45cm) dated to c.100-1000 cal BP and a thin lower layer (c.15cm) dated to 1147 cal BP. The following sections describe the Wirrngaji site and its stratigraphy, chronology and contents followed by a discussion of the data from an OFT perspective for understanding foraging behaviours of the site users.

9.2 Site Description and Setting

Wirrngaji is a large shell midden located in the upper units of an elevated beach ridge, on the central south coast of Bentinck Island (Figures 9.1-9.2). The site was first mentioned in 1997 to Nicholas Evans by the late Kaiadilt Elder, Dawn Naranatjil, as a place 'where the old people used to live'. Evans (Native Title Claim Transcript) notes 'special stones are found around here that look like a sort of sandstone conglomerate. They are used in wind magic, to stop storms. We also found a lot of oyster-crackers, dangkankuru, as well as mariwu - slate rocks for clearing the sky.' In 2008, based on Dawn's testimony and informed by the positive results of a pedestrian survey of the area (Latitude: 17.11337S, Longitude: 139.48508E), Sean Ulm undertook an excavation at Wirrngaji to investigate sub-surface deposits. The beach ridge containing the site is thought to date to the mid-Holocene sea-level highstand (Sloss *et al.* 2012) and is c.9m high located some c.500m north of the current shoreline, behind a series of cheniers and beach ridges (Figure 9.3).

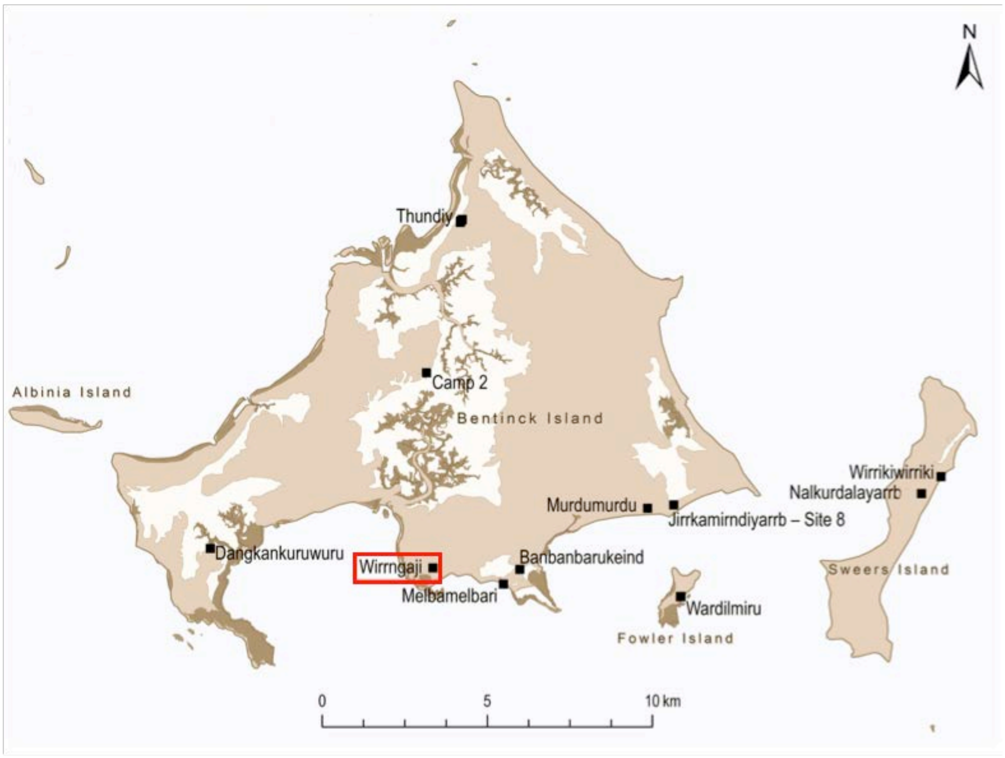


Figure 9.1: Map of South Wellesley Islands showing Wirrngaji site location (map prepared by Lincoln Steinberger and Sean Ulm).

Figure 9.2: Aerial view map showing Wirrngaji site location (after Google Earth).

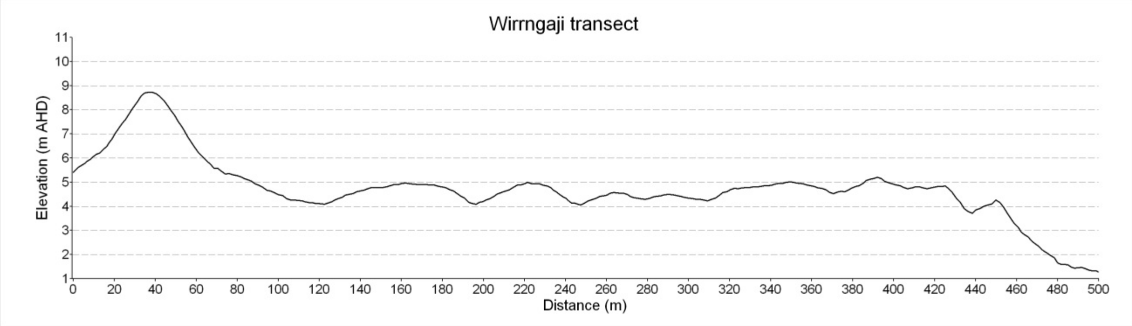


Figure 9.3: Topographical profile of landscape along GPR transect from Wirrngaji to the coast (prepared by Lincoln Steinberger and Sean Ulm).

Vegetation is patchy across the top of the ridge with a sparsely spread tall open eucalypt forest (*Eucalyptus* spp.) with *Acacia* spp. and wallaby grass (Figure 9.4). Seasonal soaks (or wells) occur in the swales between the high ridge and the coastline. Vast areas of coastline can be accessed within a 1km radius of the site that comprises intertidal and subtidal mud and sandy-mud flats, rocky/coral reefs and mangrove communities (Figures 9.5-9.6). Wirrngaji is only 2km SSE of the mouth of the Kombali (MacKenzie) River, hosting further rich estuarine resources. Along the shoreline, there are extensive intertidal mud flats backed by a dense mangrove fringe that forms a semi-barrier to the sea. The rocky reefs support colonies of oysters (*Saccostrea glomerata*) while telescope mud whelks (*Telescopium telescopium*) and mud shells (*Geloina erosa*) are common amongst the mangroves. The intertidal sandy-mud flats along the shoreline adjacent to the site support hiant venus clams (*Marcia hiantina*). The shallow waters in this area provide good conditions for seagrass beds, which attract fish and dugong.

Figure 9.4: Wirrngaji view southeast toward coastline (Photo by Sean Ulm).

Figure 9.5: Mangroves and Tidal-Mud Flats adjacent to Sandy-Mud Flats near Wirrngaji.

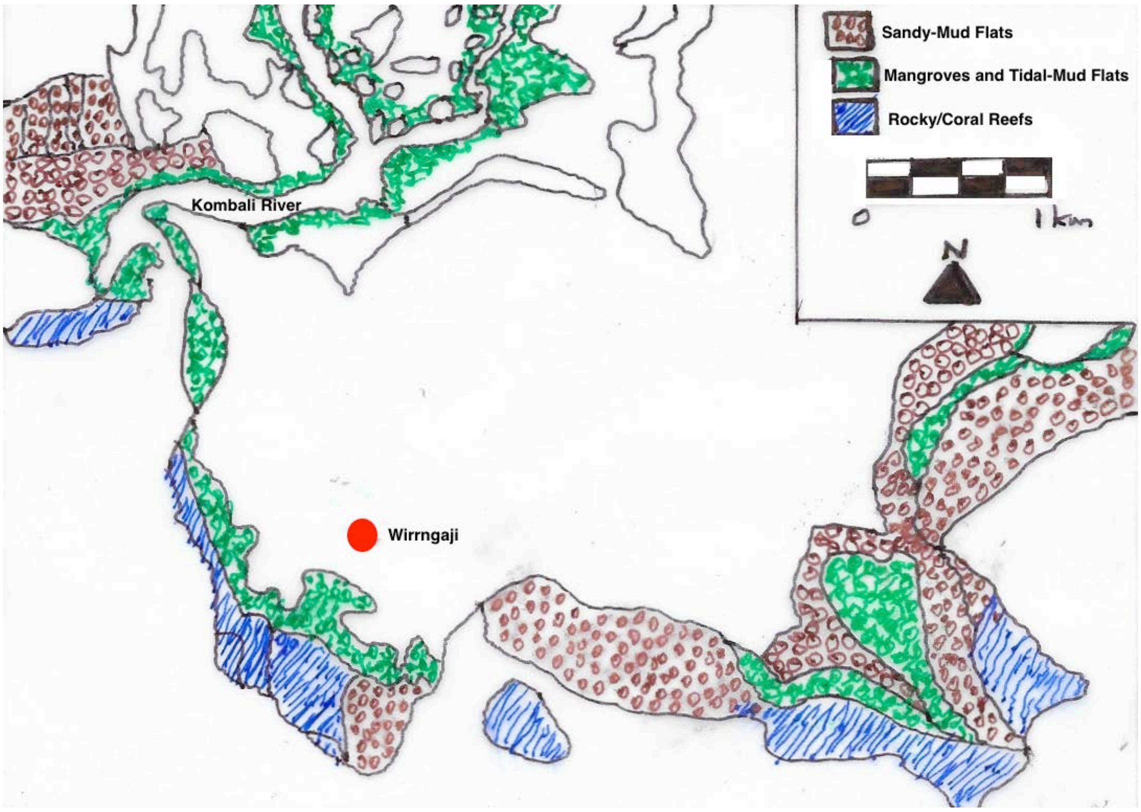


Figure 9.6: Resource habitat communities near Wirrngaji.

9.3 Excavation Methods

The site covers a minimum area of 25,000m^2, based on the observation of intermittent surface exposures. Archaeological excavations at Wirrngaji consisted of one 50cm x 50cm square (Square A) located c.16m east of a large isolated eucalypt on the crest of the main Wirrngaji beach ridge that is oriented NE-SW (Figure 9.7). The pit was placed on a flat area with little surface shell, but no obvious signs of major deflation in contrast to the adjacent southern slopes where surface deflation had exposed quantities of extensive shell. Excavations proceeded in c.3cm increments to a depth of c.80cm and averaging 11.7kg per XU (Figure 9.8). 305kg of midden materials were dry sieved through 2.3mm mesh on site and the materials retained in the sieve were bagged for later sorting and identification in the laboratory.

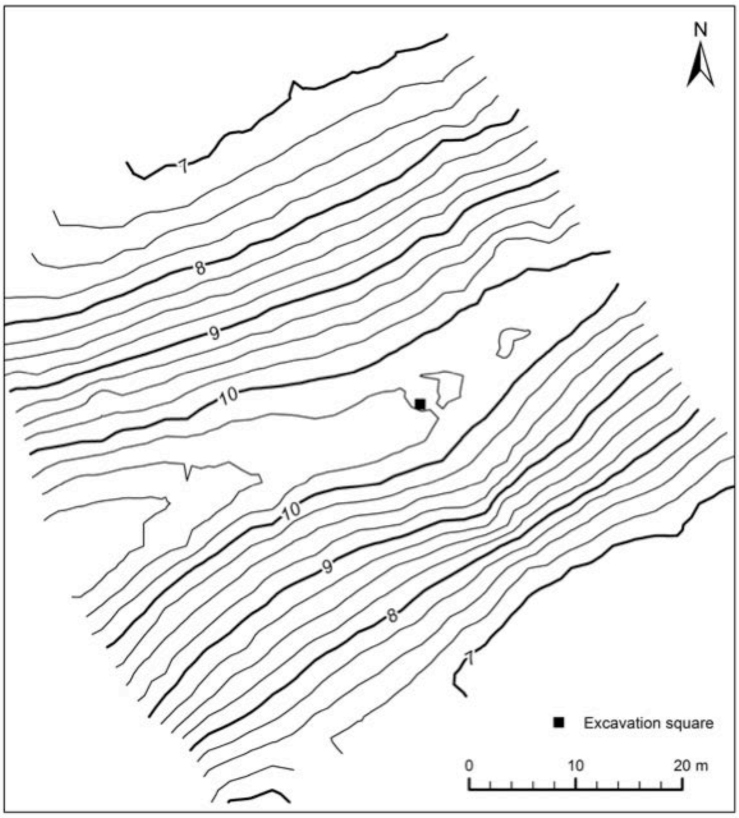


Figure 9.7: Topographic plan of ridgeline showing landscape contours and position of Wirrngaji Square A excavation square (prepared by Lincoln Steinberger and Sean Ulm).

Figure 9.8: Wirrngaji Square A, 50cm x 50cm excavation pit profile (facing north) (photo by Sean Ulm).

9.4 Cultural Deposit and Stratigraphy

Cultural deposits were identified in sediments up to c.66cm (XU23) deep, with excavations terminating at a depth of c.80cm (XU26) in culturally sterile sediments. The excavation revealed a c.45cm thick upper layer of shell (XU2-16) dated to c.100-1000 cal BP and a thin (c.12cm) lower layer (XU19-23) dated to 1147 cal BP with mollusc shell, bone, stone artefacts and charcoal recovered. The apparent vertical and horizontal discreteness of the shell material, restricted range of shellfish taxa, the dominance of larger shellfish size-classes and presence of burnt shell and fish remains support a cultural origin for the deposit. The deposit can be divided into four stratigraphic units (SUs) based on sediment colour and texture (Figure 9.9; Table 9.1). SUI includes a high density of materials located between XU2 to XU10 that have cultural origins. The cultural materials continue into SUII reducing in density with depth. SUIII contains brown to reddish-yellow fine sands and a thin layer of shell. SUIV contains reddish-yellow fine sands and sparse materials with occasional shell fragments.

Table 9.1: Stratigraphic Unit (SU) descriptions, Wirrngaji Square A.

SU	Description
I	SUI extends across the entire square with depths ranging between 25cm to 35cm below ground surface. The unit comprises angular to subangular dry and loosely consolidated sands, which are brown (7.5YR-5/4) to dark brown in colour (7.5YR-3/4). Coarse shell grit occurs throughout. The top 10cm contains grass roots. Cultural materials include whole and fragmented molluscs (venus clams, longbums and oyster), fish bones and otoliths, some small fragments of charcoal and a pitted stone. pH values are alkaline (8.5-9.5). Shell and bone materials appear to be reasonably well preserved. At the base of the unit, several conglomerate rocks of laterite and sandstone were recovered, possibly used for heat retainers.
II	Transitional unit with mainly brown (7.5YR-4/4) sands with smaller/finer shell grit throughout. Cultural shell is occasionally present throughout along with fragments of charcoal and rock. This layer has thickness of 10cm to 20cm. pH values are highly alkaline (9.5).
III	Brown (7.5YR-5/4) finer sands grading to reddish-yellow in colour (7.5YR-6/6) with very occasional cultural shell. This layer extends across the entire square with an average thickness of 27cm. pH values remain highly alkaline (9.5). A laterite rock approximately 10cm long features in the north section. A small concentration of shell was encountered in XUs 19-23.
IV	Reddish yellow (7.5YR-6/6) fine sands encountered at the base of excavation. pH values are strongly alkaline (10). Approximately 8cm of this layer has been exposed and it is expected that additional excavations will likely encounter more of the same. Subsequent augering of the beach ridge undertaken as part of geomorphological sterile and very thick (base not reached) (Craig Sloss, QUT, pers. comm., 2013).

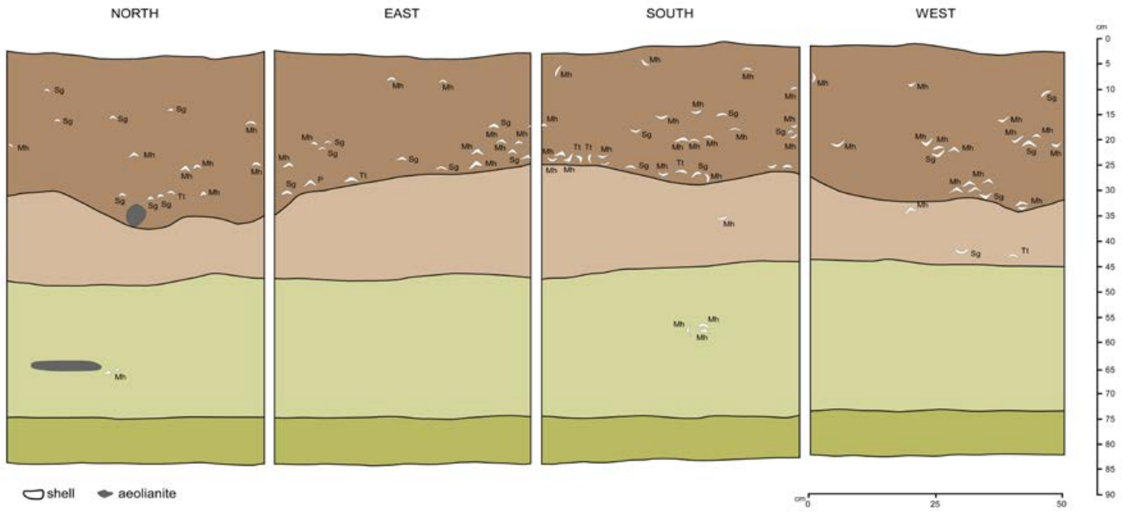


Figure 9.9: Stratigraphic section drawing, Wirrngaji Square A (prepared by Michelle Langley and Sean Ulm).

9.5 Site integrity and taphonomy

Although there does appear to be major bioturbation of the upper sediments of the beach ridge in the general excavation area from tree roots and active goanna burrowing, other evidence suggests that the deposit exhibits reasonable stratigraphic integrity. There is a predictable shell decay profile with highly weathered tiny gastropod and bivalve specimens recovered from the base of the deposit and relatively well-preserved specimens from the upper deposit. Sparse fragments of shell recovered from XU26 are highly weathered. Low shell-fragmentation (193 fragments per 100g of shell) enabled a higher success rate of shell identification in the upper units (XU1-10) that correlates with the period of cultural deposition (see Hoffman 2011). This contrasts with high/increased shell-fragmentation (347 fragments per 100g of shell) and consequently low rates of identification in deeper and older units (XU11-26). Reviewing effects of site taphonomy on vertebrate remains it appears that degradation of fish bone materials is greatest in lower XUs with fewer bone fragments recovered and those that are found are generally unidentifiable. There is evidence of some minor disturbance within the matrix in the form of wasp and other insect burrows.

9.6 Radiocarbon Dating and Chronology

Five radiocarbon dates were obtained from Square A, suggesting initial use of the site by c.1147 cal BP (Wk-23662) and probable abandonment in the contact period (Table 9.2). The site appears to have seen low cultural use initially with time for sediments to build up before a period of more intensive use commencing c.974 cal BP.

Table 9.2: Radiocarbon ages on marine shell from Wirrngaji Square A. Calibrations undertaken using OxCal v.4.1 (Bronk Ramsey 2009) and the Marine13 calibration dataset (Reimer *et al.* 2013). For marine samples a ΔR of −49±102 as recommended by Ulm *et al.* (in prep.) is employed.

Sq	XU	Lab. Code	Depth (cm)	Specimen	^{14}C	δ^{13}C	Calibrated Age BP (95.4%)	Calibrated Age BP Median
A	2	Wk-35850	0.01-3.3	*Marcia hiantina*	364±28	-0.9±0.2	0*-255	101
A	5	Wk-35851	9.4-12.5	*Marcia hiantina*	486±25	-1.2±0.2	0*-366	169
A	8	Wk-35852	18.3-21.5	*Marcia hiantina*	1144±25	0±0.2	553-936	751
A	12	Wk-23661	30.3-33.2	*Marcia hiantina*	1373±33	0.3±0.2	740-1207	974
A	23	Wk-23662	63.4-66.4	*Marcia hiantina*	1549±32	-0.7±0.2	923-1342	1147

As we are particularly interested in potential changes through time, the assemblages have been divided into temporal phases of 250-year periods for comparative purposes. Excavation units were assigned to chronological periods based on an age-depth model derived from the calibrated radiocarbon ages and stratigraphic observations (Figure 9.10; Table 9.3), interpolating between individual data points. Even though time-averaging these open shell deposits only allows for identification of broad-scale trends and not subtle changes, it allows determination of variation in relative taxa abundance, indicative of taxa exploitation patterns and/or environmental changes affecting the distribution of taxa.

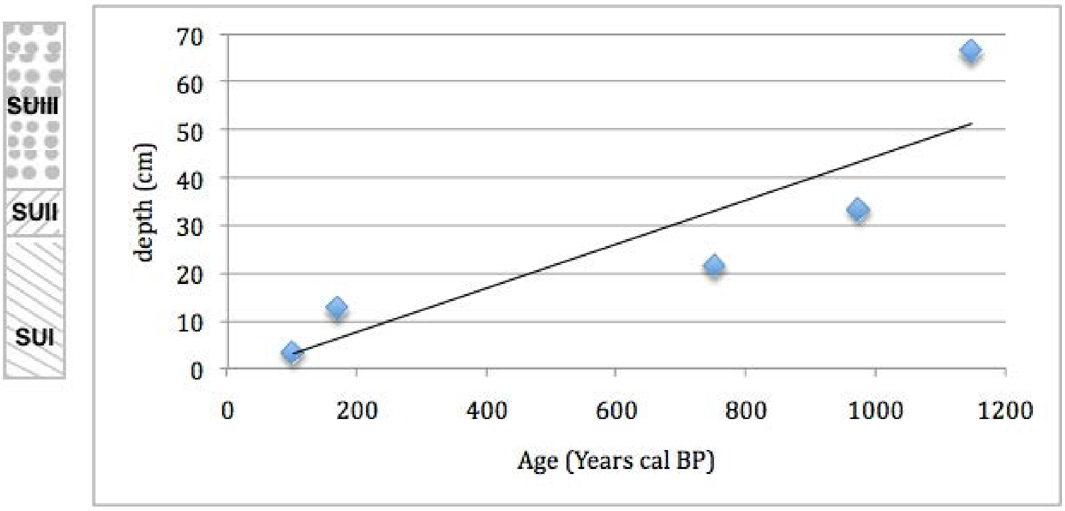


Figure 9.10: Age-depth relationship of radiocarbon determinations obtained from Wirrngaji.

Table 9.3: Temporal phases of 250-year periods, showing allocation of XUs.

Temporal phase	0-250	250-500	500-750	750-1000	1000-1250
XUs	1-5	6	7-8	9-14	15-26

9.7 Laboratory Methods

All materials retained in the 2.3mm mesh sieve were analysed and reported below. See Chapter 6 for a detailed discussion of the standard excavation and laboratory methods employed.

9.8 Cultural Materials

8,822.5g (3% of the total sediment and materials) were retained in the 2.3mm sieve residue for analysis. Table 9.4 shows the overall summary results of the retained materials. Molluscan shell makes up 92.18% (8132.08g) of the total assemblage and fishbone contributes 0.02% (1.57g). Small quantities of crustacea (16.4g) were recovered from XU2-25, represented by mud crab (*Scylla* spp.) (0.86g) and goose barnacle (Pedunculata) (15.56g). Stone (including beach rock and pisoliths) contribute 5.6% and organics make up the rest of the assemblage. A possible *nara* artefact (fragment from a shell knife) fashioned from *Melo amphora*, a possible *dangkankuru* 'oyster-pick' or millstone hammerstone artefact, charcoal and possible heat-retainers comprising conglomerate rocks of sandstone and/or ironstone are also associated with the shell deposit (Figures 9.11-9.14). Shell knives (*nara*) are mentioned in ethnographic literature (e.g. Tindale 1962a, 1962b).

Figure 9.11: *Melo amphora* fragment (scale bar represents 1000 microns). Ethnographically used as a knife.

Figure 9.12: Baler shell (*Melo amphora*) exhibiting usewear marks. microscope 10x magnification (scale bar = 100 microns).

Figure 9.13: Possible hammerstone artefact for removing and smashing oysters from rocks (scale bar in 1cm increments).

Figure 9.14 Hammerstone - note stone compaction visible with a microscope at 45x magnification (scale bar= 100 microns)

Table 9.4: Summary excavation data and retained materials from Wirrngaji Square A.

XU	Depth Below Surface (cm)	Mean Thickness (cm)	Weight (kg)	Vol cm^3	pH	Marine Shell (g)	Bone (g)	Barnacles (g)	Stone Artefacts (g)	Crab (g)	Charcoal (g)	Other Organic (g)	Rock Rubble (g)	Retained Materials (g)	% of Total Midden
1	0.80	0.8	0.1	2000	8.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
2	3.26	2.5	9.6	6150	9	330.63	0.03	0.77	0.00	0.00	0.20	18.22	13.52	363.37	3.79%
3	6.38	3.1	11.6	7800	9	343.30	0.43	0.13	0.00	0.00	0.42	8.85	12.20	365.33	3.15%
4	9.36	3.0	11.7	7450	9	295.66	0.06	0.15	0.00	0.28	0.36	14.17	15.84	326.52	2.79%
5	12.50	3.1	12.5	7850	9.5	196.61	0.02	0.17	108.85	0.00	0.48	18.27	21.11	346.51	2.77%
6	15.34	2.8	11.2	7100	9	237.74	0.00	0.44	0.00	0.02	0.13	11.36	15.63	265.32	2.37%
7	18.32	3.0	12.1	7450	9	893.34	0.00	1.88	0.00	0.00	0.42	9.44	21.64	926.72	7.66%
8	21.52	3.2	13.1	8000	9	1173.96	0.00	5.07	0.00	0.56	0.40	7.30	36.60	1223.89	9.34%
9	24.60	3.1	11.4	7700	9.5	1525.63	0.00	2.51	0.00	0.00	0.11	5.70	34.30	1568.25	13.76%
10	27.36	2.8	12.6	6900	9	1614.94	0.00	1.24	0.00	0.00	0.00	6.64	88.44	1711.26	13.58%
11	30.32	3.0	10	7400	9.5	333.79	0.00	1.08	0.00	0.00	0.09	5.11	13.75	353.82	3.54%
12	33.24	2.9	12.6	7300	9.5	136.46	0.00	0.27	0.00	0.00	0.20	4.61	36.82	178.36	1.42%
13	36.52	3.3	12.1	8200	9	161.11	0.00	0.29	0.00	0.00	0.14	4.82	16.76	183.12	1.51%
14	39.40	2.9	10.9	7200	9.5	144.49	0.02	0.20	0.00	0.00	0.00	4.81	6.86	156.38	1.43%
15	42.60	3.2	12.2	8000	9.5	146.53	0.00	0.38	0.00	0.00	0.07	4.89	10.79	162.66	1.33%
16	45.40	2.8	9.7	7000	9.5	70.71	0.00	0.30	0.00	0.00	0.21	6.39	2.54	80.15	0.83%
17	48.48	3.1	12	7700	9.5	29.83	0.00	0.06	0.00	0.00	0.15	4.65	1.90	36.59	0.30%
18	51.42	2.9	9.8	7350	9.5	27.12	1.01	0.15	0.00	0.00	0.02	4.59	1.71	34.60	0.35%
19	54.76	3.3	12.7	8350	9.5	60.65	0.00	0.10	0.00	0.00	0.03	4.57	3.53	68.88	0.54%
20	57.52	2.8	10.7	6900	10	44.37	0.00	0.15	0.00	0.00	0.00	3.26	3.70	51.48	0.48%
21	60.54	3.0	12	7550	10	81.42	0.00	0.00	0.66	0.00	0.14	3.58	2.94	89.74	0.75%
22	63.42	2.9	10.7	7200	10	121.04	0.00	0.02	0.00	0.00	0.00	2.12	8.29	131.47	1.23%
23	66.40	3.0	11.3	7450	10	80.02	0.00	0.01	0.00	0.00	0.07	2.21	3.57	85.88	0.76%
24	69.46	3.1	12.5	7650	10	21.62	0.00	0.18	0.00	0.00	0.02	4.07	3.55	29.44	0.24%
25	72.52	3.1	12.1	7650	10	22.08	0.00	0.01	0.00	0.00	0.08	3.05	3.12	28.34	0.23%
26	79.62	7.1	27.8	17750	10	39.03	0.00	0.00	0.00	0.00	0.00	5.70	9.69	54.42	0.20%
Total:		79.62	305.00	199050		8132.08	1.57	15.56	109.51	0.86	3.74	168.38	388.80	8822.50	2.89%

9.8.1 Invertebrate Mollusc Remains

Shell represents the most common component (92.18%) of excavated materials by weight. 21 molluscan taxa weighing 8,132.09g (with an MNI=899) were recovered from Square A, consisting of 9 marine bivalve taxa and 12 gastropod taxa (Figures 9.15- 9.16). MNI and weight tables are presented in Tables 9.5 and 9.6.

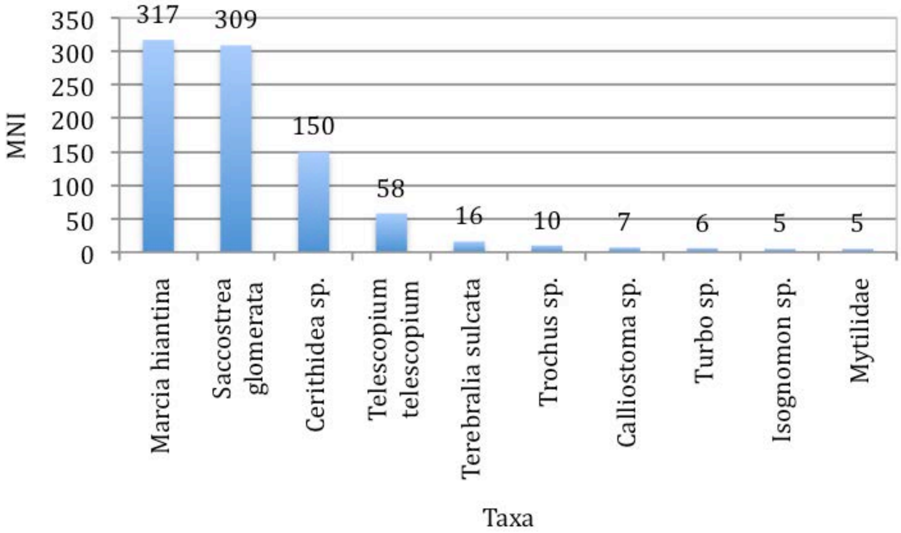


Figure 9.15: Wirrngaji Square A, top 10 mollusc taxa by MNI.

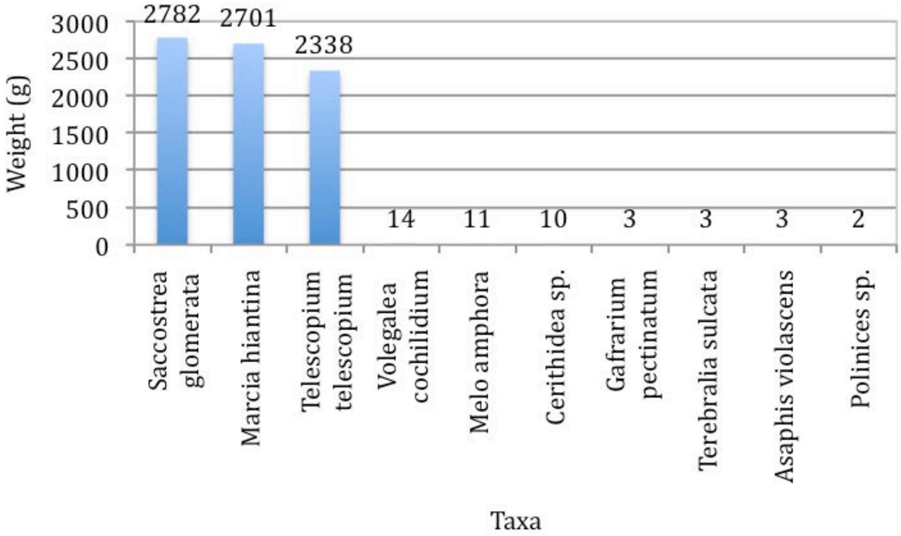


Figure 9.16: Wirrngaji Square A, top 10 mollusc taxa by weight.

Table 9.5: Wirrngaji Square A molluscan assemblage taxa MNIs.

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
MIRNE BIVALVIA														
Asaphis violascens														
Barbatia sp.							1							
Beguina semiorbiculata					1					2	1			
Corbula fortisulcata								2				1		
Isognomon isognomon							1							
Marcia hiantina		20	30	16	9	10	58	58	34	38	7	3	3	5
Mytilidae							2	2			1			
Saccostrea glomerata		10	2	3	3	11	47	61	79	40	11	9	8	4
MARINE GASTROPODA														
Calliostoma sp.										2		3		
Cerithidea sp.		13	6	7	10	10	5	27		17	12	13		7
Melo amphora								1						
Patellidae												1		
Polinices sp.			1											
Rhinoclavis sp.														
Telescopium telescopium			3	1	4		1	2	12	15	4	3	2	
Terebralia sulcata			2	1			5							
Trochus sp.		1	1			1		3	1		1			
Turbo sp.								1		2	1		1	1
Volegalea cochlidium							1							
XU Totals	**0**	**44**	**45**	**28**	**27**	**32**	**121**	**157**	**126**	**116**	**38**	**33**	**14**	**17**

Table 9.5: Wirrngaji Square A molluscan assemblage taxa MNIs (cont.).

Taxon XU	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**Species Totals**
MIRNE BIVALVIA													
Asaphis violascens													**0**
Barbatia sp.													**1**
Beguina semiorbiculata													**4**
Corbula fortisulcata													**3**
Isognomon isognomon				1	2				1				**5**
Marcia hiantina	7	2	1	3	3	3	3			1	1	2	**317**
Mytilidae													**5**
Saccostrea glomerata	3	2	3	1	1	1	5	1	2	1	1		**309**
MARINE GASTROPODA													
Calliostoma sp.		1	1										**7**
Cerithidea sp.		3	3	2	5		3	1			6		**150**
Melo amphora													**1**
Patellidae			1						2				**4**
Polinices sp.													**1**
Rhinoclavis sp.		1											**1**
Telescopium telescopium	2	1			1	1		2	2	1	1		**58**
Terebralia sulcata	6											2	**16**
Trochus sp.	1							1					**10**
Turbo sp.													**6**
Volegalea cochlidium													**1**
XU Totals	**19**	**10**	**9**	**7**	**12**	**5**	**11**	**5**	**7**	**3**	**9**	**4**	**899**

Table 9.6: Wirrngaji Square A molluscan assemblage taxa weights (g).

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
MARINE BIVALVIA														
Asaphis violascens			2.62											
Barbatia sp.							0.01							
Beguina semiorbiculata		0.11			0.19					1.05	0.23			
Corbula fortisulcata								0.47				0.16		
Gafrarium pectinatum			0.81					2.09	0.11					
Isognomon isognomon		0.07					0.40				0.23			
Marcia hiantina		219.00	238.26	191.13	97.02	109.58	420.12	520.34	298.30	321.20	44.13	16.02	18.99	29.16
Mytilidae					0.02		0.12	0.29	0.03		0.10	0.06		
Saccostrea glomerata		39.23	25.37	30.98	27.81	94.06	397.02	463.10	682.60	626.10	128.55	44.50	37.70	47.74
MARINE GASTROPODA														
Calliostoma sp.										0.10		0.08		
Cerithidea sp.		0.66	0.46	0.21	0.68	0.46	0.52	1.39	0.43	1.55	0.72	0.57		0.44
Melo amphora								10.65	0.02					
Nerita sp.										0.44				
Patellidae												0.07		
Polinices sp.			1.76											
Rhinoclavis sp.														
Telescopium telescopium		47.19	48.19	56.51	51.98	18.64	49.42	145.20	533.70	638.70	145.20	64.90	94.92	60.87
Terebralia sulcata			0.95	0.00			0.40		0.33	0.40				
Trochus sp.		0.22	0.25			0.03		0.09	0.02		0.08			
Turbo sp.								0.01		0.35	0.20		0.25	0.02
Volegalea cochlidium							14.22							
Unidentified shell		24.15	24.63	16.82	18.91	14.97	11.11	30.32	10.10	25.05	14.34	10.10	9.25	6.26
XU Totals	**0**	**330.63**	**343.30**	**295.66**	**196.61**	**237.74**	**893.34**	**1173.96**	**1525.63**	**1614.94**	**333.79**	**136.46**	**161.11**	**144.49**

Table 9.6: Wirrngaji Square A molluscan assemblage taxa weights (g) (cont.).

Taxon XU	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**Species Totals**
MIRNE BIVALVIA													
Asaphis violascens													**2.62**
Barbatia sp.													**0.01**
Beguina semiorbiculata													**1.58**
Corbula fortisulcata													**0.64**
Gafrarium pectinatum													**3.01**
Isognomon isognomon				0.13	0.58		0.30		0.04				**1.74**
Marcia hiantina	38.91	17.78	8.26	17.37	24.10	18.91	22.06	2.61	3.62	5.12	5.94	13.30	**2701.23**
Mytilidae													**0.62**
Saccostrea glomerata	22.36	31.50	9.59	2.45	3.33	6.32	25.92	25.05	4.83	4.82	1.34		**2782.27**
MARINE GASTROPODA													
Calliostoma sp.		0.09	0.02										**0.29**
Cerithidea sp.	0.10	0.28	0.16	0.11	0.44		0.05	0.05			0.43		**9.72**
Melo amphora													**10.67**
Nerita sp.													**0.44**
Patellidae			0.03						0.02				**0.12**
Polinices sp.													**1.76**
Rhinoclavis sp.		0.01											**0.01**
Telescopium telescopium	78.62	18.01	7.34	4.26	29.93	16.34	30.24	89.70	68.80	9.19	12.37	17.41	**2337.63**
Terebralia sulcata	0.40											0.32	**2.80**
Trochus sp.	0.02							0.02					**0.74**
Turbo sp.													**0.83**
Volegalea cochlidium													**14.22**
Unidentified shell	6.12	3.04	4.44	2.81	2.27	2.80	2.86	3.61	2.71	2.49	2.00	8.00	**259.15**
XU Totals	**146.53**	**70.71**	**29.83**	**27.12**	**60.65**	**44.37**	**81.42**	**121.04**	**80.02**	**21.62**	**22.08**	**39.03**	**8132.09**

The shell deposit is concentrated between XU2-5 (c.0-250 cal BP) and XU7-16 (c.500-1000 cal BP) (Figure 9.17). The assemblage is dominated by oyster (*Saccostrea glomerata*), comprising 34.2% of the total shell assemblage by weight, followed closely by hiant venus clams (*Marcia hiantina*; 33.2%) and long bums or telescope mud whelks (*Telescopium telescopium*; 28.7%). The remaining 18 taxa are relatively rare, each contributing less than 1% of the shell assemblage by weight. The assemblage exhibits high diversity with a calculated Shannon-Weaver Function 1.57 (4.78). The oysters, hiant venus clams and mangrove whelks, suggest foraging strategies focused on the mangrove fringe and adjacent intertidal and subtidal flats.

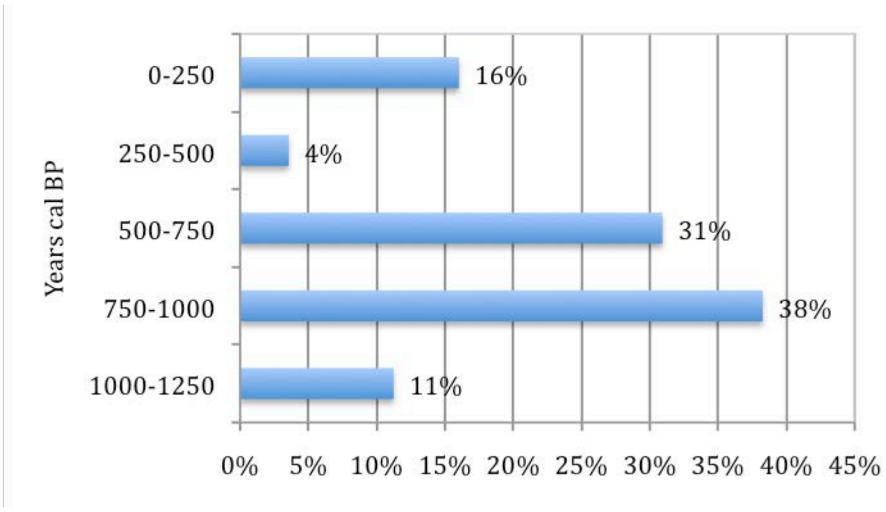


Figure 9.17: Proportion of Square A total mollusc assemblage MNI per 250-year period.

9.8.2 Vertebrate Remains

Fishbone is present in the cultural deposit, totalling 1.57g and consisting of 7 pieces of bone with an estimated MNI of 3. The MNI is a conservative estimate based on four different species identified. However, there was one maxilla and two bone fragments that could only be identified as Osteichthyes, which may be additional MNIs. Identified taxa include Catfish (Aridae, MNI=1), grass emperor (*Lethrinus laticaudis* MNI=1) and wrasse (Labridae MNI=1) (Table 9.7). An otolith recovered from XU14 best matches a rockcod (Serranidae MNI=1). The highest quantity of fishbone occurs in the upper five units.

Table 9.7: Fishbone remains at Wirrngaji Square A.

XU	Taxon	Element	MNI	NISP	Weight
2	Osteichthyes	maxilla		1	0.0275
3	Ariidae	otolith	1	1	0.3314
3	*Lethrinus laticaudis*	otolith	1	1	0.101
4	Osteichthyes	unidentified		1	0.0634
5	Osteichthyes	unidentified		1	0.0155
14	cf. Serranidae	otolith	1	1	0.024
18	Labridae	lpgp	1	1	1.0097
		Totals	4	7	1.5725

9.9 Application of Models

9.9.1 Diet-Breadth/Prey Choice

Species richness and abundance measures can be used to identify broad patterns in the breadth and diversity of molluscan exploitation at Wirrngaji. The species richness graph shows the number of species collected from each habitat per chronological period (Figure 9.18). Rocky/Coral Reefs exhibit the most variety of species collected in all time periods with the lowest variance seen in the Sandy-Mud Flats habitat. The level of species richness by habitat varies between chronological periods however this variation is not considered statistically significant (X^2=2.41, d.f.=8, p>0.5). Figure 9.19 shows exploitation patterns of the dominant three species consistently exploited based on MNIs, which incidentally represent three different habitats. Note that *Telescopium telescopium* has been selected as the dominant species from Mangroves and Tidal Mud Flats patch because *Cerithidea* sp. is considered too small to be a viable source of food here (however see Rowland 1994). Oysters dominate the assemblage during the period 500-1000 cal BP while the hiant venus clam (*M. hiantina*) has a greater presence in the period 0-250 cal BP. These results suggest that the same species were foraged from the local area, and also that the diet breadth was reasonably broad.

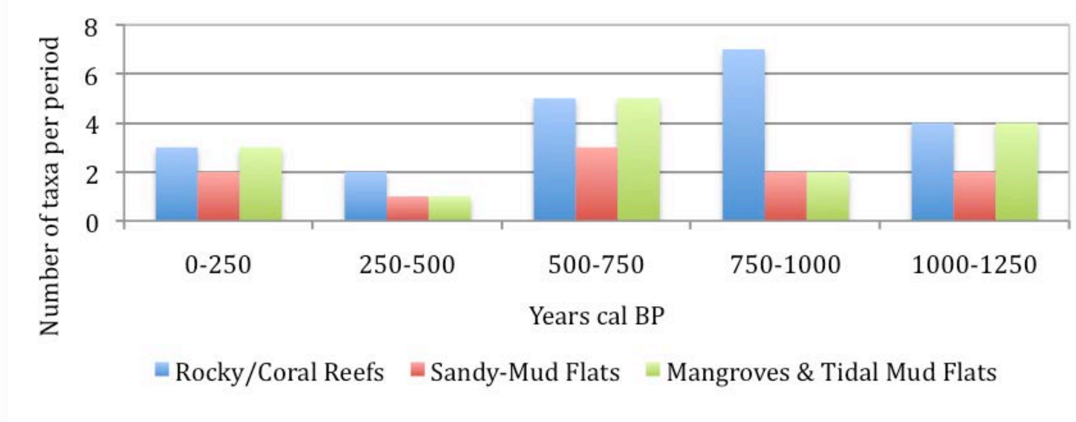


Figure 9.18: Wirrngaji Square A, mollusc species richness per habitat per period.

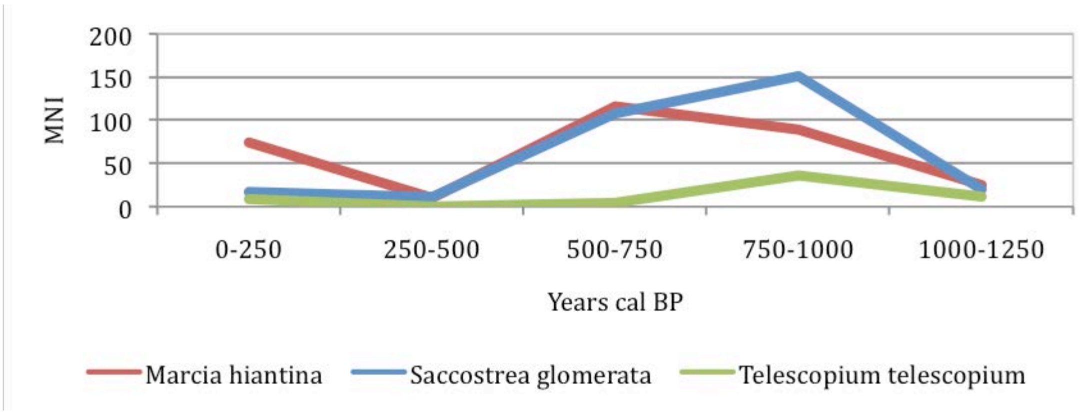


Figure 9.19: Top three mollusc taxa MNI per 250-year period, Square A.

9.9.2 Habitats/Patch Choice

The graph in Figure 9.20 shows the percentage of species MNI by habitat per chronological period. The Wirrngaji mollusc assemblage includes taxa that come from all three patches or habitats; however, there is temporal variance in the quantities of taxa taken from each patch. The chi-square results indicate that this variance is statistically significant (X^2=92.10, d.f.=8, p<0.0001).

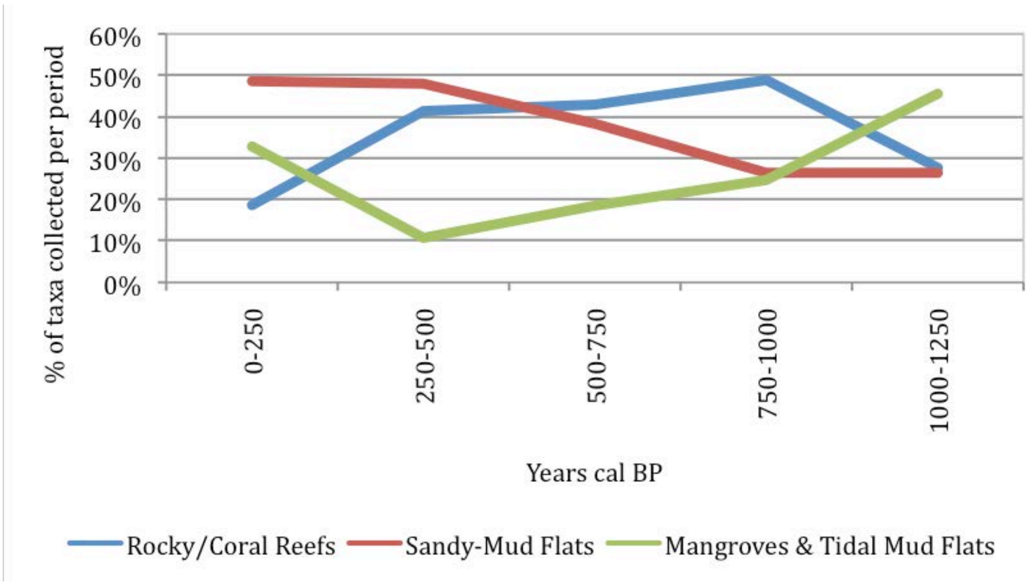


Figure 9.20: Wirrngaji Square A, percentage of mollusc species MNI collected from each patch by 250-year period.

The Mangroves and Tidal Mud Flats Patch is the dominant focus of resource exploitation during 1000-1250 cal BP contributing almost half the assemblage for that period. Rocky Reef species are at their highest (49%) between 750-1000 cal BP associated with higher species richness. During 500-750 cal BP collection of species from these two habitats declines and there is an increase in numbers collected from the Sandy-Mud Flats patch. In the last 500 years Rocky Reef species dramatically decline in numbers contrasted with a matching incline in Sandy-Mud

Flats patch species; this could reflect a changing environment – if mangroves encroached the shoreline, then it may be harder to access Rocky Reef species. Alternatively, because it may also be harder to extract the molluscs from the rocks, consumption of these molluscs might have occurred at the rocks.

Changes in patch use between the Rocky Reef patch and Sandy-Mud Flats patch can be tracked through the use of an index (Figure 9.21). The decline in the index in more recent times indicates that foragers' preference is switching from Rocky Reefs taxa to Sandy-Mud Flats taxa through time. The chi-square result indicates that the decline in Rocky Reef species is significantly correlated with the increase in Sandy-Mud Flats patch species.

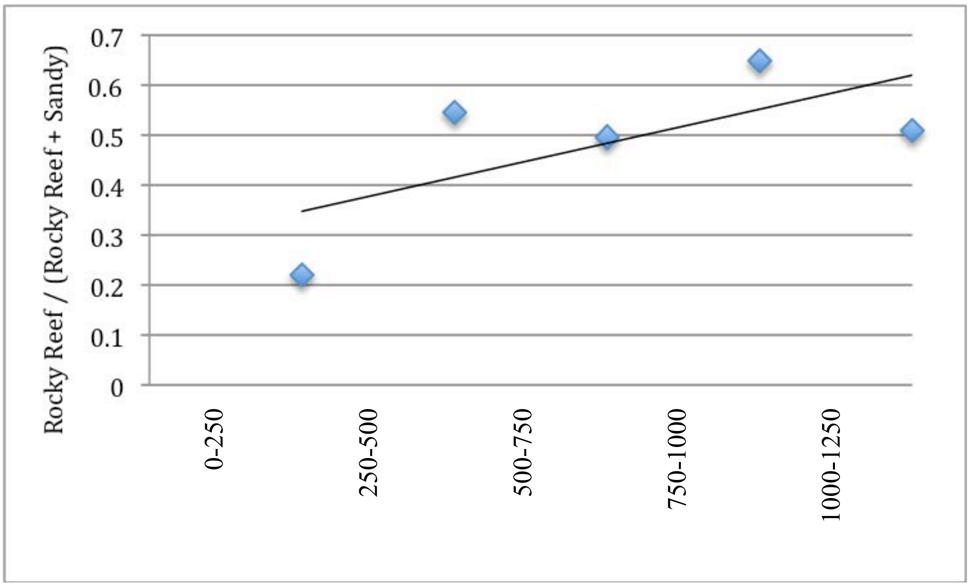


Figure 9.21: Change in patch use as indicated by Rocky Reef-Sandy-Mud Flats Patch Index.

When we review the top three species we can see a shift toward more intensive exploitation of the hiant venus clam (a Sandy-Mud Flats species), away from oyster (a Rocky Reef species) and telescope mud whelks (a Mangrove and Mud-Flats species). This further confirms that there was a shift away from exploiting Rocky Reef habitats suggesting that there was possibly a changing distribution or decline of Rocky Reef habitats, or foragers chose to intensify their exploitation of the Sandy-Mud Flats patch for socio-cultural reasons.

9.9.3 Resource Intensification and Foraging Efficiency

At Wirrngaji, we see the co-dominance of oysters and hiant venus clams in the assemblage. While these are both documented throughout the entire period of occupation, there is a clear shift away from oyster toward hiant venus clam. Both these taxa would be classed as high-ranked taxa based on the prey choice model.

At this site, very low values of high-ranked taxa before 1000 cal BP, suggests there may have been a low-level cultural occupation prior to this time. From 1000 cal BP to present higher taxa abundance and species richness indicates more intensive site use. When reviewing the relationship between the hiant venus clam MNI and specimen sizes for each period, there are corresponding changes such that MNI increases are followed by a reduction in mean valve length, which co-occurs with increased exploitation for the next 250-year period (Figure 9.22 and Table 9.8). This scenario matches with similar patterns at other Bentinck Island southern coastline sites, such as Dangkankuruwuru. It was noted at this location resource intensification of *M. hiantina* in some periods did result in reducing specimen sizes, although this does not seem to be a lasting effect when predation pressure eases. However, if exploitation of this species had continued without abatement we could likely see the long-term effects of resource depression that would eventually deplete the clam population.

Table 9.8: Metrical data for intact *M. hiantina* valves from Wirrngaji Square A.

XU	Mean (mm)	Median (mm)	S.D. (mm)	Min (mm)	Max (mm)	Range (mm)	No.
2	36.2	35.75	1.28	35.3	38	2.7	6
3	37.4	37.9	2.23	33	40.2	7.2	14
4	36.6	34.9	4.37	29.8	42.6	12.8	19
5	35.7	35.6	2.8	31.8	40.5	8.7	5
6	34.4	36.5	4.49	26.6	37.6	11.0	5
7	35.6	35.8	4.01	26.2	42.6	16.4	37
8	37.7	37.6	4.08	30.2	50.5	20.3	41
9	38.7	39	3.09	32.1	43.7	11.6	24
10	37.7	37.6	2.92	32.5	43.4	10.9	34
11	37.7	37.8	3.66	33.4	42.1	8.7	6
12	33.8	32.45	1.2	31.6	33.3	1.7	1
13	32.4	31.6	0	31.6	31.6	0	2
14	32.8	31.5	3.14	30	37.5	7.5	5
15	37.2	35.8	4.46	33.6	42.2	8.6	3
16	35.3	35.25	2.47	33.5	37	3.5	2
17	33.8	33.8	0	33.8	33.8	0.0	1
18	34	34.3	4.55	29.3	38.4	9.1	3
19	34.2	33.5	2	32.7	36.5	3.8	3
20	39.6	39.6	0	39.6	39.6	0.0	1

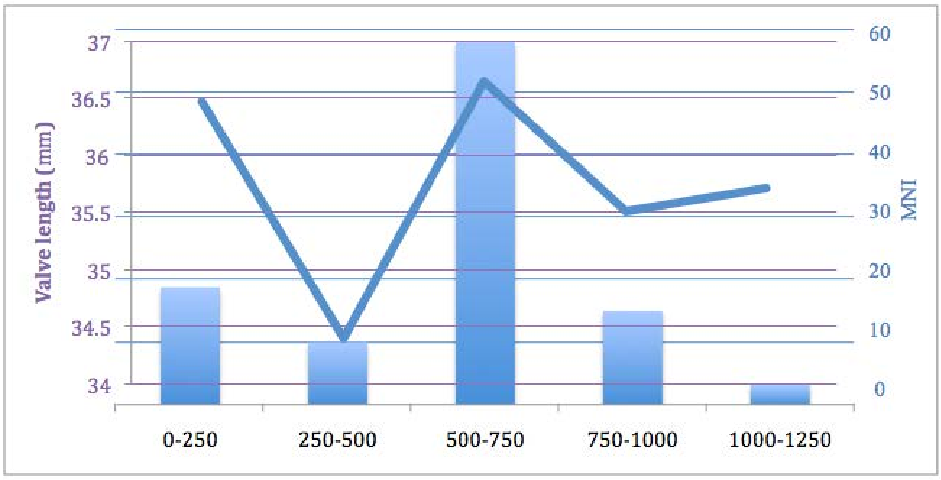


Figure 9.22: Relationship between *M. hiantina* MNI (columns) and mean valve length per 250-year period.

9.10 Discussion

Excavations at Wirrngaji revealed a c.45cm thick upper layer of shell (XU2-16) dated to c.100-1000 cal BP and a thin (c.12cm) lower layer (XU19-23) dated to 1147 cal BP with mollusc shell, bone, stone artefacts and charcoal recovered. Molluscs were foraged from three main habitats – Sandy-Mud Flats, Rocky Reefs and Mangroves and Tidal-Mud Flats – in varying quantities and proportions over the time the site was occupied. The fish were likely caught using spears in the near-shore shallow waters. A few fishtraps can be seen along the shoreline in close proximity to Wirrngaji.

Concentrated midden creation at Wirrngaji between 500-1000 cal BP accounts for 69% of the mollusc assemblage based on MNI, suggesting a significant use of the site around this time. This correlates with high deposition rates in the period 500-750 cal BP with 31% of the midden based on MNI accumulating in a depth of 6.2cm. There is also evidence that foragers diversified diet breadth at this time with the highest species richness recorded for the Rocky Reef habitat. Further intensive site use occurred between 250 years ago to present, accounting for 16% of the assemblage based on MNI. At other times midden creation occurs more slowly. There may even be a hiatus or limited use period between 250-500 cal BP where taxa quantities are at their lowest.

Stones that potentially represent hearthstones or the 'special stones' described by Nicholas Evans (see Section 9.2) were recovered from XU10-XU12 and have therefore been attributed to the period 500-1000 cal BP (see Figure 9.14). Tindale (1960:97) describes similar millstones as being tools that were used to hammer oysters from rocks and smash them open. Tindale

(1960:94) witnessed Kaiadilt men using a shell knife manufactured on baler shell for cutting turtle, which was also reportedly used for butchering dugong and fish. The fragment of *Melo amphora* shell in Figure 9.10 could likely have broken off such a tool.

Identified vertebrate taxa include catfish (Ariidae), grass emperor (*Lethrinus laticaudis*), a wrasse (Labridae) and probably a rockcod (Serranidae) based on the otolith specimen recovered from XU14. Catfish are generally found in clear to muddy waters around estuaries. Grass emperors and wrasses are fish species that inhabit shallow coastal waters over seagrass beds and rocky/coral reefs. Juvenile grass emperors are also spotted feeding on mangrove mud flats. Table 9.9 shows the lengths of the fish otoliths collected from the Wirrngaji midden as well as the lengths of comparative fish otoliths in the TARL fish reference collection (Tomkins *et al.* 2013). Although we do not have a comparative osteo specimen to match the wrasse bone, there are four species of wrasse commonly found in the Wellesley Island waters that weigh on average 1.8kg (Grant 2004). Taking this into account, the four fish identified in the Wirrngaji assemblage would weigh around 2.8kg and contribute high energetic returns based on the assumption that c.70% of the fish mass is meat weight (Smith 2011).

Table 9.9: Estimated weights of fishes based on otolith lengths of archaeological specimens compared with reference collection specimens.

Taxon	XU	Comparative otolith length (mm)	Comparative taxon weight (g)	Length of archaeological otolith (mm)	Estimated weight (g) / energy return* of archaeological fish (kcal/hr)
Ariidae	3	9.5	300	9.0	c.250/1048
Lethrinus laticaudis	3	9.8-12.8	400-1200	9.0	c.250/1237
cf. Serranidae	14	6.9-16.5	185-3850	8.8	c.500/ 810
Labridae	14				c.1800/1000

* estimated from Smith (2011)

M. hiantina grows to a length of 20-50mm with a high meat:shell ratio of around 50%, depending on size and provides low energy returns of c.797 kcal/kg (Smith 2011). *S. glomerata* grow to a length of 4-25cm and an average weight of 40-70g with meat:shell ratio of approximately 25% providing similar energy returns (data on shellfish returns from Bird *et al.* (2004), and Thomas (2007a); on meat:shell ratios from Bird and Bliege Bird (1997). Based on the weight of identified shell in the Wirrngaji assemblage we can conservatively estimate that *M. hiantina* yielded around 1.35kg of meat and *S. glomerata* contributed around 900g of meat to the diet. *T. telescopium* grows between 8-10cm (Willan 2013). Smaller specimens appear to have a better meat:shell ratio, as the mollusc increases shell mass with growth. Although longbums are consumed after light roasting, steaming or boiling by Aboriginal people, middens tend to reflect the more popular bivalve diet. Meehan (1982) indicates this is because longbums have a very low protein content and/or their peppery taste increases the desire for drinking (Willan 2013). Based on comparative data of live collected specimens, we estimate that approximately 600g of meat (=600 calories) could have been yielded from *T. telescopium* in the Wirrngaji midden.

Intensified exploitation of the hiant venus clam corresponds with a reduction in the targeting of high-ranked species from other habitats such as oyster and longbums. Bourke *et al.* (2007) and Faulkner (2006) suggest this pattern reflects long-term coastline alteration. A decrease in mangrove and rocky reef species is also reported from Myaoola Bay, NT, which Faulkner indicates is due to environmental processes that affected species availability. Other archaeological research in the Gulf of Carpentaria at Mornington Island and Groote Eylandt provides evidence for a more intensive use of sites post-500 cal BP with middens containing a diversity of species from sand-mud shellbeds in the immediate site environments. Rosendahl *et al.* (2014) and Clarke (1994) suggest this is the result of a possible strategy designed to provision larger groups of people camped at one location for longer periods of time.

I cannot conclusively determine if the results at Wirrngaji reflect environmental changes impacting resources, or if they are more indicative of hunter-gatherer foraging choices. However, based on available information we suggest that intensified exploitation of hiant venus clams along with diversified diet breadth in all local habitats at certain times, likely indicates increased demand for existing resources to provision growing populations using Wirrngaji. Based on a reduction in the mean size of specimens that correspond with increases in MNI, we suggest that intensive focus on *M. hiantina* affected the population structure of this species, which would eventually have led to declining foraging efficiency and likely resource depression if exploitation continued in earnest for extensive lengths of time.

9.11 Summary

Wirrngaji is a large shell midden located in the upper units of an elevated beach ridge (Ulm *et al.* 2010). Concentrated midden creation occurred between 500-1000 cal BP, accounting for 69% of the mollusc assemblage along with an accumulation of an array of stone artefacts used for different cultural purposes. Based on analysis of the food remains from the midden, I suggest that people accessed a range of habitats to forage for a diversified assortment of marine finfish and shellfish resources.

Chapter 10. Nalkurdalayarrb, Sweers Island

10.1 Introduction

Archaeological investigations at Nalkurdalayarrb on Sweers Island revealed a cultural deposit dominated by marine shell dated between c.126 cal BP to c.1829 cal BP. Aboriginal fishtraps and extensive surface midden scatters on Sweers Island suggest widespread settlement and intensive exploitation of marine resources; however no dates have been obtained for these fishtraps. This chapter describes the Nalkudalayarrb site and its stratigraphy, chronology and contents followed by a discussion of the data from an OFT perspective for understanding foraging behaviours of the site users.

10.2 Site Description and Setting

Nalkurdalayarrb is part of a large shell midden complex intermittently exposed for c.2km (Ulm *et al.* 2010) along an NNE-SSW trending dunerunning along the central portion of the island parallel to the east coast (Latitude: 17.09400S, Longitude: 139.62440E). The site is in the approximate centre of Sweers Island, c.300m inland from the east coast and c.900m from the closest point on the west coast (Figures 10.1-10.2). Most of the observed shell midden deposits appeared to be in deflated contexts. This could be the result of heavy livestock grazing in the vicinity during the mid-1800s (Saenger 2005). The dune containing the Nalkurdalayarrb midden marks the eastern border of the old township of Carnarvon. A small area at the northern end of the dune, which was thought to contain *in situ* deposits, appeared more intact and was targeted for test excavation (Figure 10.3).

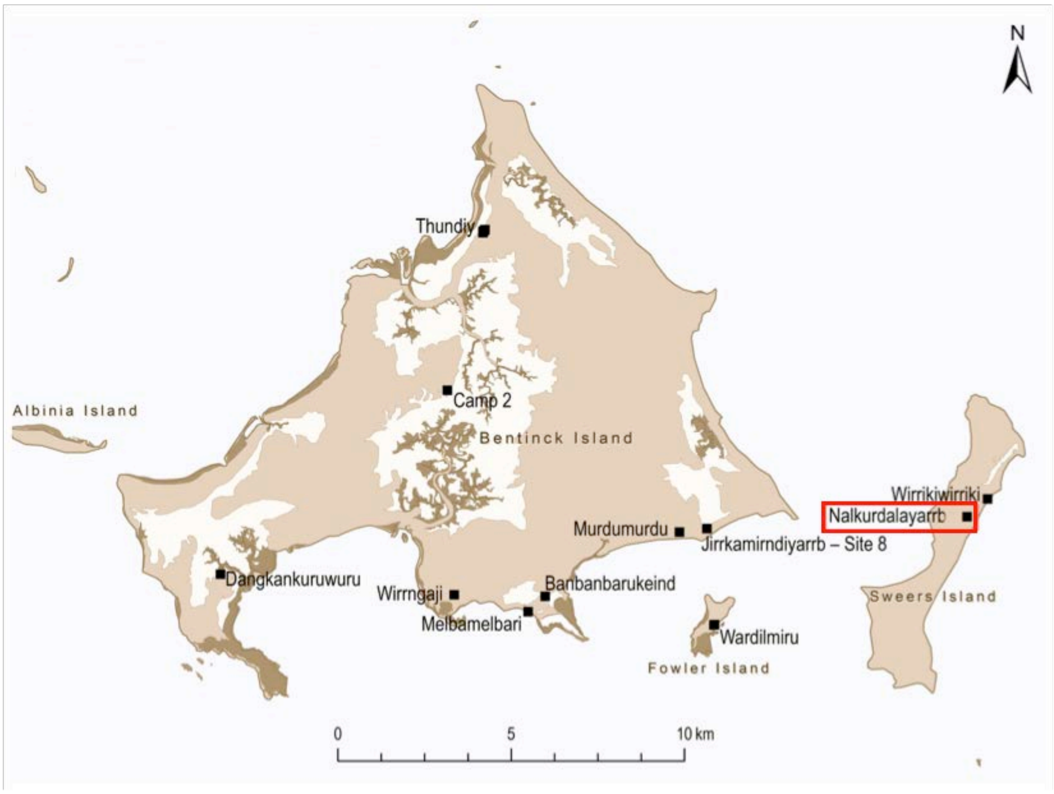


Figure 10.1: Map of South Wellesley Islands showing Nalkurdalayarrb site location (map prepared by Lincoln Steinberger and Sean Ulm).

Figure 10.2: Aerial view map of Nalkurdalayarrb site location (after Google Earth).

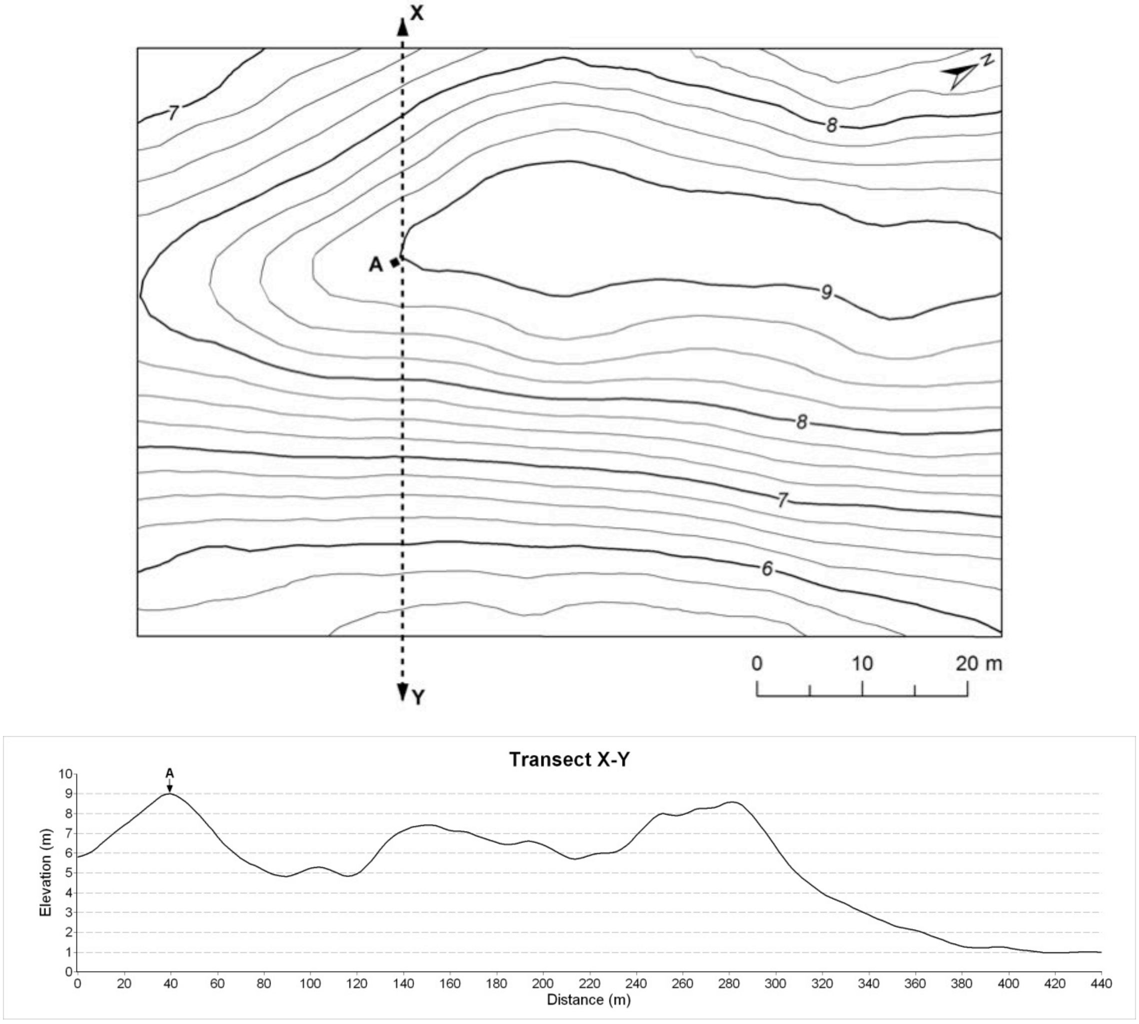


Figure 10.3: Contour map with transect showing landscape elevations (map prepared by Lincoln Steinberger and Sean Ulm).

The site is situated adjacent to near-surface freshwater soaks (Gale and Carden 2005). The island's central dune ridges are vegetated by sandy grasslands and bordered by stands of pandanus palms and eucalypts (Figure 10.4-10.6). The eastern coastline has long expanses of sandy beaches with scattered she-oak trees occurring along the strandline and a small pocket of mangroves (Figure 10.7-10.8). Intertidal sandy-mud flats along the eastern shoreline support hiant venus clams (*Marcia hiantina*) and tumid venus clams (*Gafrarium pectinatum*) that are both dominant taxa found in the midden (Figure 10.9). Coral fringing reefs and rocky reef platforms occur on the island's southern and eastern shoreline between 1-4m depth (Johnson and Gill 2008). The rocks support clumps of oysters (*Saccostrea glomerata*) and turban snails (*Lunella cinerea* and *Turbo* sp.). Sweers Island has five mangrove colonies dotted around its shoreline, with the nearest mangroves located within 1-2km from the site (Figure 10.9). There are few mangrove dwelling taxa in the midden.

Figure 10.4: Excavations at Nalkurdalayarrb in foreground and pandanus stands behind, facing south (Photo by Daniel Rosendahl).

Figure 10.5: View west looking across sandy grasslands toward leeward coastline and Fowler Island.

Figure 10.6: View east looking across to windward coastline.

Figure 10.7: Eastern coastline sandy beaches teeming with birdlife and marine fauna. Note rocky reefs in background (Photo by Daniel Rosendahl).

Figure 10.8: View north along windward (eastern) coastline, showing a small pocket of mangroves in the distance.

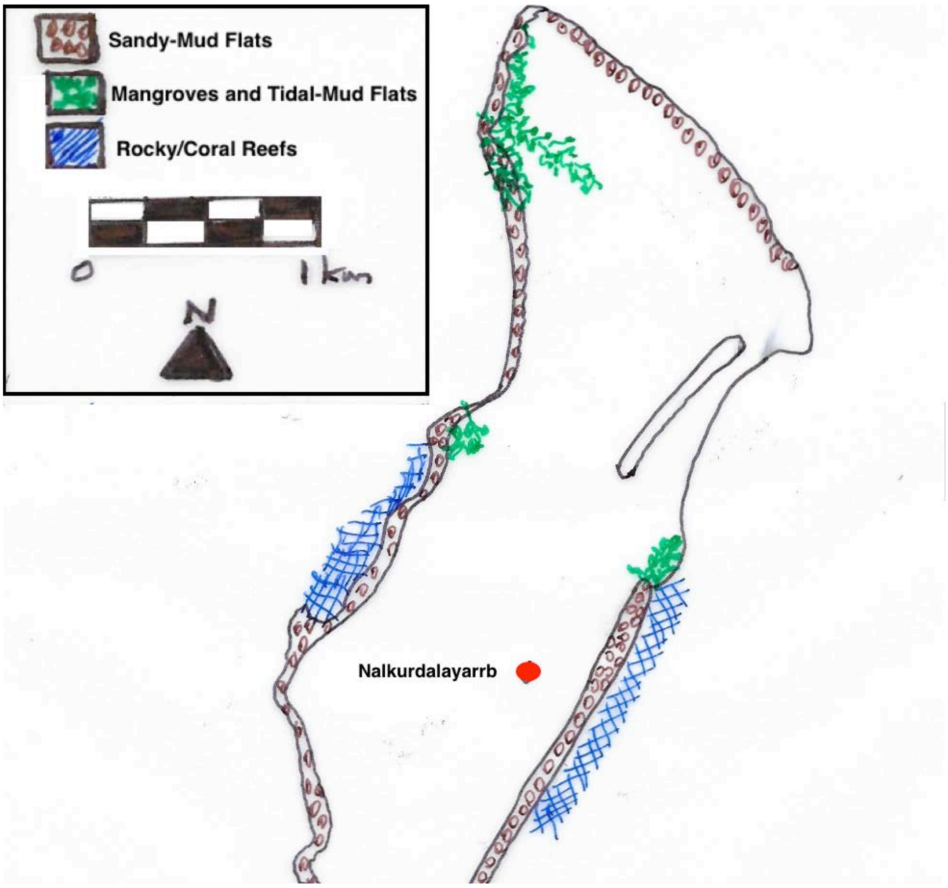


Figure 10.9: Resource habitat communities near Nalkurdalayarrb.

10.3 Excavation Methods

In April 2008, Sean Ulm and Daniel Rosendahl excavated 216.8kg of midden materials from a single 50cm x 50cm pit dug in the northern part of the midden. Excavations proceeded in shallow, arbitrary excavation units (XUs) averaging 3.0cm in depth and 11.8kg in weight. Excavations ceased at c.56cm below the ground surface when a consolidated aeolianite unit was encountered, however cultural materials ceased being recovered after c.40cm. All midden materials were dry sieved through 2.3mm mesh on site and materials retained in the sieve were retained for later sorting and identification in the laboratory (see Chapter 6 for a detailed discussion of the standard excavation and laboratory methods employed at all sites).

10.4 Cultural Deposit and Stratigraphy

Excavations revealed a 40cm-thick deposit of reasonably dense cultural deposit with shell, bone and charcoal, resting on degrading beach rock and coarse sands (Figure 10.10). The majority of shell was recovered from between XU3-13 (c.3cm-40cm depth). The deposit can be divided into three stratigraphic units (SUs) – a cultural unit and a transitional unit overlying an aeolianite base (Figure 10.11; Table 10.1). SU1 includes materials located between XU1 to

XU13. SUII includes materials located between XU14-20 and appears to be the original ground surface at initial time of use c.1800 cal BP. SUII contains sparse quantities of cultural materials that have filtered down from upper layers. SUIII is theconsolidated aeolianite base and appears culturally sterile.

Figure 10.10: Nalkurdalyarrb Square A, 50cm x 50cm excavation pit profile (facing south) (Photo by Sean Ulm).

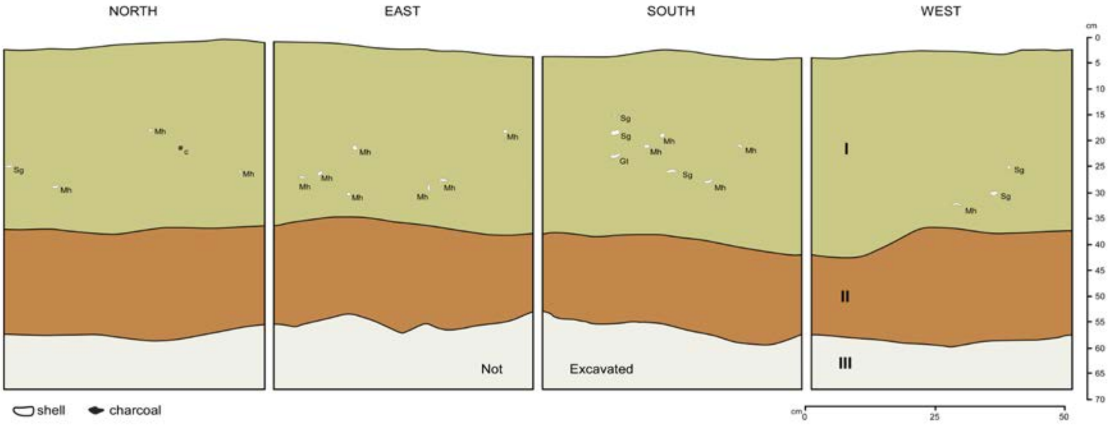


Figure 10.11: Stratigraphic section drawing, Nalkurdalayarrb, Square A (prepared by Michelle Langley and Sean Ulm).

Table 10.1: Stratigraphic Unit (SU) descriptions, Nalkurdalayarrb Square A.

SU	Description
I	SUI extends across the entire square with depths ranging between 35cm to 40cm below ground surface. The unit comprises angular to subangular dry and loosely consolidated sands that are more consolidated with depth. Sediments are brown (7.5YR-5/4 to 7.5YR-4/3) in colour and there is coarse shell grit interspersed throughout the unit. The top 10cm contains grass roots. Some evidence of insect disturbance with small ant nests present. Cultural materials include charcoal fragments, whole and fragmented molluscs (dominated by venus clams, oysters and turban shells), crab fragments, fish bones and otoliths. pH values are highly alkaline (10.0). Shell and bone materials appear to be reasonably well-preserved. There is a distinct change in colour at the interface of SUI and SUII to a light brown (7.5YR-6/4).
II	Transitional unit grading from light brown (7.5YR-6/4) to reddish yellow (7.5YR-6/6) less consolidated sands with numerous beach rock and gravel inclusions throughout the SU. Small fragments of charcoal and shell (possibly cultural) are occasionally present throughout. pH values are highly alkaline (10.0).
III	A continuous layer of aeolianite forms the base of this unit at c.55-60cm below surface. This is culturally sterile. Pink (7.5YR-7/4) coarse sands and tiny shell inclusions. pH values remain highly alkaline (10.0).

10.5 Site Integrity and Taphonomy

The deposit exhibits reasonable stratigraphic integrity. There is a predictable shell decay profile with highly weathered tiny gastropod specimens recovered from the lower XUs of the deposit and relatively well-preserved specimens from the upper deposit. There is evidence of some minor disturbance within the pit in the form of ant nests and some other insect burrows however only minor quantities of cultural shell fragments appear to have filtered down through the transition unit between SUI and SUII. There is a pattern of low shell fragmentation (754 frags / 100g) contributing to high rates of identification in the units (XU2-11) that correlate with the main period of cultural deposition (see Hoffman 2011). This contrasts with high/increased shell fragmentation (c.5000 frags / 100g) and consequently low rates of identification in deeper and older units. Reviewing effects of site taphonomy on vertebrate remains it seems that degradation of fish bone materials is greatest in lower XUs.

10.6 Radiocarbon Dating and Chronology

Four radiocarbon determinations have been obtained for Nalkurdalayarrb (Table 10.2). A date of c.1829 cal BP was obtained on a burnt fish otolith located in XU14 at the interface between SUI and SUII. This indicates the site has been used either permanently or intermittently for the past c.1800 years. A second date of c.1699 cal BP was obtained on a *Marcia hiantina* valve collected from XU10. This XU contains the highest density shell in the deposit and the date indicates people were intensively using Nalkurdalayarrb around 1700 years ago. Dates of c.126 cal BP and c.339 cal BP were obtained on *Marcia hiantina* valves collected from XU2 and XU7, which bracket a second period of what appears to be intensive site use. These dates suggest permanent or regular intermittent use of the site from 500 years ago until Sweers Island was occupied by Europeans in the 1880s.

Table 10.2: Radiocarbon ages on marine shell for Nalkurdalayarrb Square A. Calibrations undertaken using OxCal v.4.2 (Bronk Ramsey 2009) and the Marine13 calibration dataset (Reimer *et al.* 2013). For marine samples a ΔR of −49±102 as recommended by Ulm *et al.* (in prep.) is employed.

Sq.	XU	Depth (cm)	Lab. Code	Sample (Species)	^{14}C	$\delta^{13}C$	Calibrated Age BP (95.4%)	Calibrated Age BP Median
A	2	0.1-3.3	Wk-35856	*Marcia hiantina*	419±25	-0.9±0.2	0*-285	126
A	7	15.3-18.3	Wk-35857	*Marcia hiantina*	652±25	-2.8±0.2	90-517	339
A	10	24.6-27.4	Wk-23666	*Marcia hiantina*	2068±39	-0.8±0.2	1420-1950	1699
A	14	36.5-39.4	Wk-27972	Fish otolith	2179±34	-0.4±0.2	1562-2096	1829

The assemblage has been divided into temporal phases of 250-year periods for comparative purposes. Excavation units have been assigned to chronological periods based on an age-depth model derived from the calibrated radiocarbon ages and stratigraphic observations (Figure 10.12; Table 10.3). Even though time-averaging these open shell deposits only allows for identification of broad-scale trends and not subtle changes, it allows determination of variation in relative taxa abundance, indicative of taxa exploitation patterns and/or environmental changes affecting the distribution of taxa.

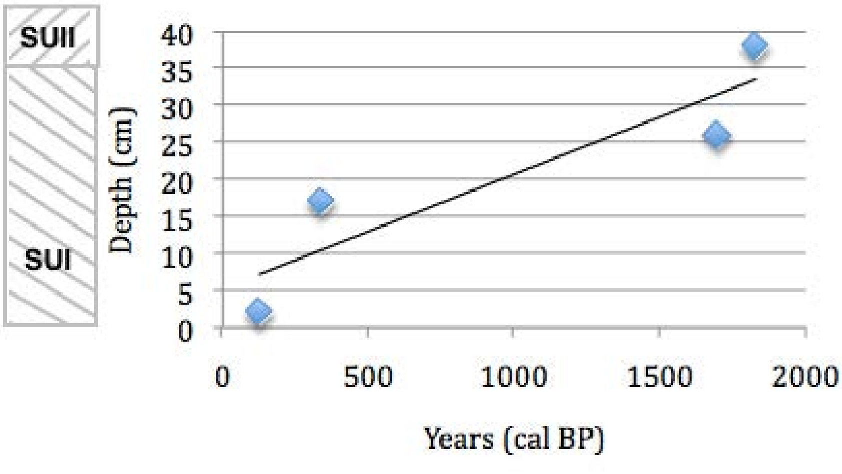


Figure 10.12: Age-depth relationship of all radiocarbon determinations obtained from Nalkurdalayarrb.

Table 10.3: Temporal phases of 250-year periods, showing allocation of XUs.

Temporal phase	**0-250**	**250-500**	**500-750**	**750-1000**	**1000-1250**	**1250-1500**	**1500-1750**	**1750-2000**
XUs	1-5	6-7	8	8	9	9	10-11	12-14

10.7 Cultural Materials

4563g (2% of the total sediment and materials) were retained for analysis. Table 10.4 shows the overall summary results of the retained materials. Molluscan shell comprises 33.6% (1786.86g) of the total assemblage and fishbone contributes 0.08% (3.79g). Small quantities of crustacea (14.7g) were recovered from XU2-15, represented by mud crab (*Scylla* spp.) (9.7g) and goose barnacle (Pedunculata) (5.0g). Stone (including beach rock and pisoliths) contribute 63.8%. Organics make up the rest of the assemblage. Pieces of shell that appear to be fragmented from a *nara* shell knife are also present in the cultural deposit (Figure 10.13). These shell knives are commonly mentioned in ethnographic literature (e.g. Tindale 1962a, 1962b).

Figure 10.13: ***Melo amphora*** **fragments.**

Table 10.4: Summary excavation data and retained materials from Nalkurdalayarrb Square A.

XU	Depth Below Surface (cm)	Mean Thickness (cm)	Weight (kg)	Vol cm3	pH	Marine shell (g)	Bone (g)	Stone Artefacts (g)	Barnacles (g)	Crab (g)	Other Organic (g)	Rock Rubble Roral (g)	Retained materials Total (g)	% of Total Midden
1	0.2	0.20	0.10	500		0	0	0	0	0	65.71	0	65.71	65.71%
2	3.78	3.58	14.00	8950	10	33.79	0.15	0	0.02	0.27	12.8	20.47	67.5	0.48%
3	6.92	3.14	12.80	7850	10	68.67	0.09	0	0	0.62	5.04	53.39	127.81	1.00%
4	9.7	2.78	11.90	6950	10	140.42	0.31	0	0.82	2.78	1.79	49.59	195.71	1.64%
5	12.98	3.28	13.30	8200	10	80.1	0.1	0	0.12	1.8	2.49	53.86	138.47	1.04%
6	15.82	2.84	11.50	7100	10	149.84	0.81	0	0.22	0.34	1.17	33.52	185.9	1.62%
7	18.82	3.00	11.60	7500	10	148.68	0	0	2.87	0.86	0.69	28.24	181.34	1.56%
8	21.9	3.08	11.80	7700	10	149.69	0.94	0	0.03	1.53	1.5	29.64	183.33	1.55%
9	24.86	2.96	11.50	7400	10	205.58	0.61	0	0.25	1.04	1.26	46.32	255.06	2.22%
10	27.84	2.98	10.80	7450	10	353.24	0.19	0	0	0.18	0.44	72.89	426.94	3.95%
11	30.82	2.98	11.30	7450	10	89.93	0.05	0	0.17	0.16	0.8	32.45	123.56	1.09%
12	33.8	2.98	11.30	7450	10	29.99	0.05	0	0.02	0.1	1.34	36.66	68.16	0.60%
13	36.82	3.02	11.80	7550	10	16.86	0.05	0	0.01	0	0.46	15.38	32.76	0.28%
14	40.1	3.28	12.50	8200	10	27.83	0.29	0	0.48	0	0.46	86.16	115.22	0.92%
15	42.94	2.84	12.20	7100	10	16.33	0	0	0.03	0	0.14	100.73	117.23	0.96%
16	45.82	2.88	11.10	7200	10	10.55	0	0	0	0	0	159.83	170.38	1.53%
17	48.86	3.04	11.10	7600	10	7.22	0	0	0	0	0	285.65	292.87	2.64%
18	51.88	3.02	12.00	7550	10	2.25	0	0	0	0	0	546.62	548.87	4.57%
19	54.76	2.88	10.60	7200	10	1.55	0.15	0	0	0	0	972.17	973.87	9.19%
20	55.56	0.80	3.60	2000	10	1.38	0	0	0	0	0	288.5	289.88	8.05%
Total:		55.56	216.80	138900		1533.90	3.79	0	5.04	9.68	96.09	2913.36	4560.57	2.10%

10.7.1 Invertebrate Mollusc Remains

In total 1,786g of shell was recovered from Square A, which represents 33.6% of the total deposit. 83% of all shell by weight was identified to family, genus or species level. The remaining 17% of shell based on weight could not be identified beyond Mollusca due to the generally small size of these specimens and the lack of diagnostic attributes that prevented identification to taxon; this portion of the assemblage is not considered further in the analyses presented below. The identified assemblage comprised 17 molluscan taxa weighing 895g (with an MNI=315) consisting of 10 marine bivalve taxa and seven marine gastropod taxa (Figures 10.14 and 10.15). The assemblage is dominated by oyster (*Saccostrea glomerata*), by weight (365g) representing 20.4% of the total shell assemblage, followed by venus clams (*Gafrarium pectinatum*) (285g, 15.9%) and (*Marcia hiantina*) (267g 14.9%). The top ten species include smooth moon turbans (*Lunella cinerea*) (138g, 7.7%), other turban shells (*Turbo* sp.) (122g 6.8%), top shells (*Trochus* sp.) (38g, 2.1%), mud creepers (*Terebralia sulcata*) (21g, 1.2%), diadem volutes or baler shells (*Melo amphora*) (19g, 1.1%), Pacific asaphis (*Asaphis violascens*) (12g, 0.7%) and trough shells (*Mactra dissimilis*) (4g, 0.2%). The remaining nine taxa are relatively rare, each contributing less than 1% of the shell assemblage by weight. Taxa MNIs and weights are presented in Tables 10.5-10.6.

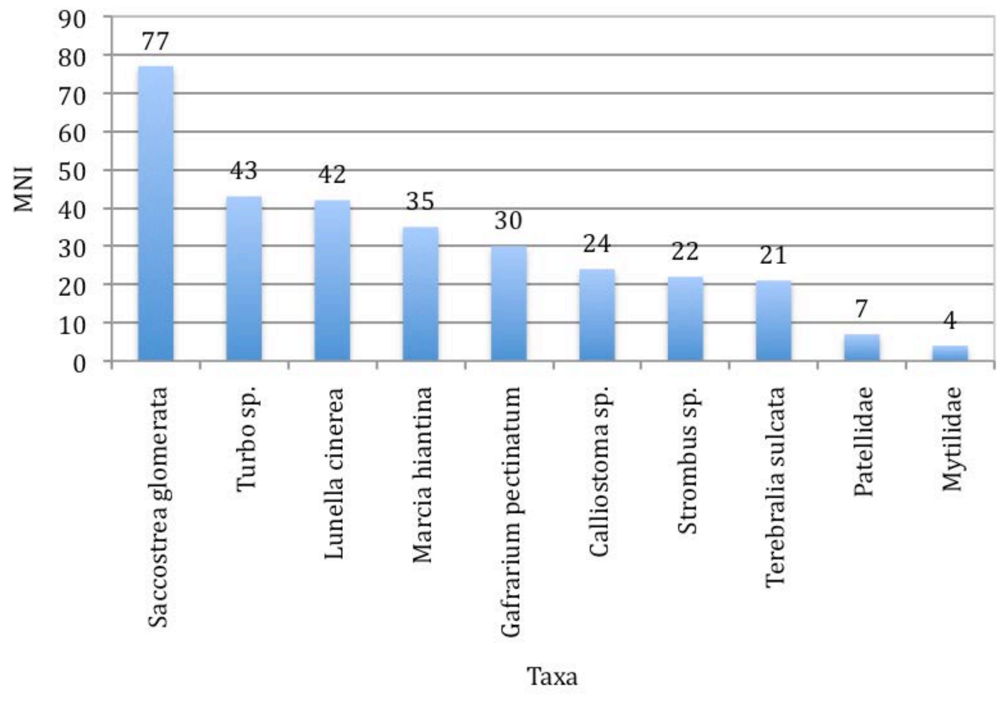


Figure 10.14: Nalkurdalayarrb Square A, top 10 mollusc taxa by MNI.

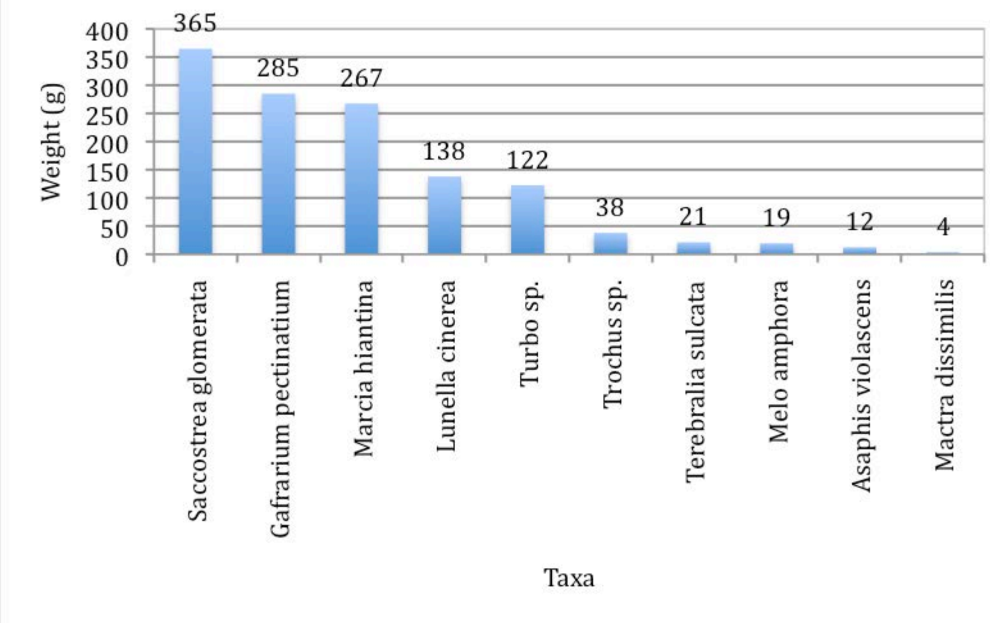


Figure 10.15: Nalkurdalayarrb Square A, top 10 mollusc taxa by weight.

The shell deposit in Square A is concentrated between XU2-7 (0-500 cal BP) and XU10-11 (1500-1750 cal BP) respectively accounting for 46% and 23% of the identified mollusc assemblage based on MNI, suggesting significant use of the site around these times (Figure 10.16). At other times, midden creation occurs much more slowly with less site use apparent during the period between 500-1500 cal BP as indicated by lower taxa quantities. The assemblage exhibits reasonably high diversity with a calculated Shannon-Weaver Index of 6.17 while 67% of the assemblage comprises four species. The high presence of oyster, moon turban snails, hiant venus clams, tumid venus clams and oyster suggest foraging strategies focused on the subtidal rocky reefs and intertidal sand-mudflats (see Figure 10.9).

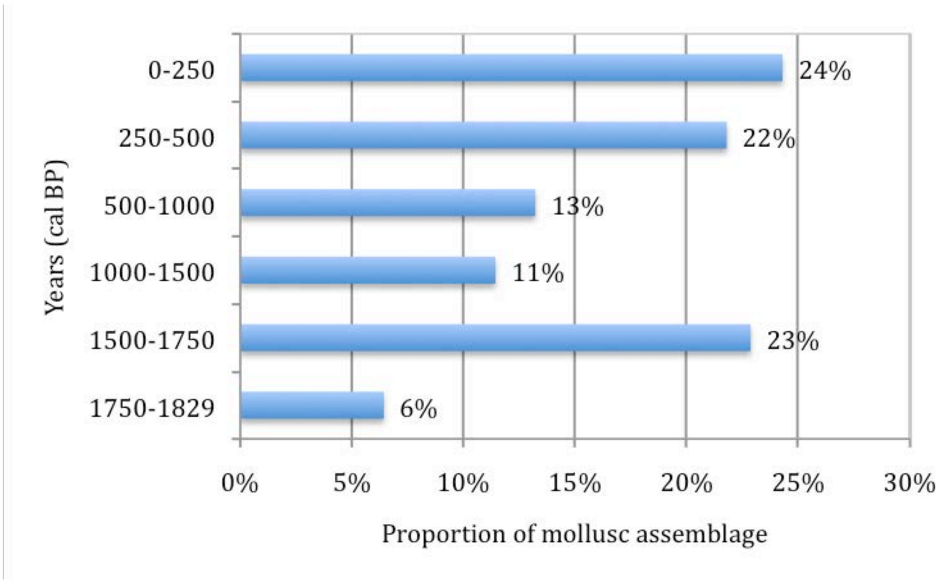


Figure 10.16: Proportion of total Square A mollusc assemblage MNI per 250-year period.

Table 10.5: Nalkurdalayarrb Square A molluscan assemblage taxa MNIs.

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Totals**
MARINE BIVALVIA																					
Asaphis violascens									1												**1**
Beguina semiorbiculata								1													**1**
Circe scripta																	1		1		**2**
Gafrarium pectinatum			2	2	1	4	4	2	3	8	2		1		1						**30**
Irus sp.													1								**1**
Isognomon isognomon						1		1					1								**3**
Mactra dissimilis													1								**1**
Marcia hiantina		1	1	2	5	2	1	4	4	7	3	1		1		1	1			1	**35**
Mytilidae					1			1				1				1					**4**
Saccostrea glomerata		1	1	3	9	15	9	13	12	7	3	2	2								**77**
MARINE GASTROPODA																					
Lunella cinerea			1	4	1	4	9	4		16	2		1								**42**
Melo amphora								1													**1**
Patellidae				1			2			2			2								**7**
Strombus sp.		4	6				3	2				2			1	3	1				**22**
Terebralia sulcata		1	1		1	2	2	5	4	1			4								**21**
Trochus sp.		1			3		1	1		3			3	5	3	3	1				**24**
Turbo sp.		2	4	6	3	2		2	8	10				3	2		1				**43**
XU Totals	**0**	**10**	**16**	**18**	**24**	**30**	**31**	**37**	**32**	**54**	**10**	**6**	**16**	**9**	**7**	**8**	**5**	**0**	**1**	**1**	**315**

Table 10.6: Nalkurdalayarrb Square A molluscan assemblage taxa weights (g).

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
MARINE BIVALVIA										
Asaphis violascens						0.53	2.08		9.75	
Beguina semiorbiculata								0.19		
Circe scripta										
Gafrarium pectinatum		1.54	9.82	36.62	14.27	26.46	33.32	12.98	33.09	89.78
Irus sp.										
Isognomon isognomon		0.01				0.01		0.25		
Mactra dissimilis										
Marcia hiantina		3.70	4.29	19.25	17.53	17.39	26.74	20.29	50.50	64.99
Mytilidae					0.05			0.19		
Pinctada sp.				1.69						
Saccostrea glomerata		8.15	13.05	16.24	16.20	66.18	36.92	65.95	50.71	59.25
MARINE GASTROPODA										
Cerithidea sp.				0.08						
Lunella cinerea			3.81	14.40	7.67	4.48	19.58	12.42		69.57
Melo amphora		0.29		0.70	0.66	1.42	1.89	4.25	1.05	8.28
Patellidae		0.01		0.02		0.04	0.01			0.02
Strombus sp.		0.11	0.11				0.03	0.02		
Terebralia sulcata			0.06		0.87	3.95	5.44	2.70	2.32	2.26
Trochus sp.		0.03	0.42		0.31	1.22	0.05	0.43	10.84	22.97
Turbo sp.		3.64	11.17	14.09	6.32	7.90	12.34	10.91	26.03	21.95
Unidentified shell		16.30	25.95	37.32	16.23	20.27	10.28	18.12	19.73	14.17
XU Totals	**0**	**33.79**	**68.67**	**140.42**	**80.10**	**149.84**	**148.68**	**148.69**	**204.02**	**353.24**

Table 10.6: Nalkurdalayarrb Square A molluscan assemblage taxa weights (g) (cont.).

Taxon XU	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Totals**
MARINE BIVALVIA											
Asaphis violascens											**12.36**
Beguina semiorbiculata											**0.19**
Circe scripta							0.06		0.37		**0.43**
Gafrarium pectinatum	20.96	1.33	1.34	1.86	1.36	0.10		0.16			**284.99**
Irus sp.			0.08								**0.08**
Isognomon isognomon			0.46								**0.72**
Mactra dissimilis			3.60								**3.60**
Marcia hiantina	21.52	10.14		4.53	2.42	2.44	0.62	0.08	0.60	0.34	**267.39**
Mytilidae		0.06				0.06					**0.35**
Pinctada sp.											**1.69**
Saccostrea glomerata	17.23	3.33	3.55	4.19	0.71	1.64	1.11	0.22			**364.63**
MARINE GASTROPODA											
Cerithidea sp.											**0.08**
Lunella cinerea	4.36		1.72								**138.01**
Melo amphora	0.66			0.26							**19.46**
Patellidae		0.01	0.03								**0.13**
Strombus sp.		0.02			0.01	0.05	0.04				**0.40**
Terebralia sulcata	0.73	0.21	1.85	0.65						0.09	**21.12**
Trochus sp.	0.42		0.57	0.12	0.29	0.16	0.08				**37.92**
Turbo sp.	1.54	0.82	0.66	1.38	2.97		0.37	0.21			**122.30**
Unidentified Shell	22.51	14.08	3.00	14.85	8.57	6.11	4.94	1.58	0.58	0.95	**255.51**
XU Totals	**89.93**	**29.99**	**16.86**	**27.83**	**16.33**	**10.55**	**7.22**	**2.25**	**1.55**	**1.38**	**1786.86**

10.7.2 Vertebrate Remains

Small numbers (n=97) of fish bones and/or otoliths were recovered from throughout the deposit, comprising the only vertebrate remains (3.8g) in Square A (see Table 10.7). Fishbone occurs in almost all cultural XUs. Most of the bone material was highly fragmented and little could be identified beyond Osteichthyes (bony fishes) but the otoliths proved more promising. The MNI of seven was calculated by summing the MNI for each excavation unit. Identified taxa include grass emperor (*Lethrinus laticaudis*), garfish (Hemiramphidae), wrasse (Labridae), and red emperor (*Lutjanus sebae*).

Table 10.7 Fishbone abundance at Nalkurdalayarrb Square A.

XU	Taxon	Element	MNI	NISP	Weight
2	Osteichthyes	unidentified		6	0.1474
3	Osteichthyes	unidentified		3	0.0874
4	*Lethrinus laticaudis*	otolith	1	1	0.1088
4	Hemiramphidae	otolith	1	1	0.0269
4	Osteichthyes	unidentified		4	0.1675
5	Osteichthyes	unidentified		5	0.1027
6	Osteichthyes	unidentified		26	0.7408
6	Osteichthyes	upgp		1	0.0716
8	*Lutjanus sebae*	otolith	1	1	0.2450
8	Hemiramphidae	otoliths	1	2	0.2553
8	Osteichthyes	unidentified		24	0.4504
9	Osteichthyes	unidentified		3	0.6153
10	Osteichthyes	unidentified		6	0.1875
11	Osteichthyes	unidentified		1	0.0093
11	Labridae	otolith	1	1	0.0360
12	Osteichthyes	unidentified		1	0.0502
13	Osteichthyes	unidentified		5	0.0555
14	Osteichthyes	burnt tooth		4	0.1480
14	Osteichthyes	burnt otolith	1	1	0.1400
19	Osteichthyes	otolith		1	0.1488
		Totals	6	97	3.7944

10.8 Application of Models

10.8.1 Diet-Breadth/Prey Choice

Broad patterns in the breadth and diversity of molluscan exploitation at Nalkurdalayarrb can be identified using species richness and abundance measures. The species richness graph shows the number of species collected from each habitat per 250-year period (Figure 10.17). Three habitats (Rocky/Coral Reefs, Sandy-Mud Flats and Mangroves and Tidal-Mud Flats) were consistently exploited, nevertheless the level of species richness by habitat varies between chronological periods. This variation is not considered statistically significant ($X^2 = 2.61$, d.f. = 10, $p>0.5$).

Figure 10.18 shows the top four species that were consistently exploited. There is a steady rise in the collection of oysters peaking in the period 250-500 cal BP and then declining slightly in 0-250 cal BP. Moon snails (*Lunella cinerea*) were most popular in the period 1500-1750 cal BP. Numbers of hiant venus clams (*Marcia hiantina*) and tumid venus clams (*Gafrarium pectinatum*) also peak in this period. These results suggest that within the Rocky Reefs and Sandy-Mud Flats habitats species collection alternated.

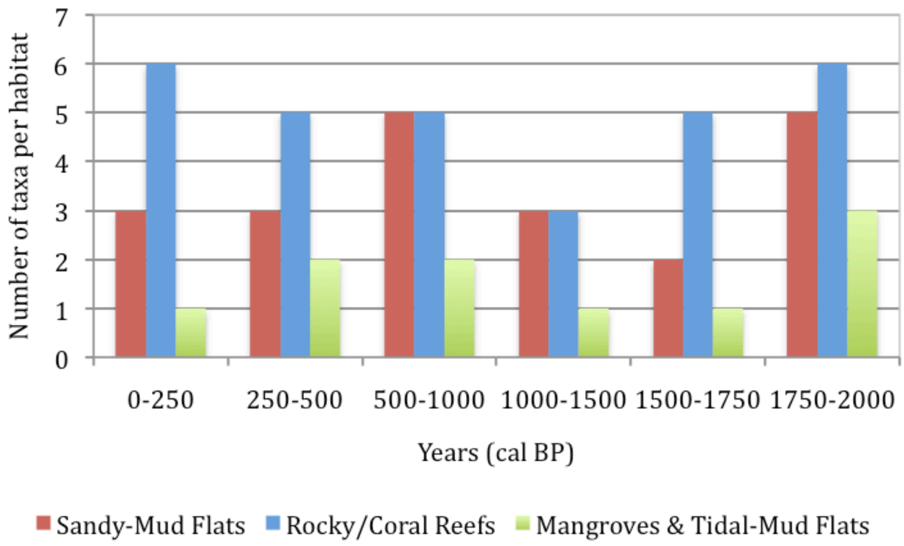


Figure 10.17: Nalkurdalayarrb Square A, species richness per habitat per 250-year period.

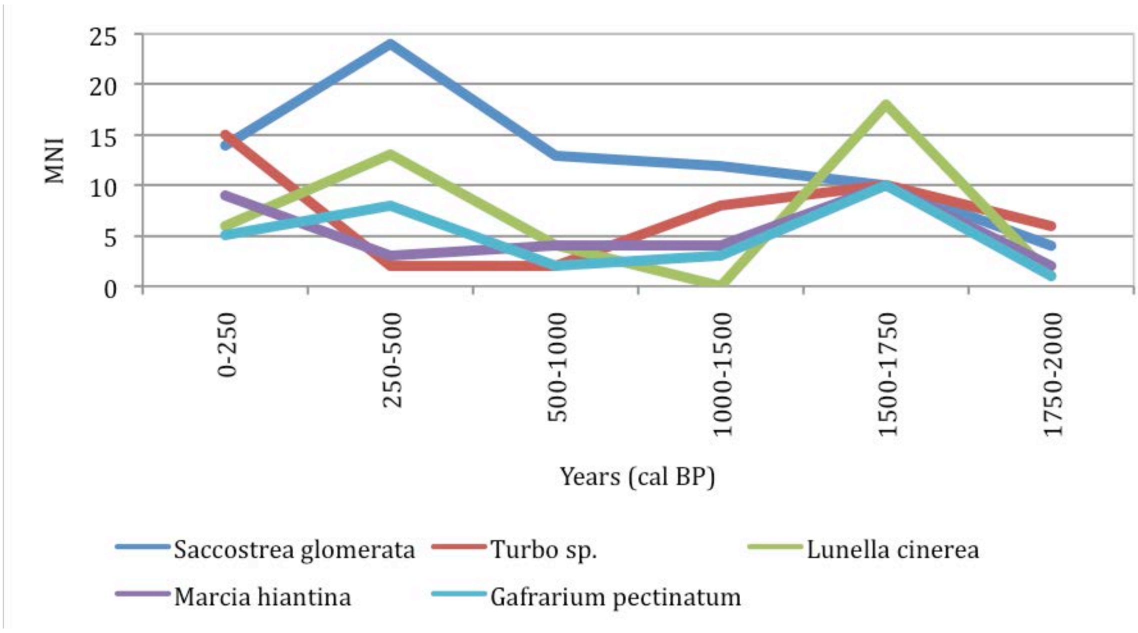


Figure 10.18: Top five mollusc taxa MNI per 250-year period, Nalkurdalayarrb Square A.

10.8.2 Habitats/Patch Choice

Figure 10.19 shows the proportion of MNI collected by habitat. As already noted the Nalkurdalayarrb mollusc assemblage includes taxa that come from three patches or habitats; however, there is temporal variance in the quantities of taxa taken from each patch. Chi-square results indicate that this variance is not statistically significant ($X^2 = 12.44$, d.f.=10, p>0.1). The Rocky Reefs patch is the dominant focus of resource exploitation throughout all periods and particularly during 250-500 cal BP contributing 74% the assemblage for that period. Sandy-Mud Flats species are at their highest (32%) between 0-250 cal BP. In contrast mangrove-dwelling species contribute only 4% of the assemblage.

Changes in patch use between the Mangroves and Tidal-Mud Flats and Sandy-Mud Flats patches can be tracked through use of an index (Figure 10.20). The index is reasonably flat suggesting that there is not a significant switch in foragers' preference from mangrove taxa to sandy-mudflats taxa through time, but there may be some correlation between the two variables. This is confirmed with the chi-square result ($X^2 = 9.25$, d.f. = 4, p>0.05).

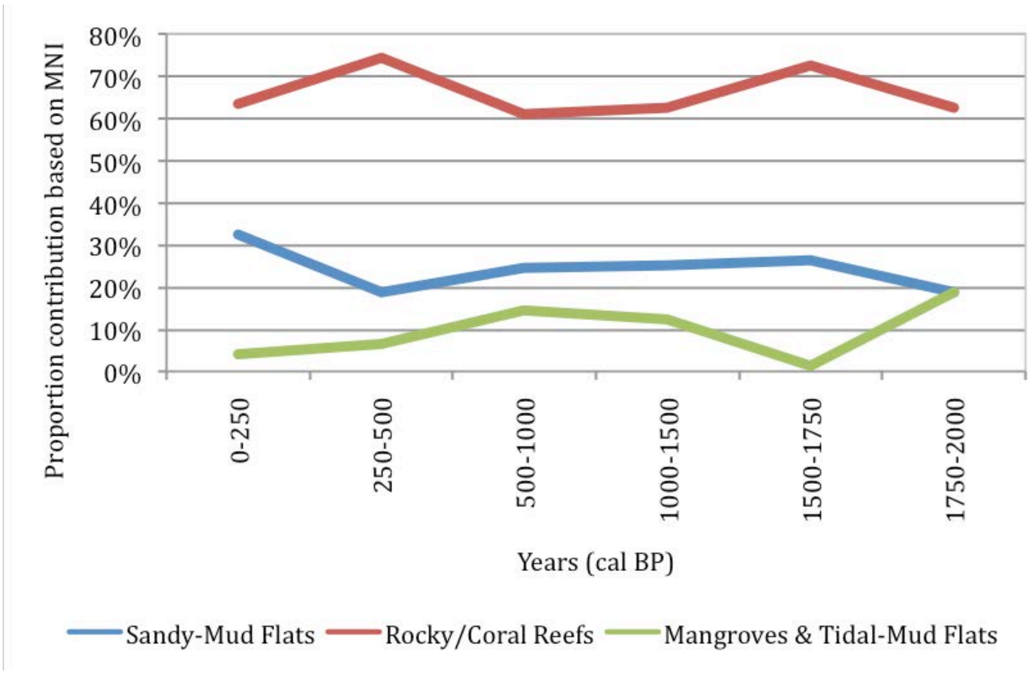


Figure 10.19: Nalkurdalayarrb Square A, percentage of mollusc taxa MNI collected from each patch by 250/500-year period.

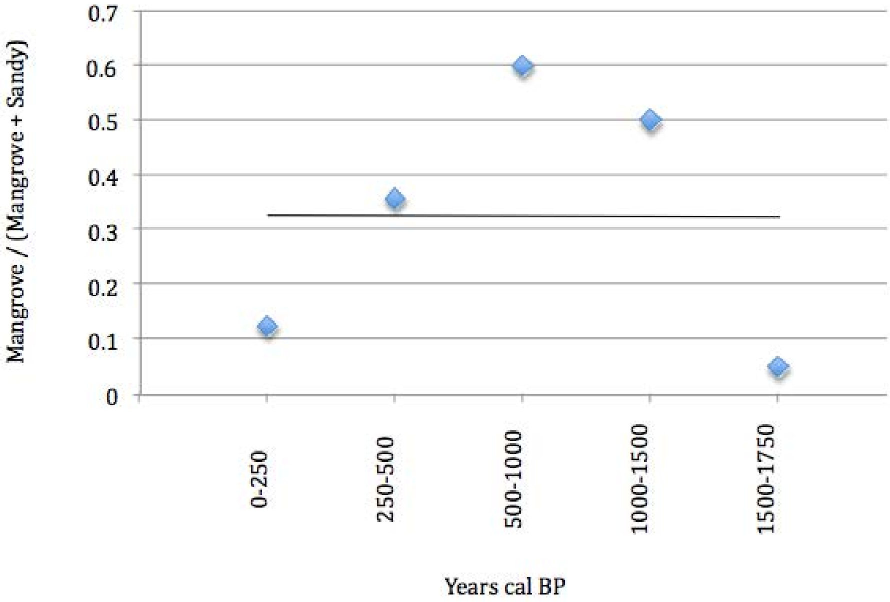


Figure 10.20: Change in patch use as indicated by Mangroves and Tidal-Mud Flats/Sandy-Mud Flats Patches Index.

Regarding the top four species, *Saccostrea glomerata* a rocky reef species is more intensively exploited than the other three taxa (*Turbo* sp. and *Lunella cinerea* combined are rocky reef species, and *Marcia hiantina* and *Gafrarium pectinatum*, both sandy-mud flats species), particularly between 250-1500 cal BP. At other times turban shells dominate the assemblage (*Turbo* sp. and *L. cinerea*). From this information we can suggest that foragers chose to exploit Rocky Reefs and Sandy-Mud Flats patches over the Mangroves and Tital-Flats patch. This is likely due to the closer proximity of the first two habitats to the site.

10.8.3 Central -Place Foraging Model

Nalkurdalayarrb appears to have been a central-place for occupation where foragers brought back food to share. Central-place foraging does impose travel costs, such as the energetic cost of carrying a food item from its procurement source back to camp. Foragers on rocky reefs are often constrained by the volume and weight of a load of unprocessed shellfish (Bird and Bliege Bird 1997:42). When travel costs outweigh the energetic return of a shellfish species, foragers will often choose to process the shell on the reef or at 'dinner-time' camps (see Meehan 1982) on the foreshore's supratidal fringe. These situations will result in differential concentrations of shell remains in the central-place midden (Bird and Bliege Bird 1997). Mangrove species make up a lower proportion of the assemblage throughout all periods, similarly perhaps because of higher associated capture costs (e.g. longer distances to habitat from site).

10.8.4 Resource Intensification and Foraging Efficiency

At Nalkurdalayarrb, *M. hiantina* and *G. pectinatum* are two of the top four species collected throughout time. Based on the prey choice model, these would be classed as high-ranked taxa and as such would be preferentially selected over lower-ranked taxa. In Figure 10.21 it is evident that *M. hiantina* and *G. pectinatum* are collected in reasonably even proportions during 1000-1829 cal BP. Between 0-1000 cal BP there then appears to be a converse relationship between the two species. One explanation for this is to suggest that people alternated exploitation of the bivalves in response to declining resource availability, possibly resulting from population depression caused by intensified exploitation of one species. To confirm this we can review changes through time in the population structure of each species using morphological attributes. Tables 10.8 and 10.9 show the average sizes for each species per XU.

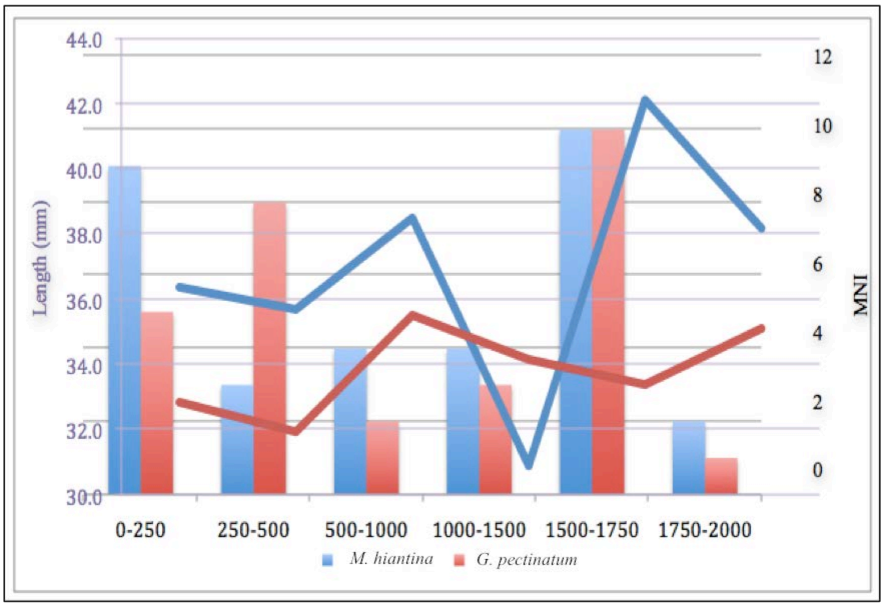


Figure 10.21: Relationship between *G. pectinatum* and *M. hiantina* MNIs (columns) and mean valve lengths (mm) per 250/500-year period.

Table 10.8: Metrical data for intact *G. pectinatum* valves from Nalkurdalayarrb Square A.

XU	Mean (mm)	Median (mm)	S.D. (mm)	Min (mm)	Max (mm)	Range (mm)	No.
4	32.86	32.86	2.41	31.15	34.56	3.41	2
6	31.93	35.80	6.87	24.00	36.00	12.00	3
7	35.51	35.51	6.66	30.80	40.22	9.42	2
8	32.00	32.00	0.00	32.00	32.00	0.00	1
9	36.29	36.29	0.00	36.29	36.29	0.00	1
10	32.73	34.10	3.95	28.20	32.25	4.05	8
12	35.12	35.12	4.05	32.25	37.98	5.73	2

Table 10.9: Metrical data for intact *M. hiantina* valves from Nalkurdalayarrb, Square A.

XU	Mean (mm)	Median (mm)	S.D. (mm)	Min (mm)	Max (mm)	Range (mm)	No.
7	38.51	38.51	0	38.51	38.51	0	1
9	30.89	30.89	0	30.89	30.89	0	1
11	42.12	42.12	0	42.12	42.12	0	1
13	38.2	38.2	0	38.2	38.2	0	1

Keeping in mind that if *M. hiantina* or *G. pectinatum* were being over-exploited, there would likely be a corresponding reduction in the size of specimens being taken because juvenile specimens would not have time to mature before being selected. Not surprisingly therefore at Nalkurdalayarrb during the first 1000 years, the average size of *G. pectinatum* reduces as more numbers are exploited (Figure 10.21). Although we see that the average size of *M. hiantina* specimens increases when more numbers are collected (see Giovas *et al.* 2013). It is possible that *G. pectinatum* populations may have been smaller/fewer in quantity than *M. hiantina* and/or that the species may take longer to mature (the average size of *G. pectinatum* molluscs being collected at this location indicate the specimens were between 2-3 years old and considered mature (Jagadis and Rajagopal 2007a:352)), therefore population sustainability levels would be exceeded more quickly than *M. hiantina* sustainability levels. During the second phase of 1000 years, *G. pectinatum* specimens increase in size when more are collected and *M. hiantina* specimens reduce in size when more are gathered. Therefore we see the inverse occurring, *M. hiantina* sustainability levels are being exceeded more quickly than *G. pectinatum* levels. These data suggest that rather than exploiting a species to extinction, Kaiadilt people appear to have efficiently managed the collection of these two species by alternating gathering times to ensure sustainability of the molluscan resources.

Similarly, we see that *Lunella cinerea* and *Turbo* sp. were targeted from Rocky Reef habitats during the first 1000 years and then *Saccostrea glomerata* became the dominant species collected during the next 1000 years (Figure 10.18). As both mollusc species inhabit the same ecosystem (Poutiers 1998:232, 418) the varying proportions of each species collected in different time periods may reflect differential abundance in the environment or dietary preference rather than access to resources.

10.9 Discussion

Radiocarbon dates attest to repeated use of Nalkurdalayarrb. The site exhibits evidence for low occupation prior to 1750 cal BP and between 500-1500 cal BP. Two phases of intensive occupation occur between 1500-1750 cal BP and between 500 cal BP to present, where MNI numbers are at their highest.

Based on the site's location and relatively diverse range of taxa present, Nalkurdalayarrb is consistent with being a central place camp for occupation, possibly during times of refuge in inclement weather/wind conditions (see Tindale 1960), where foragers brought back food to share. A key characteristic of long-term residential base camps compared with one-off use dinnertime camps is the diversity of taxa targeted, with more taxa found in base-camp assemblages (Meehan 1982). Meehan (1982) also noted the small size of dinnertime camps (maximum of 15m x 10m) versus base camps (200m x 100m) and the presence of manufacturing and maintenance activities at base camps.

Occupants of the site consistently exploited three resource zones; resources from Rocky/Coral Reefs and Sandy-Mud Flats were preferred over Mangroves and Tidal-Mud Flats, most likely due to the close proximity of the first two habitats. *Lunella (Turbo) cinerea* and *Turbo* sp. were targeted from Rocky Reef habitats during the first 1000 years the site was used and then *Saccostrea glomerata* became the dominant species collected during the next 1000 years. Because both species inhabit the same zone, it is suggested that the varying proportions of each species collected in different time periods reflect differential abundance in the environment or dietary preference rather than access to resources.

Lunella cinerea takes approximately 3-4 years to mature and grow to a length of 35-50mm with a high meat:shell ratio of 25% providing low energy returns of 520-606 kcal/hr. *Saccostrea glomerata* grow to a length of 6-25cm and an average weight of 40-60g with meat:shell ratio of approximately 25% providing similar energy returns (data on shellfish returns from Bird *et al.* (2004), and Thomas (2007a); on meat:shell ratios from Bird and Bliege Bird (1997). We should expect that *Turbo* sp. would be exploited when abundance of higher-ranking resources is low and it would be one of the first taxa within the lower ranked set to exhibit signs of over-exploitation (Thomas 2009).

S. glomerata (rock oyster) inhabits sheltered rocky shores in the mid-to-intertidal zones (Lamprell and Healy 1998). Oysters rapidly reproduce with a high spawning frequency and broad distribution of offspring (Catterall and Poiner 1987) enabling efficient re-colonisation of habitats following events of depletion and intensive extraction (Sullivan 1987:103). *S. glomerata* often cement to substrates in large clumps (Kent 1992), and bulk ‘stripping’ of clumps may have been a more effective harvesting technique than selecting individual specimens (e.g. Whitaker 2008), as this would likely decrease costs of search time and processing of the resource (Alvard 1998).

M. hiantina and *G. pectinatum* are both Sandy-Mud Flats species that were co-collected in reasonably even proportions during 1000-2000 cal BP. Between 0-1000 cal BP, there appears to be a converse relationship between the two species with *M. hiantina* numbers high when *G. pectinatum* numbers are low and vice versa in different time periods. I also note that during 1000-2000 cal BP while the average size of *G. pectinatum* molluscs delines through time (as would be expected in cases of intensified human predation pressure), the average size of *M. hiantina* specimens increases when more numbers are collected (see Giovas *et al.* 2010; Giovas *et al.* 2013). It is possible that *G. pectinatum* populations may have been smaller/fewer in quantity than *M. hiantina* and/or that the species may take longer to mature, therefore population sustainability levels would be exceeded more quickly than *M. hiantina* sustainability levels. During the second phase of 1000 years, *G. pectinatum* specimens increase in size when more are collected and *M. hiantina* specimens reduce in size when more are gathered. Therefore we see the inverse occurring, *M. hiantina* sustainability levels are being exceeded more quickly than *G. pectinatum* levels. These data suggest that rather than exploiting a species to extinction, Kaiadilt people efficiently managed the collection of these two species by alternating gathering times to ensure sustainability of the molluscan resources (e.g. Whitaker 2008).

But as demonstrated with oysters, these sessile mollusc species may have been harvested in bulk where people are not always selective regarding size to obtain high calorific returns (Whitaker 2008). Potentially, the shell size increase could occur because of mollusc population thinning, thereby reducing competion for the species (Giovas et al. 2013). *M. hiantina* grow to a length of 20-50mm with a high meat:shell ratio of between 50% to 85% depending on size providing low energy returns of approx 797 kcal/kg (Smith 2011). It is likely at Nalkurdalayarrb that people are not choosing the largest bodied prey wherever they are encountered, and assemblages may just reflect the natural size range of a specific mollusc population. *G. pectinatum* grow to lengths of 24-37mm in one to three years. They have a lower meat:shell ratio of around 20% and also provide low energy returns of approx 797 kcal/kg (Smith 2011). Table 10.10 shows comparative data of live bivalve specimens collected for the TARL shell reference collection, which can be used to estimate the dietary contribution of *M. hiantina* and *G. pectinatum*.

Table 10.10: Estimated weights of bivalves based on valve lengths of archaeological specimens compared with reference collection specimens.

Taxon	Comparative valve lengths (mm)	Comparative dry shell weight (dsw) (g)	Comparative meat weights (g)	Weight of all archaeological specimens (g)	Estimated mean meat weight (g) of archaeological specimens
Marcia hiantina	36.2-37.8	4.1-7.0	3.5-6.0 (85% dsw)	267	226.9
Gafrarium pectinatum	31.4-46.5	11.1-43.9	2.1-8.3 (18.9% dsw)	285	53.8

From the figures above we can estimate that based on each taxon's MNI, hiant venus clams contributed 226.9g of meat and tumid venus clams contributed 53.8g of meat. To place this in perspective of energetic returns for foraging effort we can look at comparative fish data below.

Identified vertebrate taxa include grass emperor (*Lethrinus laticaudis*), garfish (Hemiramphidae), wrasse (Labridae), and red emperor (*Lutjanus sebae*). Apart from the red emperor, which is usually found in deeper waters, these are fish species that inhabit shallow coastal waters over seagrass beds and rocky/coral reefs. Juvenile grass emperors are also spotted feeding on mangrove mud flats. Table 10.11 shows the lengths of the fish otoliths collected from the Nalkurdalayarrb midden as well as the measurements of comparative fish otoliths in the TARL fish reference collection (Tomkins *et al.* 2013). In total these fish weighed over 3kg, taking into consideration that the *Lethrinus laticaudis* specimen weighed at least 400g. These specimens would therefore have been a good boost for energetic return based on a large proportion of the fish weight being meat weight.

Table 10.11: Estimated weights of fishes based on otolith lengths of archaeological specimens compared with reference collection specimens.

Taxon	XU	Comparative otolith length (mm)	Comparative taxon weight (g)	Length of archaeological otolith (mm)	Estimated weight (g) / energy return* of archaeological fish (kcal/hr)
Lethrinus laticaudis	4	9.8 / 12.8	400 / 1200	only ½ otolith	-
Hemiramphidae	4	5.5	50	12.4	112 / 695
Lutjanus sebae	8	16.1	950	9.1	537 / 1174
Hemiramphidae	8	5.5	50	21.5	195 / 695
Labridae	11	7.1	2800	5.2	2050 / 1000

* estimated from Smith (2011) and Vleig (1988).

10.10 Summary

Excavation at Nalkurdalayarrb revealed a relatively deep, high-density shell deposit consistent with observations of the material exposed across the deflated dune context. The restricted range of shellfish taxa, dominance of larger molluscan size-classes and presence of burnt shell and fish remains, support a cultural origin for the deposit. Kaiadilt oral tradition indicates that Sweers Island was not permanently inhabited but rather hunting parties would frequent the island, although the presence of numerous fishtraps along the coastline suggests more regular occupation. The site at Nalkurdalayarrb is consistent with being a central place camp that was mainly utilised during 1500-1750 cal BP and 0-500 cal BP. Here occupants shared resources hunted in the clear nearshore waters and gathered from Sandy-Mud Flats and Rocky Reefs habitats. The results at Nalkurdalayarrb are more indicative of hunter-gatherer foraging choices rather than a reflection of environmental changes impacting resources.

Chapter 11. Murdumurdu, Bentinck Island

11.1 Introduction

Archaeological investigations at Murdumurdu on the south coast of Bentinck Island indicate deposition of cultural materials at the site commenced around 300 years ago. This chapter describes the Murdumurdu site and its stratigraphy, chronology and contents followed by a discussion of the data from an OFT perspective for understanding foraging behaviours of the site users.

11.2 Site Description and Setting

Murdumurdu was recorded during pedestrian transect surveys in 2012 and during subsequent palaeoecological investigations at the nearby Marralda Swamp (see Moss *et al*. 2015). Murdumurdu is one of a number of surface shell exposures documented along the low coastal dunes between Jirrkamirndiyarrb and Mirdidingki Creek (Latitude: 17.09746S, Longitude: 139.54625E), c.200m inland from the coast (Figures 11.1-11.2).

The midden site is approximately 3000m^2 in size, situated c.10m-20m south of Marralda Swamp on one of a series of low prograding coastal dunes that separate the swamp from the modern coastline. Murdumurdu is c.800m west of the Jirrkamindiyarrb Site 8 excavation. A sediment core has been extracted from the adjacent Marralda Swamp, which indicates that around c.500 years ago a well-established mangrove forest dominated the swamp until the late 1940s. Moss *et al.* (2015) report that the mangrove wetland would have formed in a barrier setting protected from wave action and with suitable silt substrate deposition (Grindrod *et al.* 1999, 2002). Then, in the 1940s a freshwater swamp developed, probably as the result of cyclone activity that created a barrier. This blocked tidal seawater flow allowing groundwater to freshen the swamp (Moss *et al.* 2015). The event may have been the unnamed cyclone that crossed directly over Bentinck Island in February 1948, which created a storm surge (estimated to be approximately 3.6m high from Kaiadilt reports) covering all but the highest parts of the island (BOM 2014b).

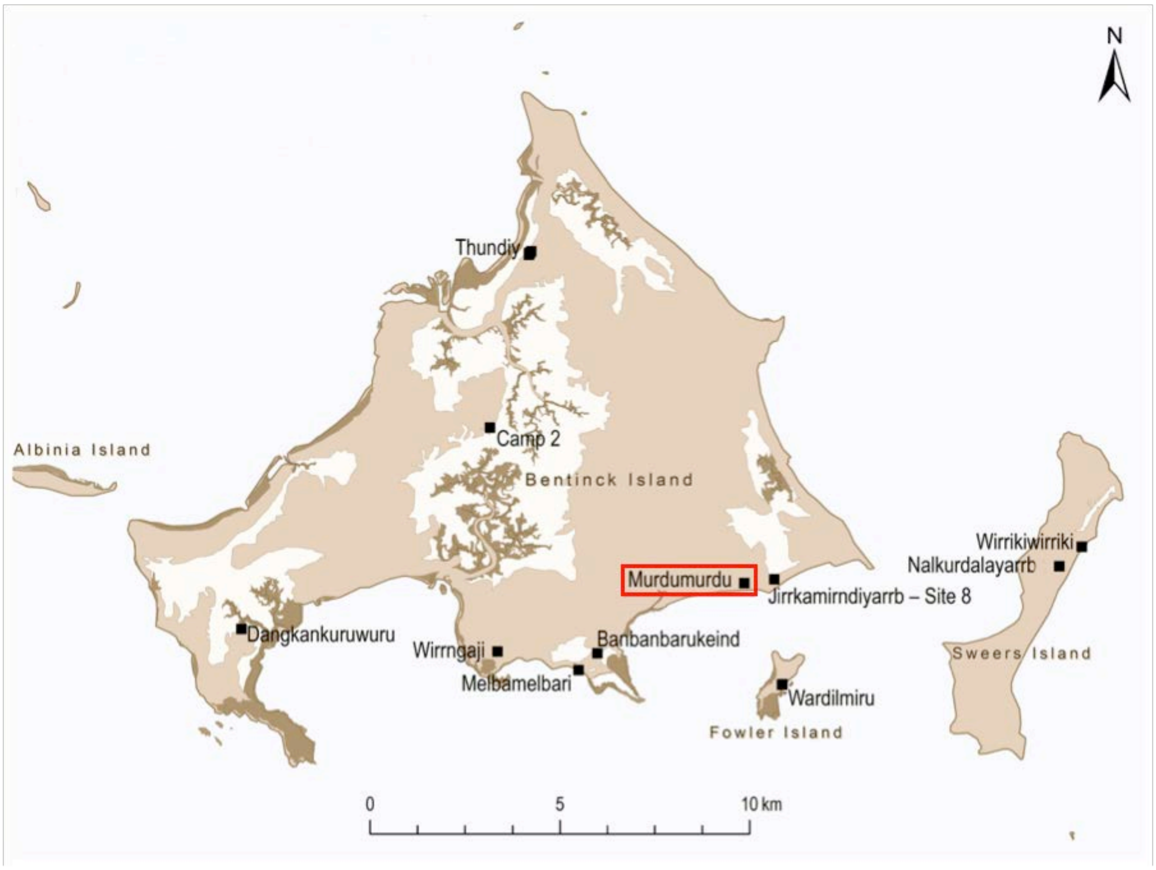


Figure 11.1: Map of South Wellesley Islands showing Murdumurdu site location (map prepared by Lincoln Steinberger and Sean Ulm).

Figure 11.2: Aerial view map of Murdumurdu site location (after Google Earth).

Today Marralda Swamp is a series of interconnected channels in the swales of a coastal dune field 1 to 3m above PMSL that join Mirdidingki Creek c.500m to the west and a claypan to the east (Figure 11.3) (Moss *et al.* 2015). Present vegetation is a mixture of *Melaleuca* and *Pandanus* forest and includes *Typha* and spike-rush corms of *Eliocharis dulcis*, known in Kayardild as *damuru* (see Evans 1992:88). Moss *et al.* (2015) report the mangrove vegetation consisted of mainly *Rhizophora, Exoecaria* and *Avicennia marina*.

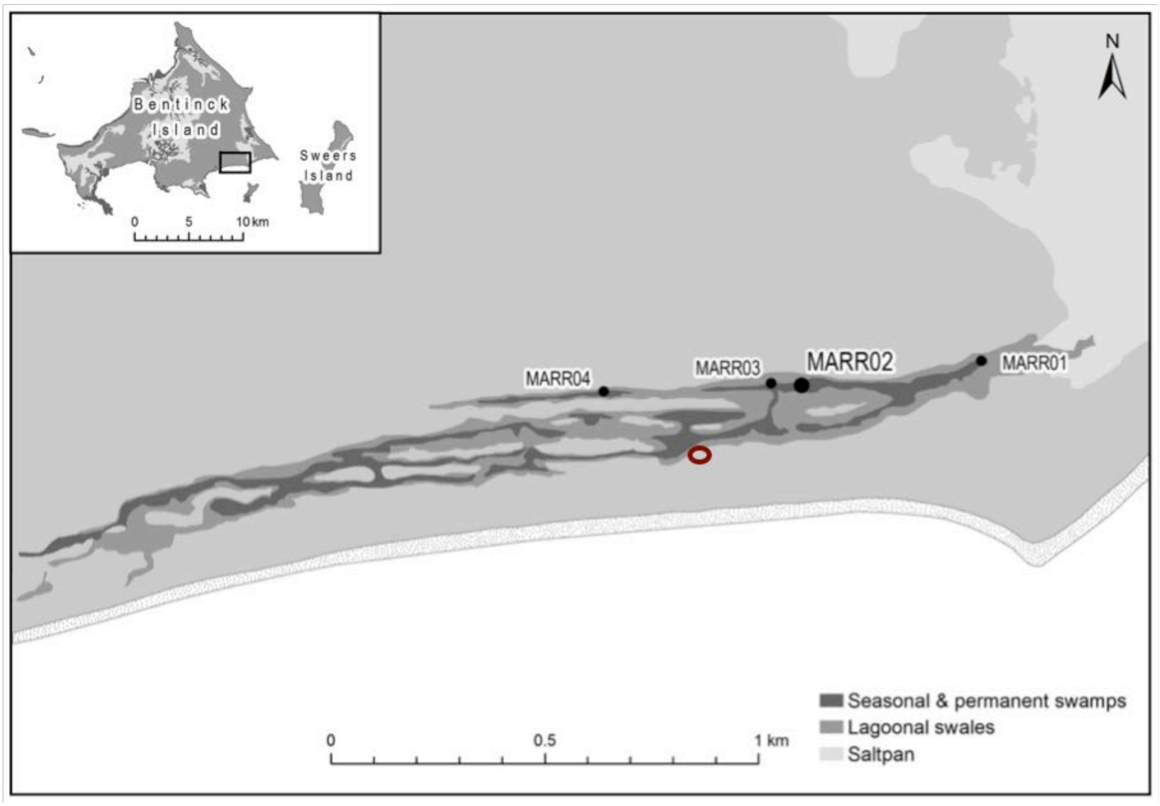


Figure 11.3: Murdumurdu in relation to Marralda Swamp and shoreline (prepared by Lincoln Steinberger and Sean Ulm).

The exposed dune system supports savannah grasses. The southern coastline has long expanses of sandy beaches with occasional she-oak trees occurring along the strandline (Figure 11.4-11.6). The intertidal sandy-mud flats along the sheltered shoreline adjacent to the site support hiant venus clams (*Marcia hiantina*) and tumid venus clams (*Gafrarium pectinatum*), which are dominant species found in the midden (see Figures 11.7-11.8). The shallow and sheltered waters in this area provide ideal conditions for seagrass beds, which attract fish and dugong. A few rocky/coral reef platforms are situated within 500m of the site near a shallow sand-spit that, when exposed at very low tide, can be used to cross to Fowler Island (Figure 11.8). The rocks support clumps of top snails (*Calliostoma* sp.) and theoretically could be expected to maintain oysters, still few have been found within the Murdumurdu midden. Mirdirdingki Creek to the west is a small tidal estuary system supporting thick stands of mangrove vegetation, hosting populations of *Geloina erosa*, *Telescopium telescopium* and *Nerita* sp.

Figure 11.4: General location view northeast showing Marralda Swamp.

Figure 11.5: Location view southwest showing excavations at Square A.

Figure 11.6: Location view southeast showing excavations in progress Square B.

Figure 11.7: Sandy-mud flats along shoreline c.400m from Murdumurdu.

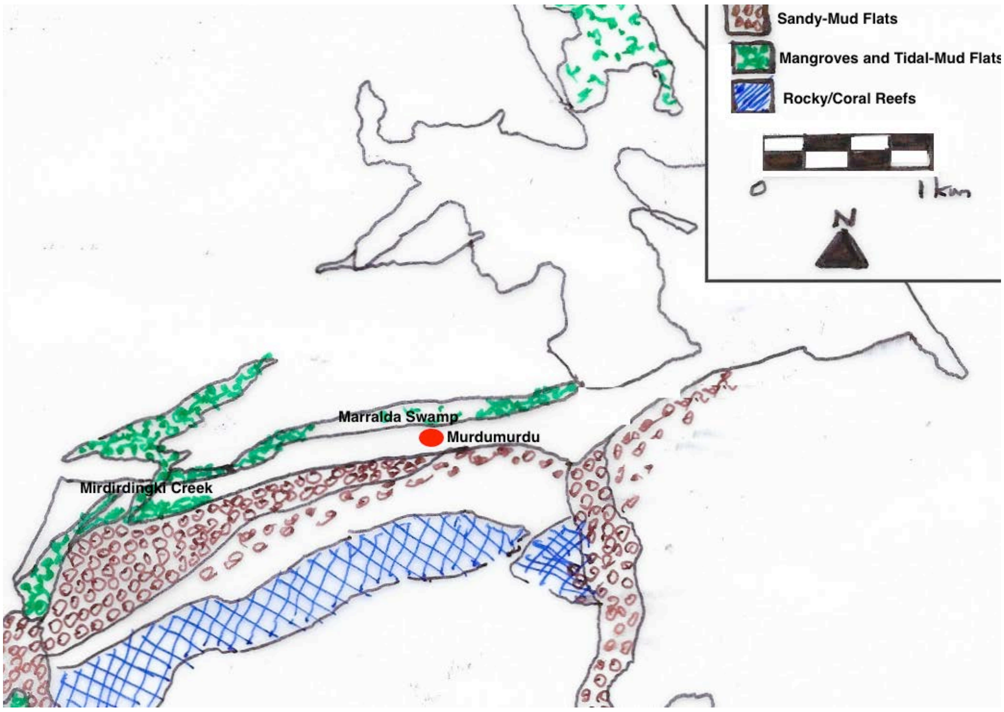


Figure 11.8 Resource habitat communities near Murdumurdu.

11.3 Excavation Methods

In 2012 a team of archaeologists under the direction of Sean Ulm excavated 485.2kg of materials from two 50cm x 50cm (Square A and Square B) pits dug 10m apart along the crest of an E-W orientated low ridge bordering Marralda Swamp in the Murdumurdu midden (Figure 11.9). Excavations proceeded in shallow, arbitrary excavation units averaging 3.0cm in depth and 12kg in weight. Excavations ceased at c.61cm and c.60cm below ground surface respectively in Square A and in Square B. All midden materials were dry sieved through 2.3mm mesh on site and materials retained in the sieve were bagged for later sorting and identification in the laboratory (see Chapter 6 for a detailed discussion of the standard excavation and laboratory methods employed at all sites). During excavation of Square A XU7 a small area at the top of the north profile collapsed, extending from c.10cm to 35cm at the top and tapering to depth of 20cm below ground surface. Collapsed material was carefully removed before excavation continued to prevent contamination of *in situ* deposits.

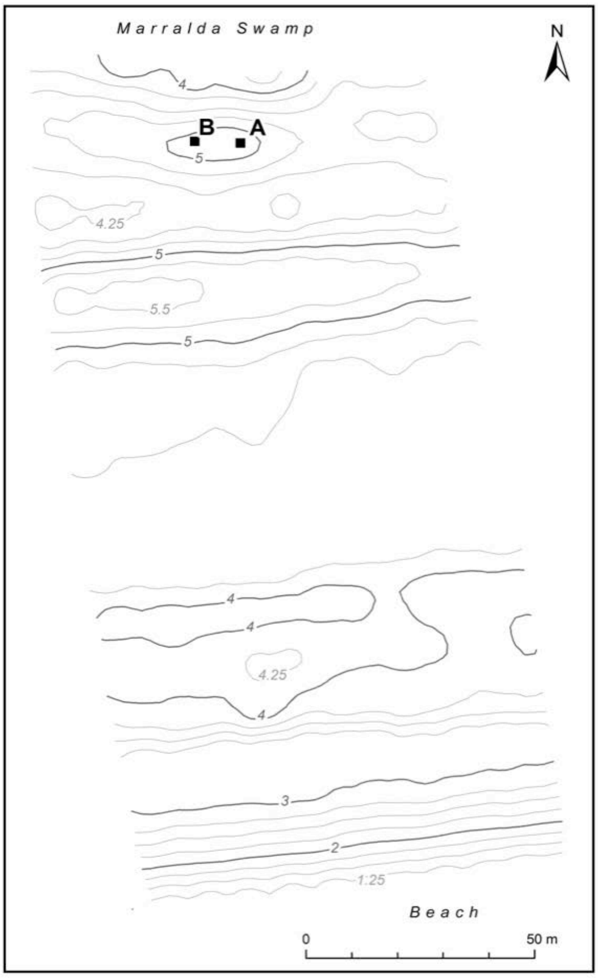


Figure 11.9: Square A and Square B pits on contour map showing site location relative to beach (map prepared by Lincoln Steinberger and Sean Ulm).

11.4 Cultural Deposit and Stratigraphy

Excavations revealed a 30cm-40cm thick deposit of reasonably dense cultural materials with shell, bone and charcoal, resting on degrading beach sands (Figures 11.10-11.11). The majority of shell was recovered in Square A from between XU3-7 (c.6cm-22cm depth) and in Square B from XU3-8 (c.6.5cm-24.5cm). The deposit can be divided into four stratigraphic units (SUs) – from the top, a disturbed layer of humic, coarse brown sands, a cultural unit and then a transitional unit overlying a beach base (Figures 11.12 and 11.13; Table 11.1). SUIa includes materials located between XU1 to XU3 (Square A and Square B). SUIb contains cultural materials between XU4 to XU8 (Square A) and XU4 to XU10 (Square B). SUII includes materials located between XU9 to XU18 (Square A) and XU11 to XU14 (Square B). SUII contains sparse quantities of cultural materials that have filtered down from upper layers. SUIII is the beach base and appears to be culturally sterile. Only small shell was recovered below XU10 (c.31cm) in both squares and these lower excavated deposits are likely to reflect non-cultural depositional processes.

Figure 11.10: Murdumurdu Square A, 50cm x 50cm excavations. Note small area of section collapse at the top of the north profile (photo by Sean Ulm).

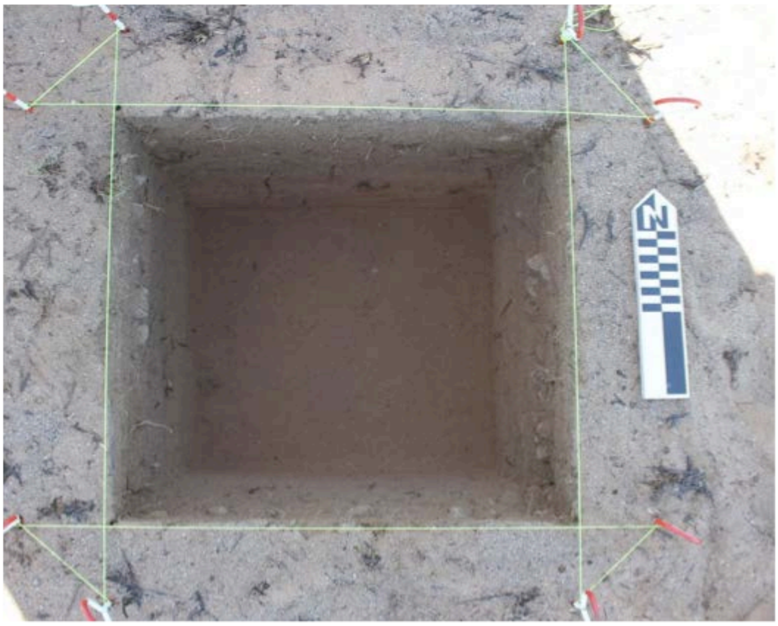


Figure 11.11: Murdumurdu Square B, 50cm x 50cm excavations (photo by Sean Ulm).

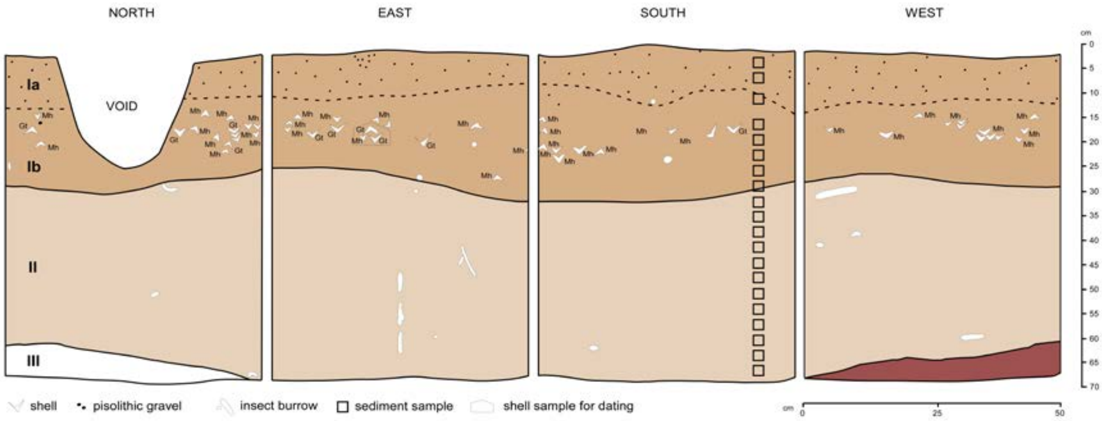


Figure 11.12: Stratigraphic section drawing, Murdumurdu Square A (prepared by Sean Ulm and Michelle Langley).

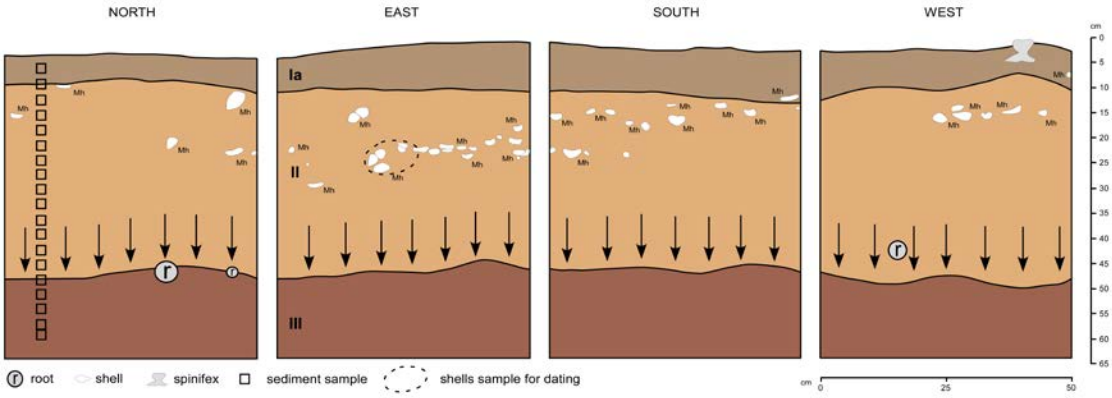


Figure 11.13: Stratigraphic section drawing, Murdumurdu Square B (prepared by Sean Ulm and Michelle Langley).

Table 11.1: Stratigraphic Unit (SU) descriptions, Murdumurdu, Square A and Square B.

SU	Description
Ia	Extends across both squares with depths ranging between 10cm to 15cm below ground surface in Square A and 5cm to 10cm in Square B. The unit comprises angular to subangular loosely consolidated coarse sands with numerous spinifex grass rootlets. These sediments are brown (7.5YR-5/4) in colour and there is coarse shell grit interspersed throughout the SU. Some evidence of insect disturbance with small burrows present. Cultural materials include charcoal fragments, whole and fragmented venus clams (*Marcia hiantina* and *Gafrarium pectinatum*). pH values are highly alkaline (8.5-10.0). Shell materials appear to be reasonably well-preserved.
Ib	More consolidated coarse brown (7.5YR-5/4) sands with fewer spinifex grass rootlets and shell grit inclusions. In Square A SUIb is between 10cm to 25cm below the surface. In Square B SUIb is between 5cm to 30cm below surface. pH values are alkaline (7.5-9.0). Features high concentration of shell between 15cm and 25cm comprising *M. hiantina* and *G. pectinatum* as well as other cultural materials (e.g. fishbone, charcoal).
II	Transitional unit grading from brown (7.5YR-5/4) to light brown (7.5YR-6/4) loosely consolidated coarse sands. There are few roots but numerous and larger insect burrows. The shells found in this unit are likely cultural in origin, but rather than being *in situ* they have been affected by insect bioturbation and other taphonomic factors that caused the shell fragments to move down the profile. In Square A SUII is between 25cm to 55cm below the surface. In Square B SUII is between 30cm to 45cm below ground surface. pH values are highly alkaline (8.5-9.5).
III	Very loosely consolidated reddish yellow (7.5YR-6/6) sands in Square A and pink (7.5YR-7/4) coarse sands in Square B. SUIII in both squares contains plentiful shell grit and small molluscs, including *Calliostoma* sp. A continuous layer of beach rock forms the base of this unit at c.45cm to 60cm below surface. This is culturally sterile. pH values remain highly alkaline (8.0–9.0).

11.5 Site Integrity and Taphonomy

The deposit exhibits reasonable stratigraphic integrity. There is a predictable shell decay profile with highly weathered tiny gastropod specimens recovered from the lower XUs of the deposit and relatively well-preserved specimens from the upper deposit. There is a pattern of low shell fragmentation (c.120 fragments per 100g of shell) contributing to high rates of identification in the upper units that correlates with the period of cultural deposition (see Hoffman 2011). This contrasts with high/increased shell fragmentation (c.850 fragments per 100g of shell) and consequently low rates of identification in deeper and older units. Identification of vertebrate remains has been hampered due to bones being heavily fragmented throughout all units. Insect burrows suggest some insect activity within the excavation pits indicating minor taphonomic disturbance of the midden has likely occured. Small quantities of cultural shell fragments may have filtered down through the transition unit.

11.6 Radiocarbon Dating and Chronology

Only two radiocarbon determinations have been obtained for the deposits at Murdumurdu, one each from Square A and Square B (Table 11.2). Both dates indicate the site has been used for at least 300 years. The mollusc specimens used for radiocarbon dating were taken from the base of the major cultural shell in each square.

Table 11.2: Radiocarbon ages on marine shell for Murdumurdu, Square A and Square B. Calibrations undertaken using OxCal v.4.2 (Bronk Ramsey 2009) and the Marine13 calibration dataset (Reimer *et al.* 2013). For marine samples a ΔR of −49±102 is used as recommended by Ulm *et al.* (in prep.). Both samples were collected from the section at the conclusion of excavations.

Sq	XU	Depth (cm)	Lab. Code	Sample (species)	^{14}C	$\delta^{13}C$	Calibrated Age BP (95.4%)	Calibrated Age BP Median
A	5-6	14-17	Wk-34780	*Gafrarium (tumidum) pectinatum*	640±25	1.7±0.2	67-508	328
B	7-8	20-24	Wk-34776	*Marcia hiantina*	634±27	0.9±0.2	67-504	322

As I am particularly interested in identifying changes through time the assemblages have been divided into temporal phases of 250-year periods for comparative purposes. Excavation units were assigned to chronological periods based on an age-depth model derived from the calibrated radiocarbon age (Table 11.3; Figures 11.14-11.15). Although it is acknowledged as potentially problematic, in the absence of multiple dates a termination date at the surface has been assumed to date to 0 cal BP. Using the termination date of 0 cal BP and the calibrated radiocarbon median date, a linear relationship model (assuming a consistent rate of deposition occurred at the site) was determined for each square (see Section 6.4 for method of calculation). Even though time-averaging these open shell deposits only allows for identification of broad-scale trends and not subtle changes, it allows determination of variation in relative taxa abundance, indicative of taxa exploitation patterns and/or environmental changes affecting the distribution of taxa.

Table 11.3 Temporal phases of 250-year periods, showing allocation of XUs.

Temporal phase	0-250	250-500	500-750	750-1000	1000-1250
Square A XUs	1-3	4-8	9-11	12-15	16-20
Square B XUs	1-5	6-11	12-17	18-20	

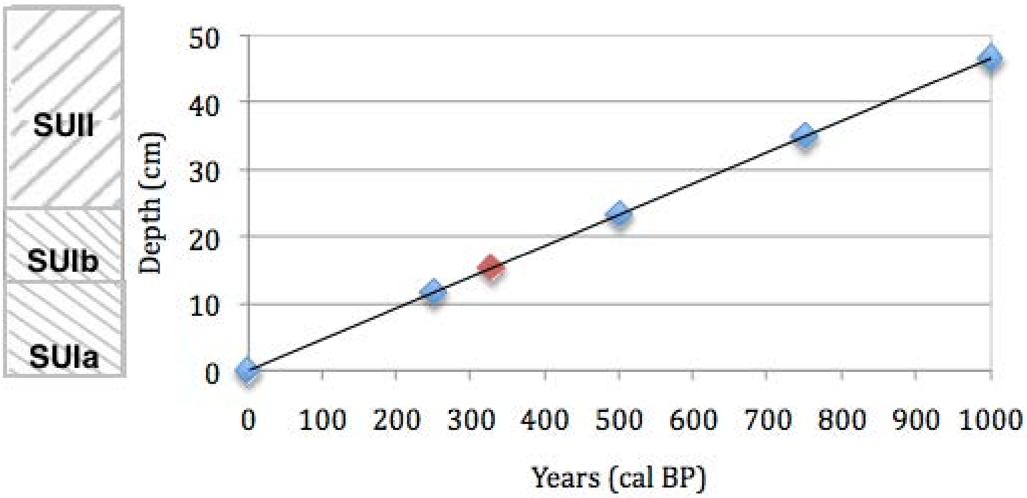


Figure 11.14: Age-depth relationship of radiocarbon determination obtained for Murdumurdu Square A. The red marker is the calibrated radiocarbon age obtained on *Gafrarium pectinatum*. Blue markers are depths determined for each 250 years.

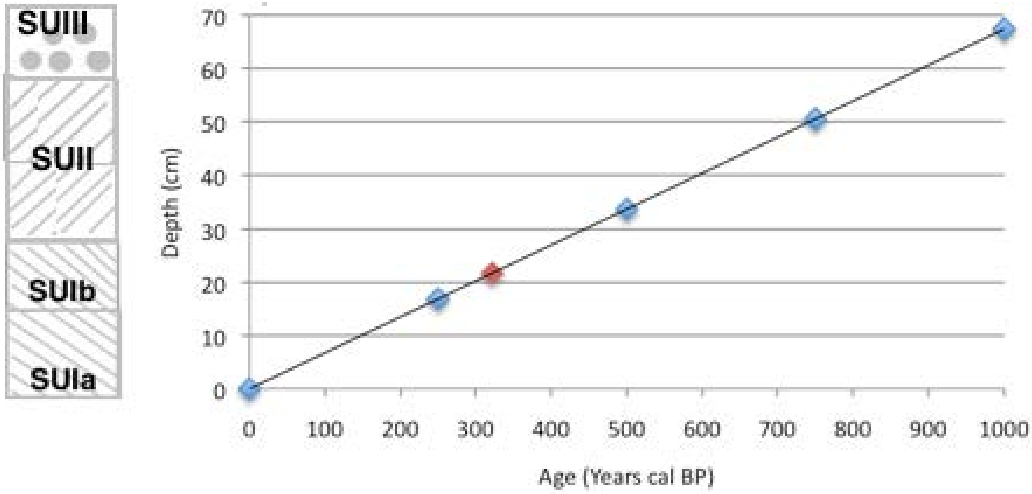


Figure 11.15: Age-depth relationship of radiocarbon determination obtained for Murdumurdu Square B. The red marker is the calibrated radiocarbon age obtained on *Marcia hiantina*. Blue markers are depths determined for each 250 years.

11.7 Laboratory Methods

For the purpose of temporally comparing the data from Murdumurdu cultural assemblage with other sites in this study I have estimated the main cultural use of Murdumurdu as occurring during the chronological period of 250-500 years. See Chapter 6 for a detailed discussion of the standard laboratory methods employed for all sites.

11.8 Cultural Materials

3,564.29g (1.4%) of the total sediment and materials excavated from Square A and 2,445.19g (1%) from Square B were retained in the 2.3mm sieve residue denoting a very low-density cultural deposit. Tables 11.4 and 11.5 show the overall summary results of the retained materials. Molluscan shell makes up 90.5% (3,226.46g) of the Square A assemblage and 83.8% (2050.27g) of the Square B assemblage. Fishbone contributes 0.08% (1.45g) for Square A and 0.02% (0.45g) for Square B. Small quantities of crustacea (16.8g) were recovered from both squares combined, represented by mud crab (*Scylla* spp.) (2.4g) and goose barnacle (Pedunculata) (14.4g). Beachrock, coral and pisoliths contribute 6.2% of Square A and 5.5% of Square B. Organics make up the rest of the assemblage.

Table 11.4: Summary excavation data and retained materials Murdumurdu Square A.

XU	Depth Below Surface (cm)	Mean Thickness (cm)	Weight (kg)	Vol cm^3	pH	Stone Artefacts (g)	Marine Shell (g)	Bone (g)	Barnacles (g)	Crab (g)	Charcoal (g)	Other Organic (g)	Rock Rubble (g)	Retained Material Total (g)	% of Total Midden
1	2.46	2.46	18.7	6150	10	0	39.92	0.05	0.11	0	0.03	49.17	5.25	94.53	0.51%
2	6.36	3.9	13.1	9750	8.5	0	17.92	0.12	0.17	0.09	0	12.31	0.29	30.9	0.24%
3	9.3	2.94	12.2	7350	9.5	0	141.95	0.2	0.1	0.19	0.06	6.15	7.69	156.34	1.28%
4	12.34	3.04	10.8	7600	8	0	128.08	0.37	0.23	0.39	0.11	5.64	11.05	145.87	1.35%
5	15.44	3.1	11.5	7750	8	0	1423.94	0.28	0.28	0.78	0.33	4.97	21.92	1452.5	12.63%
6	18.32	2.88	12	7200	8.5	0	653.38	0.34	0	0	0.05	2.01	7.78	663.56	5.53%
7	21.54	3.22	12.3	8050	9.5	0	76.65	0.01	0.06	0.09	0.17	3.91	11.34	92.23	0.75%
8	24.42	2.88	10.5	7200	8.5	0	36.48	0.04	0.05	0.13	0.08	2.2	6.49	45.47	0.43%
9	27.6	3.18	11.8	7950	8.5	0	22.89	0.04	0.21	0.04	0.08	2.5	3.56	29.32	0.25%
10	31.36	3.76	12.9	9400	8.5	0	43.5	0	0.05	0.13	0.05	1.29	2.79	47.81	0.37%
11	34.32	2.96	11.4	7400	8.5	0	19.48	0	0.1	0	0.02	1.52	2.19	23.31	0.20%
12	37.4	3.08	12.2	7700	7.5	0	22.3	0	0	0	0	1.07	1.81	25.18	0.21%
13	40	2.6	12.7	6500	8	0	19.77	0	0.16	0	0	1.68	1.45	23.06	0.18%
14	43.36	3.36	10.6	8400	8.5	0	19.89	0	0.15	0	0	0.93	1.27	22.24	0.21%
15	46.36	3	11.2	7500	8	0	21.66	0	0.17	0	0.03	1.14	2.25	25.25	0.23%
16	49.34	2.98	10.6	7450	9	0	36.01	0	0.21	0	0.12	1.21	4.88	42.43	0.40%
17	52.4	3.06	12.2	7650	8	0	42.19	0	0.45	0	0	0.85	6.04	49.53	0.41%
18	55.24	2.84	10	7100	8	0	77.04	0	0.66	0.1	0	1.05	17.25	96.1	0.96%
19	58.4	3.16	10.8	7900	8	0	146.13	0	1.23	0	0	1.77	37.09	186.22	1.72%
20	61.36	2.96	11.7	7400	8	0	237.28	0	4.25	0.14	0.01	1.66	69.1	312.44	2.67%
Total:	-	61.36	239.20	153400	-	0	3226.46	1.45	8.64	2.08	1.14	103.03	221.10	3564.29	1.49%

Table 11.5: Summary excavation data and retained materials Murdumurdu Square B.

XU	Depth below Surface (cm)	Mean Thickness (cm)	Weight (kg)	Vol cm^3	pH	Stone Artefacts (g)	Marine Shell (g)	Bone (g)	Barnacles (g)	Crab (g)	Charcoal (g)	Other Organic (g)	Rock Rubble (g)	Retained Material Total (g)	% of Total Midden
1	3.64	3.64	13.2	9100	8	0	29.3	0.01	0	0	0	42.69	2.63	74.63	0.57%
2	6.42	2.78	11	6950	8	0	42.18	0.03	0.06	0.05	0.01	5.7	5.03	53.06	0.48%
3	9.94	3.52	13.4	8800	9	0	78.21	0.03	0.19	0	0.03	10.38	10.72	99.56	0.74%
4	12.46	2.52	8.9	6300	9	0	207.37	0.05	0.02	0	0.01	6.63	7.95	222.03	2.49%
5	15.46	3.00	12.4	7500	9	0	386.54	0.07	0.34	0.07	0	8.39	12.37	407.78	3.29%
6	18.74	3.28	19	8200	9	0	263.94	0.11	0.13	0	0.07	7.47	13.43	285.15	1.50%
7	21.6	2.86	11.4	7150	9	0	419.14	0.06	0.09	0	0.17	5.33	13.45	438.24	3.84%
8	24.66	3.06	12.4	7650	9	0	228.62	0.08	0.57	0.01	0.14	5.46	18.05	252.93	2.04%
9	27.84	3.18	13	7950	8.5	0	66.15	0.01	0.25	0	0.21	4.8	10.12	81.54	0.63%
10	30.92	3.08	12.1	7700	8.5	0	35.78	0	0.2	0.01	0	5.27	6.94	48.2	0.40%
11	33.48	2.56	9.9	6400	8.5	0	25.42	0	0.35	0	0	3.54	5.32	34.63	0.35%
12	36.62	3.14	13.2	7850	9	0	29.14	0	0.31	0	0	4.58	5.02	39.05	0.30%
13	40.26	3.64	13.4	9100	9.5	0	31.7	0	0.31	0.07	0	4.22	3.17	39.47	0.29%
14	42.6	2.34	9.1	5850	9	0	17.66	0	0.22	0	0	3.04	1.57	22.49	0.25%
15	45.66	3.06	12.3	7650	9	0	33.88	0	0.38	0.01	0.01	111.94	2.49	148.71	1.21%
16	48.58	2.92	12.3	7300	9	0	39.48	0	1.07	0.06	0	5.82	4.09	50.52	0.41%
17	51.6	3.02	12.8	7550	9	0	41.52	0	0.38	0	0	3.44	4.51	49.85	0.39%
18	54.68	3.08	12.5	7700	9	0	28.57	0	0.38	0.01	0	6.19	2.74	37.89	0.30%
19	57.58	2.9	11.3	7250	9	0	19.9	0	0.31	0.04	0	4.34	3.26	27.85	0.25%
20	60.68	3.1	12.4	7750	9	0	25.77	0	0.23	0	0	3.76	1.85	31.61	0.25%
Total:	-	60.68	246.00	151700	-	0	2050.27	0.45	5.79	0.33	0.65	252.99	134.71	2445.19	0.99%

11.8.1 Invertebrate Mollusc Remains

Square A

In total 3,226.46g of shell was recovered from Square A, which represents 90.5% of the total assemblage. 75% of all shell by weight was identified to family, genus or species level. The remaining 25% of shell based on weight could not be identified beyond Mollusca due to the generally small size of these specimens and the lack of diagnostic attributes that prevented identification to taxon; this portion of the assemblage has not been included in analyses presented below. The identified assemblage comprised 27 molluscan taxa weighing 2,430.69g (with an MNI=593) consisting of 17 marine bivalve taxa and 10 marine gastropod taxa (Figures 11.16-11.17). By weight the assemblage is dominated by tumid venus clams (*G. pectinatum*) (54.3%) and hiant venus clams (*M. hiantina*) (41.8%) with tiar venus clams (*Placamen retroversum*) representing 1.1% of the shell assemblage by weight. The remaining 24 taxa are relatively rare, each contributing less than 1% of the shell assemblage by weight. MNI and weight tables are presented in Tables 11.6 and 11.7.

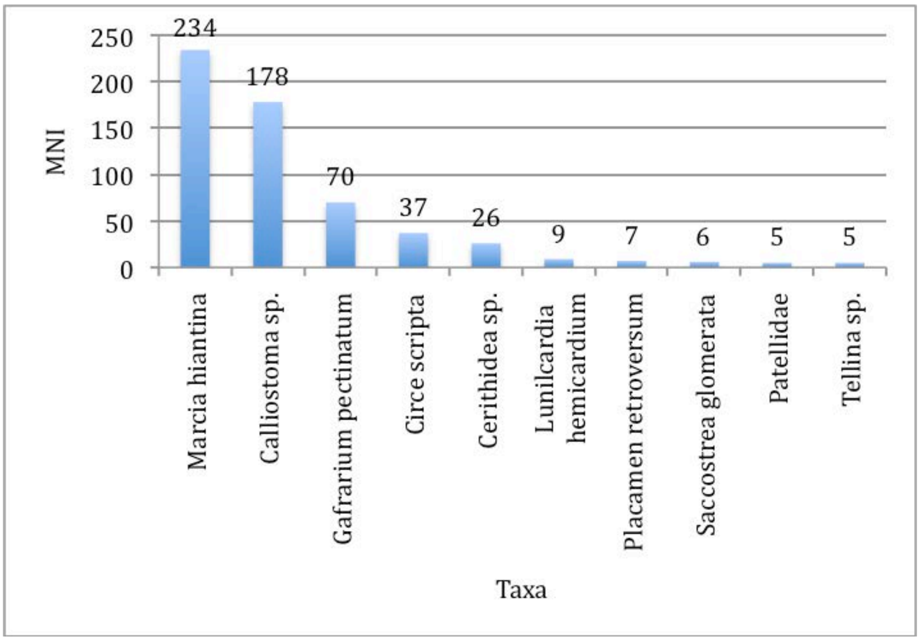


Figure 11.16: Murdumurdu Square A, top 10 mollusc taxa by MNI.

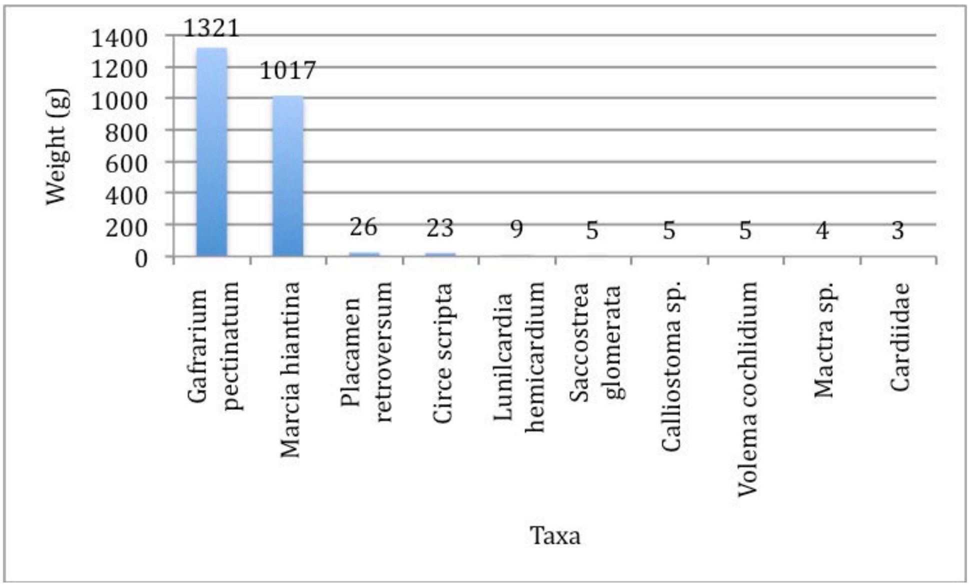


Figure 11.17: Murdumurdu Square A, top 10 mollusc taxa by weight.

The shell deposit in Square A is concentrated between XU3-7 (dated to c.300 cal BP) accounting for 61% of the identified mollusc assemblage based on MNI, suggesting a significant use of the site around this time (Figure 11.18). Although XU19-20 contain high mollusc MNI numbers this is mostly attributed to small gastropods that are not considered cultural in nature. The assemblage exhibits moderate diversity with a calculated Shannon-Weaver Index of 2.74 while 91% of the assemblage comprises five species. The high presence of venus clams, top shells, Pacific cockles and cerithid snails suggest foraging strategies across all three habitats (i.e. intertidal sand-mud flats, rocky reefs and mangroves and tidal-mud flats (see Figures 11.7-11.8).

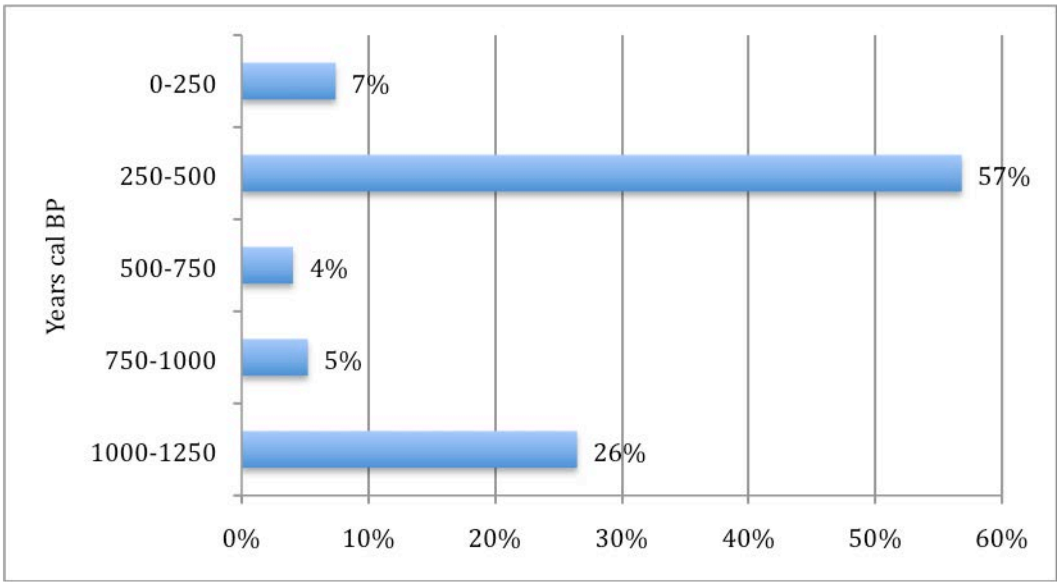


Figure 11.18: Proportion of Square A total mollusc assemblage MNI per 250-year period.

Table 11.6: Murdumurdu Square A molluscan assemblage taxa MNIs.

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Totals**
MARINE BIVALVIA																					
Cardiidae																				1	**1**
Chama sp.																				1	**1**
Circe scripta				6	7	7		1					1					2	4	9	**37**
Corbula fortisulcata						1													1	1	**3**
Gafrarium pectinatum				3	39	26	1			1											**70**
Glauconome virens																			1		**1**
Lunulicardia hemicardium					2	2								1						4	**9**
Mactra sp.				1																	**1**
Marcia hiantina			20	67	90	47	3	2	1						1				1	2	**234**
Mytilidae															1						**1**
Placamen retroversum	6																1				**7**
Placuna placenta			1																		**1**
Saccostrea glomerata										2		1								3	**6**
Tellina sp.			1											1			1			2	**5**
MARINE GASTROPODA																					
Calliostoma sp.	3		9	4	7	5	6	4	6	6	2	6	10	4	3	10	13	16	23	41	**178**
Cerithidea cingulata																				1	**1**
Cerithidea sp.			2		2	2					4							6	10		**26**
Clypeomorus sp.																				1	**1**
Mitrella scripta					1															1	**2**
Nassarius sp.					1																**1**
Patellidae			1							1	1		2								**5**
Rhinoclavis sp.																				1	**1**
Turbo sp.		1																			**1**
XU Totals	**9**	**1**	**34**	**81**	**14**	**90**	**10**	**7**	**7**	**10**	**7**	**7**	**13**	**6**	**5**	**10**	**15**	**24**	**40**	**68**	**593**

Table 11.7: Murdumurdu Square A molluscan assemblage taxa weights (g).

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
MARINE BIVALVIA										
Asaphis violascens	0.04				0.44				0.78	
Cardiidae										
Chama sp.										
Circe scripta			0.70	3.89	5.44	3.45		1.25		
Corbula fortisulcata						0.22				0.25
Gafrarium pectinatum		3.33	4.27	87.84	810.04	378.04	16.18	1.52		18.18
Glauconome virens					0.40		0.29			
Lunulicardia hemicardium					0.63	1.50		0.09		
Mactra sp.				4.27						
Marcia hiantina	2.28		116.22		579.56	242.88	32.37	7.65	4.55	6.08
Mytilidae								0.01		
Pitar pellucidus										
Placamen retroversum	24.09									
Placuna placenta			0.07			0.05				
Saccostrea glomerata		0.17		0.13	0.70	1.02		0.15		0.18
Semele sinensis					1.30					
Tellina sp.			0.09							
MARINE GASTROPODA										
Calliostoma sp.	0.06		0.13	0.07	0.12	0.11	0.13	0.02	0.19	0.13
Cerithidea cingulata										
Cerithidea sp.			0.06		0.08	0.06				
Clypeomorus sp.										
Mitrella scripta					0.09					
Nassarius sp.					0.07					
Patellidae			0.01							0.02
Rhinoclavis sp.										
Turbo sp.		0.49								

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Volegalea cochlidium				4.52						
Unidentified shell	13.45	13.93	20.4	27.36	25.07	26.05	27.68	25.79	17.37	18.66
XU Totals	**39.92**	**17.92**	**141.95**	**128.08**	**1423.94**	**653.38**	**76.65**	**36.48**	**22.89**	**43.50**

Table 11.7: Murdumurdu Square A molluscan assemblage taxa weights (g) (cont).

Taxon XU	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Totals**
MARINE BIVALVIA											
Asaphis violascens										0.92	2.18
Cardiidae				0.05						3.07	3.12
Chama sp.								0.03	0.78	0.23	1.04
Circe scripta			0.17					0.34	3.42	4.35	23.01
Corbula fortisulcata									0.21	0.13	0.81
Gafrarium pectinatum	1.47						0.11				1320.98
Glauconome virens											0.69
Lunulicardia hemicardium				0.06				1.54	0.66	4.52	9.00
Mactra sp.											4.27
Marcia hiantina		2.09		0.42	0.44	0.29	0.31		10.23	11.78	1017.15
Mytilidae					0.06						0.07
Pitar pellucidus									1.36		1.36
Placamen retroversum							1.74				25.83
Placuna placenta		0.49	0.01								0.62
Saccostrea glomerata		0.38			0.18		0.03		0.14	2.29	5.37
Semele sinensis											1.30
Tellina sp.				0.09			0.10		0.79	1.25	2.32
MARINE GASTROPODA											
Calliostoma sp.	0.05	0.11	0.21	0.08	0.06	0.21	0.18	0.12	0.90	1.68	4.56
Cerithidea cingulata										0.13	0.13
Taxon XU	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Totals**

Cerithidea sp.	0.14							0.10	0.66		1.10
Clypeomorus sp.										0.16	0.16
Mitrella scripta										0.31	0.40
Nassarius sp.											0.07
Patellidae	0.01		0.01	0.06							0.11
Rhinoclavis sp.										0.03	0.03
Turbo sp.											0.49
Volegalea cochlidium											4.52
Unidentified shell	17.81	19.23	19.37	19.13	20.92	35.51	39.72	74.91	126.98	206.43	795.77
XU Totals	**19.48**	**22.30**	**19.77**	**19.89**	**21.66**	**36.01**	**42.19**	**77.04**	**146.13**	**237.28**	**3226.46**

Square B

In total 2,050.27g of shell was recovered from Square B, which represents 83.8% of the total deposit. 74% of all shell by weight was identified to family, genus or species level. The remaining 26% of shell based on weight could not be identified beyond Mollusca due to the generally small size of these specimens and the lack of diagnostic attributes that prevented identification to taxon; this portion of the assemblage is not considered in analyses presented below. The identified assemblage comprised 21 molluscan taxa weighing 1,515.91g (with an MNI=466) consisting of 15 marine bivalve taxa and six marine gastropod taxa (Figures 11.19-11.20). The assemblage is dominated by hiant venus clams (*Marcia hiantina*), representing 98.9% of the shell assemblage by weight. The remaining 20 taxa are relatively rare, each contributing less than 1% of the shell assemblage by weight. MNI and weight tables are presented in Tables 11.8 and 11.9.

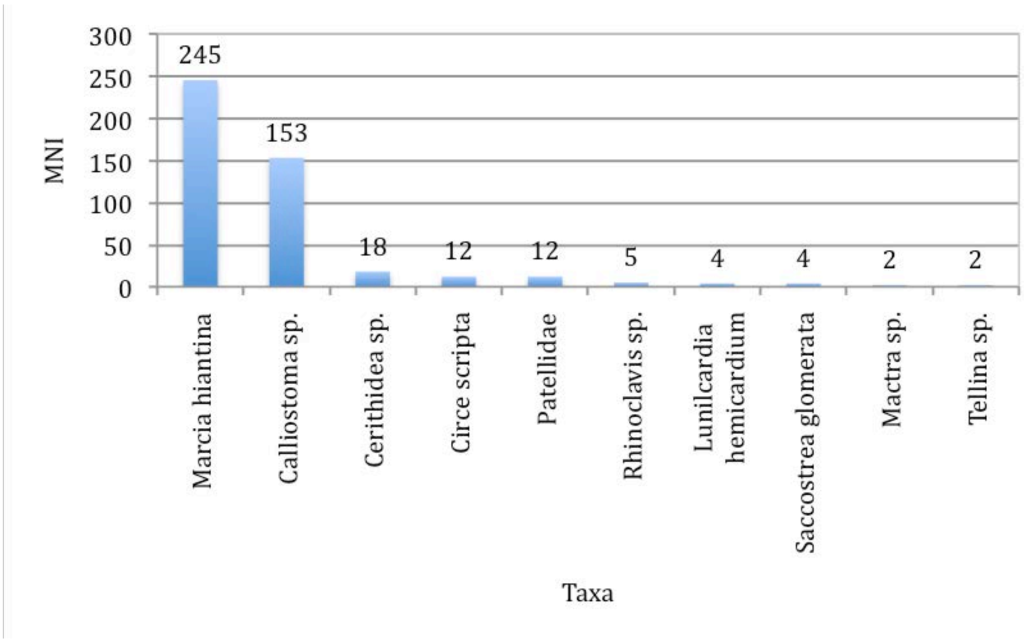


Figure 11.19: Murdumurdu Square B, top 10 mollusc taxa by MNI.

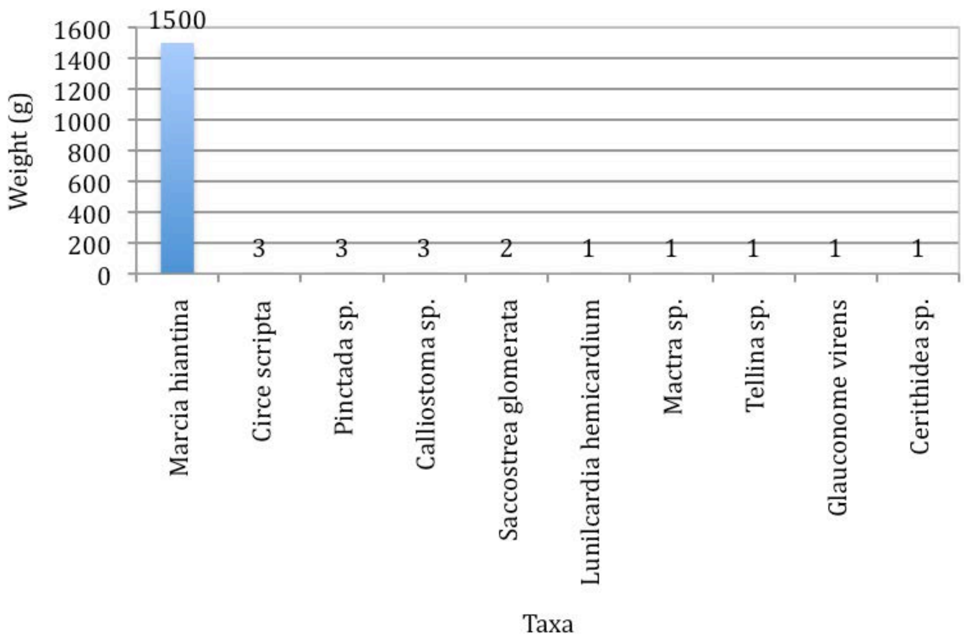


Figure 11.20: Murdumurdu Square B, top 10 mollusc taxa by weight.

The shell deposit in Square B is concentrated between XU3-9 (dated to c.300 cal BP) accounting for 65% of the identified mollusc assemblage based on MNI, suggesting significant use of the site around this time (Figure 11.21). The assemblage exhibits moderate diversity with a calculated Shannon-Weaver Index of 2.85 while 90% of the assemblage comprises three species. The high presence of hiant venus clams suggests foraging strategies focused on the intertidal sand-mud flats (see Figures 11.7-11.8).

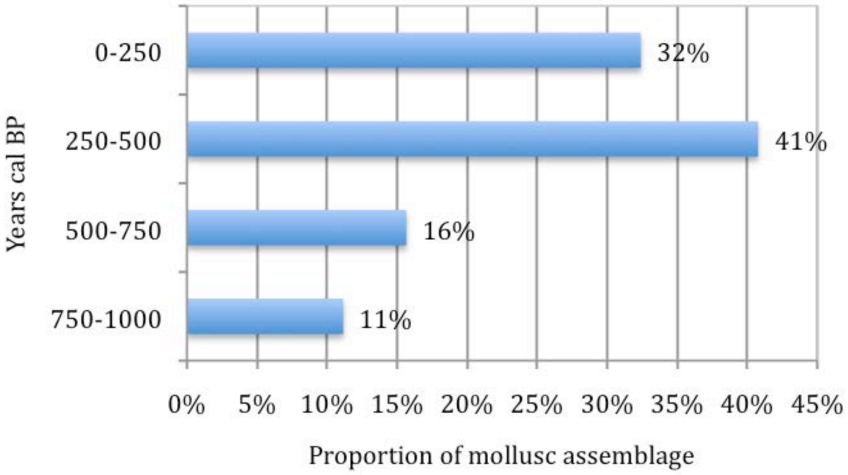


Figure 11.21: Proportion of total Square B mollusc assemblage MNI per 250-year period.

Table 11.8: Murdumurdu Square B molluscan assemblage taxa MNIs.

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Species Totals**
MARINE BIVALVIA																					
Arca ventricosa	1																				**1**
Asaphis violascens																		1			**1**
Beguina semiorbiculata	1																				**1**
Cardiidae																	1				**1**
Chama sp.													1								**1**
Circe scripta			1		2	1		2		2			2				1	1			**12**
Corbula fortisulcata															1						**1**
Lunulicardia hemicardium						1						1			1			1			**4**
Mactra sp.	1															1					**2**
Marcia hiantina	2	2	10	28	63	44	54	32	5	1	1	1	1	1							**245**
Pinctada sp.	1																				**1**
Saccostrea glomerata														1		1	1	1			**4**
Tellina sp.									1			1									**2**
MARINE GASTROPODA																					
Calliostoma sp.	2	6	6	6	7	10	4	7	6	6	5	7	11	4	7	7	11	14	13	14	**153**
Cerithidea sp.				5	4				1		1		4					2		1	**18**
Clypeomorus sp.				1																	**1**
Nassarius sp.																				1	**1**
Patellidae								1			3		3				2	1	2		**12**
Rhinoclavis sp.				2		1				1					1						**5**
XU Totals	**8**	**8**	**17**	**42**	**76**	**57**	**58**	**42**	**13**	**10**	**10**	**10**	**22**	**6**	**10**	**9**	**16**	**21**	**15**	**16**	**466**

Table 11.9: Murdumurdu Square B molluscan assemblage taxa weights (g).

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
MARINE BIVALVIA										
Arca ventricosa		0.02								
Asaphis violascens										
Beguina semiorbiculata	0.05									
Cardiidae						0.05			0.01	
Chama sp.										
Circe scripta			0.13		1.02	0.10		0.54		0.37
Corbula fortisulcata										
Glauconome virens										
Lunulicardia hemicardium						0.15				0.30
Mactra sp.	0.01	0.40	0.16							
Marcia hiantina	15.33	27.41	51.48	179.59	354.64	236.01	387.00	194.17	31.56	9.03
Mytilidae										
Pinctada sp.					2.84					
Saccostrea glomerata			0.39				0.23			
Tellina sp.							0.47		0.43	
MARINE GASTROPODA										
Calliostoma sp.	0.07	0.10	0.12	0.11	0.16	0.27	0.06	0.12	0.11	0.06
Cerithidea sp.				0.10	0.03				0.09	
Clypeomorus sp.				0.18						
Nassarius sp.										
Patellidae								0.02		
Rhinoclavis sp.				0.01		0.07				0.12
Unidentified shell	13.84	14.25	25.93	27.38	27.85	27.29	31.38	33.77	33.95	25.90
XU Totals	**29.30**	**42.18**	**78.21**	**207.37**	**386.54**	**263.94**	**419.14**	**228.62**	**66.15**	**35.78**

Table 11.9: Murdumurdu Square B molluscan assemblage taxa weights (g) (cont).

Taxon XU	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Species**
MARINE BIVALVIA											
Arca ventricosa											**0.02**
Asaphis violascens								0.35			**0.35**
Beguina semiorbiculata											**0.05**
Cardiidae							0.05	0.20			**0.31**
Chama sp.			0.26								**0.26**
Circe scripta			0.34			0.06	0.31	0.10	0.05		**3.02**
Corbula fortisulcata					0.07						**0.07**
Glauconome virens			0.63								**0.63**
Lunulicardia hemicardium		0.56			0.12			0.08			**1.21**
Mactra sp.						0.07	0.45			0.09	**1.18**
Marcia hiantina	3.65	3.82	1.03	2.42	0.54	0.23	0.43	0.21	1.09		**1499.64**
Mytilidae											**0.00**
Pinctada sp.											**2.84**
Saccostrea glomerata				0.28		0.07	0.28	0.29			**1.54**
Tellina sp.		0.05									**0.95**
MARINE GASTROPODA											
Calliostoma sp.	0.05	0.19	0.25	0.10	0.10	0.14	0.24	0.19	0.19	0.19	**2.82**
Cerithidea sp.	0.04		0.10					0.01		0.02	**0.39**
Clypeomorus sp.											**0.18**
Nassarius sp.										0.01	**0.01**
Patellidae	0.01		0.05				0.02	0.03	0.06		**0.19**
Rhinoclavis sp.					0.05						**0.25**
Unidentified shell	21.67	24.52	29.04	14.86	33.00	38.91	39.74	27.11	18.51	25.46	**534.36**
XU Totals	**25.42**	**29.14**	**31.70**	**17.66**	**33.88**	**39.48**	**41.52**	**28.57**	**19.90**	**25.77**	**2050.27**

11.8.2 Vertebrate Remains

Square A

Small numbers of fish bones (n=58) were recovered from the upper nine XUs of the Square A deposit, comprising the only vertebrate remains (1.44g) in Square A (Table 11.10). Most of the bone material was highly fragmented and little could be identified to taxon beyond Osteichthyes (bony fishes). The MNI of two was calculated by summing the MNI for each excavation unit. Identified taxa include grass emperor (*Lethrinus laticaudis*) and wrasse (Labridae). Based on comparison with a grass emperor otolith in the TARL Fish Reference Collection specimen that measures 9.5mm and weighs 400g, the specimen from XU5 that measures 11mm is estimated to come from a fish weighing around 450g. Similarly, the wrasse specimen from XU4 that measures 9.0mm is estimated to come from a fish weighing around 350g.

Table 11.10: Fish remains at Murdumurdu Square A.

Sq	XU	Taxon	Element	MNI	NISP	Weight
A	1	Osteichthyes	unidentified		5	0.0456
A	2	Osteichthyes	unidentified		6	0.1244
A	3	Osteichthyes	unidentified		7	0.1195
A	3	Labridae	upgp	1	1	0.0697
A	4	Osteichthyes	unidentified		8	0.2276
A	4	Labridae	upgp		1	0.1414
A	5	Osteichthyes	unidentified		11	0.1963
A	5	*Lethrinus laticaudis*	left otolith	1	1	0.0845
A	6	Osteichthyes	unidentified		10	0.2060
A	6	Labridae	lpgp		1	0.1333
A	7	Osteichthyes	unidentified		1	0.0164
A	8	Osteichthyes	unidentified		3	0.0427
A	9	Osteichthyes	unidentified		3	0.038
			Totals	2	58	1.4454

Square B

As with Square A, only small numbers (n=28) of fish bones were recovered from the upper nine XUs of the Square B deposit, comprising the only vertebrate remains (0.45g) in Square B (Table 11.11). Most of the bone material was highly fragmented and little could be identified beyond Osteichthyes, except for three teeth in XU6 and XU7 representing at least one wrasse (Labridae).

Table 11.11: Fish remains at Murdumurdu Square B.

Sq	XU	Taxon	Element	MNI	NISP	Weight
B	1	Osteichthyes	unidentified		1	0.0090
B	2	Osteichthyes	unidentified		1	0.0273
B	3	Osteichthyes	unidentified		3	0.0318
B	4	Osteichthyes	unidentified		3	0.0468
B	5	Osteichthyes	unidentified		4	0.0717
B	6	Osteichthyes	unidentified		5	0.0857
B	6	Labridae	tooth	1	1	0.0248
B	7	Osteichthyes	unidentified		2	0.0312
B	7	Labridae	teeth		2	0.0342
B	8	Osteichthyes	unidentified		4	0.0774
B	9	Osteichthyes	unidentified		2	0.0099
			Totals	1	28	0.4498

11.9 Application of Models

11.9.1 Diet-Breadth/Prey Choice

Broad patterns in the breadth and diversity of molluscan exploitation at Murdumurdu can be identified using species richness and abundance measures. The species richness graphs show the number of species collected from each habitat per chronological period (Figures 11.22-11.23). The level of species richness by habitat varies between chronological periods. However chi-square results for Square A ($X^2 = 10.90$, d.f. = 8, $p>0.05$) and for Square B ($X^2 = 0.59$, d.f. = 6, $p>0.05$) indicate this variation is not significant.

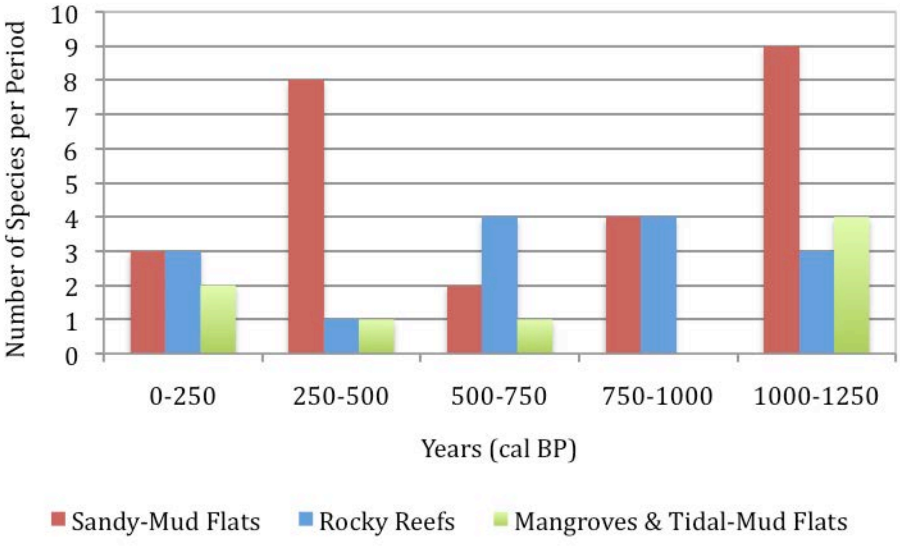


Figure 11.22: Murdumurdu Square A, species richness per habitat per 250-year period.

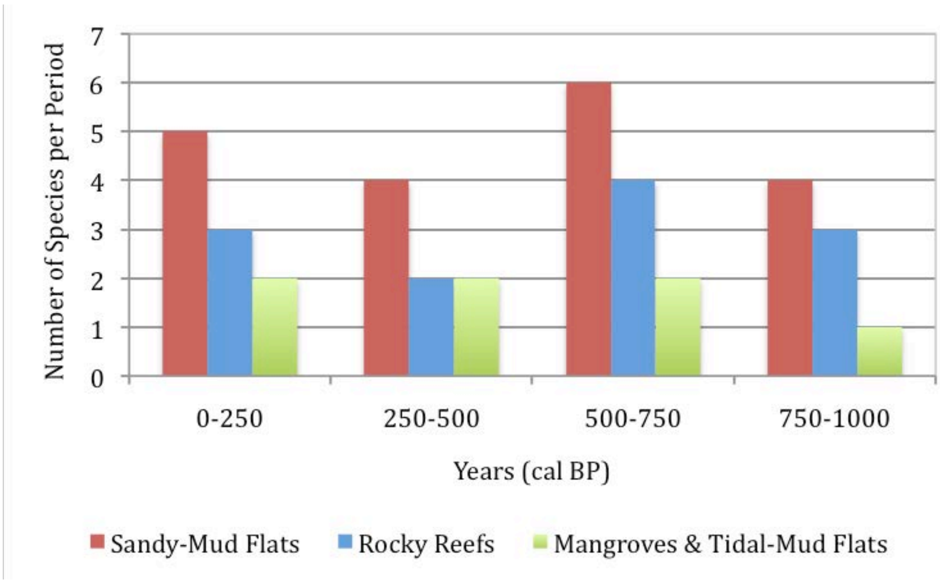


Figure 11.23: Murdumurdu Square B, species richness per habitat per 250-year period.

Based on species richness it appears that several species were collected, except if we look at MNI it is apparent that the majority of the deposit is made up of six species, four of which are common to both Square A and Square B – hiant venus clams (*Marcia hiantina*), top shells (*Calliostoma* sp.), script venus clams (*Circe scripta*) and cerithid snails (*Cerithidea* sp.). Square A also contains high numbers of tumid venus clams (*Gafrarium pectinatum*) (Figure 11.24) while Square B has strong representation of limpets (Patellidae) (Figure 11.25).

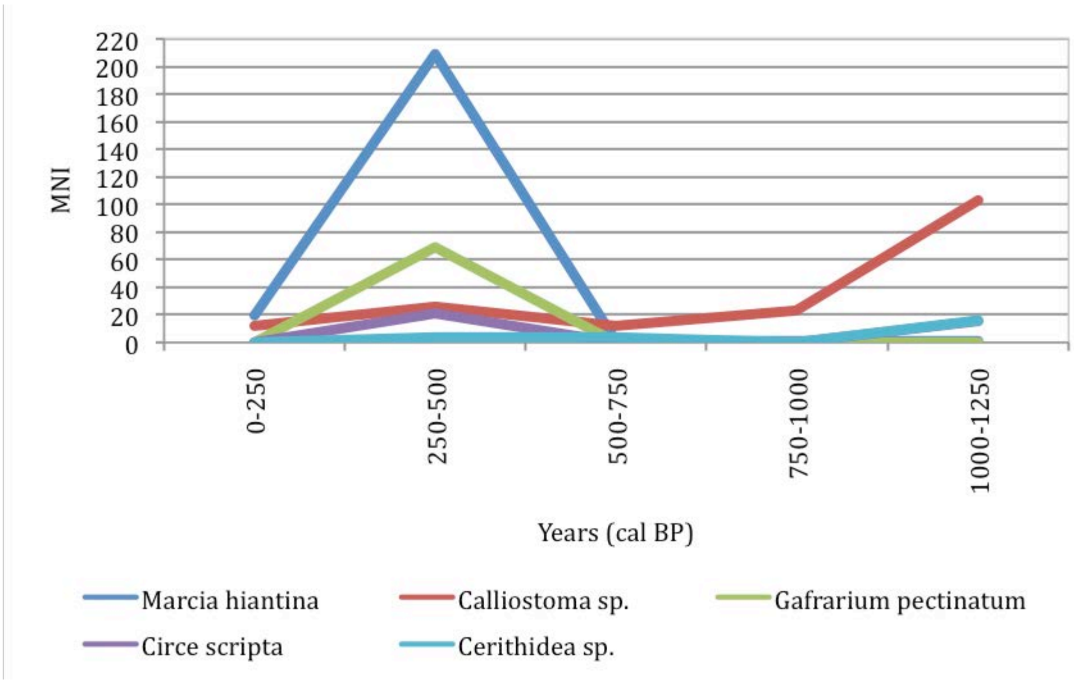


Figure 11.24: Top five mollusc taxa MNI per 250-year period Square A.

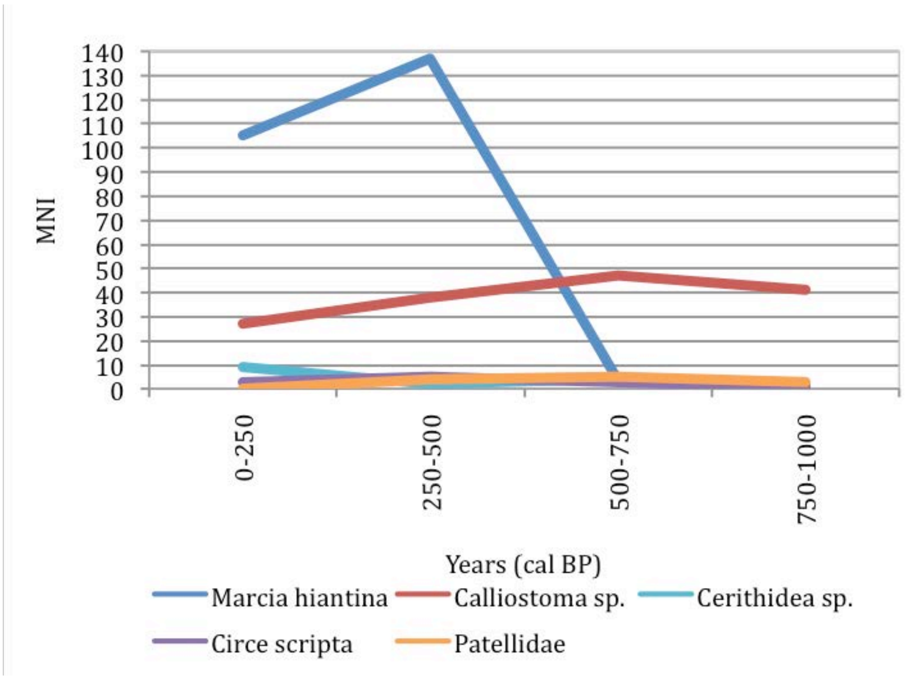


Figure 11.25: Top five mollusc taxa MNI per 250-year period Square B.

The top six species are represented in all 250-year periods although ratios vary. Only Square A has the *G. pectinatum* species that appears to have been popular in the 250-500 year period. *M. hiantina* is the dominant species in both squares, which also peaks with high numbers in the 250-500 year period. *Calliostoma* sp. and *Cerithidea* sp. numbers decline through time as larger taxa become more prevalent in more recent periods. These results suggest that the same species were being foraged from the local area, and also that the diet breadth was quite broad. However, deposits assigned to earlier than 500 BP are considered non-cultural.

Identified vertebrate taxa include grass emperor (*Lethrinus laticaudis*) and wrasse (Labridae). Both these species are demersal and can be found in the coastal shallow waters feeding over sand in and around seagrass beds and coral and rocky reefs. Juvenile grass emperors can also be spotted feeding on mangrove mud flats.

11.9.2 Habitats/Patch Choice

The graphs in Figures 11.26 and 11.27 show the percentage of species MNI by habitat. The Murdumurdu mollusk assemblage includes taxa that come from all three patches or habitats, however there is temporal variance in the quantities of taxa taken from each patch. The chi-square results for Square A (X^2=314.49, d.f.=8, p<0.0001) and Square B (X^2=156.42, d.f.=6, p<0.0001) indicate that this variance is significant.

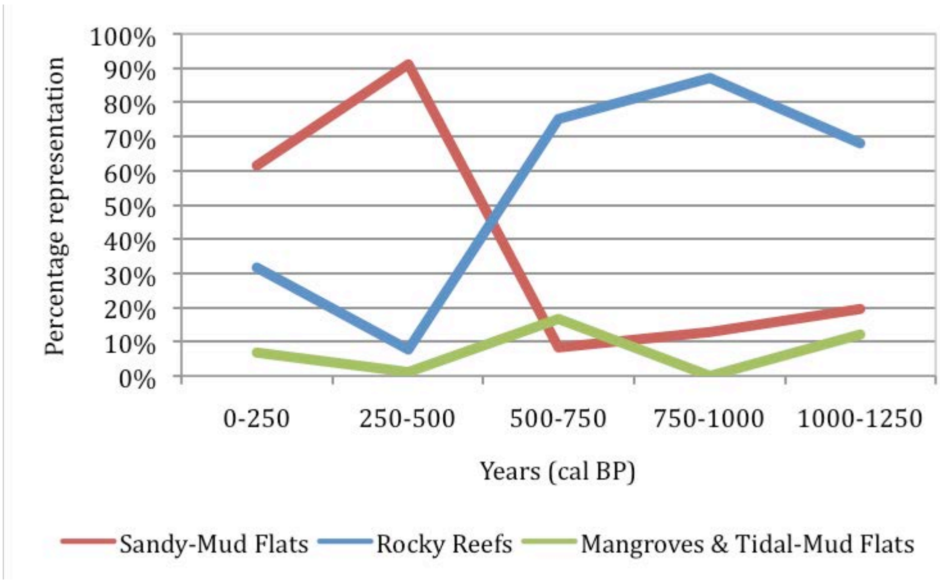


Figure 11.26: Percentage of MNI collected from each patch by 250-year period Square A.

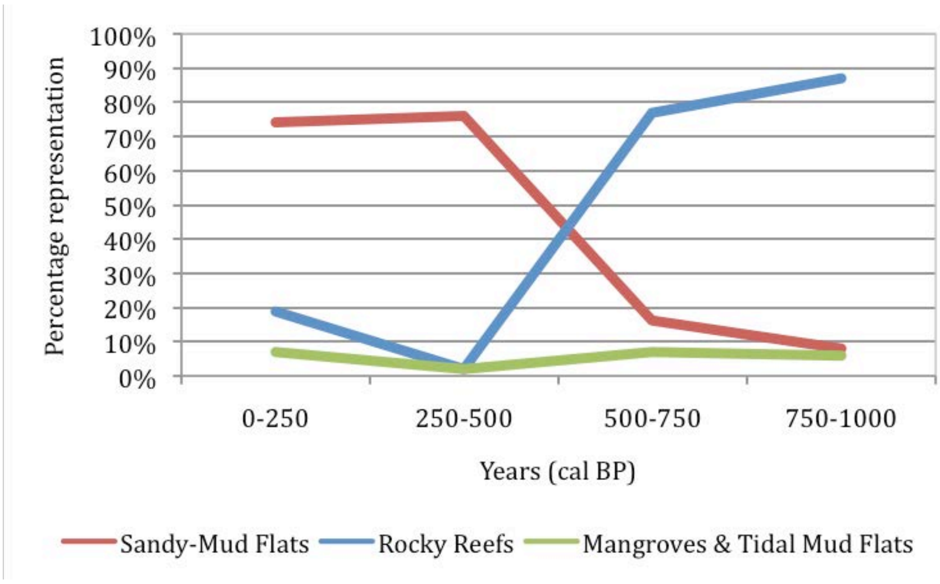


Figure 11.27: Percentage of MNI collected from each patch by 250-year period Square B.

The Rocky Reef taxa naturally deposited during 500-1000 years cal BP contributes 75%-87% of the assemblage for this period. In contrast sandy-mud species contribute only 8%-13% of the assemblage at this time even though there is higher species richness. The Sandy-Mud Flats patch is heavily exploited in the last 250 years. Mangrove-dwelling species are at their highest (17%) between 500-750 yrs however only a limited range of taxa is present. There is a noticeable reversal for the 250-500 year period in the percentages of Rocky Reef species (8%) compared with Sandy-Mud Flats species (91%) indicative of peoples foraging choices.

Changes in patch use between the Rocky Reef patch and Sandy-Mud Flats patches can be tracked through the use of an index (Figure 11.28). The decline in the index indicates that foragers' preference is is for Sandy-Mud Flats taxa over Rocky Reef taxa. The chi-square result (X^2=184.13, d.f.=4, $p<0.0001$) indicates that the decline in Rocky Reef species is significantly correlated with the increase in Sandy-Mud Flats patch species.

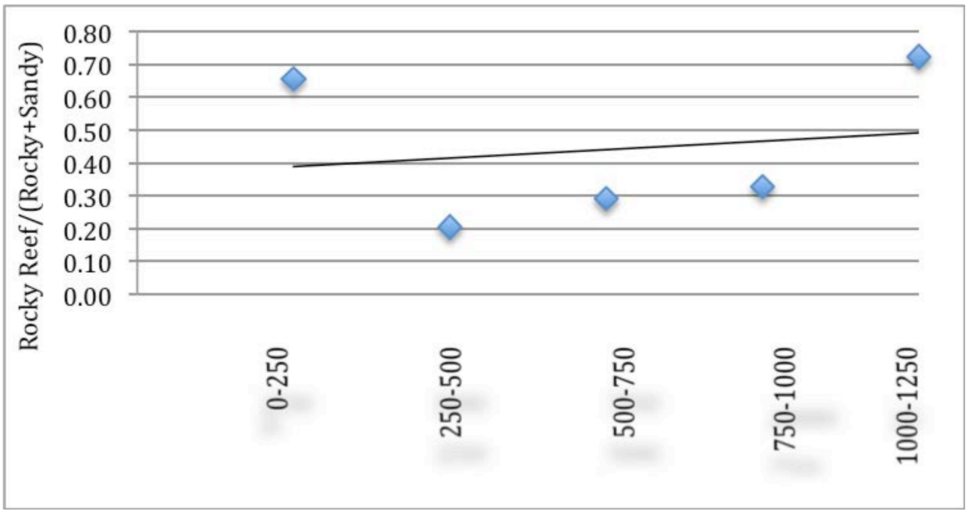


Figure 11.28: Change in patch use as indicated by Rocky Reef/Sandy-Mud Flats Patch Index.

The hiant venus clam, a Sandy-Mud Flats species, is more intensively exploited than other species, particularly in the last 500 years. Not shown on the graph, but of some relevance is the fact that other Sandy-Mud Flat patch species not previously collected in quantity are being exploited in greater numbers at this time too, for example *Gafrarium pectinatum* and *Circe scripta*. From this information we can suggest that there was possibly a changing distribution or decline of Rocky Reef and Mangrove habitats, or foragers chose to intensify exploitation of the Sandy-Mud Flats patch for socio-cultural reasons.

11.9.3 Resource Intensification and Foraging Efficiency

At Murdumurdu low values of high-ranked taxa occur before 500 years ago, suggesting there may have been a low-level cultural occupation prior to this time. As most of the high-ranked taxa are predominantly found in the Sandy-Mud Flats patch an alternative explanation is that this habitat may have had limited productivity prior to 500 years ago or there was a definite change in forager's exploitation patterns. At this site, we see that the hiant venus clam is the most prevalent taxon in the assemblage and based on the prey choice model, it is classed as a high-ranked taxon.

When reviewing the relationship between the hiant venus clam MNI and specimen sizes for each period, there is a decrease in hiant venus clam MNI quantities through time matched by an increase in mean valve length (Table 11.12; Figure 11.29). This may suggest a relationship exists between these variables, however without further definitive dates it is difficult to know if this reflects foraging efficiency in the Sandy-Mud Flats patch or forager's cultural choice or if this reflects lower occupation numbers in more recent times.

Table 11.12: Metrical data for *M. hiantina* valves from Murdumurdu Squares A and B combined.

XU	Mean (mm)	Median (mm)	S.D. (mm)	Min (mm)	Max (mm)	Range (mm)	No.
2	34.82	34.35	2.98	30.48	38.32	7.84	6
3	34.88	35.24	1.34	33.03	36.36	3.33	7
4	33.42	33.72	2.44	24.73	38.47	13.74	66
5	32.82	32.90	2.23	27.42	38.21	10.79	87
6	33.49	33.10	2.31	29.27	39.32	10.05	51
7	34.58	34.56	3.02	24.97	40.08	15.11	42
8	35.09	35.13	3.06	30.32	41.72	11.40	9
9	31.90	31.90	0.00	31.90	31.90	0.00	1

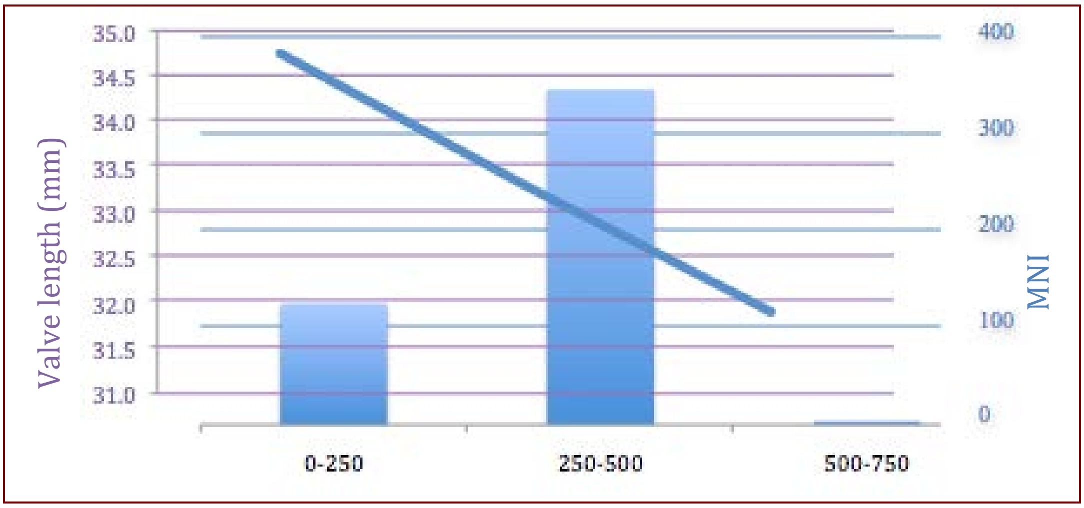


Figure 11.29: Relationship between *M. hiantina* MNI (columns) and mean valve length (mm) per time period.

11.10 Discussion

To best determine temporal changes at the site, the recovered cultural materials have been divided into chronological period intervals of 250 years. This also facilitates comparison with other sites being reviewed for the purpose of establishing spatial and temporal patterns across the study area. ^{14}C radiocarbon dating of the archaeological evidence suggests limited or low-level cultural occupation prior to 500 cal BP. In terms of midden contents the initial 750 years

(500-1250 cal BP) of Murdumurdu reflects a beach-like environment, with 80% of identified taxa species (based on MNI) considered to be non-economic species found to be naturally deposited in coastal dunes and chenier ridges via aeolian or wave processes. Further the low values of high-ranked taxa (e.g. *Marcia hiantina, Gafrarium pectinatum*) before 750 cal yrs BP, suggests there was limited cultural occupation prior to this time.

Based on the reduction in MNI during 0-250 cal BP we can suggest that people used Murdumurdu less intensively in more recent times. There does not appear to have been any adverse effects on intensive exploitation of M. *hiantina*, although if foragers had continued to intensively target this species resource depression may have occurred temporarily or permanently impacting *M. hiantina* populations. The assemblage exhibits moderate diversity with a calculated Shannon-Weaver Index of 2.74 while 91% of the assemblage comprises five species. The majority of cultural shell was recovered from between XU3-7 in Square A and XU3-8 in Square B, which indicates the main cultural use of Murdumurdu occurred during 250-500 cal BP (Figures 11.18-11.19). When percentages from the two squares are combined, we see that almost half the total assemblage based on MNI was deposited during this period. Variation in the intensity of shell deposition could indicate either short-term fluctuation in local resource availability, an increased need for shellfish, or both. The molluscan evidence from both squares indicates that foragers intensively focused on Sandy-Mud Flat species at this time, particularly exploiting the hiant venus clam and tumid venus clam. Species intensification occurs in conjunction with diversification.

Overall there is a noticeable decline in mangrove and rocky reef species – a pattern that reflects long-term coastline alteration (Faulkner 2006; Bourke *et al.* 2007). A decrease in mangrove and rocky reef species is also reported from Myaoola Bay, NT, which Faulkner indicates is due to environmental processes that affected species availability. Other archaeological research in the Gulf of Carpentaria at Mornington Island and Groote Eylandt provides evidence for more intensive use of sites post-500 cal BP with middens containing a diversity of species from sand-mud shellbeds in the immediate site environments. Rosendahl *et al.* (2014) and Clarke (1994) suggest this is the result of a possible strategy designed to provision larger groups of people camped at one location for longer periods of time. Still, it is perplexing that there are limited taxa numbers and diversity from the mangroves and tidal-mud flats habitat, particularly when we take into account that Murdumurdu is only metres away from Marralda Swamp that exhibited mangrove-like environmental conditions from 500 years ago until recently (Moss *et al.* 2015). However, Murdumurdu is only one place in a broad landscape exhibiting similar attributes and people likely camped in different locations along the ridge systems between Marralda Swamp.

11.11 Summary

Excavations at Murdumurdu revealed a 30cm-40cm thick deposit of reasonably dense cultural deposit with shell, bone and charcoal, resting on degrading beach sands. Occupation of the site peaks during the period 250-500 cal BP, continuing to the present albeit on a lesser scale. Molluscs were foraged from three main habitats – Sandy-Mud Flats, Rocky Reefs and Mangroves and Tidal-Mud Flats – in varying quantities and proportions over the time the site was occupied. Fish were likely caught using spears in the near-shore shallow waters. Although we cannot conclusively determine if the results at Murdumurdu reflect environmental changes impacting resources or if they are more indicative of hunter-gatherer foraging choices, based on data presented for Murdumurdu and other Wellesley Islands sites it appears that people were preferentially selecting resources from clear waters and Sandy-Mud Flats.

Chapter 12. Wardilmiru, Fowler Island

12.1 Introduction

Archaeological investigations at Wardilmiru on the east coast of Fowler Island indicate deposition of cultural materials at the site occurred from around 900 years ago. This chapter describes the Wardilmiru site and its stratigraphy, chronology and contents followed by a discussion of the findings from an OFT perspective for understanding foraging behaviours of the site users.

12.2 Site Description and Setting

The Kaiadilt site of Wardilmiru as noted on Tindale's (1960) Native Place Names Map was recorded by Sean Ulm during a thorough, systematic pedestrian survey covering 100% of Fowler Island in 2012. The shell midden is intermittently exposed for 300m covering a minimum area of approximately 3000m^2 along the top of an NNE-SSW trending sand dune on the southeast coastline of Fowler Island (Latitude: 17.121780S, Longitude: 139.555480E) (Figures 12.1-12.2). Shell midden material is deflating from the exposed eastern margin of the sand dune however the upper part towards the dune crest appears reasonably intact.

Fowler Island is composed of labile sandstone in the north and a rocky platform along the east coast. Sandy/shelly beach ridges make up the remaining terrain that is elevated up to c.8m in places. Across the sandy ridges and plateau, vegetation is predominantly coast spinifex grasses (*Spinifex longifolius*) and thick tussock grasses (*Themeda australis*). Inland some 100m from the site is a freshwater swamp supporting a mixture of *Melaleuca* and *Pandanus* forest and includes *Typha* and spike-rush corms of *Eliocharis dulcis*, known in Kayardild as *damuru* (see Evans 1992:88). Substantial low-height mangrove forests occur to the southwest of the site with vegetation consisting of mainly *Exoecaria* and *Avicennia marina* (Figure 12.3). Mangrove and Tidal-Mud Flat species are well represented in the midden (e.g. *Telescopium telescopium*, *Terebralia sulcata*, *Cerithidea* sp., *Rhinoclavis* sp.).

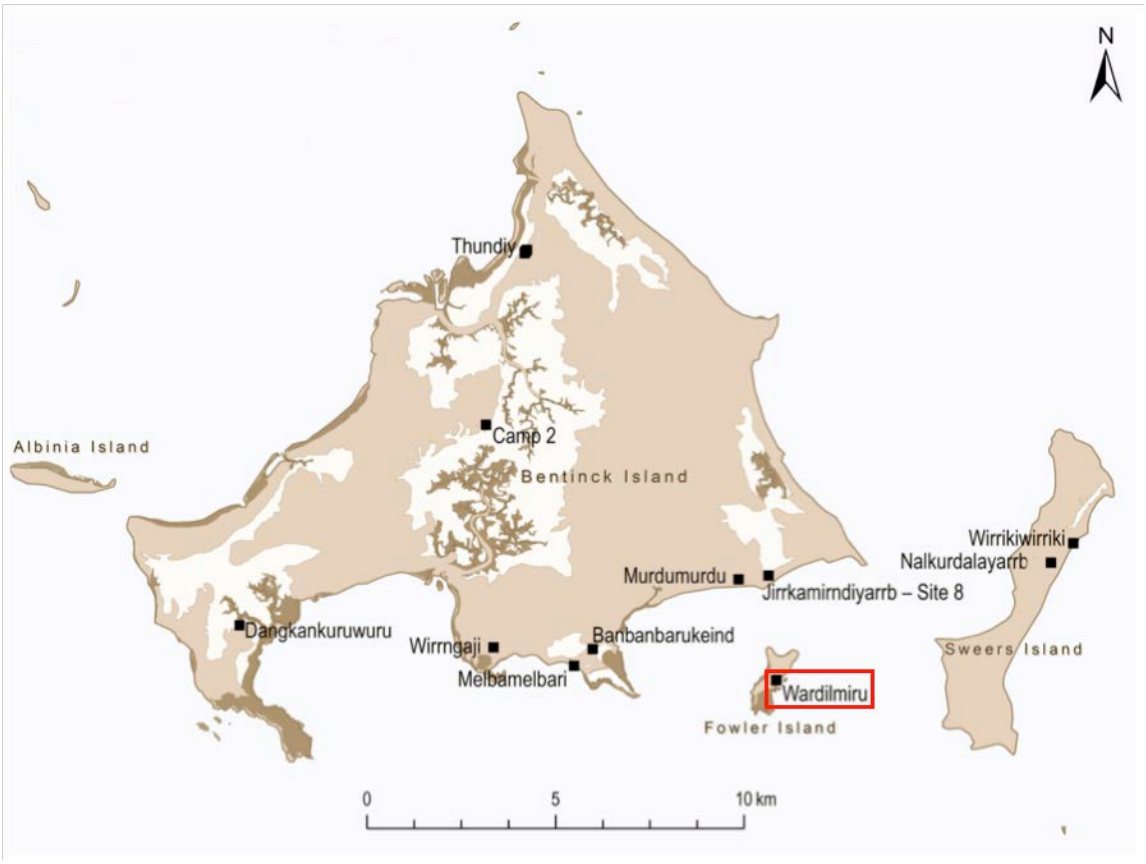


Figure 12.1: Map of South Wellesley Islands showing Wardilmiru site location (map prepared by Lincoln Steinberger and Sean Ulm).

Figure 12.2: Aerial view of Fowler Island showing Wardilmiru (after Google Earth).

The eastern half of the island is surrounded by extensive rock and reef platforms (Figure 12.3) that support several small gastropod species (e.g. *Calliostoma* sp., *Planaxis sulcatus*), limpets (Patellidae) and small mussels (Mytilidae). The intertidal sandy-mud flats along the western and northern shorelines of Fowler Island support the hiant venus clams (*Marcia hiantina*), which are dominant species found in the midden (Figure 12.4). Few oysters have been found in the Wardilmiru midden (Figure 12.6). A native well or soak is located at the southwest end of the site and there are also numerous discrete scatters of mudshell (*Geloina erosa*) throughout the swale between the sand dune and mangrove vegetation, which fringe the shoreline to the southwest (Figure 12.7). Figure 12.8 shows the location of Wardilmiru in relation to resource habitats.

Figure 12.3: General location view south showing Mangroves and Rocky Reef Platform.

Figure 12.4: View east toward Sweers Island showing Sandy-Mud Flats.

Figure 12.5: View toward Bentinck Island showing Rocky Reefs and fishtrap in centre.

Figure 12.6: Excavations at Wardilmiru Square B on ridge. Mangroves and Tidal-mud Flats in background.

Figure 12.7: Native well/soak located at the southwest end of the midden site (Photo by Sean Ulm).

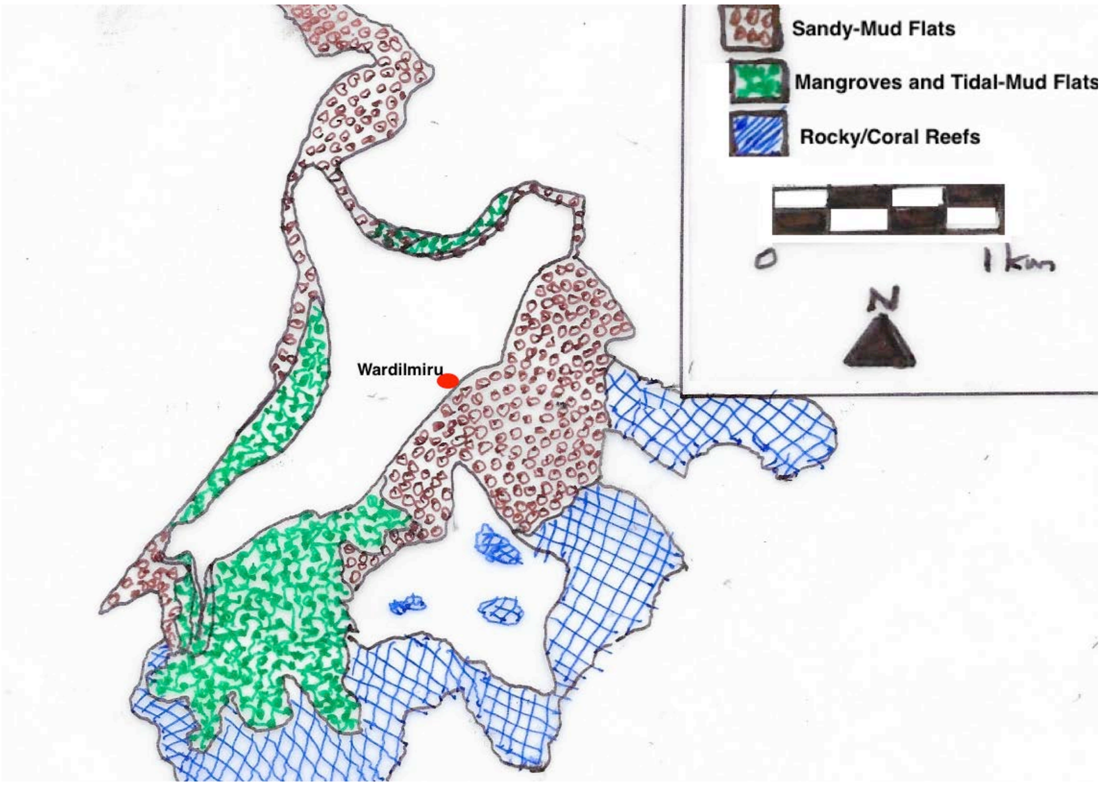


Figure 12.8: Resource habitat communities near Wardilmiru.

12.3 Excavation Methods

In 2012, a team of archaeologists under the direction of Sean Ulm excavated 407.7kg of midden materials from two 50cm x 50cm (Square A and Square B) pits dug 10m apart along the crest of an NNE-SSW oriented sand dune ridge on the east coast of Fowler Island (Figure 12.9). Excavations proceeded in shallow, arbitrary excavation units averaging 3.0cm in depth and 10kg in weight. Excavations ceased at c.59cm and c.60cm below the ground surface respectively in Square A and Square B. All midden materials were dry sieved through 2.3mm mesh on site and materials retained in the sieve were bagged for later sorting and identification in the laboratory (see Chapter 6 for a detailed discussion of the standard excavation and laboratory methods employed at all sites).

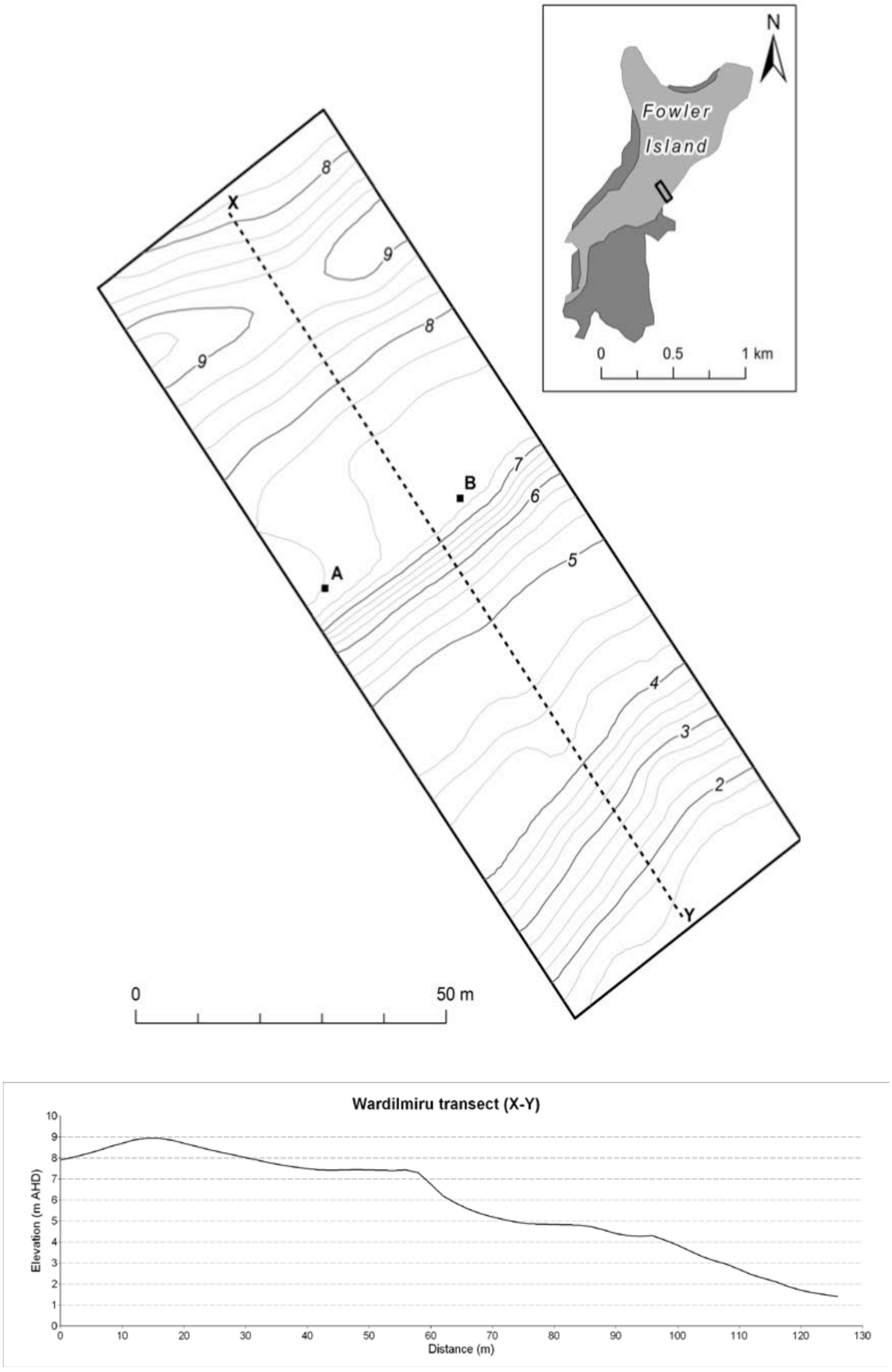


Figure 12.9: Contour map showing dune profile and location of Square A and Square B Wardilmiru (map prepared by Lincoln Steinberger and Sean Ulm).

12.4 Cultural Deposit and Stratigraphy

Excavations revealed a 35cm-40cm thick deposit of reasonably dense cultural deposit with shell, bone and charcoal, resting on degrading beach sands (Figures 12.10 and 12.11). The majority of cultural shell was recovered in Square A from between XU4-12 (c.7.5cm-35cm depth) and in Square B from XU4-14 (c.9.8cm-42.5cm). The deposit can be divided into three stratigraphic units (SUs). SUI is a disturbed layer of fine aeolian brown sands containing a relatively high density of cultural materials, located between XU1 to XU9 (Square A) and XU1 to XU8 (Square B). SUII is a transitional unit of mixed sediments from SUI and SUIII that still contains cultural materials located between XU10-13 (Square A) and XU9-14 (Square B). SUIII has coarse brown sands, numerous tiny gastropods and shell grit that represents sand-dune base, which contains sparse quantities of cultural materials that are not *in situ* and have likely filtered down from the upper midden layers (Figures 12.12-12.13; Table 12.1).

Figure 12.10: Wardilmiru Square A 50cm x 50cm square excavations (Photo by Sean Ulm).

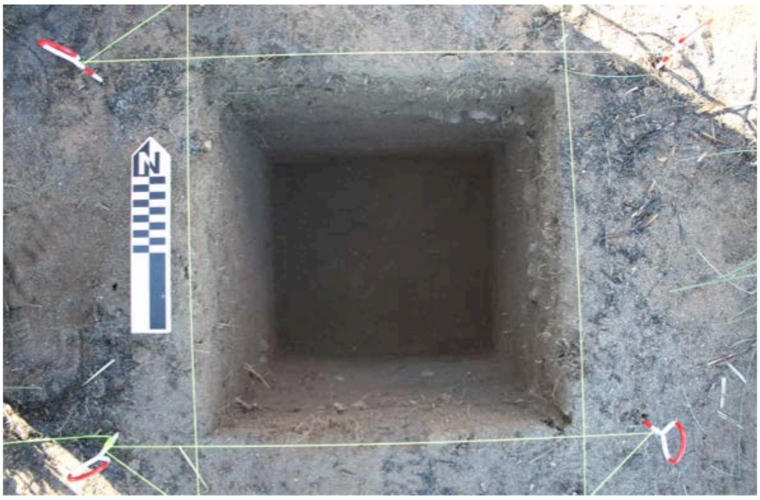


Figure 12.11: Wardilmiru Square B 50cm x 50cm square excavations (Photo by Sean Ulm).

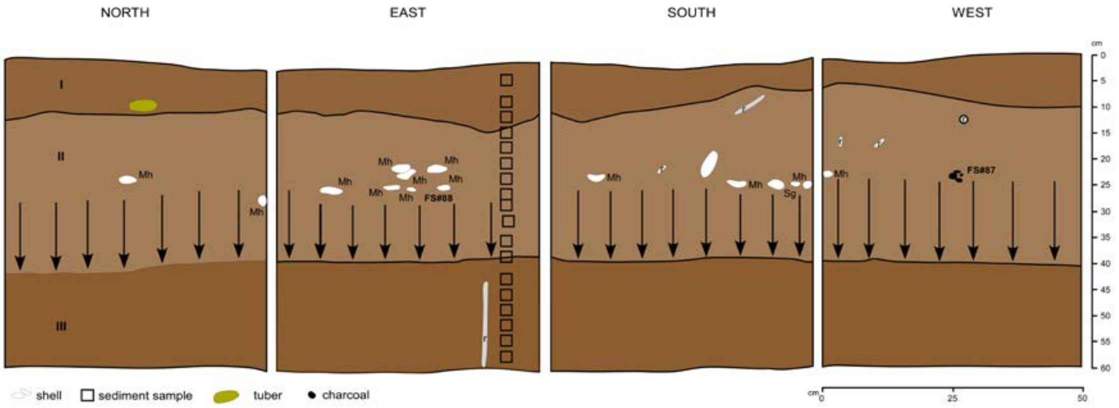


Figure 12.12: Stratigraphic section drawing, Wardilmiru Square A (prepared by Sean Ulm and Michelle Langley).

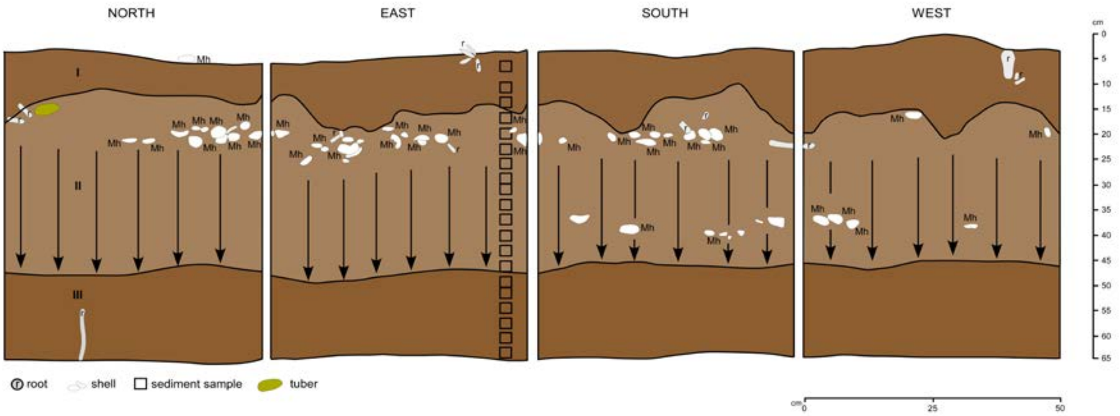


Figure 12.13: Stratigraphic section drawing, Wardilmiru, Square B (prepared by Sean Ulm and Michelle Langley).

Table 12.1 Stratigraphic Unit (SU) descriptions, Wardilmiru, Squares A and B.

SU	Description
I	SUI extends across both squares to a depth of 26cm in Square A and up to 24cm in Square B below the surface. There are numerous spinifex grass roots, small tubers and vine roots in the upper 10-15cm. The unit comprises angular to subangular loosely consolidated coarse brown (7.5YR-4/3) sands. Some evidence of insect disturbance with small burrows present. Cultural materials include charcoal pieces, mud crab exoskeleton fragments, baler shell (*Melo amphora*), fragments of longbum (*Telescopium telescopium*) and whole and fragmented venus clams (*Marcia hiantina*). pH values are highly alkaline (8.5-10.0). Shell materials appear to be reasonably well-preserved.

SU	Description
II	Transitional unit grading from brown (7.5YR-4/3) fine sands to lighter-toned brown (7.5YR-5/4) loosely consolidated coarse sands. There are fewer roots but numerous and larger insect burrows. The shells found in this unit are cultural in origin, but are likely to have been affected by insect bioturbation and other taphonomic factors (e.g. downward growth of roots) that caused the shell to move down the deposited sediments. In Square A SUII is between 26cm to 38cm below the surface. In Square B SUII is between 24cm to 44cm below the surface. pH values are highly alkaline (9.0).
III	Very loosely consolidated coarse brown (7.5YR-5/4) sands in both squares. In Square A SUIII is between 38cm to 58cm below the surface. In Square B SUIII is between 44cm to 60cm below the surface. The unit contains plentiful shell grit and small gastropods, including *Cerithidea* sp. and *Rhinoclavis* sp. The layer is for the most part culturally sterile with any fragments of shell having filtered down the deposited sediments. pH values remain highly alkaline (9.0-9.5).

12.5 Site Integrity and Taphonomy

The deposit exhibits reasonable stratigraphic integrity. There is a predictable shell decay profile with highly weathered tiny gastropod specimens recovered from the lower XUs of the deposit and relatively well-preserved specimens from the upper deposit. A pattern of low-level shell fragmentation (c.170 fragments per 100g of shell) in the units that correlate with the period of cultural deposition contributed to high rates of identification (see Hoffman 2011). This contrasts with high/increased shell fragmentation (c.900 fragments per 100g of shell) and consequently low rates of identification in deeper and older units. Large quantities of tiny gastropod specimens (<2mm) are also present that have most likely been blown or washed into the site. Unfortunately, identification of vertebrate remains has been hampered due to bones being heavily fragmented throughout all units. Numerous small insect burrows suggest moderate insect activity within the pits indicating minor taphonomic disturbance of the midden from insects. Roots have penetrated quite deep as well causing minor taphonomic disturbance of midden materials. Therefore small quantities of cultural shell fragments are likely to have filtered down through the transition unit into the lowest SU.

12.6 Radiocarbon Dating and Chronology

Four radiocarbon determinations have been obtained for the deposits at Wardilmiru. All dates were obtained from *Marcia hiantina* specimens – one from Square A, two from Square B and one from a *Marcia hiantina* lens encountered in an auger hole 15-20cm below ground surface on the ridge immediately west of Squares A and B. This sequence of dates indicates the site has been used for approximately 900 years.

Table 12.2: Radiocarbon ages on marine shell from Wardilmiru Squares A and B. Calibrations undertaken using OxCal v.4.1 (Bronk Ramsey 2009) and Marine13 calibration datasets (Reimer *et al.* 2013). For marine samples a ΔR of −49±102 as recommended by Ulm *et al.* (in prep.) is employed.

Sq	XU	Lab. Code	Depth (cm)	Specimen	^{14}C	δ^{13}C	Calibrated Age BP (95.4%)	Calibrated Age BP Median
B	5-6	Wk-34781	14-16	*M. hiantina*	431±25	0.3±0.2	0*-296	132
A	9	Wk-34773	22.5-25.6	*M. hiantina*	637±25	0±0.2	73-505	326
B	11	Wk-34775	30.7-33.6	*M. hiantina*	692±32	0.4±0.2	127-549	372
Auger 2	-	Wk-34783	15.0-20.0	*M. hiantina*	1337±25	6.0±0.2	711-1164	934

For the purpose of temporally comparing the data from the Wardilmiru cultural assemblage with other sites in this study I have divided the deposit from each square into temporal phases of 250-year periods. Although it is acknowledged as potentially problematic, in the absence of multiple dates a termination date at the surface has been assumed to date to 0 cal BP. Excavation units have been assigned to chronological periods based on an age-depth model derived from the calibrated radiocarbon age and stratigraphic observations (Figure 12.14; Table 12.3). From this we estimate the main period of cultural site use was between c.250-500 cal BP. Unfortunately without further ^{14}C dates it is not possible to more accurately determine the length of time that Kaiadilit used Wardilmiru. Even though time-averaging these open shell deposits only allows for identification of broad-scale trends and not subtle changes, it allows determination of variation in relative taxa abundance, indicative of taxa exploitation patterns and/or environmental changes affecting the distribution of taxa.

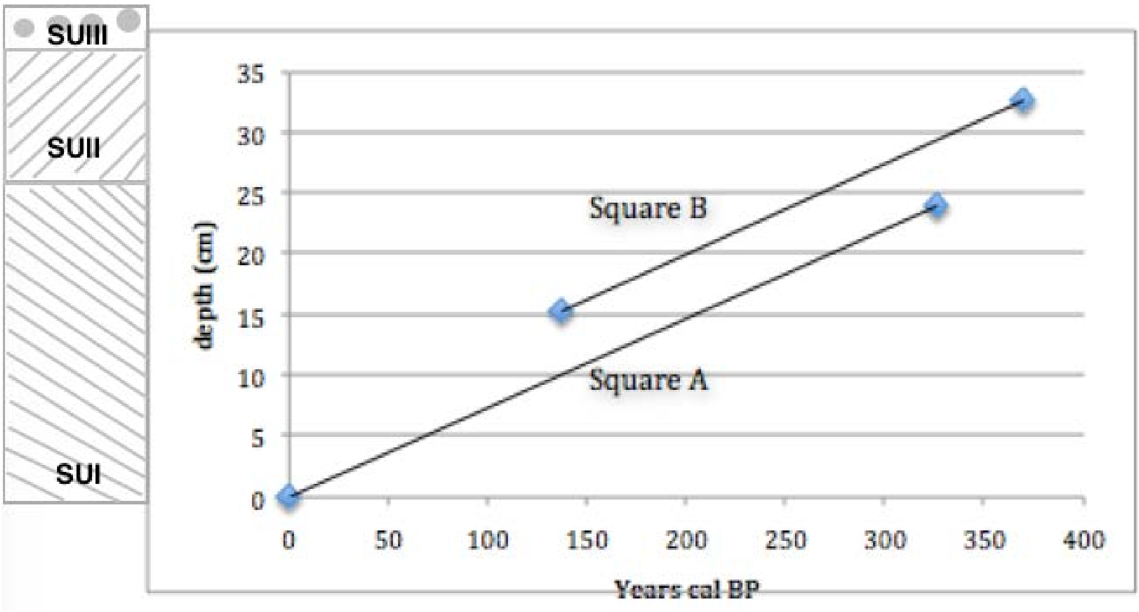


Figure 12.14: Age-depth relationships of radiocarbon determinations for Wardilmiru Squares A and B.

Table 12.3: Temporal phases of 250-year periods, showing allocation of XUs.

Temporal phase	**0-250**	**250-500**	**500-750**	**750-1000**
Square A XUs	1-7	8-13	14-19	20
Square B XUs	1-7	8-13	14-19	20

12.7 Cultural Materials

3984.06g (1.8%) of the retained sediment and materials in Square A and 4,867.93g (2.5%) from Square B were retained for analysis. Tables 12.4 and 12.5 show the overall summary results of the retained materials. Molluscan shell makes up 62.3% (2484.2g) of the Square A assemblage and 70.8% (3447.78g) of the Square B assemblage. Vertebrate bone contributes 0.19% (7.61g) for Square A and 0.01% (0.4g) for Square B. Small quantities of crustacea (38.89g) were recovered from both squares combined, represented by mud crab (*Scylla* spp.) (8.0g) and goose barnacle (Pedunculata) (30.89g). Beach rock, coral and pisolith stones contribute 30.6% of Square A and 22.2% of Square B. Organics make up the rest of the assemblage.

Table 12.4: Summary excavation data and retained materials from Wardilmiru Square A.

XU	Depth Below Surface (cm)	Mean thickness (cm)	Weight (kg)	Vol cm^3	pH	Marine shell (g)	Bone (g)	Barnacles (g)	Crab (g)	Charcoal (g)	Other Organic (g)	Rock Rubble coral (g)	Retained Materials Total (g)	Retained % of Total Midden
1	1.64	1.64	4.5	4100	9.5-10	8.54	0.03	0.12	0	0	83.15	4.65	96.49	2.14%
2	4.58	2.94	8.8	7350	9.5-10	34.39	0.11	0.69	0.54	0.2	16.59	25.7	78.22	0.89%
3	7.42	2.84	8.5	7100	9.5-10	27.04	0.17	0.33	0	0.01	17.57	22.18	67.3	0.79%
4	10.54	3.12	9.5	7800	9.5-10	72.43	0.09	0.48	0	0	28.77	32.53	134.3	1.41%
5	13.34	2.8	9.3	7000	9.5-10	53.17	0	0.57	0.27	0.07	10.46	20.38	84.92	0.91%
6	16.48	3.14	11.8	7850	9.5-10	88.2	0.14	1.15	0.29	0.3	15.92	43.51	149.51	1.27%
7	19.56	3.08	11.2	7700	9.5-10	84.9	1.22	0.83	0.17	1.3	18.24	45.13	151.79	1.36%
8	22.46	2.9	10.8	7250	9.5-10	540.28	1.06	0.31	0.16	12.68	7.08	35.13	596.7	5.53%
9	25.56	3.1	11.5	7750	9.5-10	269.4	0.36	1.52	2.51	4.04	4.34	53.5	335.67	2.92%
10	28.56	3	12	7500	9	69.44	4.27	0.22	0.34	0.3	5.8	47.72	128.09	1.07%
11	31.5	2.94	10.5	7350	9	101.98	0.13	0.59	0	0.1	4.06	61.26	168.12	1.60%
12	34.78	3.28	12.7	8200	9	96.08	0	0.17	0	0.05	2.97	65.73	165	1.30%
13	37.48	2.7	11.2	6750	9	67.72	0	1.68	0.03	0	1.78	66.46	137.67	1.23%
14	40.36	2.88	10.3	7200	9	56.78	0.03	1.66	2.4	0	2.53	35.46	98.86	0.96%
15	43.28	2.92	11.1	7300	9	74.31	0	2.34	0	0	2.89	49.35	128.89	1.16%
16	46.48	3.2	12.5	8000	9	92.16	0	0.39	0	0	0.73	50.84	144.12	1.15%
17	49.48	3	12.2	7500	9	95.04	0	0.24	0.11	0	2.38	82.41	180.18	1.48%
18	52.52	3.04	12.2	7600	9	136.31	0	0.15	0	0	0.83	103.97	241.26	1.98%
19	54.48	1.96	12	4900	9	163.54	0	0.5	0	0	0.82	123.78	288.64	2.41%
20	58.68	4.2	14.1	10500	9.5	352.47	0	2.08	0	0	0.95	252.83	608.33	4.31%
Total:	-	58.68	216.70	146700	-	2484.18	7.61	16.02	6.82	19.05	227.86	1222.52	3984.06	1.84%

Table 12.5: Summary excavation data and retained materials from Wardilmiru Square B.

XU	Depth Below Surface (cm)	Mean Thickness (cm)	Weight (kg)	Vol cm^3	pH	Stone artefacts (g)	Marine Shell (g)	Bone (g)	Barnacles (g)	Crab (g)	Charcoal (g)	Other Organic (g)	Rock Rubble Coral (g)	Retained Materials Total (g)	Retained % of total Midden
1	3.44	3.44	8.8	8600	9	0	15.73	0	0	0.01	0	108.24	6.45	130.43	1.48%
2	6.56	3.12	8.2	7800	9	0	24.32	0.06	0	0	0.42	58.64	11.47	94.91	1.16%
3	9.86	3.3	9.6	8250	9	0	26.82	0	0.34	0	0.05	32.16	14.76	74.13	0.77%
4	12.76	2.9	9	7250	8.5	0	91.25	0	0.48	0.03	0.01	36.15	25.9	153.82	1.71%
5	15.52	2.76	9.4	6900	8.5	0	178.85	0.02	0	0	0	29.62	32.54	241.03	2.56%
6	18.46	2.94	10	7350	9	0	1116.9	0	0	0	0	16.62	28.38	1161.90	11.62%
7	21.8	3.34	10.1	8350	8.5	0	246.53	0	0.93	0.17	0	5.56	42.11	295.30	2.92%
8	24.62	2.82	10.3	7050	9	0	92.25	0	0.9	0.16	0.05	6.27	68.97	168.60	1.64%
9	27.64	3.02	11.5	7550	9	0	111.16	0.03	0	0	0	4.23	58.04	173.46	1.51%
10	30.66	3.02	6.5	7550	9	0	78.48	0	0	0.1	0	1.64	55.66	135.88	2.09%
11	33.62	2.96	10.9	7400	9	0	84.65	0.27	1.75	0	0	3.53	61.48	151.68	1.39%
12	36.58	2.96	9	7400	9	0	231.00	0	0.79	0	0	2.04	48.64	282.47	3.14%
13	39.54	2.96	10.7	7400	9	0	127.67	0	1.02	0	0.14	3.10	72.77	204.70	1.91%
14	42.56	3.02	9.7	7550	9	0	182.71	0	1.53	0.46	0	2.07	74.69	261.46	2.70%
15	45.66	3.1	9.8	7750	8.5	0	107.73	0	0.6	0.04	0	4.28	75.64	188.29	1.92%
16	48.54	2.88	9.7	7200	9	0	88.21	0	2.02	0.20	0	0.81	67.63	158.87	1.64%
17	51.4	2.86	10.6	7150	9	0	133.13	0.02	1.16	0.01	0.02	1.25	106.5	242.09	2.28%
18	54.6	3.2	10.9	8000	9	0	158.18	0	1.48	0	0	1.78	112.66	274.1	2.51%
19	57.52	2.92	7.6	7300	9	0	121.24	0	1.87	0	0	1.06	119.67	243.84	3.21%
20	60.52	3	10.6	7500	9	0	230.97	0	0	0	0	0	0	230.97	2.18%
Total:	-	60.52	192.90	151300	-	0.00	3447.78	0.40	14.87	1.18	0.69	319.05	1083.33	4867.93	2.52%

12.7.1 Invertebrate Mollusc Remains

Square A

2484.18g of shell were recovered from Square A, which represents 62.35% of the total assemblage. 48.7% of all shell by weight was identified to family, genus or species level. This is the lowest rate of identification of all South Wellesley assemblages analysed, which may be indicative of taphonomic processes affecting the site. The remaining 51.3% of shell based on weight could not be identified beyond Mollusca due to the generally small size (<2mm) of these specimens and the lack of diagnostic attributes that prevented identification to taxon. These tiny specimens are highly likely to have been blown into the site and are not considered cultural; this portion of the assemblage is not considered further in analyses presented below. The identified assemblage comprised 21 molluscan taxa weighing 1211.15g (with an MNI=3661) consisting of 10 marine bivalve taxa and 11 marine gastropod taxa (Figures 12.15-12.16). The assemblage is dominated by hiant venus clams (*Marcia hiantina*) (33.7%) with very small gastropods (*Cerithidea* sp., *Rhinoclavis* sp. and *Clypeomorus* sp.) accounting for 10.9% of the total shell assemblage by weight. *Telescopium telescopium* and *Terebralia sulcata* represent 3% of the shell weight. The remaining 15 taxa are relatively rare, each contributing less than 1% of the shell assemblage by weight. Taxa MNI counts and weights per XU are presented in Tables 12.6 and 12.7.

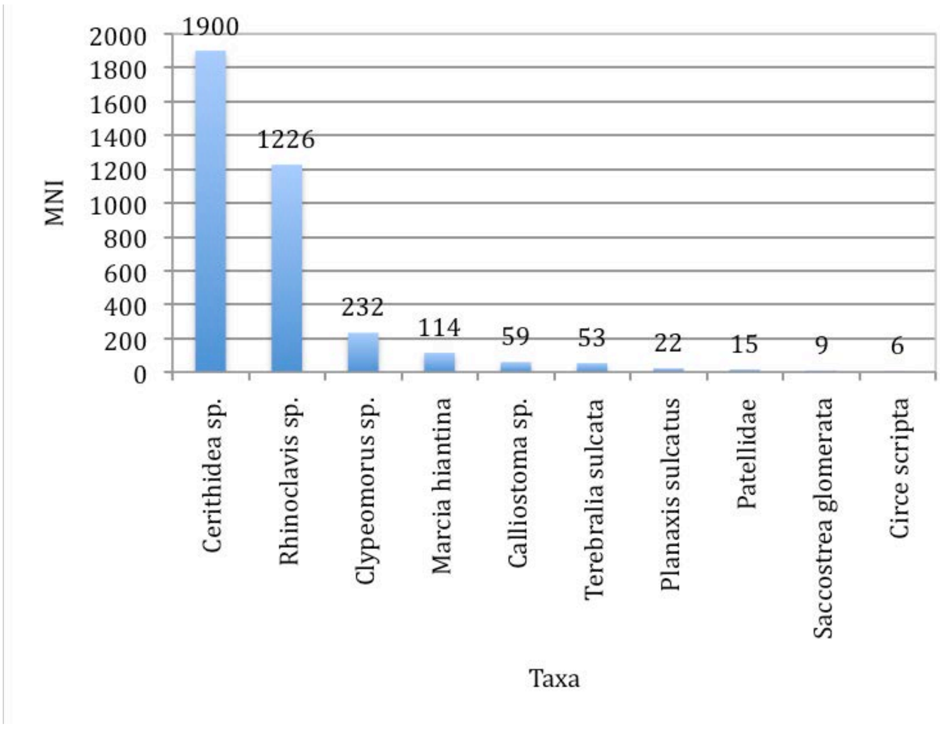


Figure 12.15: Wardilmiru Square A, top 10 mollusc taxa by MNI.

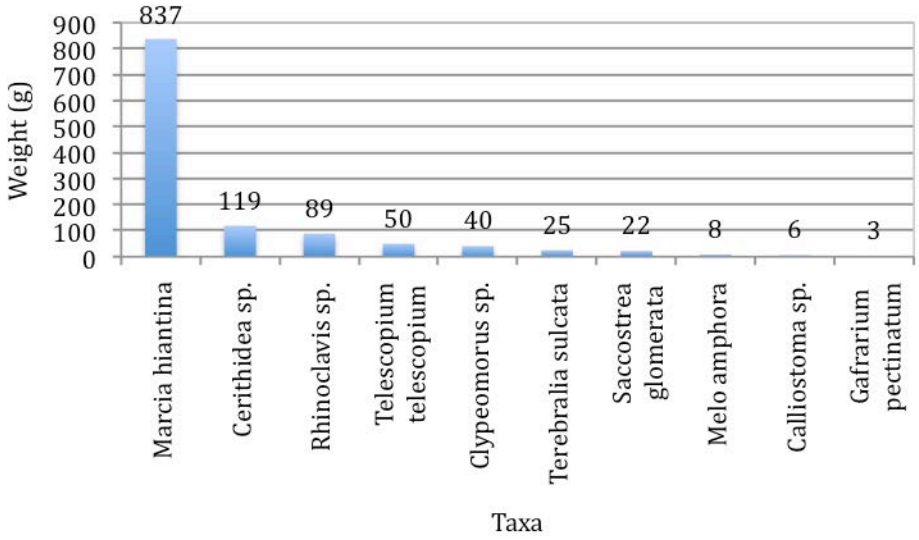


Figure 12.16: Wardilmiru Square A, top 10 mollusc taxa by weight.

The shell deposit in Square A is concentrated in the lower XUs between XU14-20 (500-1000 cal BP) indicating large quantities of natural shells were deposited (63% of the excavated deposit based on weight) on the ridge prior to human occupation. Shell deposited between XU1-13 (0-500 cal BP) represents a mix of cultural and non-cultural materials and accounts for 37% of the assemblage based on weight. The assemblage exhibits reasonably high diversity with a calculated Shannon-Weaver Index of 1.25 while 98% of the assemblage comprises six species. Species more likely to have been foraged for food include *Marcia hiantina,* and *Gafrarium pectinatum* from the Sandy-Mud Flats and *Saccostrea glomerata* from Rocky Reefs (see Figure 12.7).

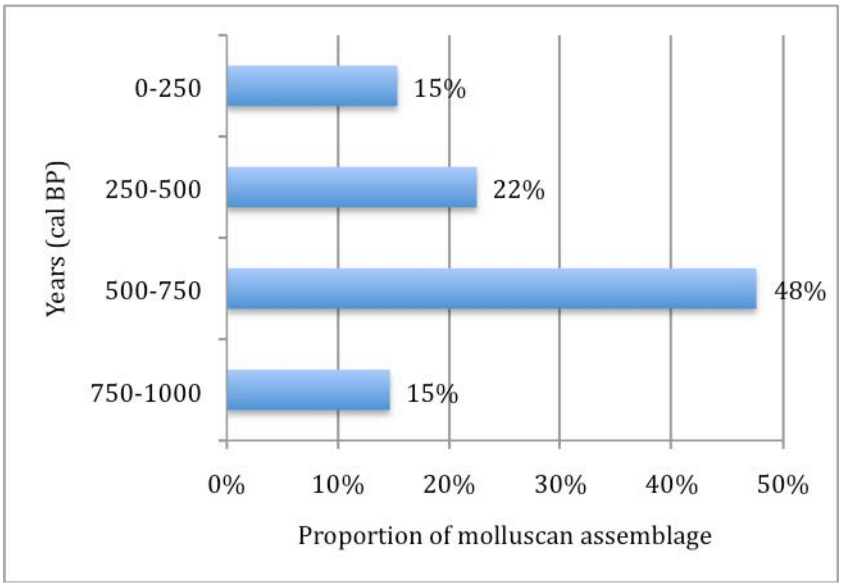


Figure 12.17: Proportion of total Square A mollusc assemblage weight per 250-year period.

Table 12.6: Wardilmiru Square A molluscan assemblage taxa MNIs.

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**1**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Specie**
MARINE BIVALVIA																					
Barbatia sp.	1			1						1											**3**
Circe scripta		2				2		1												1	**6**
Corbula fortisulcata																				1	**1**
Gafrarium pectinatum			1										1							1	**3**
Isognomon isognomon												1									**1**
Marcia hiantina		1		4	1	4	6	66	29	3											**114**
Mytilidae				1		1				1										1	**4**
Saccostrea glomerata					1	2				2										4	**9**
Semele sinensis									1												**1**
Tellina sp.	1							1													**2**
MARINE GASTROPODA																					
Calliostoma sp.	2		1	5	1	3	3	2	3	3	3	4		3		4		4	10	8	**59**
Cerithidea cingulata			3						1						2						**6**
Cerithidea sp.		117	9	1	5	86	61	48	77	85	4	45	55	70	12	13	61	19	28	34	**1900**
Clypeomorus sp.					1	7	4	4	2	7	6	3	6	4	19	3	16	19	5	11	**232**
Littoraria scabra																1					**1**
Mitrella scripta																				2	**2**
Patellidae				2		5				2	3					1	2				**15**
Planaxis sulcatus	1		2	2	1	1	2	2		1		1					2	3	3	1	**22**
Rhinoclavis sp.	3	18	5	6	2	39	35	22	50	45	3	50	46	37	50	88	96	10	15	28	**1226**
Telescopium							1														**1**
Terebralia sulcata					2	2	2	2	1		2	2		4			5	2	3	26	**53**
XU Totals	**37**	**138**	**2**	**34**	**9**	**15**	**11**	**14**	**16**	**15**	**9**	**10**	**10**	**11**	**19**	**23**	**18**	**32**	**46**	**78**	**3661**

Table 12.7: Wardilmiru Square A molluscan assemblage taxa weights (g).

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
MARINE BIVALVIA										
Barbatia sp.	0.36			0.02						0.19
Circe scripta	0.13	0.16				0.13		0.34		
Corbula fortisulcata										
Gafrarium pectinatum			0.07			0.39			0.84	
Isognomon isognomon										
Marcia hiantina	0.48	5.75	1.40	21.75	10.17	31.32	38.13	487.14	208.42	10.35
Mytilidae	0.14			0.01		0.11		0.04		0.05
Saccostrea glomerata	0.29	0.50		0.04	0.89	3.56		0.12	0.47	0.43
Semele sinensis				0.32					2.65	
Tellina sp.	0.10							0.04		
MARINE GASTROPODA										
Calliostoma sp.	0.04		0.01	0.07	0.08	0.23	0.13	0.20	0.24	0.12
Cerithidea cingulata			0.22						0.23	
Cerithidea sp.		3.16	0.69	0.22	2.03	4.18	2.38	1.78	3.31	3.58
Clypeomorus sp.	0.25				2.17	1.22	0.48	0.56	0.39	1.40
Littoraria scabra										
Melo amphora				0.02						
Mitrella scripta				8.14		0.18				0.10
Patellidae										
Planaxis sulcatus	0.11		0.05	0.01	0.08	0.34	0.09	0.13		0.09
Rhinoclavis sp.	0.78	1.22	0.30	0.68	2.07	2.60	1.99	1.40	2.57	2.41
Telescopium telescopium			0.57		2.26		0.33	5.22	1.69	3.29
Terebralia sulcata					0.20	1.32	0.38	1.27	0.31	0.31
Unidentified shell	5.86	23.60	23.73	41.15	33.22	42.62	40.99	42.04	48.28	47.12
XU Totals	**8.54**	**34.39**	**27.04**	**72.43**	**53.17**	**88.20**	**84.90**	**540.28**	**269.40**	**69.44**

Table 12.7: Wardilmiru Square A molluscan assemblage taxa weights (g) (cont).

Taxon XU	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Species**
MARINE BIVALVIA											
Barbatia sp.											**0.57**
Circe scripta										1.60	**2.36**
Corbula fortisulcata										0.38	**0.38**
Gafrarium pectinatum			1.13						0.20	0.79	**3.42**
Isognomon isognomon		0.45									**0.45**
Marcia hiantina	16.67	1.24		3.21	0.75		0.51				**837.29**
Mytilidae							0.18				**0.53**
Saccostrea glomerata		1.21	0.31	0.17		0.30	2.59			11.10	**21.98**
Semele sinensis											**2.97**
Tellina sp.											**0.14**
MARINE GASTROPODA											
Calliostoma sp.	0.09	0.33		0.13		0.22		0.15	1.46	2.66	**6.16**
Cerithidea cingulata	0.12				0.22						**0.79**
Cerithidea sp.	2.23	2.91	2.73	3.26	5.18	8.62	10.06	12.54	22.29	27.60	**118.75**
Clypeomorus sp.	1.04	0.38	1.06	0.33	1.98	0.78	2.77	3.61	1.04	20.92	**40.38**
Littoraria scabra						0.02				0.17	**0.19**
Melo amphora	0.23					0.01	0.05				**0.59**
Mitrella scripta											**8.14**
Patellidae										0.27	**0.27**
Planaxis sulcatus		0.60					0.28	0.38	0.39	0.20	**2.75**
Rhinoclavis sp.	2.10	3.40	2.99	1.57	2.62	4.97	6.77	7.69	12.40	27.97	**88.50**
Telescopium telescopium	26.38	9.89									**49.63**
Terebralia sulcata	1.30	1.24	0.77	0.45	0.06		2.58	1.40	0.53	12.79	**24.91**
Unidentified shell	51.82	74.43	58.73	47.66	63.50	77.24	69.25	110.54	125.23	246.02	**1273.03**
XU Totals	**101.98**	**96.08**	**67.72**	**56.78**	**74.31**	**92.16**	**95.04**	**136.31**	**163.54**	**352.47**	**2484.18**

Square B

In total 3447.78g of shell was recovered from Square B, which represents 70.8% of the total deposit. 62% of all shell by weight was identified to family, genus or species level. The remaining 38% of shell based on weight could not be identified beyond Mollusca due to the generally small size (<2mm) of these specimens and the lack of diagnostic attributes that prevented identification to taxon. Like the tiny gastropod specimens in Square A, these are highly likely to have been blown into the site and are not considered cultural; this portion of the assemblage is not considered further in analyses presented below. The identified assemblage comprised 14 molluscan taxa weighing 1515.91g (with an MNI=3400) consisting of 6 marine bivalve taxa and 8 marine gastropod taxa (Figure 12.18). The assemblage is dominated by hiant venus clams (*Marcia hiantina*), representing 54.6% of the shell assemblage by weight followed by small gastropods (e.g. *Cerithidea* sp., 3.2% and *Rhinoclavis* sp., 2.1%). The remaining 11 taxa are relatively rare, each contributing less than 1% of the shell assemblage by weight. MNI and weight tables are presented in Tables 12.8 and 12.9.

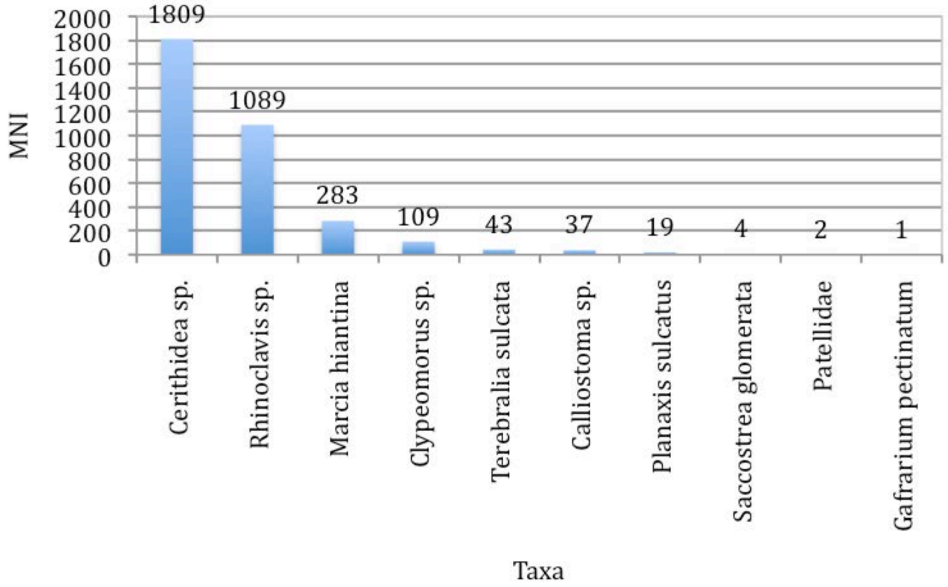


Figure 12.18: Wardilmiru Square B, top 10 mollusc taxa by MNI.

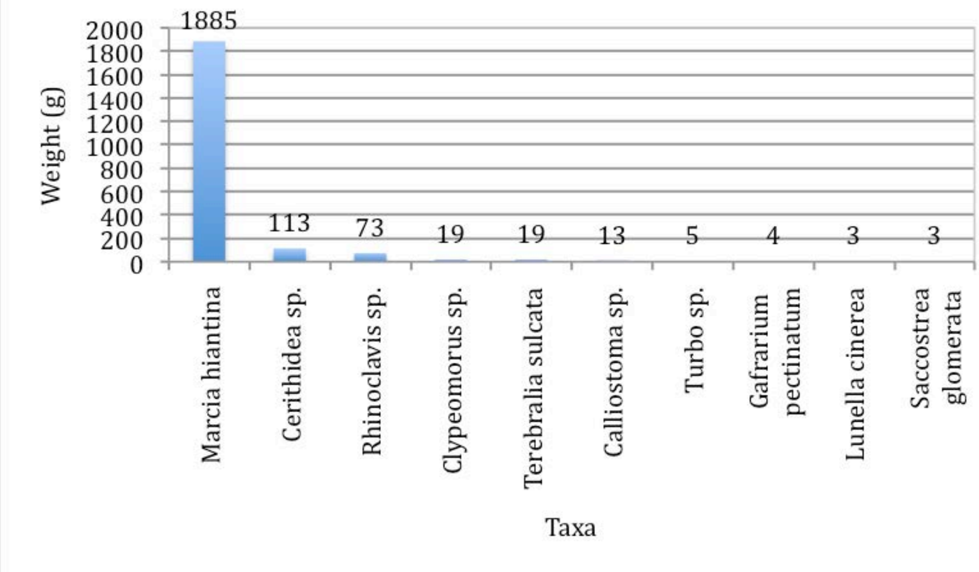


Figure 12.19: Wardilmiru Square B, top 10 mollusc taxa by weight.

Square B XU15-20 (500-1000 cal BP) account for 44% of the assemblage by weight, representing taxa deposited before human use of the site. XU1-14 (0-500 cal BP) accounts for 56% of the identified mollusc assemblage based on weight (Figure 12.20). This suggests that site use focused around the location of Square B due to higher rates of cultural shell deposition than Square A. The assemblage exhibits reasonably high diversity with a calculated Shannon-Weaver Index of 3.23, while 96% of the assemblage comprises four species. The prevalence of *Cerithidea* sp. and *Rhinoclavis* sp. from Tidal-Mud Flats in the upper XUs is probably due to natural processes (e.g. aeolian deposition or storm surges). However it is possible that these may have been collected for a purpose other than diet.

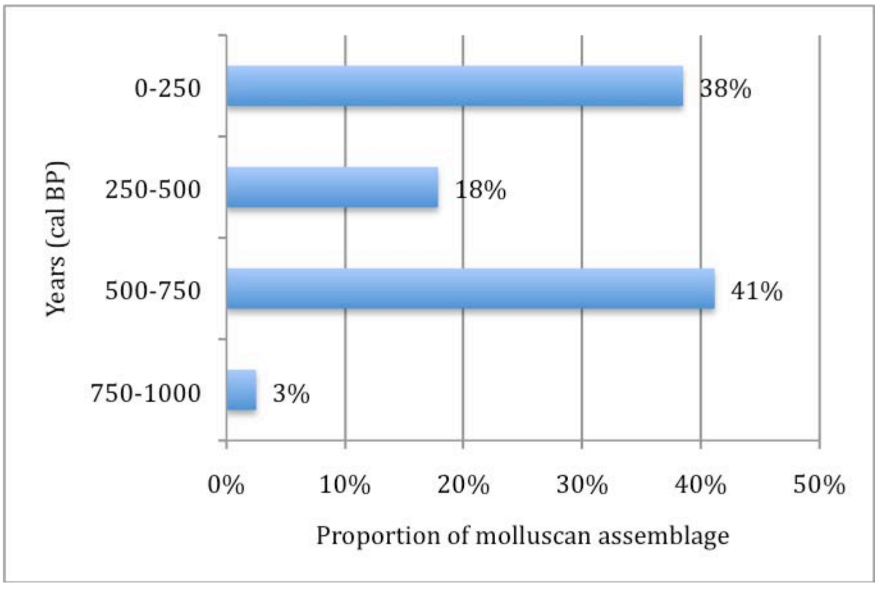


Figure 12.20: Percentage of Square B total mollusc assemblage weight per 250-year period.

Table 12.8: Wardilmiru Square B molluscan assemblage taxa MNIs.

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Totals**
MARINE BIVALVIA																					
Circe scripta									1												**1**
Gafrarium pectinatum											1										**1**
Marcia hiantina	3	2	1	10	15	159	28	8	5	2	2	29	3	16							**283**
Saccostrea glomerata												2	1		1						**4**
Semele sinensis												1									**1**
Tellina sp.				1																	**1**
MARINE GASTROPODA																					
Calliostoma sp.		1		2		1		5		1	3		2	3	2	1	6		3	7	**37**
Cerithidea sp.		4	15	16	24	29	77	30	81	74	152	17	149	60	99	196	141	187	250	208	**1809**
Clypeomorus sp.		3		2		2	1	2	3	1		2	5	6		8		17	17	40	**109**
Lunella cinerea							1														**1**
Patellidae				1													1				**2**
Planaxis sulcatus															5		7		2	5	**19**
Rhinoclavis sp.	10	14	15	22	37	30	62	57	59	17		48	93	63	58		164	146		194	**1089**
Terebralia sulcata					1		1				1	4	2	1	1	3		10	7	12	**43**
XU Totals	**13**	**24**	**31**	**54**	**77**	**221**	**170**	**102**	**149**	**95**	**159**	**103**	**255**	**149**	**166**	**208**	**319**	**360**	**279**	**466**	**3400**

Table 12.9: Wardilmiru Square B molluscan assemblage taxa weights (g).

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
MARINE BIVALVIA										
Circe scripta									0.43	
Gafrarium pectinatum							0.06			
Marcia hiantina	15.73	7.04	8.28	58.20	127.76	1052.15	196.24	41.98	31.56	19.88
Saccostrea glomerata						0.31		1.52		
Semele sinensis										
Tellina sp.				0.02						
MARINE GASTROPODA										
Calliostoma sp.		0.02		0.29	0.01	0.12		0.20		0.12
Cerithidea sp.		0.26	0.68	0.64	1.45	1.47	2.98	1.52	3.37	3.12
Clypeomorus sp.		0.44		0.34		0.33	0.08	0.70	0.04	0.22
Lunella cinerea					2.41	0.84	1.87	1.68		
Patellidae				0.01						
Planaxis sulcatus										
Rhinoclavis sp.			0.36	0.64	0.74	1.68	2.29	1.74	3.12	2.50
Telescopium telescopium		0.09		1.10						
Terebralia sulcata					0.40		0.05		0.14	
Unidentified shell		16.47	17.50	30.01	46.08	60.03	42.96	42.91	72.50	52.64
XU Totals	**15.73**	**24.32**	**26.82**	**91.25**	**178.85**	**1116.93**	**246.53**	**92.25**	**111.16**	**78.48**

Table 12.9: Wardilmiru Square B molluscan assemblage taxa weights (g) (cont.).

Taxon XU	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Totals**
MARINE BIVALVIA											
Circe scripta											**0.43**
Gafrarium pectinatum	3.06			0.28		0.14					**3.54**
Marcia hiantina	9.98	174.04	40.91	97.42	1.36	1.38	0.54		0.34		**1884.79**
Saccostrea glomerata		0.31	0.64			0.14			0.14		**3.06**
Semele sinensis		1.89									**1.89**
Tellina sp.											**0.02**
MARINE GASTROPODA											
Calliostoma sp.	0.35		0.13		0.15	0.38		9.63	0.43	0.73	**12.56**
Cerithidea sp.	7.84	1.19	5.67	6.82	6.48	10.77	8.71	13.01	14.40	22.36	**112.74**
Clypeomorus sp.		0.41	0.98	1.98		1.20		2.27	3.24	7.05	**19.28**
Lunella cinerea			1.73								**8.53**
Patellidae							0.01				**0.02**
Planaxis sulcatus					0.50		0.54		0.30	1.01	**2.35**
Rhinoclavis sp.	4.23	1.28	4.63	2.82	3.48	3.68	6.77		12.78	20.05	**72.79**
Telescopium telescopium		0.06									**1.25**
Terebralia sulcata	0.53	0.79	0.40	1.84	2.54	0.34		2.91	2.71	6.19	**18.84**
Unidentified shell	58.66	51.03	72.58	71.55	93.22	70.18	116.56	130.36	86.90	173.58	**1305.72**
XU Totals	**84.65**	**231.00**	**127.67**	**182.71**	**107.73**	**88.21**	**133.13**	**158.18**	**121.24**	**230.97**	**3447.81**

12.7.2 Vertebrate Remains

Square A

Small numbers of fish bones (n=88) were recovered from the upper 14 XUs of the Square A deposit, comprising the only vertebrate remains (7.61g) in Square A (Table 12.10). Most of the bone material was highly fragmented and little could be identified to taxon higher than Osteichthyes (bony fishes). Identified taxa include a bream (*Acanthopagrus* sp.) and a black-spotted tuskfish (Labridae: *Choerodon schoenleinii*). The MNI of two was calculated by summing the MNI of each taxon for the square. Although there are several elements representing the Labridae family, it is highly probable that all of these bones have come from the one fish. The bream archaeological specimen appears to be two-thirds the size of a similar one in the TARL Fish Reference Collection, which would indicate that the archaeological specimen comes from a fish weighing approximately 180g. The *Choerodon schoenleinii* specimen in XU7 measures 40mm and is estimated to come from a fish weighing around 2240g based on comparison with a similar specimen in the TARL Fish Reference Collection.

Table 12.10: Fishbone abundance at Wardilmiru Square A.

Sq	XU	Taxon	Element	MNI	NISP	Weight
A	1	Osteichthyes	unidentified		1	0.0280
A	2	Osteichthyes	unidentified		5	0.1129
A	3	Osteichthyes	unidentified		6	0.1414
A	3	*Acanthopagrus* sp.	left dentary	1	1	0.0264
A	4	Osteichthyes	unidentified		3	0.0905
A	6	Osteichthyes	unidentified		5	0.1050
A	6	Labridae	dentary		1	0.0361
A	7	Osteichthyes	unidentified		9	0.1439
A	7	*Choerodon schoenleinii*	right premax	1	1	1.0762
A	8	Osteichthyes	unidentified		14	0.5720
A	8	Labridae	lpgp part		4	0.4867
A	9	Osteichthyes	unidentified		7	0.1950
A	9	*Choerodon schoenleinii*	left premax		1	0.1672
A	10	Osteichthyes	right otolith		1	0.0624
A	10	Osteichthyes	unidentified		21	0.8081
A	10	*Choerodon schoenleinii*	lpgp part & upgpx2		3	3.4039
A	11	Osteichthyes	unidentified		4	0.1285
A	14	Osteichthyes	unidentified		1	0.0340
			Totals	2	88	7.6182

Square B

As with Square A only small numbers (n=5) of fish bones were recovered from the Square B deposit, comprising the only vertebrate remains (0.40g) in Square B (Table 12.11). Most of the bone material was highly fragmented and little could be identified to taxon higher than Osteichthyes (bony fishes), except for a rockcod otolith (*Epinephelus* sp.) in XU9, a wrasse/tuskfish pharyngeal (Labridae) in XU11 and one shark tooth in XU17. The rockcod otolith measures 10mm and is estimated to come from a fish weighing approximately 900g based on comparison with similar specimens in the TARL Fish Reference Collection. The Labridae specimen in XU11 measures 10mm and would come from a fish weighing 350g and the shark tooth comes from a specimen estimated to weigh a minimum of 1000g.

Table 12.11: Fishbone abundance at Wardilmiru Square B.

Sq	XU	Taxon	Element	MNI	NISP	Weight
B	2	Osteichthyes	unidentified		1	0.0589
B	5	Osteichthyes	unidentified		1	0.0161
B	9	*Epinephelus* sp.	left otolith	1	1	0.0272
B	11	Labridae	pharyngeal	1	1	0.2740
B	17	Shark	tooth	1	1	0.0263
			Totals	3	5	0.4025

12.8 Application of Models

12.8.1 Diet-Breadth/Prey Choice

An overview of patterns in the breadth and diversity of molluscan exploitation at Wardilmiru can be identified using species richness and abundance measures. The species richness graph shows the number of species collected from each habitat per chronological period (Figures 12.21-12.22). The level of species richness by habitat varies between chronological periods however chi-square results for Square A (X^2 = 2.72, d.f. = 6, p>0.5) and for Square B (X^2 = 2.11, d.f. = 6, p>0.5) indicate this variation is not considered statistically significant.

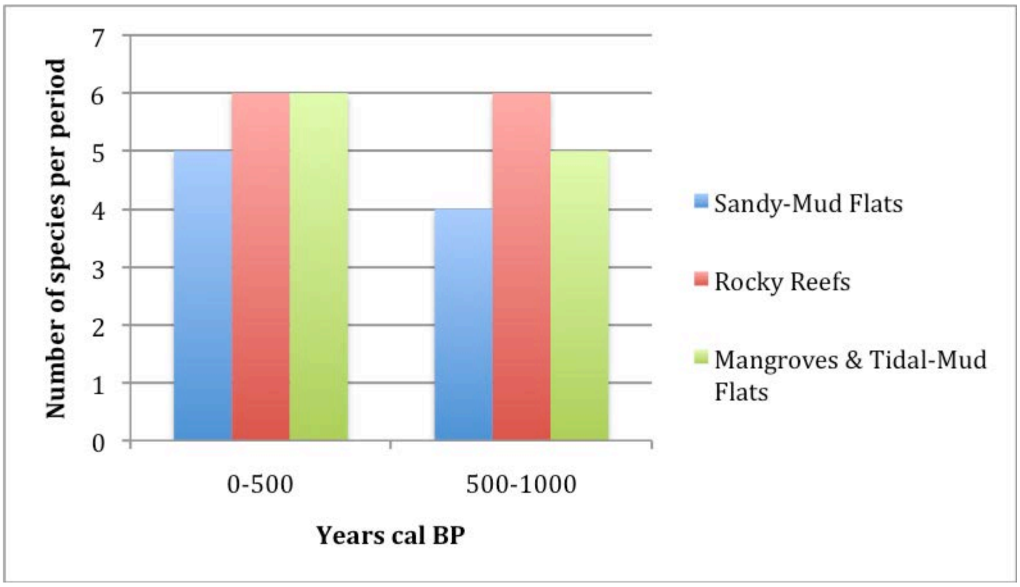


Figure 12.21: Wardilmiru Square A, species richness per habitat per period.

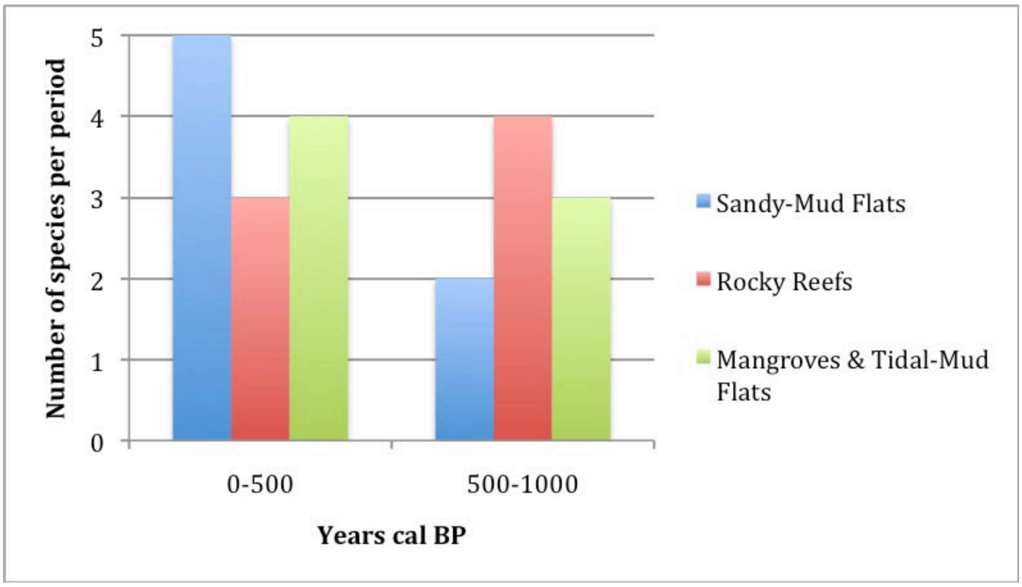


Figure 12.22: Wardilmiru Square B, species richness per habitat per period.

Based on species richness it appears that several species were collected, however MNI data demonstrate that the majority of the deposit is made up of six species, which are common to both Square A and Square B (see Figures 12.23-12.24) – cerithid snails (*Cerithidea* sp., *Rhinoclavis* sp., *Clypeomorus* sp. and *Terebralia sulcata*), hiant venus clams (*Marcia hiantina*), and top shells (*Calliostoma* sp.). Sandy-Mud Flats taxa are more prevalent in the period 0-500 cal BP associated with cultural use.

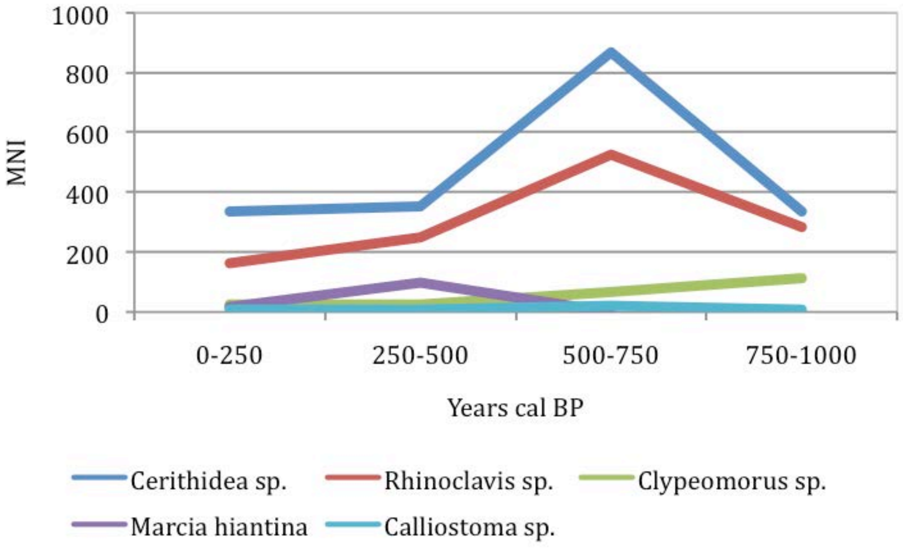


Figure 12.23: Top five mollusc taxa MNI per 250-year period Square A.

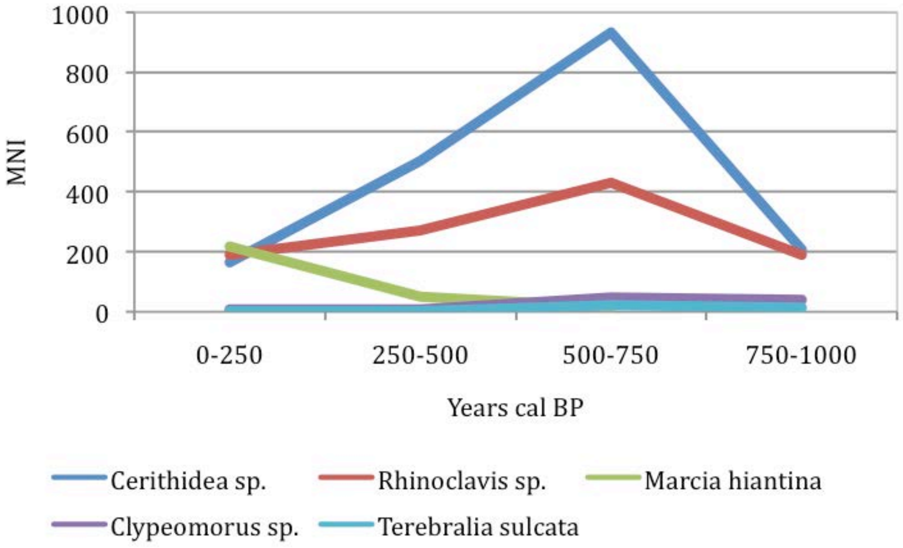


Figure 12.24: Top five mollusc taxa MNI per 250-year period Square B.

Two of these species (*Cerithidea* sp. and *Rhinoclavis* sp.) are tiny gastropods generally less than 1cm in length and are most likely non-economic (i.e. not deliberately collected for food or other economic purposes). In this instance they are regarded as having been introduced to the matrix by natural processes (e.g. aeolian or wave deposition), or brought in accidentally as bycatch (e.g. attached to larger shells or small twigs/wood) (Gill 1954:251; cf. Rowland 1994).

Five of the top six species have representation in all 250-year periods. *M. hiantina* is the dominant species collected for food and is present in the Square A midden between 0-750 years and in Square B between 0-500 years. These results suggest that for the most part the same species were being foraged from the local area, and also that the diet breadth was fairly consistent across all periods.

Identified vertebrate taxa include rock-cod (*Epinephelus* sp.) and wrasse (Labridae). A shark tooth was also recovered but appears to be in non-cultural sediments. All of these species can be found in the shallow coastal waters surrounding Fowler Island, feeding over sand in and around seagrass beds and coral and rocky reefs.

12.8.2 Habitats/Patch Choice

The graphs in Figures 12.25 and 12.26 show the proportion of species MNI by habitat. The Wardilmiru mollusc assemblage includes taxa that come from all three patches or habitats, however there is temporal variance in the quantities of taxa taken from each patch. The chi-square results for Square A (X^2=147.5, d.f.=6, $p<0.0001$) and Square B (X^2=454.88, d.f.=6, $p<0.0001$) indicate that this variance is statistically significant. This statistic is possibly skewed by the extremely high MNI numbers of *Cerithidea* sp. and *Rhinoclavis* sp. from the Mangroves and Tidal-Flats habitat, which are not thought to have been collected for economic purposes. So in this instance additional graphs have been created using weight quantities (Figures 12.27-12.28). Still, the chi-square results for Square A (X^2=510.86, d.f.= 6, $p<0.0001$) and Square B (X^2=872.37, d.f.=6, $p<0.0001$) confirm that this variance is statistically significant.

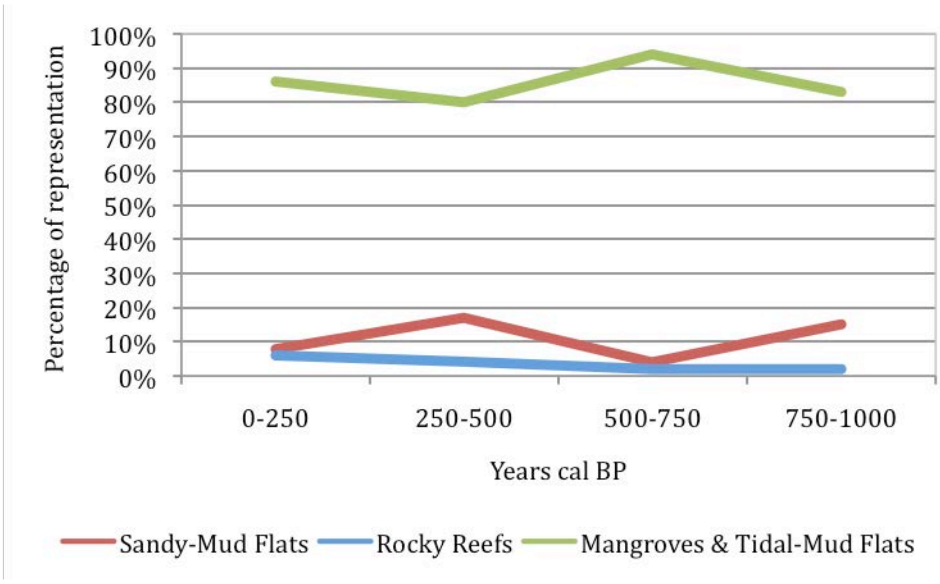


Figure 12.25: Percentage of mollusc taxa MNI collected from each patch by 250-year period in Square A.

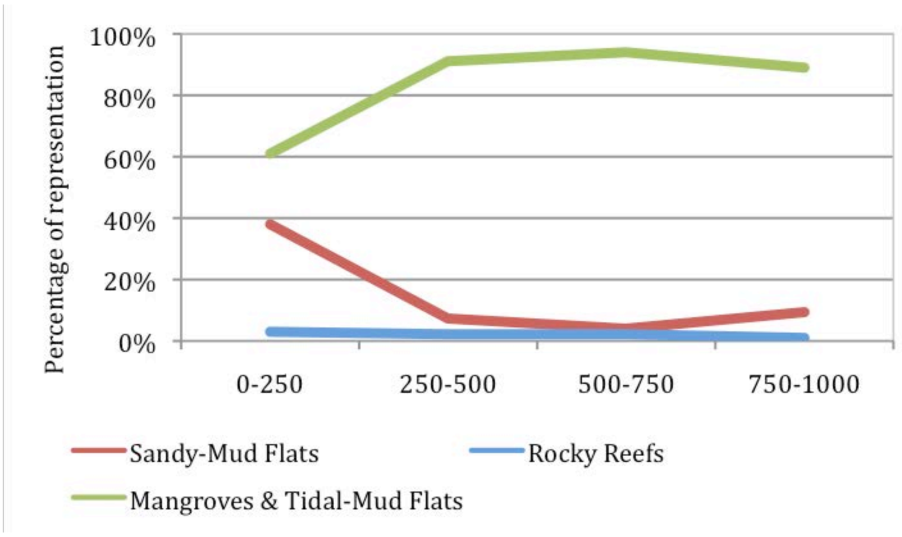


Figure 12.26: Percentage of mollusc taxa MNI collected from each patch by 250-year period in Square B.

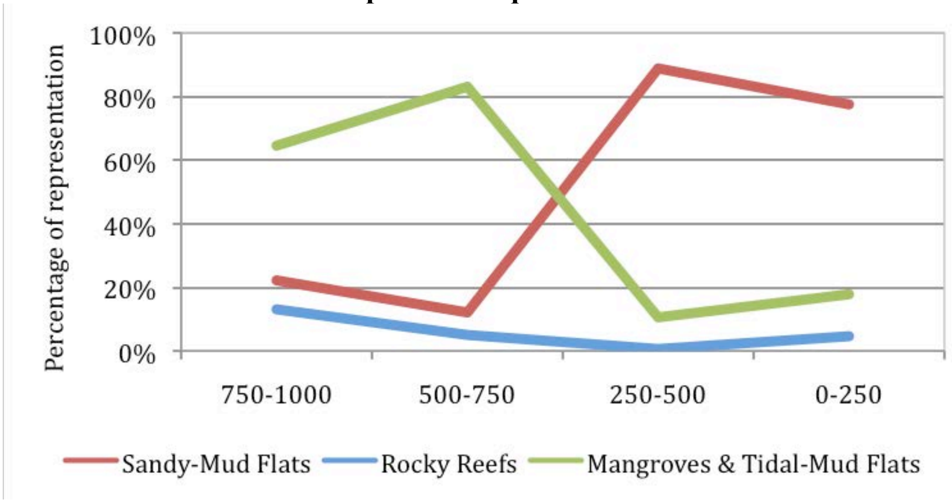


Figure 12.27 Percentage of mollusc taxa weight collected from each patch by 250-year period Square A.

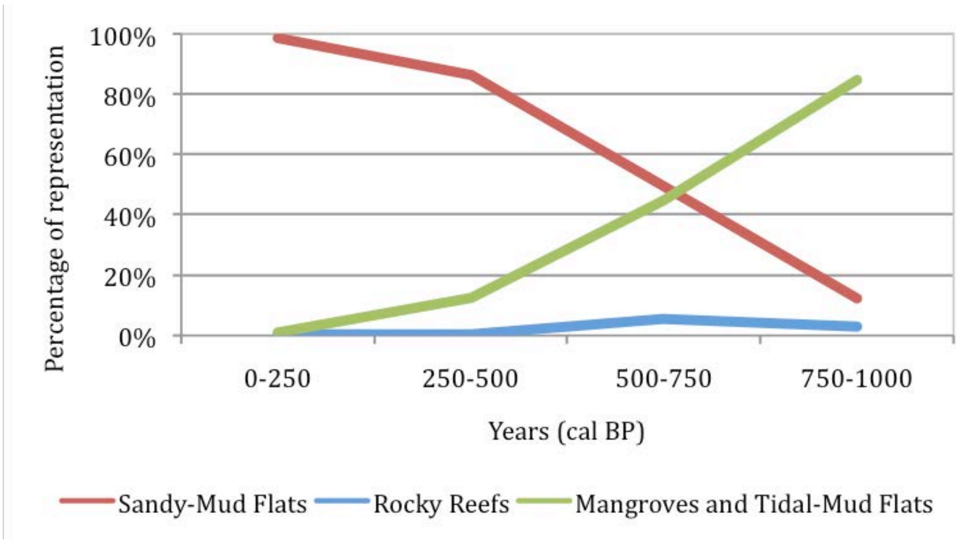


Figure 12.28: Percentage of mollusc taxa weight collected from each patch by 250-year period Square B.

From the MNI graphs the Mangroves and Tidal-Mud Flats appear to have provided the greatest percentage (from 60%-94%) of taxa numbers for the Wardilmiru midden. Sandy-Mud Flats have contributed between 4%-38% of taxa numbers, while Rocky Reefs have contributed between 1%-6% at various times. These figures are in stark contrast to habitat percentage contributions by taxa weight. The second pair of graphs is considered to be more meaningful in terms of assessing habitat choices for resource collection.

In the Square A weight graphs (Figures 12.27-12.28) we can see that Mangroves and Tidal-Mud Flats contribute greater mass in the earlier periods (64%-83% in 750-1000 year and 500-750 year periods respectively) and Sandy-Mud Flats contribute higher mass in more recent times (78%-89% in 0-250 year and 250-500 year periods respectively). Rocky Reef species (1%-13%) have the lowest presence throughout. As mentioned before, the majority of Mangroves and Tidal-Mud Flats taxa are likely to be non-economic species, although they cannot be ruled out from diet as it is possible that they could provide a good meal based on the sheer numbers.

Changes in patch use between the Mangrove and Tidal-Mud Flats patch and Sandy-Mud Flats patch can be tracked through use of an index (Figure 12.29). The chi-square result (X^2=1251.58, d.f.=3, p<0.0001) indicates that the decline in Mangrove and Tidal-Mud Flats species is significantly correlated with the increase in Sandy-Mud Flats patch species.

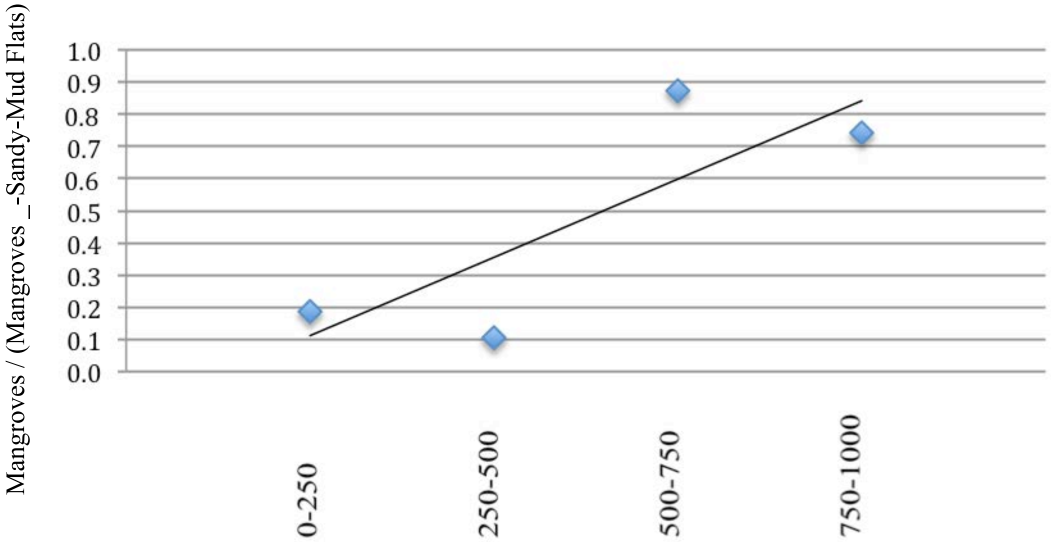


Figure 12.29: Change in patch use as indicated by Mangroves-Sandy-Mud Flats Patch Index.

While the declining index indicates that foragers' preference is switching from Mangroves and Tidal-Mud Flats taxa to Sandy-Mud Flats taxa through time, this could just be a reflection of natural versus cultural deposition. The hiant venus clam (a Sandy-Mud Flats species) is considered to be a large species with high calorific return in this assemblage, which is more intensively exploited than other species in the last 500 years. From this information we can suggest that there was possibly a changing distribution or decline of Mangrove habitats or foragers chose to intensify exploitation of the Sandy-Mud Flats patch for socio-cultural reasons.

12.8.3 Central Place Foraging Model

Rocky Reef species make up a lesser proportion of the assemblage throughout all periods, perhaps due to higher associated capture costs, such as difficulty in accessing the habitat. It may also be harder to extract the molluscs from the rocks, therefore consumption of these molluscs might likely be occurring at the site of collection. Wardilmiru appears to have been a central-place for occupation where foragers brought food back to share. Central place foraging does impose travel costs, such as the energetic cost of carrying a food item from its procurement source back to camp. Although the rocky reefs directly adjacent to the Wardilmiru midden site, Sandy-Mud Flats and Mangroves and Tidal-Mud Flats were more easily accessible, despite being slightly further away by linear distance.

One point of note is that there is not a high representation of high-ranked taxa (for dietary purposes) in the Wardilmiru midden from Mangroves and Tidal-Mud Flats even though this habitat was easily accessible. An explanation for this might be gained by comparing the contents of nearby shell surface scatters between the Mangroves habitat and Wardilmiru. These feature high quantities of mangrove mudshell (*Geloina erosa*) suggesting people were stopping closer to the mangroves to eat instead of carrying the reasonably heavy mudshells back to camp.

12.8.4 Resource Intensification and Foraging Efficiency

At Wardilmiru we see that the hiant venus clam is the most prevalent high-ranked taxon in the assemblage, in terms of the prey-choice model. When reviewing the relationship between the hiant venus clam MNI and specimen sizes for each period, such that the MNI increases are associated with a very slight increase in mean valve length Table 12.12; Figure 12.30). This suggests that the hiant venus clam was the subject of intensified exploitation, which unabated could have led to resource depression and declining foraging efficiency in the Sandy-Mud Flats patch. Resource intensification of *M. hiantina* in the period 250-500 cal BP did appear to result in reducing specimen sizes slightly, although this may just reflect cultural selection practices at that time. Certainly the range (13.02mm) between small and large specimens was greatest during peak consumption, but all shells come from molluscs that were mature and in their second or third year of growth. However, if exploitation of this species continued without abatement, we could likely see the long-term effects of resource depression that would eventually deplete the clam population.

Table 12.12: Metrical data for intact *M. hiantina* valves from Wardilmiru, Square A.

XU	Mean (mm)	Median (mm)	S.D. (mm)	Min (mm)	Max (mm)	Range (mm)	No.
4	34.43	35.05	2.68	29.87	37.15	7.28	6
5	34.76	34.68	3.83	28.62	40.02	11.40	11
6	34.36	34.49	2.53	28.03	41.10	13.07	200
7	34.70	34.62	2.54	30.48	42.40	11.92	35
8	35.50	35.75	2.98	26.83	41.68	13.05	66
9	34.85	35.60	2.67	30.32	40.95	10.63	30
10	33.52	34.01	0.94	32.44	34.12	1.68	3
11	34.57	34.57	0.00	34.57	34.57	0.00	1
12	35.22	35.65	2.94	29.78	41.10	11.32	23
13	35.55	34.90	3.20	31.92	41.59	9.67	6
14	34.84	34.73	1.74	32.22	37.84	5.62	13

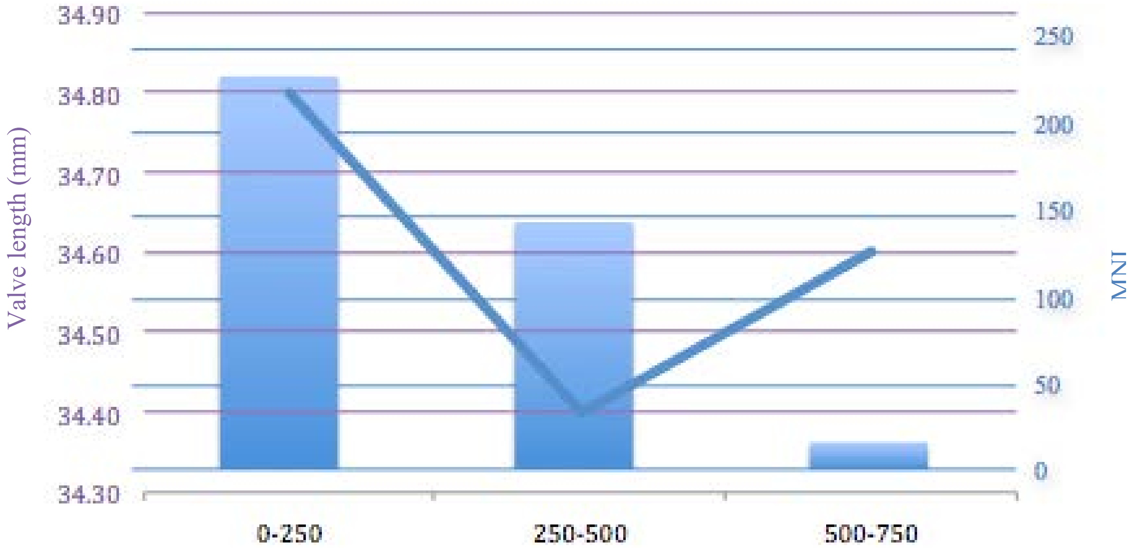


Figure 12.30: Relationship between *M. hiantina* MNI (columns) and mean valve length (mm) per 250-year period.

12.9 Discussion

In order to best determine temporal changes at the site, the recovered cultural materials have been divided into chronological period intervals of 250 years. This also facilitates comparison with other sites being reviewed for the purpose of establishing spatial and temporal patterns across the study area.

The majority of cultural shell by weight was recovered from between XU4-9 in Square A and XU4-7, XU12 and XU14 in Square B, suggesting greater use of Wardilmiru during a period straddling 0-250 cal BP and 250-500 cal BP. ^{14}C radiocarbon dating of the archaeological evidence confirms the main period of cultural site use was between c.100-400 cal BP. The presence of other cultural materials (e.g. charcoal, vertebrate remains, shell artefact) in the midden recovered from the upper XUs further supports this idea. Unfortunately without further ^{14}C dates it is not possible to more accurately determine the length of time that Kaiadilit used Wardilmiru.

Figures 12.17 and 12.20 appear to indicate that greater MNI numbers occurred between 500-750 cal BP, but these numbers actually reflect the multitude of tiny gastropods in the assemblage, not thought to have been collected for food, but rather deposited by natural events. In terms of midden contents the initial 500 years (500-1000 cal BP) of Wardilmiru seems to reflect a beach-like environment, with 85% of identified taxa species (based on MNI) considered to be found to be naturally deposited in coastal dunes and chenier ridges via aeolian or wave processes (e.g. *Cerithidea* sp., *Rhinoclavis* sp.). Willan (2013) reports that while northern Australian Aboriginal communities targeted *Telescopium telescopium* and *Terebralia* species for food, people did not select the smaller taxa from the Potamididae family to eat. Further the low ocurrence of high-ranked taxa (e.g. *Marcia hiantina*) prior to 500 cal BP, suggests there was limited cultural occupation prior to this time. Although there are several oyster shells in the lowest period, it is more likely that these were deposited during a storm-surge event, as all specimens are oyster lids that are highly weathered.

Although people increased consumption of *M. hiantina* in the period 250-500 cal BP there is no evidence to suggest this had an adverse effect on the mollusc populations. A small reduction in specimen sizes could indicate slight overpredation or it may just reflect cultural selection practices at that time.

Overall there is a noticeable decline in mangrove and tidal-mud flat species, particularly visible in Figures 12.27 and 12.28. However it should be noted that dotted between the mangroves and

Wardilmiru are dozens of dinner-time camps, which date to the same timeframe as Wardilmiru. Based on Meehan's (1982) definitions of camp-types these were determined to be dinner-time camps due to the lack of species diversity in contents and the small size of each site relative to central-place campsites. These dinner-time camps are laden with Mangrove and Tidal-Mud Flat species (e.g. mudshells and longbums), suggesting that people probably consumed these species closer to the source. This was likely an optimal foraging choice best explained by the Central-Place Foraging model, whereby energetic returns have been offset by higher associated travel costs. This theory could also explain why there is limited oyster in the Wardilmiru site.

12.10 Summary

Excavations at Wardilmiru revealed a 35-40cm thick cultural deposit with shell, bone and charcoal resting on a sand-dune base. Molluscs were foraged from three habitat zones – Sandy-Mud Flats, Rocky/Coral Reefs and Mangroves and Tidal-Mud Flats – in varying quantities and proportions over the time the site was occupied. Fish were likely caught using spears in the near-shore shallow waters. Radiocarbon dates obtained on shell from the two squares indicate primary site use occurred between c.100-400 cal BP. Based on various analyses I have concluded that Wardilmiru represents a central-place camp that along with numerous dinner-time camp sites, a nearby native well and several proximate fishtraps, indicate people effectively utilised the Fowler Island landscape and resources.

Chapter 13. Banbanbarukeind, Bentinck Island

13.1 Introduction

Archaeological investigations at Banbanbarukeind on Bentinck Island revealed a cultural deposit dominated by marine shell that suggests Kaiadilt people used the site for c.300 years. Aboriginal fishtraps on Bentinck Island suggest widespread settlement in the area at some stage in the past and intensive exploitation of marine resources. This chapter describes the Banbanbarukeind site and its stratigraphy, chronology and contents followed by a discussion of the data from an OFT perspective for understanding foraging behaviours of the site users.

13.2 Site Description and Setting

In 2012 Sean Ulm recorded a shell midden complex intermittently exposed for c.300m along an NE-SW trending ridgeline northeast of Melbamelbari on Bentinck Island (between Latitude 17.11339S, Longitude 139.51027E and Latitude: 17.11556S, Longitude: 139.5087E), some 70m inland from the south coast (Figures 13.1-13.3). Surface shell is exposed across the top southern part of the ridge deflating in some patches; however deflation at the top is relatively minor due to the gradual slope of the ridgeline.

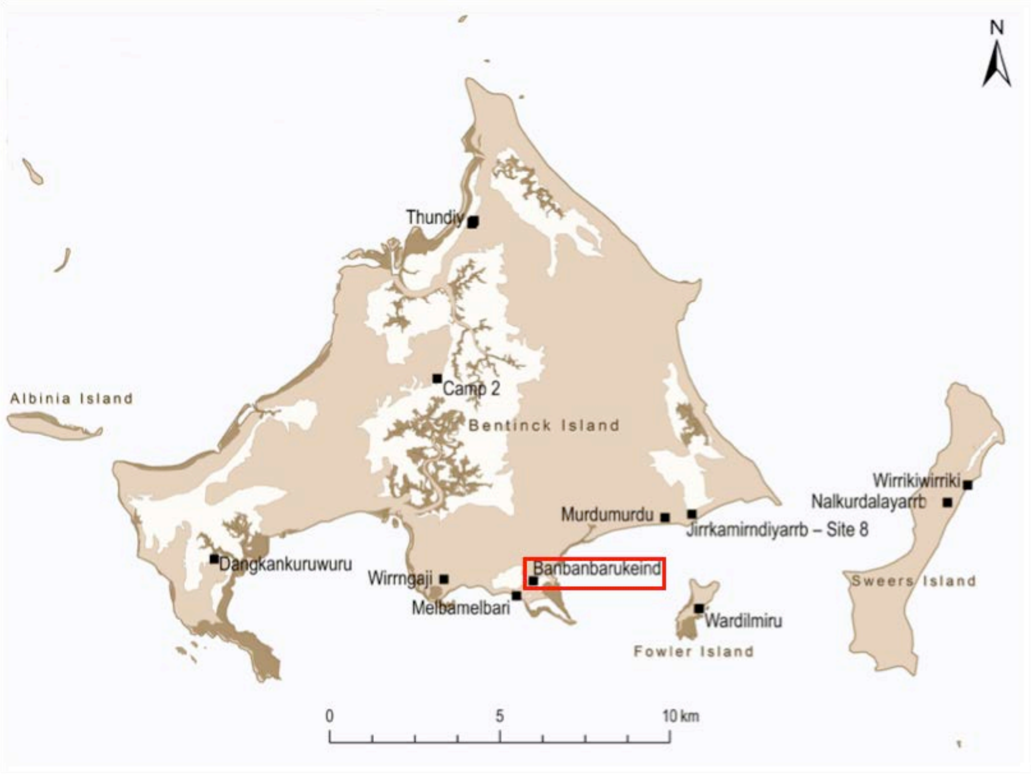


Figure 13.1: Map of South Wellesley Islands showing Banbanbarukeind site location (map prepared by Lincoln Steinberger and Sean Ulm).

Figure 13.2: Aerial view map showing location of Banbanbarukeind (after Google Earth).

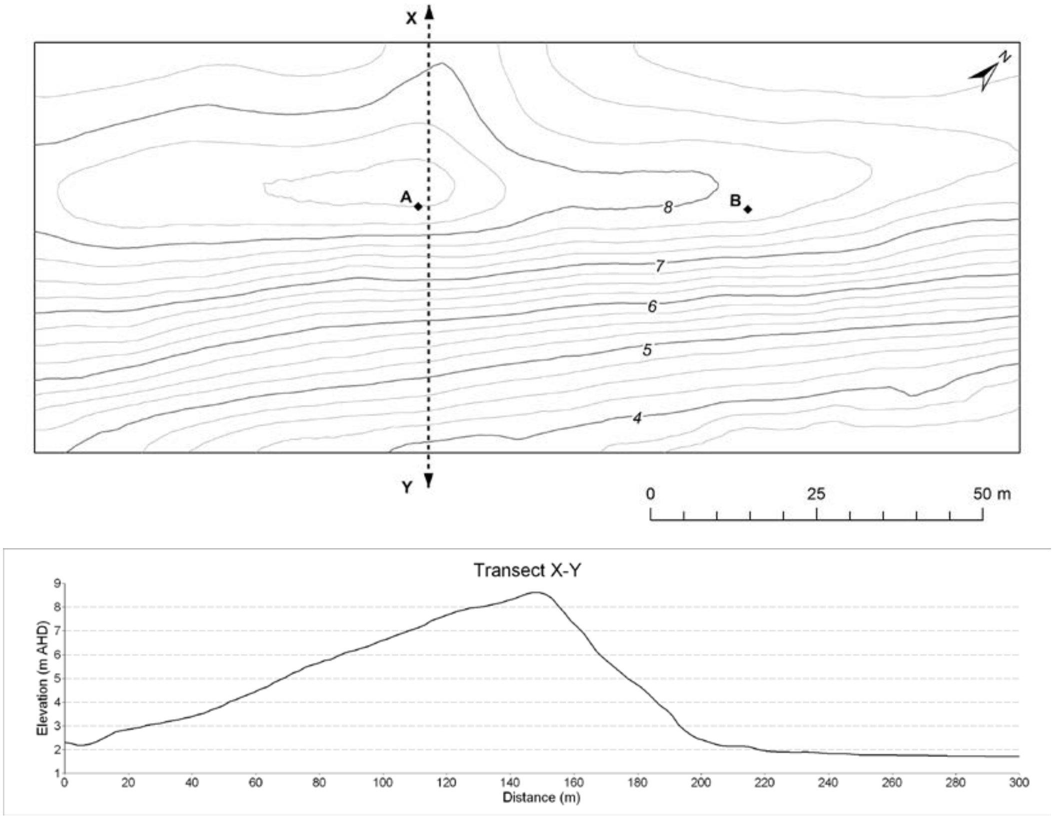


Figure 13.3: Contour map with transect between sandy-dune ridge and coastline showing elevations (map prepared by Lincoln Steinberger and Sean Ulm).

The dune ridge is openly vegetated by sandy grasslands and open forests of Eucalypt, Acacia and Grevillea (Figure 13.4). Shell is visible around the base of large eucalypts indicating the presence of subsurface deposits. Strong prevailing winds from the southeast buffet the dune ridge. At the base of the dune, between the ridge and the shoreline, pandanus trees and mangrove stands fringe a salt/claypan. An extensive mangrove forest separates the salt/claypan from the sea.

The intertidal sandy-mud flats along the shoreline adjacent to Banbanbarukeind support hiant venus clams (*Marcia hiantina*) and tumid venus clams (*Gafrarium pectinatum*). Rocky/Coral Reef platforms occur on the island’s south coast. The rocks support clumps of oysters (*Saccostrea glomerata*), top shells (*Calliostoma* sp.), periwinkles (*Planaxis sulcatus*) and limpets (Patellidae). The mangrove forest is a habitat for cerithids (*Cerithidea* sp. and *Rhinoclavis* sp.), mud creepers (*Terebralia sulcata*), mangrove mussels (*Glauconome virens*), longbums (*Telescopium telescopium*), mudshells (*Geloina erosa*) and black nerites (*Nerita balteata*) (Figure 13.5).

Figure 13.4: Banbanbarukeind view north to open eucalypt / acacia forest and savannah grasses.

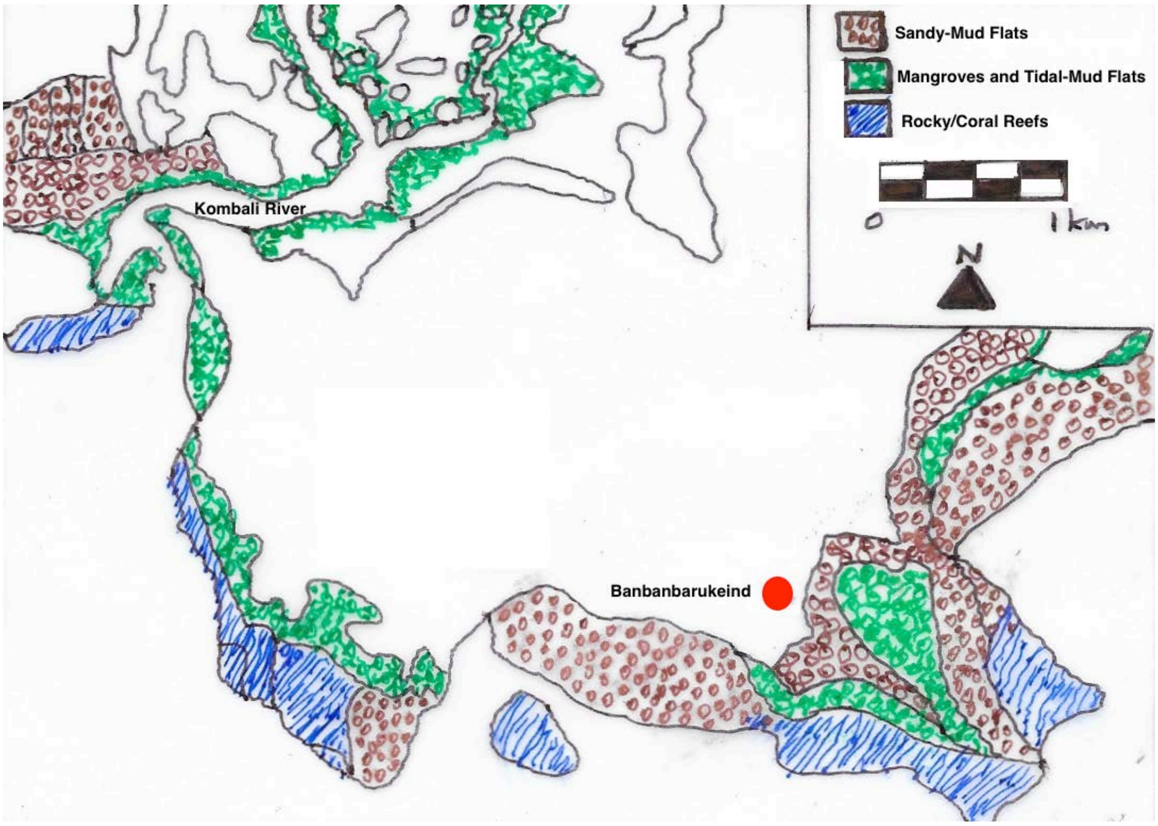


Figure 13.5: Resource habitat communities near Banbanbarukeind.

13.3 Excavation Methods

In July 2013 Daniel Rosendahl selected a portion of the shell midden complex to excavate where shell scatters were visible on the surface. Two 50cm x 50cm squares (Squares A and B) were placed 50m apart on top of the ridge (Figures 13.6-13.7). 373.5kg of sediments were removed from the two squares dug at the southern end of the midden. Excavations proceeded in shallow, arbitrary excavation units (XUs) averaging 2.8cm in depth and 9.3kg in weight. Excavations ceased at c.53cm below ground surface (in both squares) when a consolidated aeoleanite unit was encountered; an auger sample in the base of Square A indicates that this layer continues for at least another c.70cm. Cultural materials decreased in density with depth and ceased after c.48cm. All midden materials were dry sieved through 2.3mm mesh on site and materials retained in the sieve were retained for later sorting and identification in the laboratory.

Figure 13.6: Banbanbarukeind Square A excavations at completion showing stratigraphic unit changes and shell in west section.

Figure 13.7: Banbanbarukeind Square B excavations at commencement showing surface shell including *T. telescopium*.

13.4 Cultural Deposit and Stratigraphy

Excavations revealed a c.48cm deposit of cultural materials including shell, bone and charcoal. The majority of shell was recovered from the top c.20cm in both Square A (XU1-8) and Square B (XU1-8). Cultural materials continue to be recovered down to XU18 in both squares, however, quantities decreased with depth. The deposit can be divided into three main stratigraphic units (SUs) (Figures 13.8-13.9; Table 13.1). SUI is a humic layer containing the main cultural unit and includes materials located between XU1 to XU7. SUII is a transitional unit containing mixed sediments with less dense proportions of cultural materials located between XU8-18. SUIII is the aeolianite base found between XU19 and XU20 and is culturally sterile.

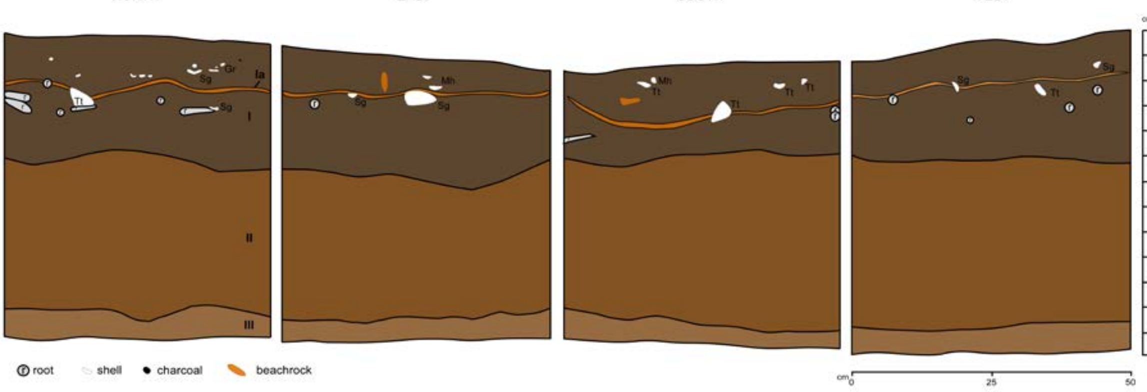


Figure 13.8: Stratigraphic section drawing, Banbanbarukeind, Square A (prepared by Michelle Langley and Sean Ulm).

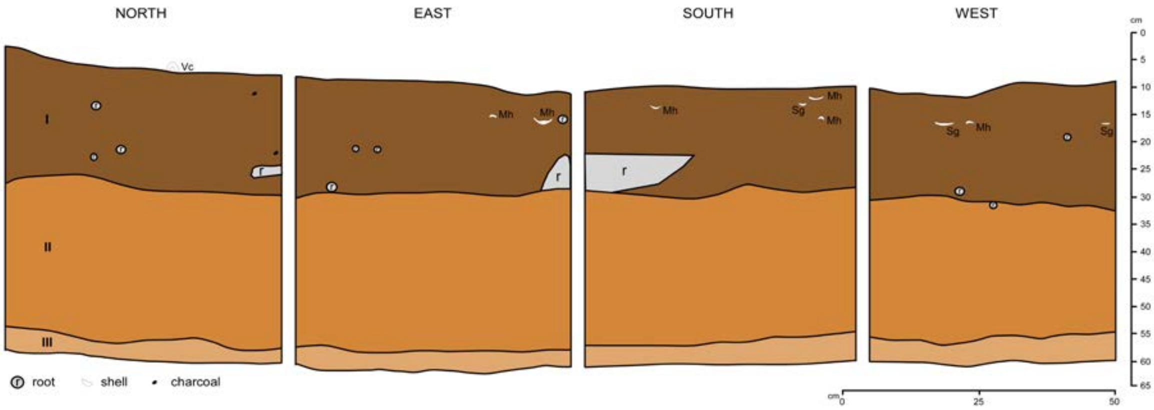


Figure 13.9: Stratigraphic section drawing, Banbanbarukeind, Square B (prepared by Michelle Langley and Sean Ulm).

Table 13.1 Stratigraphic Unit (SU) descriptions for Banbanbarukeind Squares A and B.

SU	Description
I	A humic layer with roots and shell that extends across both squares with depths ranging between 18cm to 25cm below ground surface. The unit comprises angular to subangular loose unconsolidated sands. Sediments are dark yellowish brown (7.5YR-3/4) in colour. In both squares rootlets from grasses occur to c.10cm below surface while roots from nearby trees penetrate to depths of c.30cm. The thickness of these roots ranges from 5mm to 60mm in diameter. Some evidence of insect disturbance with small insect burrows and insect casings encountered. Cultural materials include charcoal fragments, whole and fragmented molluscs (dominated by oysters, venus clams and longbum shells), crustacea fragments and fish bones. pH values are alkaline (6.0-8.5). Shell and bone materials appear to be reasonably well-preserved.
Ib	A thin band of angular to subangular dry and loosely consolidated sands extends across the entire Square A and Square B with a thickness of c.1-2cm at c.10cm depth. This layer was not seen during excavations but is readily visible in the profiles of all four walls.
II	Transitional unit grading from dark yellowish brown (7.5YR-3/4) through brown (7.5YR-4/4) to light brown (7.5YR-6/4) loosely consolidated sands becoming more consolidated with depth. This unit is c.30cm thick located between c.18-48cm below surface. Unit contains numerous beach rock and gravel inclusions. Small fragments of cultural shell are present throughout. pH values are alkaline (6.0-8.5).
III	A continuous layer of compact coarse sand and shell grit forms the base of this unit at c.48-53cm below surface in both squares. This SU exhibits light brown (7.5YR-6/4) coarse sands in Square A and yellowish red (5.0YR-5/6) coarse sands in Square B. The unit contains beach rock, tiny gastropod shells and highly fragmented shell grit. It is culturally sterile. pH values remain alkaline (7.5-8.0). An auger sample in the base of the pit indicates that this layer continues for at least another c.70cm.

13.5 Site Integrity and Taphonomy

The deposit exhibits good stratigraphic integrity. There is a predictable shell decay profile with highly weathered tiny gastropod specimens recovered from the base of the deposit and relatively well-preserved, larger cultural shell specimens from the upper deposit. Reviewing effects of site taphonomy on vertebrate remains it seems that fish bones have likely degraded, as the fragments are unidentifiable except for a fish otolith recovered from Square B, XU2. No bone was recovered below Square A, XU10 and Square B, XU8. Insect burrows in the pit suggest some minor disturbance and tree roots (some 60mm in diameter) have contributed to further disturbance. Nevertheless, there are only minor quantities of cultural shell fragments that have filtered down through SUII, the transition unit. There is a pattern of low shell fragmentation (145 fragments per 100g of shell) contributing to high rates of identification in the upper units that correlates with the period of cultural deposition (see Hoffman 2011). This contrasts with increased shell fragmentation (1020 fragments per 100g of shell) and lower rates of identification in deeper and older units.

13.6 Radiocarbon Dating and Chronology

Two radiocarbon determinations have been obtained for Banbanbarukeind Square A (Table 13.2). A date of c.302 cal BP from XU8 at the interface between SUI and SUII indicates the site has been used either permanently or intermittently for the past c.300 years. A second date of c.324 cal BP was obtained on a *Marcia hiantina* valve collected from XU1 suggesting that the bulk of the cultural deposit was rapidly deposited in a short space of time.

Table 13.2: Radiocarbon ages on marine shell for Banbanbarukeind, Square A. Calibrations undertaken using OxCal v.4.2 (Bronk Ramsey 2009) and the Marine13 calibration dataset (Reimer *et al.* 2013). For marine samples a ΔR of −49±102 as recommended by Ulm *et al.* (in prep.) is employed. Both determinations are on *Marcia hiantina*.

Sq.	XU	Depth (cm)	Lab. Code	^{14}C	$\delta^{13}C$	Calibrated Age BP (95.4%)	Calibrated Age Median
A	1	0.1-4.0	Wk-41402	635±20	N/A	72-504	324
A	8	18.6-21.3	Wk-41403	614±20	N/A	59-491	302

The assemblage has been divided into temporal phases of 250-year periods for comparative purposes. Excavation units have been assigned to chronological periods based on an age-depth model derived from the calibrated radiocarbon ages and stratigraphic observations (Figure 13.10, Table 13.3). Excavation units were assigned to chronological periods based on an age-depth model derived from the calibrated radiocarbon age (Table 11.3; Figures 11.14-11.15). In the absence of radiocarbon dates from Square B, and in view of its proximity and stratigraphic coherence with Square A, the age-depth profile for Square A has been adopted for Square B. Although it is acknowledged as potentially problematic, in the absence of multiple dates a termination date at the surface has been assumed to date to 0 cal BP. Using the termination date of 0 cal BP and the calibrated radiocarbon median date, a linear relationship model (assuming a consistent rate of deposition occurred at the site) was determined for each square (see Section 6.4 for method of calculation). Even though time-averaging these open shell deposits only allows for identification of broad-scale trends and not subtle changes, it allows determination of variation in relative taxa abundance, indicative of taxa exploitation patterns and/or environmental changes affecting the distribution of taxa.

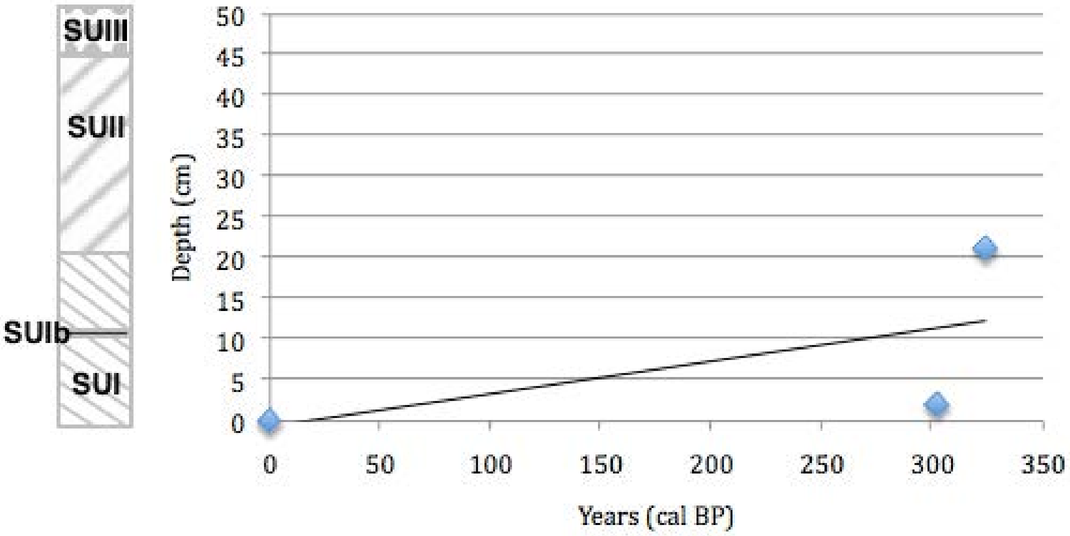


Figure 13.10: Age-depth relationships of all radiocarbon determinations obtained from Banbanbarukeind Square A.

Table 13.3: Temporal phases of 250-year periods, showing allocation of XUs.

Temporal phase	0-250	250-500	500-750
Square A XUs	1-7	8-14	15-20
Square B XUs	1-7	8-14	15-20

13.7 Cultural Materials

3,856.5g (1%) of the total sediment and materials excavated in Square A and 4,428.33g (1%) from Square B were retained in the 2.3mm sieve residue denoting a very low-density cultural deposit. Tables 13.4 and 13.5 show the overall summary results of the retained materials. Molluscan shell makes up 33.6% (1,420.5g) of the Square A assemblage and 33.0% (1,478.27g) of the Square B assemblage. Fishbone contributes 0.08% (2.78g) for Square A and 0.04% (1.67g) for Square B. Small quantities of crustacea (12.6g) were recovered from both squares combined, represented by mud crab (*Scylla* spp.) (3.1g) and goose barnacle (Pedunculata) (9.5g). Non-artefactual stone (including beachrock and pisoliths) contribute 44.8% of Square A and 64.0% of Square B. Organics make up the rest of the assemblage.

Table 13.4: Summary excavation data and retained materials from Banbanbarukeind Square A.

XU	Depth Below Surface (cm)	Mean Thickness (cm)	Weight (kg)	Vol cm^3	pH	Stone Artefacts (g)	Marine Shell (g)	Bone (g)	Barnacles (g)	Crab (g)	Charcoal (g)	Other Organic (g)	Rock Rubble Coral (g)	Retained Materials Total (g)	% of Total Midden
1	4.02	4.02	12.2	10050	6.5	0	179.19	0	2.56	0.44	0	286.25	110.84	579.28	4.75%
2	6.78	2.76	9.5	6900	6.5	0	409.94	0.11	1.86	0.32	0	38.21	69.42	519.86	5.47%
3	8.66	1.88	6.3	4700	7	0	265.83	0.01	0.44	0	0.05	110.82	44.24	421.39	6.69%
4	10.9	2.24	8	5600	6	0	238.35	0	0.65	0.03	0.24	76.02	220.63	535.92	6.70%
5	13.42	2.52	9	6300	6	0	62.15	0	0.05	0.03	0.23	42.13	45.52	150.11	1.67%
6	15.98	2.56	10	6400	6	0	51.76	0	0.05	0	0.26	23.37	52.3	127.74	1.28%
7	18.6	2.62	10.5	6550	5.5	0	23.59	0	0.21	0	0.01	26.67	49.28	99.76	0.95%
8	21.24	2.64	8.5	6600	6	0	14.3	0	0.05	0	0.03	45.99	40.74	101.11	1.19%
9	23.92	2.68	8.4	6700	6	0	14.44	0	0	0.03	0	11.49	35.59	61.55	0.73%
10	26.56	2.64	7.5	6600	6	0	11.78	0.07	0.05	0	0	8.69	42.46	63.05	0.84%
11	29.16	2.6	9.7	6500	7	0	10.69	0	0	0	0	6.38	38.57	55.64	0.57%
12	31.62	2.46	9	6150	5.5	0	11.47	0	0	0	0	6.51	54.21	72.19	0.80%
13	34.14	2.52	10.1	6300	7.5	0	11.49	0	0.05	0	0	6.67	61.86	80.07	0.79%
14	37.54	3.4	12	8500	6.5	0	21.87	0	0.09	0	0	4.58	97.62	124.16	1.03%
15	40.06	2.52	8.5	6300	6.5	0	13.33	0	0.11	0	0	2.64	73.22	89.3	1.05%
16	42.58	2.52	9.2	6300	6	0	12.93	0	0	0	0	3.14	90.14	106.21	1.15%
17	44.98	2.4	8.9	6000	7.5	0	12.49	0	0.12	0.02	0	2.13	108.68	123.44	1.39%
18	47.52	2.54	9.3	6350	8	0	14.68	0	0	0	0	1.89	131.86	148.43	1.60%
19	50	2.48	10.4	6200	7.5	0	23.66	0	0	0	0	1.88	170.29	195.83	1.88%
20	53.2	3.2	11.7	8000	8	0	16.65	0	0	0	0	2.36	182.49	201.5	1.72%
Total:		53.20	188.70	133000		0.00	1420.59	0.19	6.29	0.87	0.82	707.82	1719.96	3856.54	2.04%

Table 13.5: Summary excavation data and retained materials from Banbanbarukeind Square B.

XU	Depth Below Surface (cm)	Mean Thickness (cm)	Weight (kg)	Vol cm^3	pH	Stone Artefacts (g)	Marine Shell (g)	Bone (g)	Barnacles (g)	Crab (g)	Charcoal (g)	Other Organic (g)	Rock Rubble Coral (g)	Retained Materials Total (g)	% of Total Midden
1	3.44	3.44	9	8600	8.5	0	462.86	0	0.97	0.33	0.35	62.22	177.58	704.31	7.83%
2	6.08	2.64	8.5	6600	8.5	0	322.38	0.84	0.14	0.62	0.2	7.28	335.53	666.99	7.85%
3	9.4	3.32	13.3	8300	8.5	0	368.3	0	0.62	1.12	0.03	12.92	193.95	576.94	4.34%
4	11.84	2.44	8.5	6100	8.5	0	51.63	0	0.26	0	0.02	5.03	87.04	143.98	1.69%
5	13.92	2.08	7.8	5200	8.5	0	26.13	0.15	0.15	0	0	15.15	68.46	110.04	1.41%
6	16.42	2.5	8.8	6250	8.5	0	25.33	0	0.05	0.12	0.01	8.51	82.71	116.73	1.33%
7	19.14	2.72	9.9	6800	8.5	0	21.87	0	0.19	0	0	4.95	83.96	110.97	1.12%
8	22.96	3.82	12.3	9550	8.5	0	23.99	0.68	0.05	0.05	0	2.89	92.87	120.53	0.98%
9	25.26	2.3	10	5750	8.5	0	19.44	0	0.16	0	0	3.45	80.58	103.63	1.04%
10	27.68	2.42	8.6	6050	8.5	0	14.04	0	0	0	0	1.8	77.33	93.17	1.08%
11	30.36	2.68	10.2	6700	8.5	0	17.04	0	0.02	0	0	1.37	105.29	123.72	1.21%
12	32.9	2.54	9.3	6350	8.5	0	13.63	0	0.18	0	0	1.06	100.02	114.89	1.24%
13	35.14	2.24	8.4	5600	8.5	0	13.26	0	0	0	0	1	110.98	125.24	1.49%
14	37.5	2.36	8.5	5900	8.5	0	12.22	0	0.14	0	0	0.64	110.5	123.5	1.45%
15	40.2	2.7	8.5	6750	8.5	0	18.11	0	0	0	0	1.18	193.6	212.89	2.50%
16	42.46	2.26	8.5	5650	8.5	0	14.33	0	0	0	0	0.48	145.58	220.53	2.59%
17	45.7	3.24	11.3	8100	8.5	0	19.74	0	0.23	0	0	0.79	220.53	133.11	1.18%
18	48.08	2.38	6.9	5950	8.5	0	11.2	0	0.04	0	0	0.34	133.11	144.69	2.10%
19	50.8	2.72	8	6800	8	0	13.83	0	0.04	0	0	0.21	218.31	232.39	2.90%
20	53.38	2.58	8.5	6450	8	0	8.94	0	0	0	0	0.29	240.85	250.08	2.94%
Total:		53.38	184.80	133450		0	1478.27	1.67	3.24	2.24	0.61	131.56	2858.78	4428.33	2.40%

13.7.1 Invertebrate Mollusc Remains

Square A

In total 1,420.5g of shell was recovered from Square A, which represents 33.6% of the total deposit. 78% of all shell by weight was identified to family, genus or species level. The remaining 22% of shell based on weight could not be identified beyond Mollusca due to the generally small size of these specimens and the lack of diagnostic attributes that prevented identification to taxon; this portion of the assemblage is not considered further in the analyses presented below. The identified assemblage comprised 21 molluscan taxa weighing 1113g (with an MNI=326) consisting of 12 marine bivalve taxa and 9 marine gastropod taxa (Figures 13.11 and 13.12). The assemblage is dominated by oyster (*Saccostrea glomerata*), by weight (506g) representing 35.6% of the total shell assemblage, followed by longbum mudwhelks (*Telescopium telescopium*) (327g, 23.0%) and hiant venus clams (*Marcia hiantina*) (150g, 10.6%). The top 10 species include mudshells (*Geloina erosa*) (53g, 3.7%), mangrove mussels (*Glauconome virens*) (42g, 2.9%), cerithids (*Cerithidea* sp.) (9g, 0.6%), nerites (*Nerita balteata*) (7g, 0.5%), mud creepers (*Terebralia sulcata*) (3g, 0.2%), tumid venus clams (*Gafrarium pectinatum*) (3g, 0.2%) and vertagus shells (*Rhinoclavis* sp.) (2g, 0.1%). The remaining 11 taxa are relatively rare, in total contributing less than 1% of the shell assemblage by weight. Taxa MNIs and weights are presented in Tables 13.6-13.7.

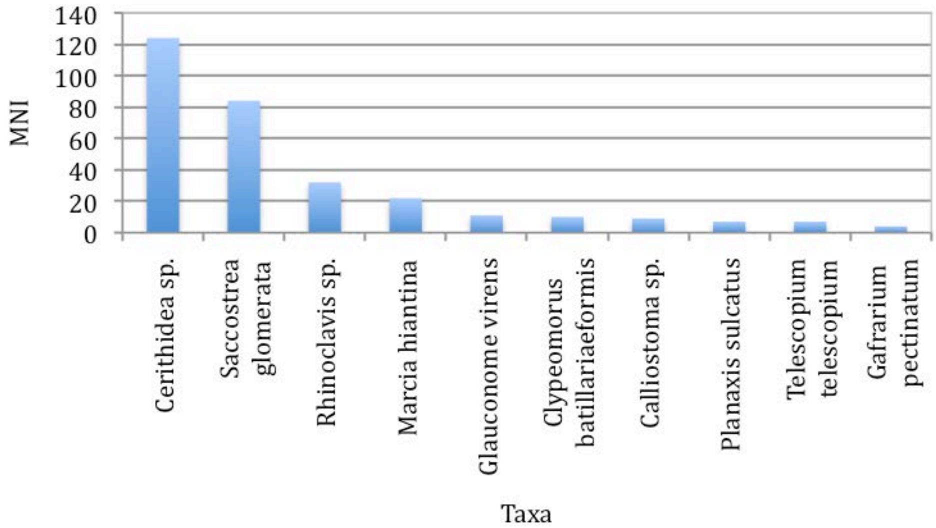


Figure 13.11: Banbanbarukeind Square A, top 10 taxa by MNI.

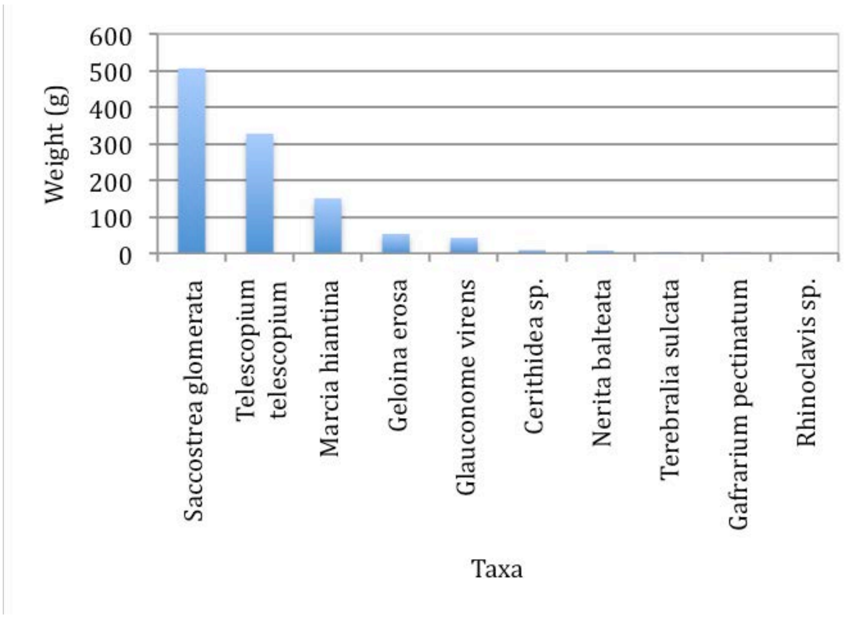


Figure 13.12: Banbanbarukeind Square A, top 10 taxa by weight.

The shell deposit in Square A is concentrated between XU1-8 (0-300 cal BP) accounting for 88% of the total shell assemblage based by weight, suggesting significant use of the site around these times (Figure 13.13). At other times midden creation occurs much more slowly with less site use apparent during the period between 500-750 cal BP as indicated by lower taxa quantities. The assemblage exhibits reasonably high diversity with a calculated Shannon-Weaver Index of 6.81, while 80% of the assemblage comprises four species. The high presence of oyster and hiant venus clams foraging strategies focused on the subtidal rocky reefs and intertidal sand-mudflats (see Figure 13.8). There is evidence that the mangrove and tidal-mud flat zone was also accessed for food resources.

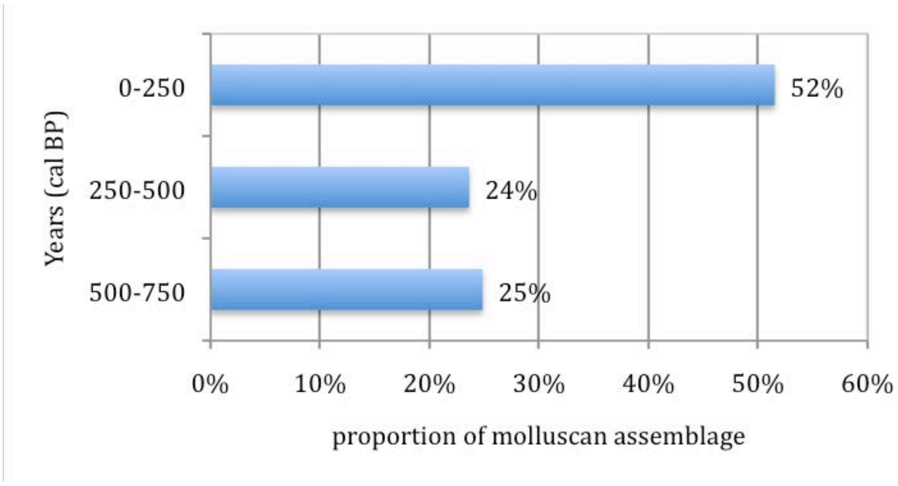


Figure 13.13: Percentage of Square A total mollusc assemblage MNI per 250-year period.

Table 13.6: Banbanbarukeind Square A molluscan assemblage taxa MNIs.

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Totals**
MARINE BIVALVIA																					
Beguina semiorbiculata			1																		**1**
Circe scripta			1																		**1**
Gafrarium pectinatum	1					1											2				**4**
Geloina erosa		1																			**1**
Glauconome virens	1	5		4				1													**11**
Isognomon isognomon								1													**1**
Marcia hiantina	10	3	4	2	1	1		1													**22**
Mytilidae				1																	**1**
Saccostrea glomerata	10	23	18	26	2	3		1					1								**84**
Semele sinensis																			1		**1**
Tellina sp.							1														**1**
MARINE GASTROPODA																					
Calliostoma sp.								2					2	1	1		2			1	**9**
Cerithidea sp.	10		4	8	3	3		5	5	5	12	8	7	4	7	10	12	7	2	12	**124**
Clypeomorus batillariaeformis		1		2						1				3					3		**10**
Nerita balteata	1	2																			**3**
Patellidae	1									1											**2**
Planaxis sulcatus												1		1					5		**7**
Rhinoclavis sp.	1						3					3	4	5		5	2		9		**32**
Telescopium telescopium	1	2	2	1	1																**7**
Terebralia sulcata	1	1											1	1							**4**
XU Totals	**37**	**38**	**30**	**44**	**7**	**8**	**4**	**11**	**5**	**7**	**12**	**12**	**15**	**15**	**8**	**15**	**18**	**7**	**20**	**13**	**326**

Table 13.7: Banbanbarukeind Square A molluscan assemblage taxa weights.

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
MARINE BIVALVIA											
Asaphis violascens											
Beguina semiorbiculata			0.07								
Circe scripta			0.60								
Gafrarium pectinatum	0.81	0.34				1.84					
Geloina erosa	5.15	10.04	6.99	26.98	2.79				1.37		
Glauconome virens	5.62	30.11	1.15	2.14	0.70	1.95	0.61	0.11			
Isognomon isognomon								0.27			
Marcia hiantina	31.36	50.96	35.91	18.46	6.32	4.23	0.15	1.74		0.79	
Mytilidae				0.07						0.16	
Saccostrea glomerata	52.19	186.52	143.22	78.28	24.17	12.03	2.95	1.29	1.96	0.38	0.32
Semele sinensis											
Tellina sp.							0.57				
MARINE GASTROPODA											
Calliostoma sp.								0.03			
Cerithidea sp.	0.80		0.27	0.28	0.27	0.25		0.23	0.39	0.30	0.85
Clypeomorus batillariaeformis		0.21		0.22						0.16	
Nerita balteata	0.77	6.69	0.25								
Patellidae	0.04									0.10	
Planaxis sulcatus											
Rhinoclavis sp.	0.17						0.09				
Telescopium telescopium	44.87	89.66	62.49	92.82	12.35	10.36	4.98	1.54	3.34		0.24
Terebralia sulcata	0.43	2.53									
Unidentified shell	36.98	32.88	14.88	19.10	15.55	21.10	14.24	9.09	7.38	9.89	9.28
XU Totals	**179.19**	**409.94**	**265.83**	**238.35**	**62.15**	**51.76**	**23.59**	**14.30**	**14.44**	**11.78**	10.69

Table 13.7: Banbanbarukeind Square A molluscan assemblage taxa weights (cont.).

Taxon XU	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Totals**
MARINE BIVALVIA										
Asaphis violascens	0.61									0.61
Beguina semiorbiculata										0.07
Circe scripta										0.60
Gafrarium pectinatum						0.22				3.21
Geloina erosa										53.32
Glauconome virens										42.39
Isognomon sp.										0.27
Marcia hiantina				0.31						150.23
Mytilidae										0.23
Saccostrea glomerata		1.44		0.98						505.73
Semele sinensis								0.51		0.51
Tellina sp.										0.57
MARINE GASTROPODA										
Calliostoma sp.		0.15	0.12	0.50		0.10	0.12		0.39	1.41
Cerithidea sp.	0.59	0.20	0.30	1.31	0.41	0.68	0.69	0.26	1.05	9.13
Clypeomorus batillariaeformis			0.87					0.57		2.03
Nerita balteata										7.71
Patellidae										0.14
Planaxis sulcatus	0.14		0.17					1.48		1.79
Rhinoclavis sp.	0.19	0.21	0.39		0.23	0.17		0.70		2.15
Telescopium telescopium		0.51	0.82	0.75	0.25	0.96		1.30		327.24
Terebralia sulcata		0.10	0.65							3.71
Unidentified shell	9.94	8.88	18.55	9.48	12.04	10.36	13.87	18.84	15.21	307.54
XU Totals	11.47	11.49	21.87	13.33	12.93	12.49	14.68	23.66	16.65	1420.59

Square B

In total 1,478g of shell was recovered from Square B, which represents 33.0% of the total deposit. 83% of all shell by weight was identified to family, genus or species level. The remaining 17% of shell based on weight could not be identified beyond Mollusca due to the generally small size of these specimens and the lack of diagnostic attributes that prevented identification to taxon; this portion of the assemblage is not considered further in the analyses presented below. The identified assemblage comprised 23 molluscan taxa weighing 1214g (with an MNI=626) consisting of 13 marine bivalve taxa and 10 marine gastropod taxa (Figures 13.14-13.15).

The assemblage is dominated by oyster (*Saccostrea glomerata*), by weight (501g) representing 33.9% of the shell assemblage, followed by longbum mudwhelks (*Telescopium telescopium*) (389g, 26.3%) and hiant venus clams (*Marcia hiantina*) (222g, 15.0%). The top 10 species include tumid venus clams (*Gafrarium pectinatum*) (47g, 3.2%), cerithids (*Cerithidea* sp.) (14g, 0.9%), mud shell (*Geloina erosa*) (11g, 0.8%), vertagus shell (*Rhinoclavis* sp.) (6g, 0.4%), baler shell (*Melo amphora*) (6g, 0.4%), top shell (*Calliostoma* sp.) (2g, 0.2%) and necklace cerith (*Clypeomorus batillariaeformis*) (2g, 0.1%). The remaining 11 taxa are rare, in total contributing less than 1% of the shell assemblage by weight. Taxa MNIs and weights are presented in Tables 13.8 and 13.9.

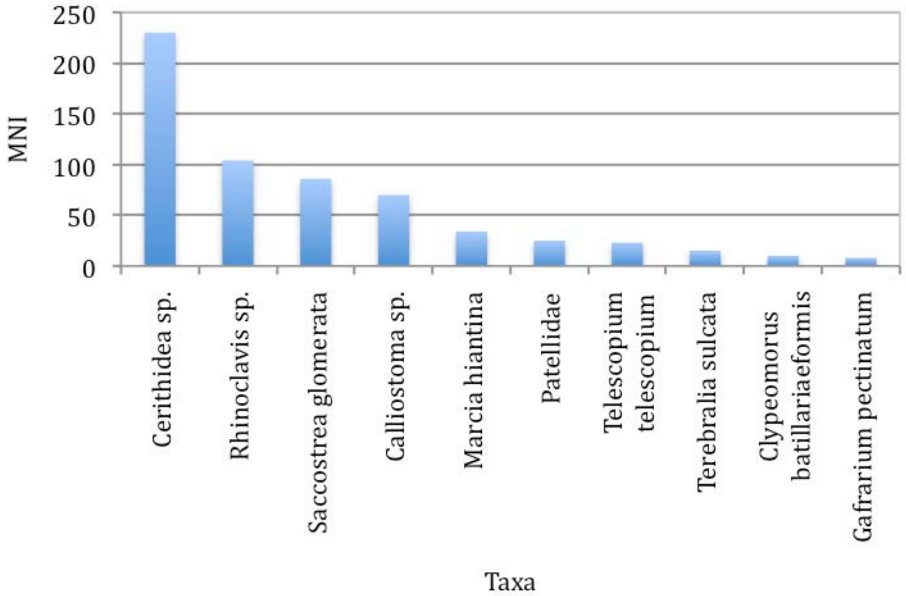


Figure 13.14: Banbanbarukeind Square B, top 10 taxa by MNI.

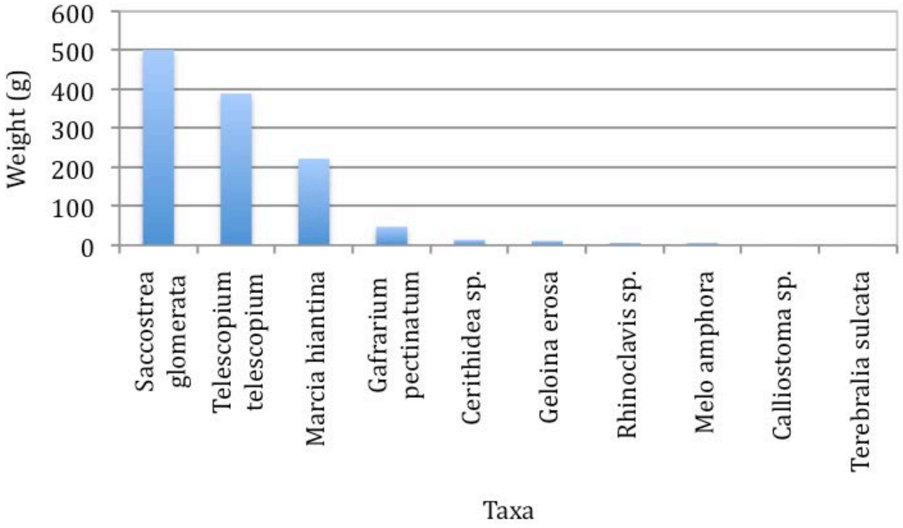


Figure 13.15: Banbanbarukeind Square B, top 10 taxa by weight.

The shell deposit in Square B is concentrated between XU1-8 (0-300 cal BP) accounting for 88% of the identified mollusc assemblage based on weight, suggesting significant use of the site around this time (Figure 13.16). At other times midden creation occurs much more slowly. The assemblage exhibits reasonably high diversity with a calculated Shannon-Weaver Index of 7.23 while 78% of the assemblage comprises four species. Almost mirroring Square A, the assemblage exhibits a high presence of oyster and hiant venus clams suggesting foraging strategies focused on the subtidal rocky reefs and intertidal sand-mudflats (see Figure 13.8). Again there is molluscan evidence (e.g. longbums and mud creepers) that the mangrove and tidal-mud flat zone was also accessed for food resources.

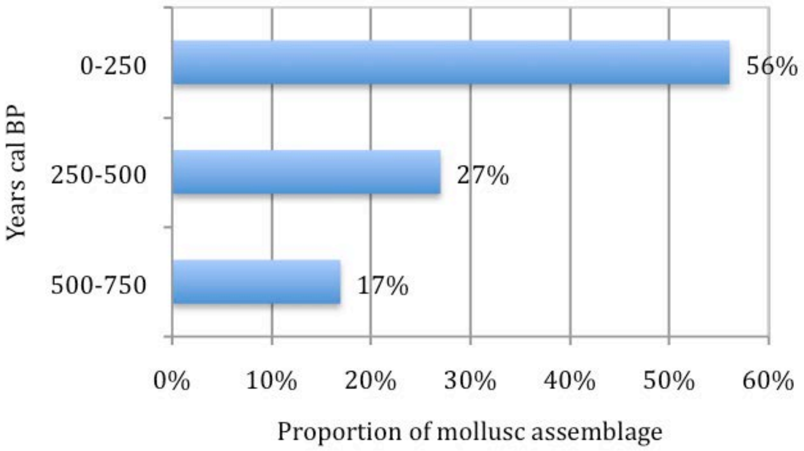


Figure 13.16: Proportion of Square B total mollusc assemblage MNI per 250-year period.

Table 13.8: Banbanbarukeind Square B molluscan assemblage taxa MNIs.

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Species Totals**
MARINE BIVALVIA																					
Beguina semiorbiculata			2					1													**3**
Circe scripta			1	1			1												1		**4**
Gafrarium pectinatum	2	1	1					1	1			1						1			**8**
Isognomon isognomon	2		2					1													**5**
Lunulicardium hemicardium	1																				**1**
Marcia hiantina	12	13	5	1		1				1	1										**34**
Saccostrea glomerata	23	20	30	8	1	1	1	1	1												**86**
Tellina sp.									1									1			**2**
MARINE GASTROPODA																					
Calliostoma sp.	5		2	4	1	7	11	2				9	1	8	5		10			5	**70**
Melo amphora	15	10	11	10	15	29	27	6	7	5	7	24	9	14	18	3	11	2		7	**230**
Patellidae			3						1				1				3		2		**10**
Planaxis sulcatus								1			1		1								**3**
Rhinoclavis sp.	2	6	21	4	3		5		5	2	6	8	4	8	10	5	8	1	1	5	**104**
Telescopium telescopium	10	6	6	1																	**23**
Terebralia sulcata	1		1					2	2	2		3	2	1			1				**15**
Turbo sp.			2															1			**3**
XU Totals	**73**	**56**	**87**	**30**	**20**	**39**	**46**	**17**	**20**	**12**	**17**	**45**	**23**	**35**	**34**	**8**	**35**	**7**	**5**	**17**	**626**

Table 13.9: Banbanbarukeind Square B molluscan assemblage taxa weights.

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
MARINE BIVALVIA											
Asaphis violascens											
Beguina semiorbiculata			0.95			0.30		0.16			
Circe scripta			0.25	0.21		0.10	0.15				
Gafrarium pectinatum	8.63	9.25	23.00	0.55	0.23	0.49		1.34	2.10		0.47
Geloina erosa		11.23									
Isognomon isognomon	0.40	0.26	0.62	0.02				0.04	0.04		
Lunulicardia hemicardium	0.04										
Mactra dissimilis											
Marcia hiantina	84.92	81.85	35.92	7.11	4.47	2.76	1.68	1.89	1.12	0.12	0.09
Mytilidae		0.06		0.01		0.18		0.12	0.04		
Placamen retroversum											
Saccostrea glomerata	179.85	109.48	172.46	19.01	3.87	3.45	2.56	2.06	3.23	1.65	0.58
Tellina sp.									0.02		
MARINE GASTROPODA											
Calliostoma sp.	0.09		0.05	0.17	0.01	0.20	0.25	0.03			
Cerithidea sp.	0.90	0.86	0.37	0.71	0.77	1.46	1.33	0.59	0.51	0.56	0.72
Clypeomorus batillariaeformis			0.63						0.43		
Melo amphora	0.41	3.95		1.64							
Patellidae				0.01		0.08	0.05	0.08	0.23	0.08	0.11
Planaxis sulcatus								0.38			0.18
Rhinoclavis sp.	0.05	0.13	0.74	0.12	0.15		0.27	0.12	0.34	0.35	0.39
Telescopium telescopium	165.67	90.28	100.85	9.40	8.15	7.40	3.84	1.16	0.26		
Terebralia sulcata	0.08		0.24					0.28	0.13	0.23	
Turbo sp.	0.42		0.98								
Unidentified shell	21.40	15.03	31.24	12.67	8.48	8.91	11.74	15.74	10.99	11.05	14.50
XU Totals	462.86	322.38	368.30	51.63	26.13	25.33	21.87	23.99	19.44	14.04	17.04

Table 13.9: Banbanbarukeind Square B molluscan assemblage taxa weights (cont.).

Taxon XU	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Species Totals**
MARINE BIVALVIA										
Asaphis violascens							0.12			0.12
Beguina semiorbiculata										1.41
Circe scripta								0.40	0.20	1.31
Gafrarium pectinatum	0.83				0.27		0.32			47.48
Geloina erosa										11.23
Isognomon isognomon						0.13		0.02		1.53
Lunulicardia hemicardium										0.04
Mactra dissimilis	0.44			0.54						0.98
Marcia hiantina										221.93
Mytilidae		0.01	0.11			0.12				0.65
Placamen retroversum							0.09			0.09
Saccostrea glomerata	0.53	0.34		0.11	0.40	1.60	0.31		0.10	501.59
Tellina sp.							0.03		0.26	0.31
MARINE GASTROPODA										
Calliostoma sp.	0.65	0.07	0.35	0.17		0.39			0.02	2.45
Cerithidea sp.	0.91	0.50	0.48	1.75	0.28	0.90	0.36		0.15	14.11
Clypeomorus batillariaeformis		0.27				0.54		0.42		2.29
Melo amphora										6.00
Patellidae		0.21	0.17	0.07		0.16	0.01	0.01		1.27
Planaxis sulcatus		0.23								0.79
Rhinoclavis sp.	0.48	0.34	0.48	0.61	0.33	0.43	0.07	0.73	0.12	6.25
Telescopium telescopium	0.22	0.60	1.13							388.96
Terebralia sulcata	0.47	0.20	0.19			0.29				2.11
Turbo sp.							0.08			1.48
Unidentified Shell	9.10	10.49	9.31	14.86	13.05	15.18	9.81	12.25	8.09	263.89
XU Totals	13.63	13.26	12.22	18.11	14.33	19.74	11.20	13.83	8.94	1478.27

13.7.2 Vertebrate Remains

Square A

Small numbers (n=7) of fish bones were recovered from 3 XUs, comprising the only vertebrate remains (0.19g) in Square A (see Table 13.10). Most of the bone material was highly fragmented and could only be identified as Osteichthyes (bony fishes).

Table 13.10: Fish remains from Banbanbarukeind Square A.

XU	Taxon	Element	MNI	NISP	Weight
2	Osteichthyes	unidentified		5	0.1125
3	Osteichthyes	unidentified		1	0.0102
10	Osteichthyes	unidentified		1	0.0735
		Totals		7	0.1962

Square B

Small numbers (n=9) of fish bones and an otolith were recovered from throughout the deposit, comprising the only vertebrate remains (3.8g) in Square B (see Table 13.11). Fishbone occurs in 3 XUs. No bone was recovered below XU8. Most of the bone material was highly fragmented and the majority could only be identified as Osteichthyes (bony fishes); however the otolith proved more promising. The MNI of one was calculated by summing the MNI for each excavation unit. Identified taxa include grass emperor (*Lethrinus laticaudis*). Table 13.12 shows the length of the fish otolith collected from the Banbanbarukeind midden as well as the length of a comparative fish otolith in the TARL fish reference collection (Tomkins *et al.* 2013).

Table 13.11: Fish remains from Banbanbarukeind Square B.

XU	Taxon	Element	MNI	NISP	Weight
2	Osteichthyes	unidentified		5	0.54
2	*Lethrinus laticaudis*	otolith	1	1	0.30
5	Osteichthyes	unidentified		1	0.15
8	Osteichthyes	unidentified		2	0.68
		Totals	1	9	1.67

Table 13.12: Estimated weights of fishes based on otolith lengths of archaeological specimens compared with reference collection specimens.

Taxon	XU	Length of archaeological otolith (mm)	Comparative otolith length (mm)	Comparative taxon weight (g)	Estimated weight of archaeological fish (g)
Lethrinus laticaudis	2	9.8	9.8mm/12.8	400/1200	400

13.8 Application of Models

13.8.1 Diet-Breadth/Prey Choice

Broad patterns in the breadth and diversity of molluscan exploitation at Banbanbarukeind can be identified using species richness and abundance measures. The species richness graphs show the number of species collected from each habitat per 250-year period for each square (Figures 13.17-13.18). Three habitats (Rocky Reefs, Sandy-Mud Flats and Mangroves and Tidal-Mud Flats) were consistently exploited. The level of species richness by habitat varies between chronological periods however chi-square results for Square A (X^2 = 1.61, d.f. = 4, p>0,5) and for Square B (X^2 = 0.07, d.f. = 4, p>0.5) indicate this variation is not considered statistically significant.

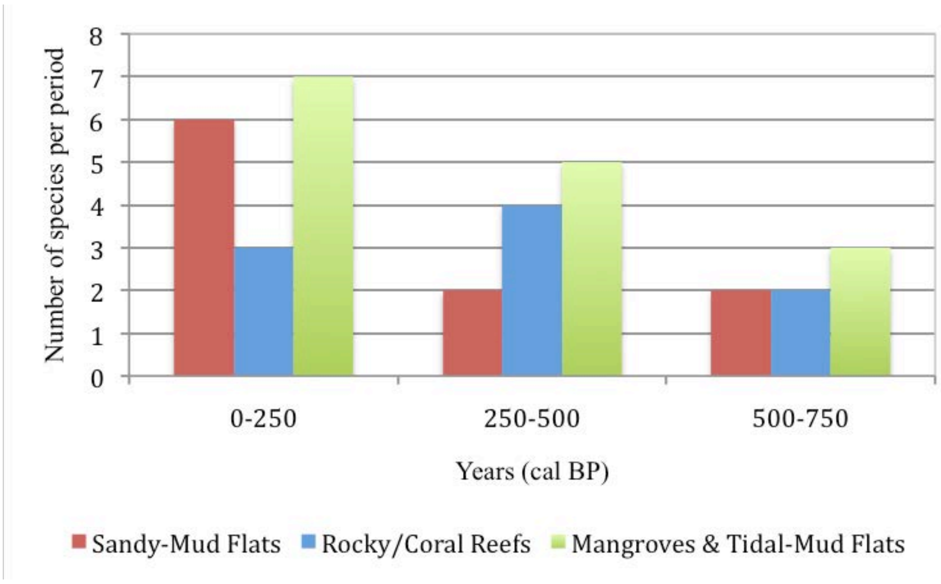


Figure 13.17: Banbanbarukeind Square A, species richness per habitat per 250-year period.

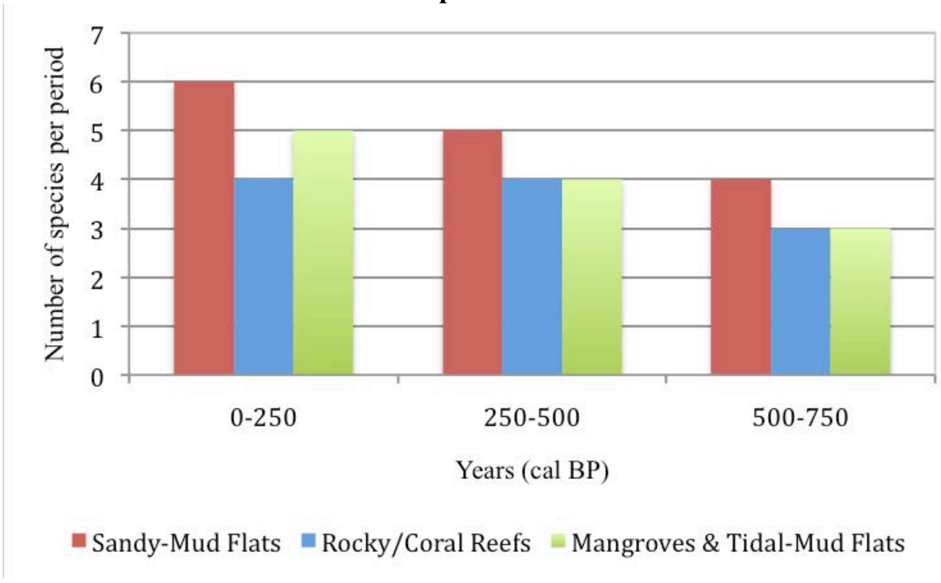


Figure 13.18: Banbanbarukeind Square B, species richness per habitat per 250-year period.

Based on species richness several taxa were collected, however when reviewing MNI it is apparent that a greater portion of the assemblage (86%) is made up of six species, all common to both Square A and Square B – oyster (*Saccostrea glomerata*), hiant venus clams (*Marcia hiantina*), top shells (*Calliostoma* sp.), longbums (*Telescopium telescopium*) and cerithid snails (*Cerithidea* sp. and *Rhioclavis* sp.). Square A also contains high numbers of mangrove mussels (*Glauconome virens*) (Figure 13.19) while Square B has good numbers of limpets (Patellidae) (Figure 13.20).

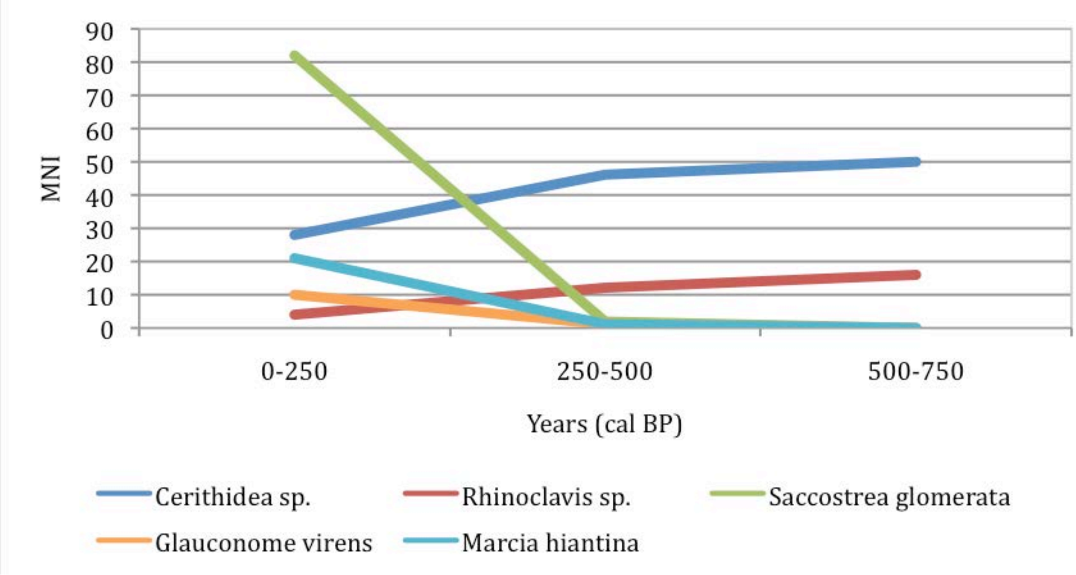


Figure 13.19: Top five mollusc taxa MNI counts per 250-year period, Square A.

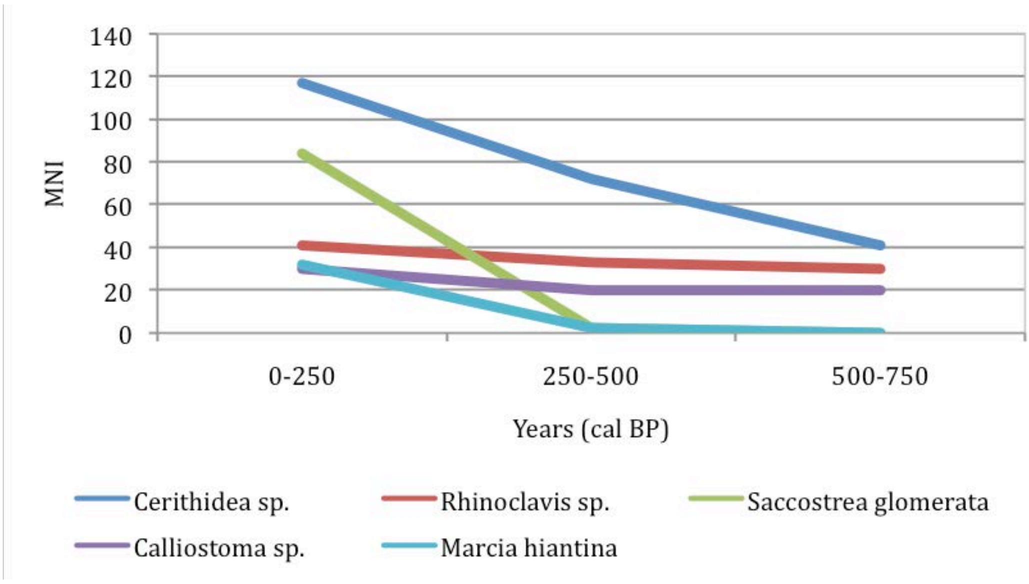


Figure 13.20: Top five mollusc taxa MNI counts per 250-year period, Square B

Of the top taxa the cerithid species (*Cerithidea* sp. and *Rhinoclavis* sp.) and possibly also top shells (*Calliostoma* sp.) are thought to be background taxa that were not deliberately collected for food due to their small size, on average <10mm in length. They are present in all 250-year periods however ratios vary. Hiant venus clams (*M. hiantina*), oysters (*S. glomerata*) and longbums (*T. telescopium*) are present in both squares, predominantly in the period 0-250 years but there continues to be minor representation in the upper XUs of the 250-500 period. There is similar temporal representation of mangrove mussels (*Glauconome virens*), however they are only found in the Square A assemblage.

The identified vertebrate taxon is a grass emperor (*Lethrinus laticaudis*). This species is demersal and can be found in the coastal shallow waters feeding over sand in and around seagrass beds and coral and rocky reefs. Juvenile grass emperors are also spotted feeding on mangrove mud flats.

13.8.2 Habitats/Patch Choice

The graphs in Figures 13.21 and 13.22 show the percentage of species MNI collected by habitat. The Banbanbarukeind mollusc assemblage includes taxa that come from three patches or habitats, however there is temporal variance in the quantities of taxa taken from each patch. The chi-square results for Square A (X^2=79.88, d.f.=4, p<0.0001) and Square B (X^2=17.97, d.f.= 4, p<0.01) indicate that this variance is statistically significant.

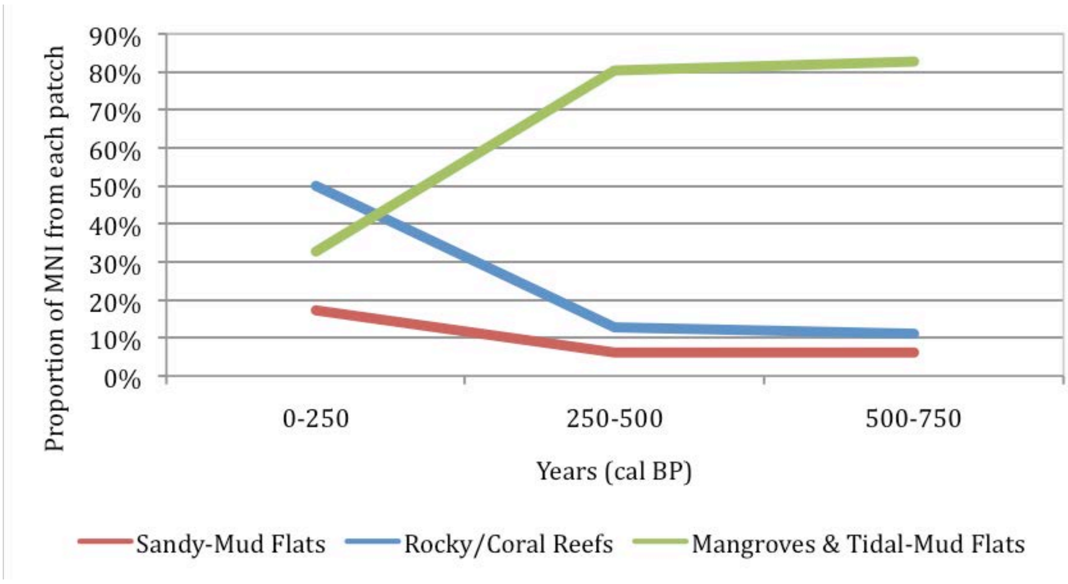


Figure 13.21: Percentage of mollusc taxa MNI collected from each patch by 250-year period Square A.

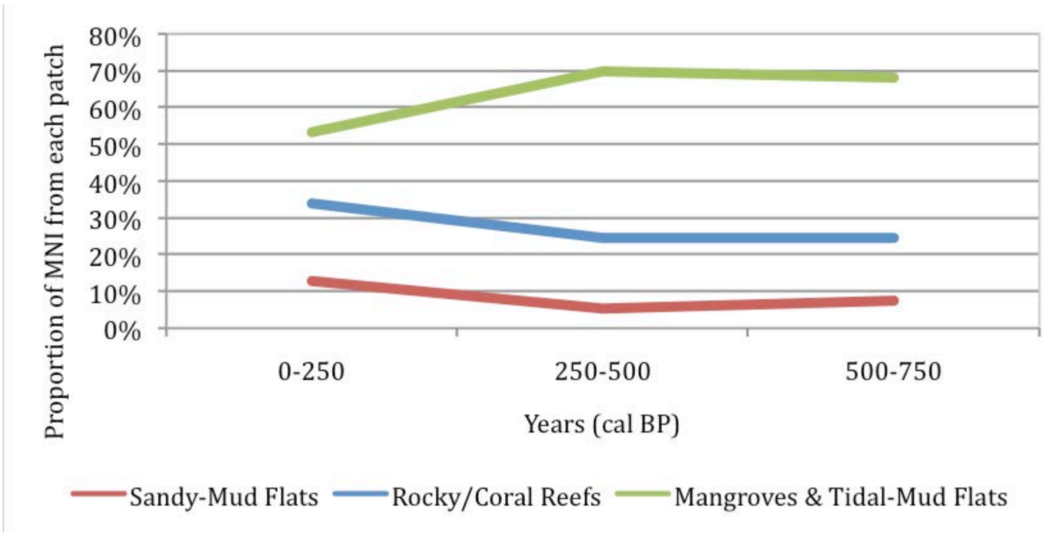


Figure 13.22: Percentage of mollusc taxa MNI collected from each patch by 250-year period Square B.

The Mangroves and Tidal-Mud Flats patch is the dominant focus of resource exploitation during the periods 250-500 cal BP and 500-750 cal BP, contributing on average 70% of the assemblage for these periods. The data curves for both Sandy-Mud Flats and Rocky/Coral Reefs habitats are quite flat during this period. Sandy-mud species only contribute less than 10% of the assemblage at these times even though there is higher species richness. In contrast during the 0-250 year period there is a sharp decline in the proportion of Mangrove and Tidal-Mud Flat species matched by increased exploitation in the other two patches, particularly in the Rocky/Coral Reefs habitat.

Changes in patch use between the Mangroves and Tidal-Mud Flats and Rocky/Coral Reefs patches can be tracked through the use of an index (Figure 13.23). The index is reasonably flat suggesting that there is not a significant switch in foragers' preference from mangrove taxa to rocky/coral reef taxa through time but there is definitely a correlation between the two variables. This is confirmed with the significant chi-square result ($X^2 = 9.92$, d.f. = 4, $p<0.01$).

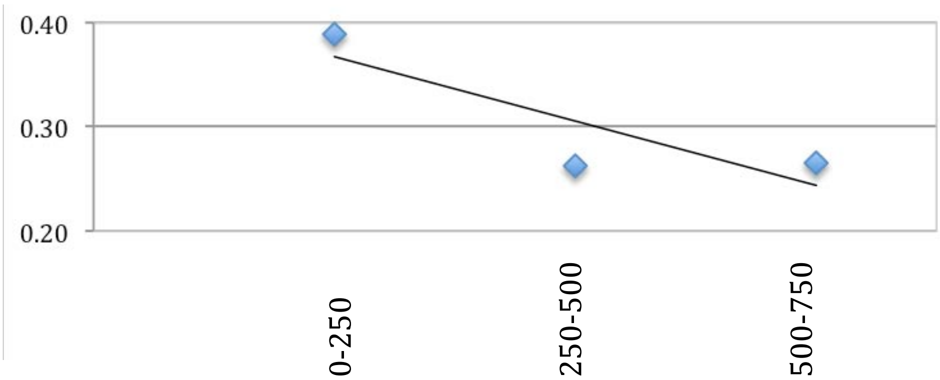


Figure 13.23: Change in patch use as indicated by Mangroves and Tidal-Mud Flats/Rocky/Coral Reefs Patches Index.

In terms of the top three species considered to be cultural species chosen for food, *Saccostrea glomerata* a rocky reef species is more intensively exploited than the other two taxa, *Marcia hiantina* (found in sandy-mud flats) and *Glauconome virens* (found in mangrove and tidal-mud flats). Nevertheless, the presence of all three species in the midden indicates that people actively targeted a range of habitats to collect food.

13.8.3 Central Place Foraging Model

Banbanbarukeind appears to have been a central-place for occupation where foragers brought food back to share. Central place foraging does however impose travel costs, such as the energetic cost of carrying a food item from its procurement source back to camp. Foragers on rocky reefs are often constrained by the volume and weight of a load of unprocessed shellfish (Bird and Bliege Bird 1997:42). When travel costs outweigh the energetic return of a shellfish species, foragers will often choose to process the shell on the reef or at 'dinner-time' camps (see Meehan 1982) on the foreshore's supratidal fringe. These situations will result in differential concentrations of shell remains in the central-place midden (Bird and Bliege Bird 1997). Mangrove species make up a higher proportion of the assemblage throughout all periods, perhaps because of the lowest associated capture costs (e.g. closer proximity of habitat to site).

13.8.4 Resource Intensification and Foraging Efficiency

At Banbanbarukeind *M. hiantina* is one of the top five species and from Figures 13.21 and 13.22 it is evident that *M. hiantina* has a relatively low presence in the period 250-750 years, however numbers increase in 0-250 years. Based on the prey choice model, because of its high calorific value this species would be classed as high-ranked taxa and as such is expected to be preferentially collected over lower-ranked taxa. Based on the central place foraging model one explanation for lower numbers of *M. hiantina* in the Banbanbarukeind midden is that people chose to collect other species instead that have higher overall energetic return rates considering transport costs. For other sites where this bivalve is the dominant species in the assemblage, we considered various factors associated with its exploitation such as declining resource availability, possibly resulting from population depression caused by intensified exploitation of the one species. At Banbanbarukeind people diversified and collected several high-ranked taxa from different habitats. We suggest that because there is less pressure on one species we should see little change in the population structure of *M. hiantina*. In order to confirm this we can review changes through time in the population structure of each species using morphological attributes. Table 13.13 shows the average sizes for each species per XU.

Table 13.13: Metrical data for intact *M. hiantina* valves from Banbanbarukeind, combined Squares A and B.

XU	Mean (mm)	Median (mm)	S.D. (mm)	Min (mm)	Max (mm)	Range (mm)	No.
1	34.42	33.70	2.56	31.10	38.00	8.90	11
2	35.24	35.20	3.28	30.71	35.73	5.02	12
3	34.05	34.45	5.11	27.40	39.00	11.60	6
4	34.31	34.76	1.91	31.10	36.19	5.09	5
5	34.00	34.00	0.00	34.00	34.00	0.00	1

Keeping in mind that if *M. hiantina* were being over-exploited there would likely be a corresponding reduction in the size of specimens being taken because juvenile specimens would not have time to mature before being selected. When reviewing the relationship between the hiant venus clam MNI and specimen sizes for each period, there are slight changes in the mean valve length of hiant venus clams through time that correlate with changes in MNI quantities (Table 13.9). However this is not significant and there appears to be no evidence for resource depression. These data suggest that rather than intensive exploitation of one species occurring at Banbanbarukeind, Kaiadilt people appear to have efficiently managed the collection of molluscan species alternating gathering times to ensure sustainability of the molluscan resources.

13.9 Discussion

Given its distance from the coastline, the site at Banbanbarukeind is consistent with being a central place camp for occupation, possibly during times of refuge, where foragers brought back food to share. Radiocarbon dates also attest to repeated use of the site in the past 300 years. The site may have experienced low occupation prior to this time but evidence for this is not conclusive.

MNI values are at their highest in the 0-250 cal BP period. The most popular molluscs collected for food are *Saccostrea glomerata, Marcia hiantina* and *Glauconome virens*. Occupants of the site consistently exploited all resource zones. Resources from Rocky Reefs and Sandy-Mud Flats were preferred over Mangroves and Tidal-Mud Flats, although the graphs in Figures 13.21 and 13.22 are slightly skewed by the presence of small cerithid species that were not likely collected for food.

S. glomerata (rock oyster) inhabits sheltered rocky shores in the mid-to-intertidal zones (Lamprell and Healy 1998). Oysters rapidly reproduce with a high spawning frequency and broad distribution of offspring (Catterall and Poiner 1987) enabling efficient re-colonisation of habitats following events of depletion and intensive extraction (Sullivan 1987:103). *S. glomerata* often cement to substrates in large clumps (Campbell 2010; Kent 1992), and bulk 'stripping' of clumps may have been a more effective harvesting technique than selecting individual specimens (e.g. Whitaker 2008) as this would likely decrease costs of search time and processing of the resource (Alvard 1998).

M. hiantina is a Sandy-Mud Flats species favoured for food. The range in size (27.04mm – 39.00mm) indicates that people were not necessarily choosing the largest bodied prey but rather whatever they encountered that seemed reasonably worthwhile in terms of meat content (e.g. Johnson 2010). All specimens present in the assemblage were aged from 2nd and 3rd year level of maturity so juveniles were not being taken.

13.10 Summary

Excavation at Banbanbarukeind revealed a medium density stratified shell deposit consistent with observations of the material exposed across the deflated dune context. The restricted range of shellfish taxa, dominance of larger molluscan size-classes and presence of burnt shell and fish remains support a cultural origin for the deposit. There is evidence that all resource zones were exploited based on the three dominant taxa species.

Chapter 14. Jirrkamirndiyarrb, Bentinck Island

14.1 Introduction

Archaeological investigations at Jirrkamirndiyarrb on Bentinck Island revealed a low-density cultural deposit dominated by marine shell dated between c.524 cal BP and c.3,483 cal BP. Aboriginal fish-traps along the coastline adjacent to Jirrkamirndiyarrb and extensive scatters of surface shell midden material suggest widespread settlement in the area in the past and intensive exploitation of marine resources. This chapter describes the Jirrkamirndiyarrb site and its stratigraphy, chronology and contents followed by a discussion of the data from an OFT perspective for understanding foraging behaviours of the site users.

14.2 Site Description and Setting

Jirrkamirndiyarrb is an extensive low-density shell midden complex located in the near-surface deposits of mobile sand dunes between 0.5 and 1.5km west of the outstation settlement of Nyinyilki (Figures 14.1-14.2). The Jirrkamirndiyarrb Site 8 excavation is located at the western end of this site complex, c.200m inland from the south coast and c.800m east of Murdumurdu (Latitude: 17.09660S, Longitude: 139.55376E) (Figure 14.3). A gravel road transects the area with minor tracks for beach access. Rubbish from the settlement at Nyinyilki is buried in large pits excavated on the sides of the road. Scatters of hiant venus clams (*Marcia hiantina*) are exposed in road cuttings and other areas disturbed by earthmoving machinery (Ulm *et al.* 2010). Three *in situ* shell lenses exposed in section were identified at Jirrkamirndiyarrb Site 8 with the main shell exposure occurring at between 23cm and 51.5cm below the surface. Sean Ulm and Daniel Rosendahl, assisted by Traditional Owners Duncan Kelly and John Roberts, excavated a 50cm x 50cm pit (Square A) on a flat portion of cleared land, immediately north of an erosion bank parallel to the 3m-wide graded road (Figure 14.4).

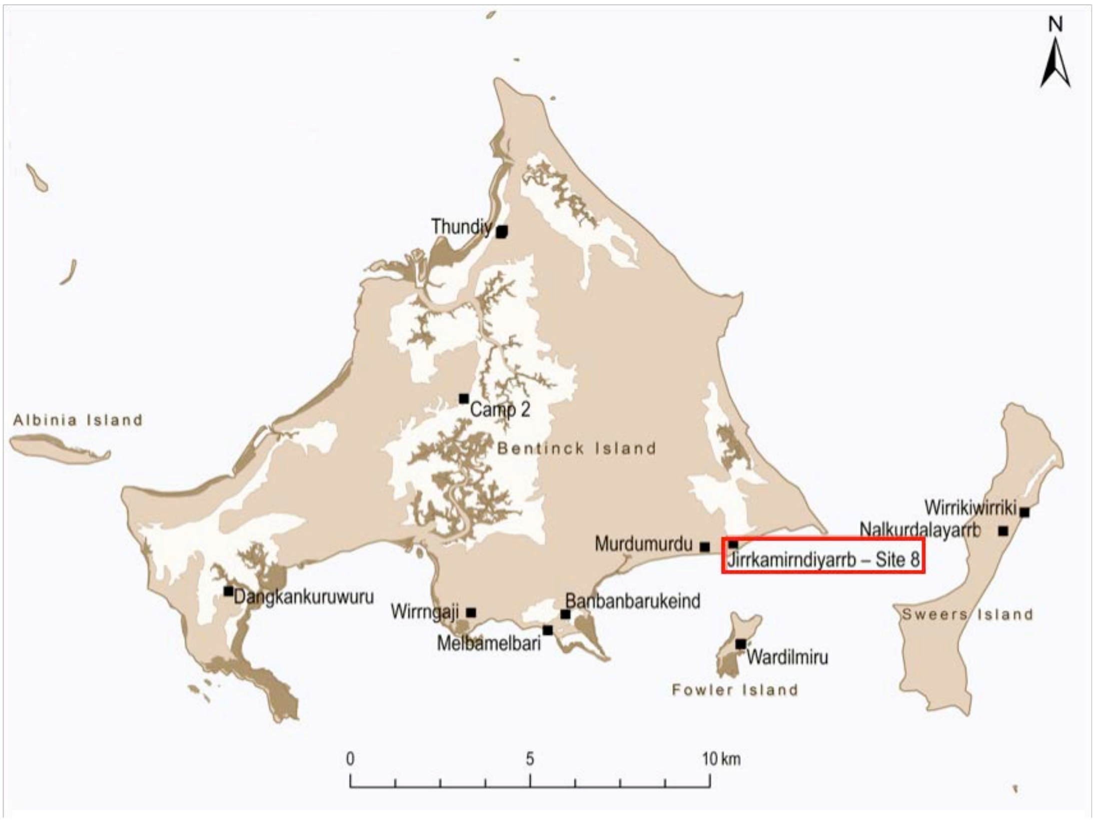


Figure 14.1: Map of South Wellesley Islands showing Jirkkamirndiyarrb location (map prepared by Lincoln Steinberger and Sean Ulm).

Figure 14.2: Aerial view of Jirrkamirndiyarrb site location (after Google Earth).

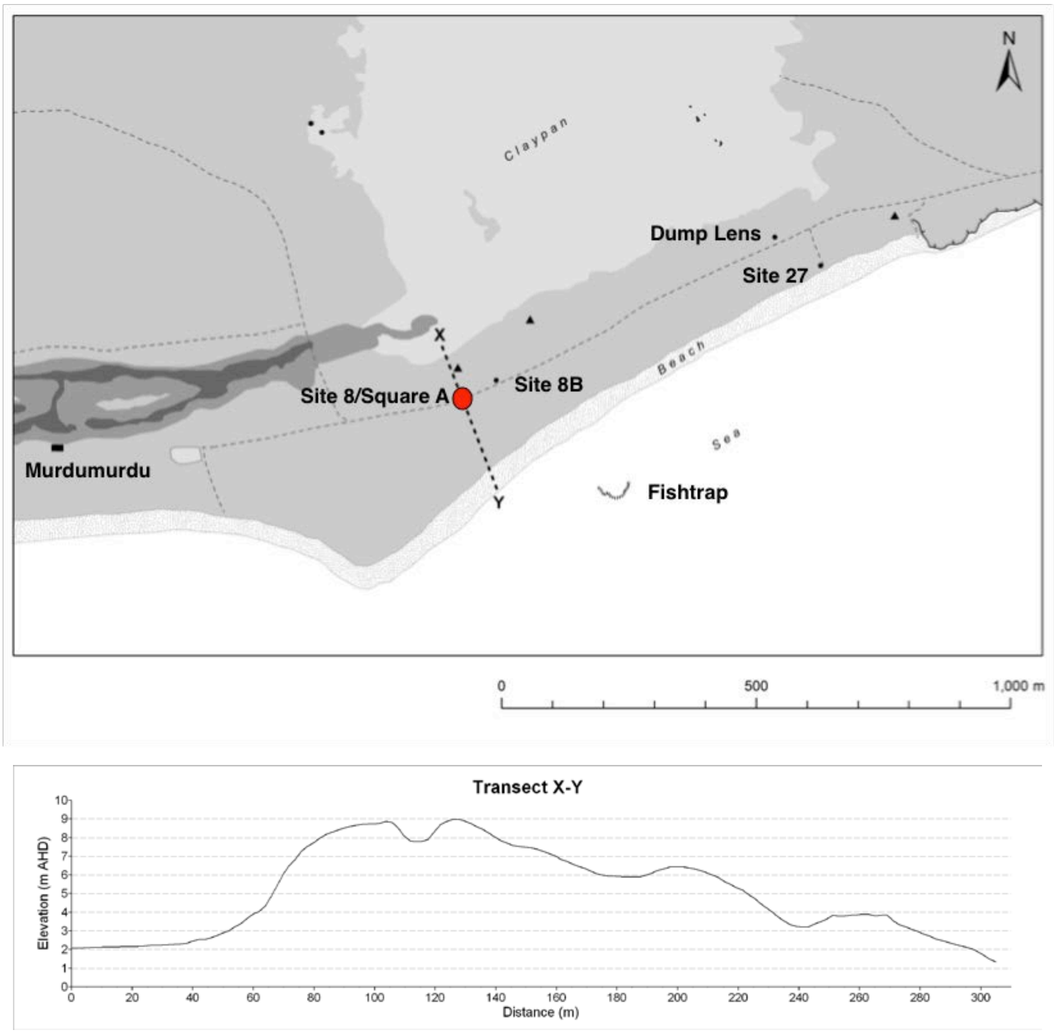


Figure 14.3: Jirrkamirndiyarrb site context showing landscape features and transect elevation (map prepared by Lincoln Steinberger and Sean Ulm).

Figure 14.4: View north showing excavations at Site 8 and clay/saltpan in background. Shell midden lens is visible in road wall profile in foreground (Photo by Sean Ulm).

Marralda Swamp is situated c.200m northwest of the site with mangrove-fringed saltflats c.50m to the north. During the wet season, the swamp and saltflats are inundated. Mollusc communities likely to be found in the mangrove fringes include mud clams (*Geloina erosa*), tree oysters (*Isognomon isognomon*) and cerithid snails (*Cerithidea* sp.). The area is very exposed to the sun and insects from nearby mangroves. There is also a native well to the east of Jirrkamirndiyarrb Site 8. The mobile dunes are vegetated by sandy grasslands with sparse stands of pandanus palms and eucalypts (Figure 14.4-14.6). The coastline has long expanses of sandy beaches with scattered she-oak trees occurring along the strandline. The intertidal sandy-mud flats along the front shoreline support cockles (*Lunulicardia hemicardium*), hiant venus clams (*Marcia hiantina*) and tumid venus clams (*Gafrarium pectinatum*). Rocky reef platforms occur within 100m of the shoreline (Figure 14.7) and support clumps of rock oyster (*Saccostrea glomerata*), limpets (Patellidae) and turban and top snails (*Turbo* sp. and *Calliostoma* sp.). The rocky/coral reefs also provide shelter for fish species such as wrasses (Labridae).

Approximately 400m southwest of the site shallow sandbars provide an access 'bridge' to Fowler Island during the lowest tides. The protected inshore coastal waters support extensive seagrass communities, an important food resource for dugongs and turtles. Dolphins, rays and sharks also frequent these shallow waters.

Figure 14.5: View southeast looking across sandy dune ridges toward south coast.

Figure 14.6: Fishtrap on nearby southeastern shoreline (see Figure 14.3 for context).

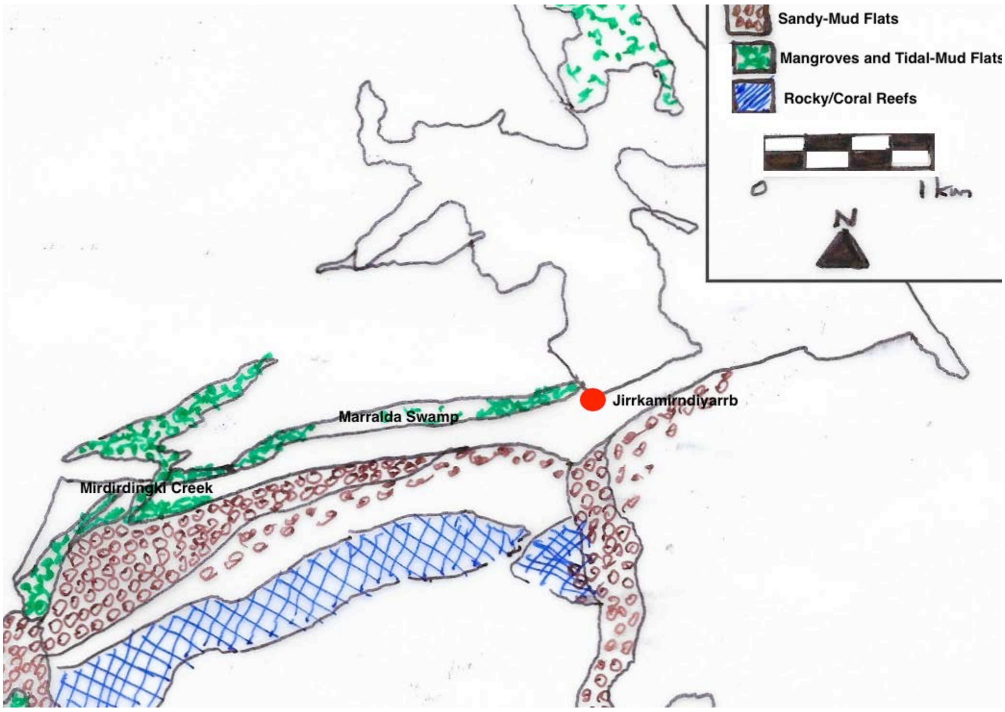


Figure 14.7: Resource habitat communities near Jirrkamirndiyarrb.

14.3 Excavation Methods

In April 2008, Sean Ulm and Daniel Rosendahl excavated 237.5kg of sediments from a single 50cm x 50cm pit dug in the midden (Square A). Excavations proceeded in shallow, arbitrary excavation units (XUs) averaging 3.0cm in depth and 11.9kg in weight. Excavations ceased at c.60cm below the ground surface though shell materials ceased being recovered after c.57cm. All midden materials were dry-sieved through 2.3mm mesh on site and materials retained in the sieve were collected for later sorting and identification in the laboratory (see Chapter 5 for a detailed discussion of the standard excavation and laboratory methods employed at all sites).

14.4 Cultural Deposit and Stratigraphy

Excavations revealed a thin lens of reasonably dense cultural deposit with shell, bone and charcoal, resting on coarse reddish yellow sands with tiny gastropod inclusions (Figures 14.8 and 14.9). The majority of shell was recovered from between XU2-10 (c.5cm-30cm depth). The deposit can be divided into three stratigraphic units (SUs) – a thin unit of aeolian sediments covering a cultural unit overlaying a thick unit of reddish yellow sands (Figure 14.10; Table 14.1). SUI includes materials located in XU1 and XU2. SUII includes materials between XU3 to XU10. SUIII includes materials located between XU11 to XU20. This unit contains sparse quantities of cultural materials that have filtered down from upper layers, which could account for fish bones and an otolith found in XU13, XU14 and XU18. Alternatively there may have been a very brief early period of site use.

Figure 14.8: Jirrkamirndiyarrb Square A, 50cm x 50cm excavations (Photo by Sean Ulm).

Figure 14.9: Stratigraphic west section profile, 50cm x 50cm Square A (Photo by Sean Ulm).

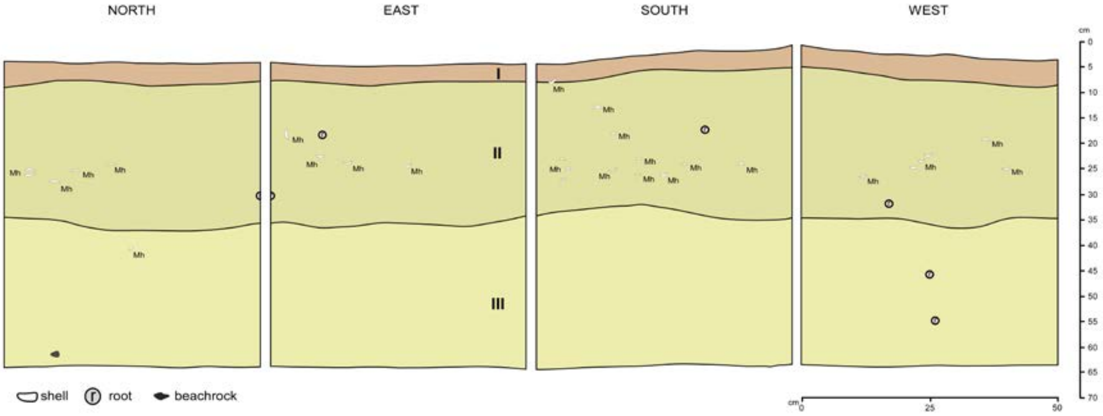


Figure 14.10: Stratigraphic section drawing, Jirrkamirndiyarrb Square A (prepared by Sean Ulm and Michelle Langley).

Table 14.1: Stratigraphic Unit (SU) descriptions for Square A.

SU	Description
I	A thin c.5cm layer of fine aeolian sediments comprising angular to subangular dry and loosely consolidated sands. Sediments are brown (7.5YR-5/4) in colour. The layer contains leaf litter, vines and numerous grass roots. Cultural materials include charcoal fragments, crab fragments and fragmented molluscs (dominated by venus clams). pH values are highly alkaline (8.0).
II	SUII extends across the entire square (c.27cm thick) between 5cm to 32cm below ground surface. It contains more consolidated brown to strong-brown (7.5YR-4/4, 7.5YR-5/6) sands with numerous gravel inclusions. A large number of roots were excavated from this unit. Cultural materials include charcoal fragments, crab and fishbone fragments and numerous whole and fragmented molluscs (dominated by venus clams). The shell lens is about midway through the unit and virtually all the cultural shell recovered from Square A is located in this SU. pH values are highly alkaline (7.5-8.5).
III	This largely culturally sterile unit is c.28cm thick located between c.32cm to 60cm below ground surface. Loosely consolidated yellowish brown (7.5YR-6/4) sands with numerous tiny gastropod (cerithids and top snails) inclusions, grading to reddish yellow (7.5YR-6/6) sands with few shell inclusions. Shell fragments greater than 5mm are rare. pH values remain strongly alkaline (8.5-9.0).

14.5 Site Integrity and Taphonomy

The excavated deposit exhibits reasonable stratigraphic integrity. The shell decay profile exhibits highly weathered tiny gastropod specimens recovered from the base of the deposit although cultural shell specimens from the upper SUI also appear highly weathered. There is evidence of varying degrees of disturbance within the pit in the form of insect burrows and vegetation roots. The bulk of cultural materials are found in SUII and this unit appears to be reasonably intact. Meagre quantities of cultural shell fragments appear to have filtered down through to SUIII. Reviewing effects of site taphonomy on vertebrate remains it seems that degradation of fish bone materials is greatest in lower XUs. There is a pattern of low shell fragmentation (c.300 fragments per 100g of shell) contributing to high rates of identification in the upper units that correlates with the period of cultural deposition (see Hoffman 2011). This contrasts with increased shell fragmentation (c.450 fragments per 100g of shell) and resulting lower rates of identification in deeper and older units.

14.6 Radiocarbon Dating and Chronology

Four radiocarbon determinations have been obtained for Jirrkamirndiyarrb Site 8 and three additional dates were collected for nearby shell exposures at Jirrkamirndiyarrb 8B, Dump Lens and Site 27 (Table 14.2). A date of c.3,483 cal BP was obtained on a fish otolith located in XU18 in the basal layer of SUIII. This suggests the site may have been used as early as c.3,500 years ago by people, although it is also possible the otolith was part of the natural matrix. A second date of c.1,521 cal BP was obtained on a *Marcia hiantina* valve collected from XU2, however this overlies two other dates of c.524 cal BP (XU9) and c.637 cal BP (XU7), also obtained on *Marcia hiantina*. This indicates that taphonomic processes have affected the site violating the law of superposition. Considering that the site is located near a roadway, it is likely that during the course of building the road, materials from the adjacent lower midden were disturbed by earthworks and re-deposited on top of the excavated midden.

Table 14.2: Radiocarbon ages on marine shell from Jirrkamirndiyarrb. Calibrations undertaken using OxCal v.4.1 (Bronk Ramsey 2009) and the Marine13 calibration datasets (Reimer *et al.* 2013). For marine samples a ΔR of −49±102 as recommended by Ulm *et al.* (in prep.) is employed.

Site/ Sq.	XU	Depth (cm)	Lab. Code	Sample	^{14}C	δ^{13}C	Calibrated Age BP (95.4%)	Calibrated Age Median
8/A	2	0.1-4.8	Wk-35853	*Marcia hiantina*	1913±29	0.1±0.2	1294-1766	1521
8/A	7	17.0-19.9	Wk-35854	*Marcia hiantina*	1018±32	2.0±0.2	478-849	637
8/A	9	23.0-26.0	Wk-23663	*Marcia hiantina*	868±44	1.6±0.2	306-681	524
8/A	18	50.9-54.0	Wk-35855	Fish otolith	3533±30	-0.2±0.2	3225-3758	3483
27/-	-	28.2	Wk-23665	*Marcia hiantina*	688±30	-0.9±0.2	126-545	369
8B/-	-	51.5	Wk-23664	*Marcia hiantina*	1266±30	1.0±0.2	655-1077	858
Dump Lens	-	0	OZ-185	*Marcia hiantina*	1260±35	-0.9±0.2	650-1075	852

In keeping with procedures adopted for other sites the assemblage has been divided into temporal phases of 250-year periods for comparative purposes. Excavation units have been assigned to chronological periods based on an age-depth model derived from the calibrated radiocarbon ages and stratigraphic observations (Figure 14.11, Table 14.3). Even though the surface of the midden appears to have been disturbed, we can be reasonably confident that dates of c.524 cal BP (XU9) and c.637 cal BP (XU7) securely bracket an intensive site use period

(500-750 cal BP) for the main shell lens in XU8. The date of c.1,521 cal BP in XU2 is anomalous and probably relates to materials that have been disturbed by earthworks elsewhere and re-deposited on Square A, therefore XU1 and XU2 have not been included in any analyses. There are insufficient data to calculate sedimentation rate for XU13 to XU20, so these have been grouped in one data bin that incorporates material not thought to be a culturally-related deposit. Even though time-averaging these open shell deposits only allows for identification of broad-scale trends and not subtle changes, it allows determination of variation in relative taxa abundance, indicative of taxa exploitation patterns and/or environmental changes affecting the distribution of taxa.

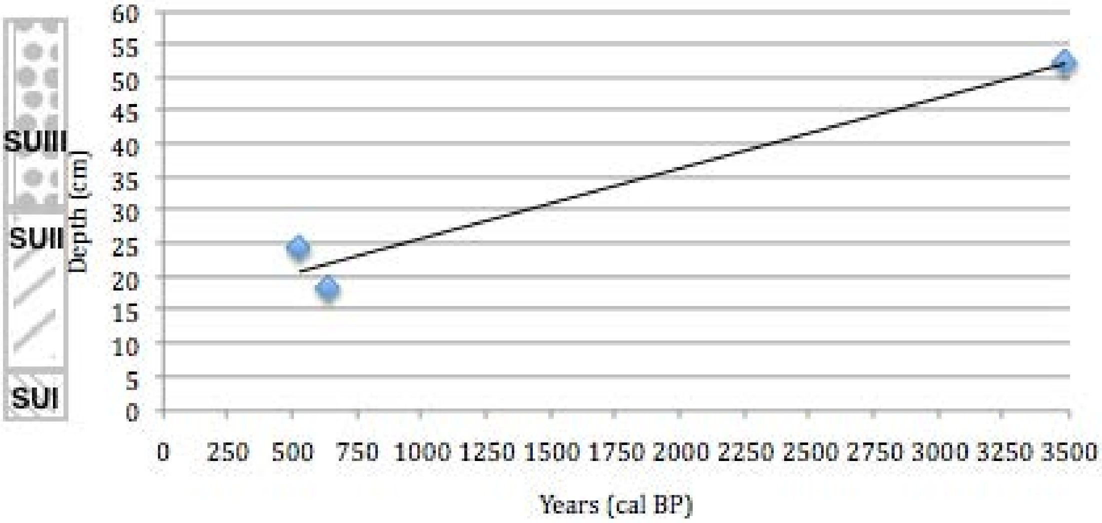


Figure 14.11: Age-depth relationships of radiocarbon determinations obtained from Square A.

Table 14.3: Temporal phases of 250-year periods, showing allocation of XUs.

Temporal phase	0-250	250-500	500-750	750-1000	1000-1500	1500-3500
XUs	3-4	5-6	7-9	10	11-12	13-20

14.7 Cultural Materials

1957.2g (<1% of the total sediment and materials) were retained for analysis in the 2.3mm mesh sieve. Table 14.4 shows the overall summary results of the retained materials. Molluscan shell comprises 27.8% (545.23g) of the total assemblage and fishbone contributes 0.02% (0.44g). Small quantities of crustacea (8.44g) were recovered from XU3-15, represented by mud crab (*Scylla* spp.) (3.17g) and goose barnacle (Pedunculata) (5.27g). Beachrock, coral and pisolith stones contribute 41.5%. Organics make up the rest of the assemblage. A fragment from a *nara* (*Melo amphora*) shell knife is also present in the cultural deposit (Figures 14.12-14.14). Knives are commonly mentioned in ethnographic literature, and this piece of shell may have been modified and used for such a purpose (e.g. Tindale 1962a, 1962b).

Figure 14.12: *Nara* baler shell knife A53168 (drawn by Tindale 1960:91).

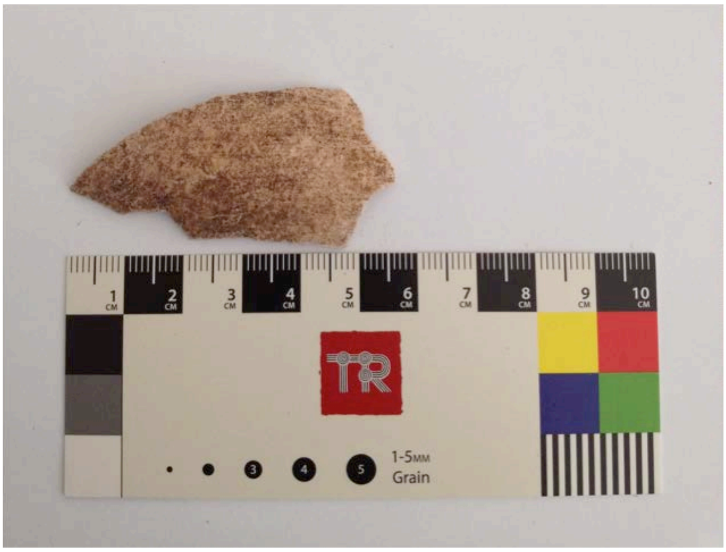


Figure 14.13: *Melo amphora* fragment (possible shell artefact broken off from baler shell knife such as one illustrated by Tindale 1960).

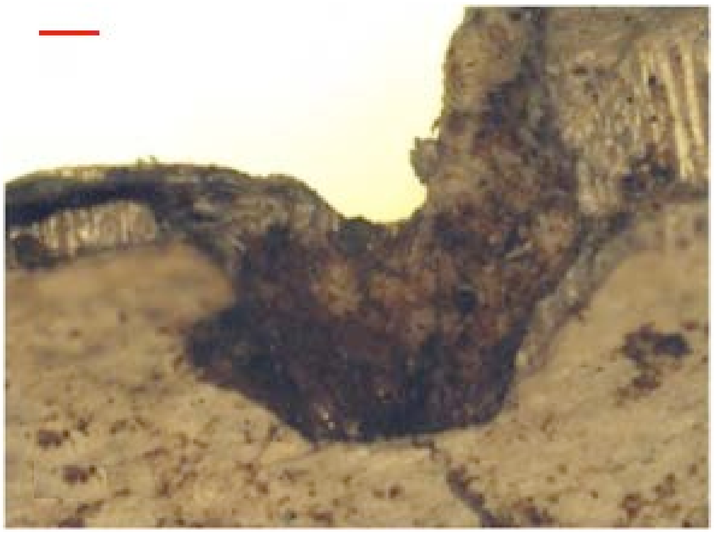


Figure 14.14: *Melo amphora* fragment in Figure 14.13 showing residue (possibly fibrous) visible in microscope image at 10x magnification (red scale bar represents 100 microns).

Table 14.4: Summary excavation data and retained materials from Jirrkamirndiyarrb Square A.

XU	Depth Below Surface (cm)	Mean Thickness (cm)	Weight (kg)	Vol cm^3	pH	Stone Artefacts (g)	Marine Shell (g)	Bone (g)	Barnacles (g)	Crab (g)	Charcoal (g)	Other Organic (g)	Rock Rubble Coral (g)	Retained Materials Total (g)	% of Total Midden
1	0.1	0.1	0.1	250	8	0	0	0	0	0	0	53.6	0	53.6	53.60%
2	4.84	4.74	17.6	11850	8	0	0	0	0	0	0	72.97	4.96	77.93	0.44%
3	8.1	3.26	13	8150	7.5	0	45.18	0.32	0	3.12	3.47	35.87	6.32	94.28	0.73%
4	10.94	2.84	10.6	7100	7.5	0	13.74	0.02	5.16	0.05	1.68	15.07	7.18	42.9	0.40%
5	13.84	2.9	11.9	7250	7.5	0	6.34	0	0	0	0.15	34.23	8.51	49.23	0.41%
6	16.98	3.14	12.5	7850	7.5	0	13.02	0	0	0	0.11	23.68	13.36	50.17	0.40%
7	19.92	2.94	11	7350	7.5	0	24.91	0	0	0	0.06	31.72	15.05	71.74	0.65%
8	22.98	3.06	12.4	7650	7.5	0	321.79	0	0	0	0.08	13.08	22.37	357.32	2.88%
9	25.98	3	12.5	7500	7.5	0	26.59	0	0	0	0	14.18	7.33	48.1	0.38%
10	29.02	3.04	11.7	7600	7.5	0	10.9	0	0	0	0	21.09	5.4	37.39	0.32%
11	31.94	2.92	10.9	7300	7.5	0	9.14	0	0	0	0	169.36	4.21	182.71	1.68%
12	34.98	3.04	12.2	7600	8	0	4.14	0	0	0	0	22.08	3.65	29.87	0.24%
13	38.02	3.04	11.9	7600	8.5	0	3.25	0.03	0	0	0	13.61	3.52	20.41	0.17%
14	41.22	3.2	13.1	8000	8.5	0	8.01	0.01	0	0	0	15.37	11.04	34.43	0.26%
15	44.54	3.32	12.9	8300	8.5	0	8	0	0	0	0	12.33	10.16	30.49	0.24%
16	47.98	3.44	13.9	8600	8	0	7.12	0	0	0	0	11.56	21.85	40.53	0.29%
17	50.9	2.92	11.4	7300	8.5	0	11.65	0	0.04	0	0	7.27	155.5	174.46	1.53%
18	54.04	3.14	13	7850	8.5	0	24.13	0.06	0.07	0	0	4.95	480.54	509.75	3.92%
19	57.1	3.06	12.8	7650	8.5	0	5.81	0	0	0	0	7.47	17.36	30.64	0.24%
20	60.06	2.96	12.1	7400	9	0	1.51	0	0	0	0	5.3	14.51	21.32	0.18%
Total:	-	60.06	237.50	150150	-	0	545.23	0.44	5.27	3.17	5.55	584.79	812.82	1957.27	0.82%

14.7.1 Invertebrate Mollusc Remains

In total 545.23 of shell was recovered from Square A, which represents 28.9% of the total deposit. 87% of all shell by weight was identified to family, genus or species level. The remaining 13% of shell could not be identified beyond Mollusca due to the generally small size of these specimens and the lack of diagnostic attributes that prevented identification to taxon; this portion of the assemblage is not considered further in the analyses presented below. The identified assemblage comprised 13 molluscan taxa weighing 453g (with an MNI=118) consisting of seven marine bivalve taxa and six marine gastropod taxa (Figures 14.15-14.16). The assemblage is dominated by venus clams (*Marcia hiantina*) (417.12g 80%). Mud clams (*Geloina erosa*) (7.92g, 1.5%), baler shell (*Melo amphora*) (7.42g, 1.4%), pearl shell (*Pinctada* sp.) (5.32g, 1.0%) and turban shells (*Turbo* sp.) (4.86g 1.0%) make up the top five species. The remaining eight taxa are relatively rare, each contributing less than 1% of the shell assemblage by weight. Taxa MNIs and weights are presented in Tables 14.5 and 14.6.

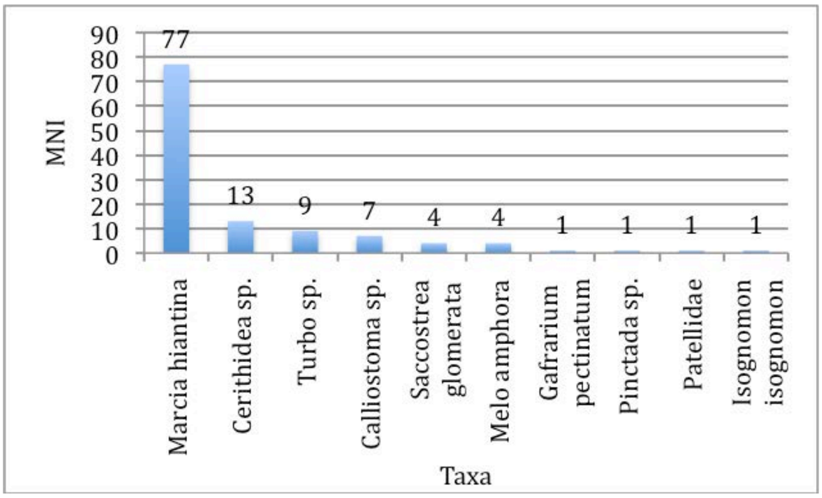


Figure 14.15: Jirrkamirndiyarrb Square A, top 10 taxa by MNI.

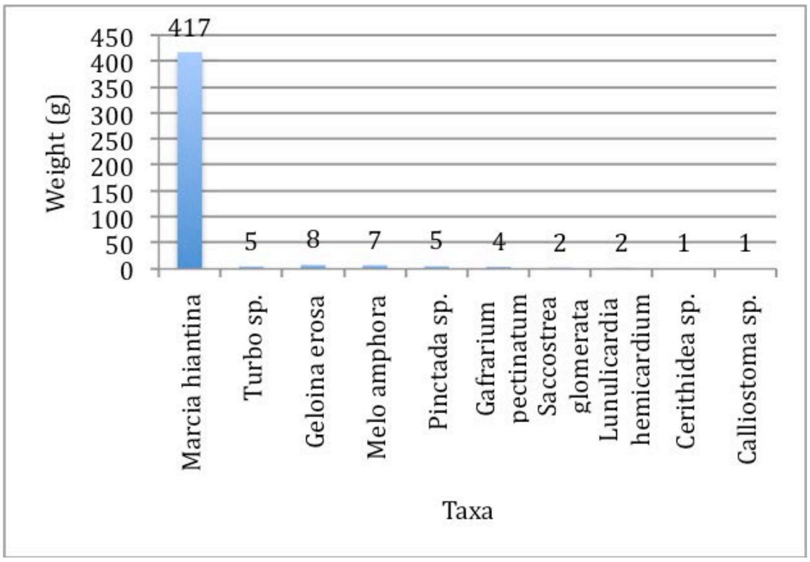


Figure 14.16: Jirrkamirndiyarrb Square A, top 10 taxa by weight.

Table 14.5: Jirrkamirndiyarrb Square A molluscan assemblage taxa MNIs.

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**Totals**
MARINE BIVALVIA																					
Gafrarium pectinatum								1													**1**
Isognomon isognomon																	1				**1**
Marcia hiantina			3	3		3	3	48	6	2	2			1	1	1	2	1	1		**77**
Pinctada sp.			1																		**1**
Saccostrea glomerata												1		1			1	1			**4**
MARINE GASTROPODA																					
Calliostoma sp.										1		1			1		1	2	1		**7**
Cerithidea sp.			1									1		1	1	2	1	4	2		**13**
Melo amphora			1	1												1			1		**4**
Patellidae												1									**1**
Turbo sp.			2	1	1								1	4							**9**
XU Totals			**8**	**5**	**1**	**3**	**3**	**49**	**6**	**3**	**2**	**4**	**1**	**7**	**3**	**4**	**6**	**8**	**5**	**0**	**118**

Table 14.6: Jirrkamirndiyarrb Square A molluscan assemblage taxa weights.

Taxon XU	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
MARINE BIVALVIA											
Gafrarium pectinatum								4.21			
Geloina erosa			7.92								
Isognomon isognomon											
Lunulicardia hemicardium											
Marcia hiantina			11.58	8.85	3.07	11.53	24.91	303.64	26.59	9.29	5.30
Pinctada sp.			4.83	0.49							
Saccostrea glomerata											
MARINE GASTROPODA											
Calliostoma sp.										0.02	

Taxon XU	1	2	3	4	5	6	7	8	9	10	11
Cerithidea sp.			0.17								
Melo amphora			5.38	0.73							
Nerita sp.											
Patellidae											
Turbo sp.			11.85	1.16	1.28						2.31
Unidentified shell			3.45	2.51	1.99	1.49	0.00	13.94	0.00	1.59	1.54
XU Totals			**45.18**	**13.74**	**6.34**	**13.02**	**24.91**	**321.79**	**26.59**	**10.9**	**9.14**

Table 14.6: Jirrkamirndiyarrb Square A molluscan assemblage taxa weights (cont.).

Taxon XU	12	13	14	15	16	17	18	19	20	Totals
MARINE BIVALVIA										
Gafrarium pectinatum										**4.21**
Geloina erosa										**7.92**
Isognomon isognomon						0.13				**0.13**
Lunulicardia hemicardium		0.01	0.52				1.40			**1.93**
Marcia hiantina	1.09	0.83	5.15	5.35	2.58	1.89	4.85	2.20		**417.12**
Pinctada sp.										**5.32**
Saccostrea glomerata	1.28		0.01			0.01	1.19			**2.48**
MARINE GASTROPODA										
Calliostoma sp.	0.05			0.03		0.08	0.37			**0.55**
Cerithidea sp.	0.01	0.05	0.07	0.02	0.24	0.02	0.27	0.20		**1.06**
Melo amphora					0.60			0.70		**7.42**
Nerita sp.							0.02			**0.02**
Patellidae	0.01									**0.01**
Turbo sp.		0.05	0.06							**4.86**
Unidentified Shell	1.70	2.26	2.13	2.58	3.45	9.51	15.76	2.70	1.51	**68.11**
XU Totals	**4.14**	**3.25**	**8.01**	**8.00**	**7.12**	**11.65**	**24.13**	**5.81**	**1.51**	**521.14**

The shell deposit in Square A is concentrated between XU3-9 (0-750 cal BP) accounting for 64% of the identified mollusc assemblage based on MNI (Figure 14.17). The assemblage exhibits low diversity with a calculated Shannon-Weaver Diversity Index of 1.54. Just one species (*Marcia hiantina*) represents 80% of the total assemblage. Its prominence suggests foraging strategies focused on the intertidal sand-mudflats (see Figure 14.7).

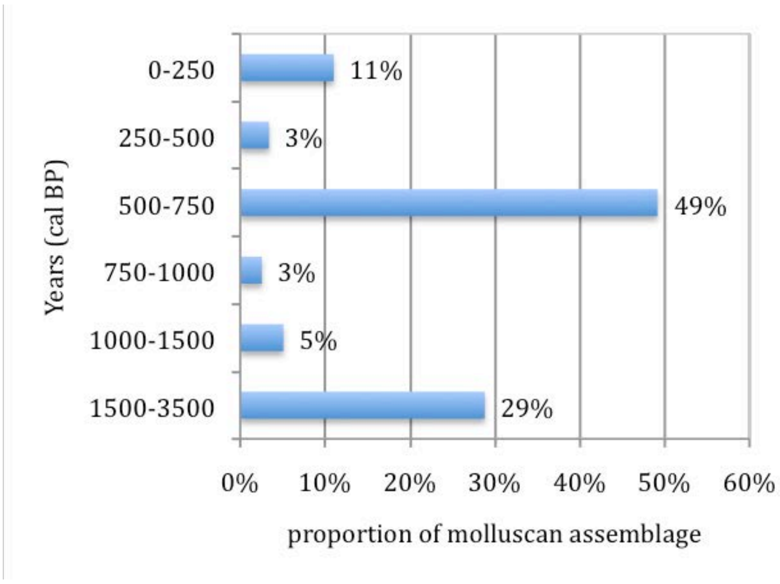


Figure 14.17: Proportion of total Square A mollusc assemblage MNI per 250-year period.

14.7.2 Vertebrate Remains

Small numbers (n=20) of fish bones and an otolith were recovered from the deposit, comprising the only vertebrate remains (0.44g) in Square A (see Table 14.7). Fishbone occurs intermittently throughout the deposit. Most of the bone material was highly fragmented and none could be identified to taxon. The MNI of two was calculated by summing the MNI for each excavation unit.

Table 14.7: Fishbone abundance at Jirrkamirndiyarrb Square A.

XU	Taxon	Element	MNI	NISP	Weight
3	Osteichthyes	unidentified		14	0.3214
4	Osteichthyes	unidentified		3	0.0222
13	Osteichthyes	dentary	1	1	0.0274
14	Osteichthyes	unidentified		1	0.0026
18	Osteichthyes	otolith	1	1	0.0697
		Totals	**2**	**20**	**0.4433**

14.8 Application of Models

14.8.1 Diet-Breadth/Prey Choice

Patterns in the breadth and diversity of molluscan exploitation at Jirrkamirndiyarrb can be identified using species richness and abundance measures. The species richness graph shows the number of species collected from each habitat per 250-year period (Figure 14.18). Three habitats (Rocky Reefs, Sandy-Mud Flats and Mangroves and Tidal-Mud Flats) were exploited, and the level of species richness by habitat varies between chronological periods. This variation is not considered statistically significant ($X^2 = 5.5$, d.f. = 10, p>0.5). Figure 14.19 shows the top six species that were exploited. Hiant venus clams (*Marcia hiantina*) were collected in all periods and were most prevalent in the period 500-750 cal BP with everything else excluded. Mangrove cerithids (*Cerithidea* sp.) dominated the pre-cultural assemblage 1500-3500 cal BP but numbers were low in later periods. Turban snails (*Turbo* sp.), top snails (*Calliostoma* sp.) and rock oysters (*Saccostrea glomerata*) also exhibited low numbers in later periods. Baler shells (*Melo amphora*) contributed not only to diet but were also useful for tool-making.

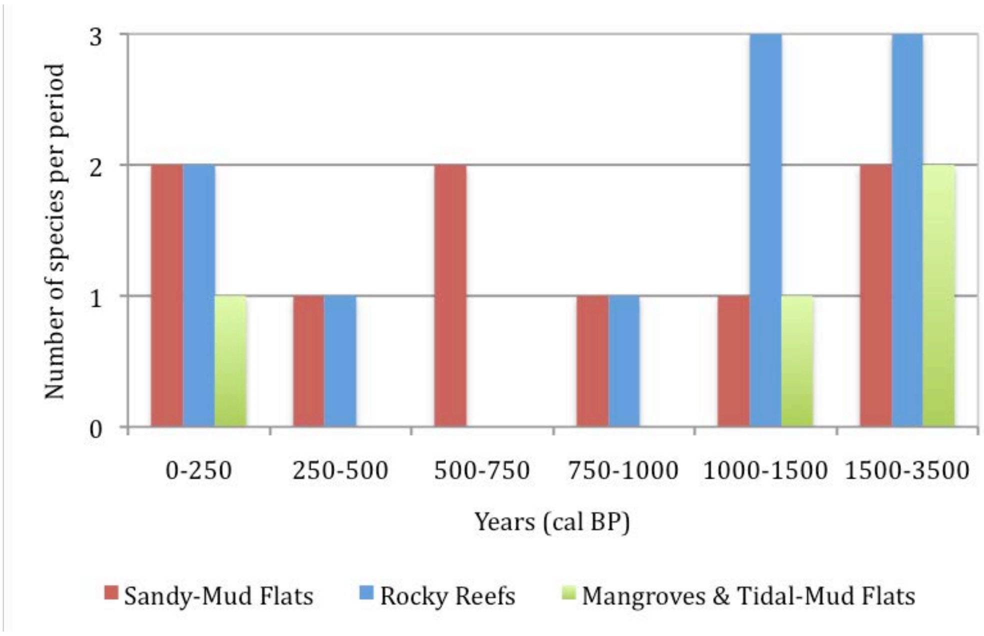


Figure 14.18: Jirrkamirndiyarrb Square A, species richness per habitat per 250/500-year period.

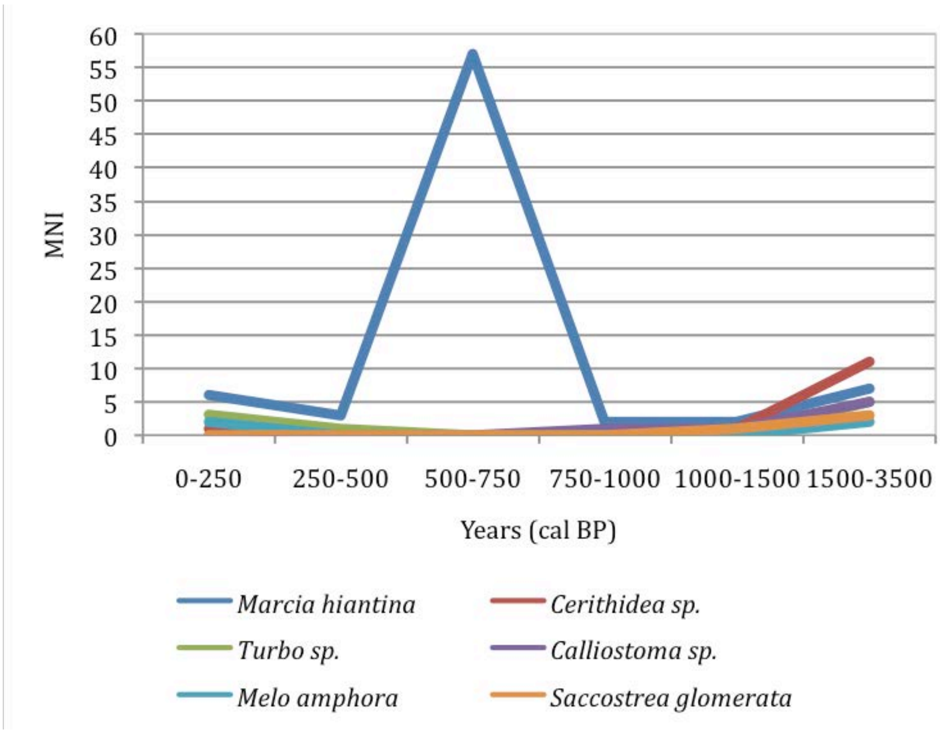


Figure 14.19: Top six mollusc taxa MNI per 250/500-year period, Square A.

14.8.2 Habitats/Patch Choice

Figure 14.20 shows the proportion of MNI collected by habitat. As already noted the Jirrkamirndiyarrb mollusc assemblage includes taxa that come from three patches or habitats; however there is temporal variance in the quantities of taxa taken from each patch. Chi-squared results indicate that this variance is statistically significant (X^2 = 64.27, d.f.=10, p<0.0001). The Sandy-Mud Flats patch is the dominant focus of resource exploitation throughout most cultural periods and particularly during 500-750 cal BP contributing 100% the assemblage for that period. Rocky Reef species are present in all periods except 500-750 cal BP, while Mangrove-dwelling species contribute less than 20% of the overall assemblage.

Changes in patch use between the Rocky Reefs and Sandy-Mud Flats patches can be tracked through the use of an index (Figure 14.21). The index declines quite sharply indicating that foragers’ preference for Sandy-Mud Flats taxa increased through time as Rocky Reef taxa decline. This is confirmed with the significant chi-squared result (X^2 = 40.43, d.f. = 5, p<0.0001).

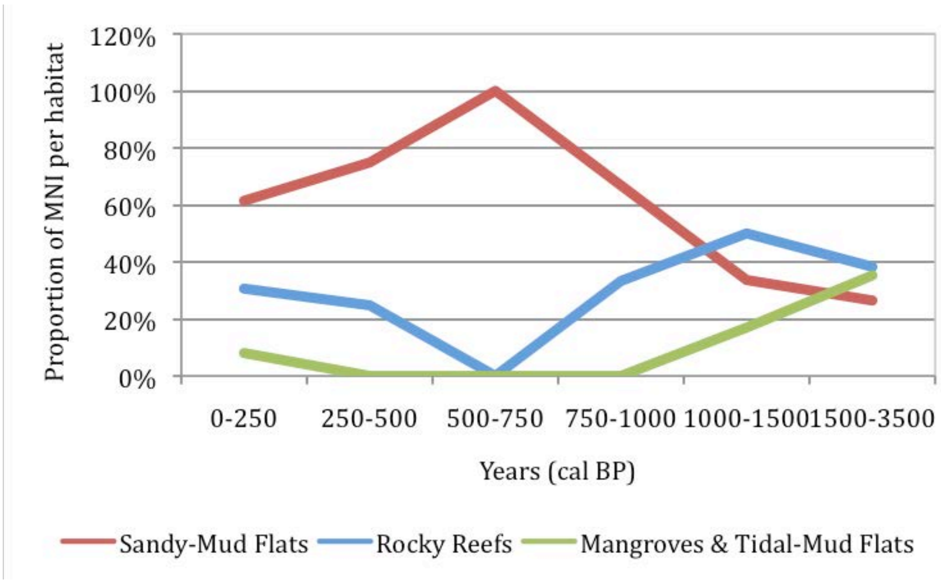


Figure 14.20: Percentage of mollusc taxa MNI collected from each patch by 250/500-year period.

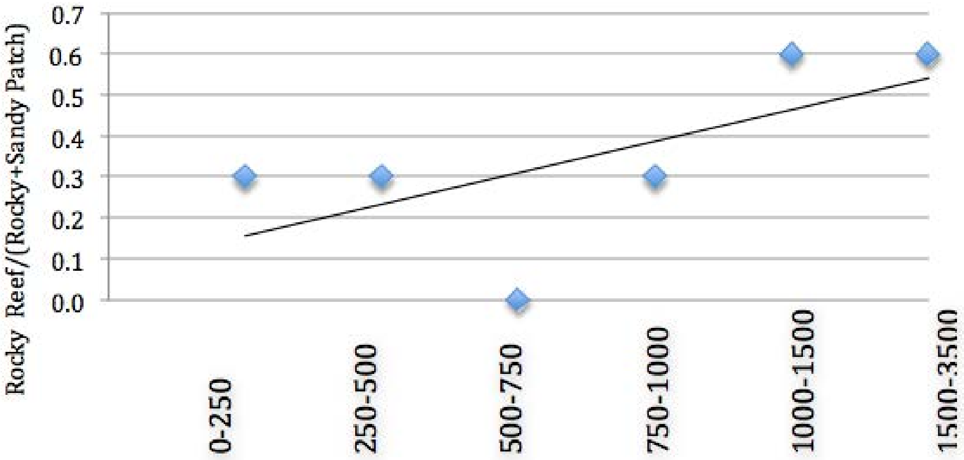


Figure 14.21: Change in patch use as indicated by Rocky Reef-Sandy-Mud Flats Patches Index.

In terms of the top five species, *Marcia hiantina* is more intensively exploited than the other sandy-mud flats species particularly between 250-1500 cal BP. *Turbo* sp. and *Calliostoma* sp. are rocky reef species, and *Marcia hiantina* and *Gafrarium tumidum*, both sandy-mud flats species. At other times, turban shells dominate the assemblage (*Turbo* (*Lunella*) sp.). From this information we can suggest that foragers chose to exploit Rocky Reefs and Sandy-Mud Flats patches for the proximity of habitats to the site and/or socio-cultural reasons. Mangrove species make up a lower proportion (0-17%) of the assemblage throughout all periods, except 1500-3500 cal BP (35%).

14.8.3 Resource Intensification and Foraging Efficiency

At Jirrkamirndiyarrb *M. hiantina* is the top species collected and is classed as a high-ranked taxon. Due to its overall higher net calorific-return rate compared with the other species found in the site's contents, this species would be preferentially collected over lower-ranked taxa. Table 14.8 shows the average sizes for each species per XU.

Table 14.8: Metrical data for intact *M. hiantina* valves from Jirrkamirndiyarrb Square A.

XU	Mean (mm)	Median (mm)	S.D. (mm)	Min (mm)	Max (mm)	Range (mm)	No.
3	37.1	37.1	0.35	36.8	37.3	0.5	2
4	31.2	31.2	0.14	31.1	31.3	0.2	2
6	31.7	31.7	2.4	30	33.4	3.4	2
8	31.6	32.6	3.64	17.2	37.4	20.2	40
9	26.7	27.3	1.86	24.4	28.9	4.5	7
10	27	27	2.55	25.2	28.8	3.6	2
11	21.9	21.9	5.94	17.7	26.1	8.4	2
14	25	25	0	25	25	0	1
15	28.5	28.5	0	28.5	28.5	0	1
16	26.1	26.1	0	26.1	26.1	0	1
17	26.3	26.3	0	26.3	26.3	0	1
18	31.3	31.2	0	31.2	31.2	0	1
19	32	32	0	32	32	0	1

Keeping in mind that if *M. hiantina* were over-exploited there would likely be a corresponding reduction in the size of specimens being taken because juvenile specimens would not have time to mature before being selected. During peak collection (XU8) there is a greater range (20.2mm) between small and large valves with the mean size of 31.6mm. This is higher than averages from previous XUs suggesting people were targeting larger specimens. Overall however, during the whole period of site use we see that the average size of *M. hiantina* specimens increases (Figure 14.22), indicating population sustainability levels of *M. hiantina* were not exceeded.

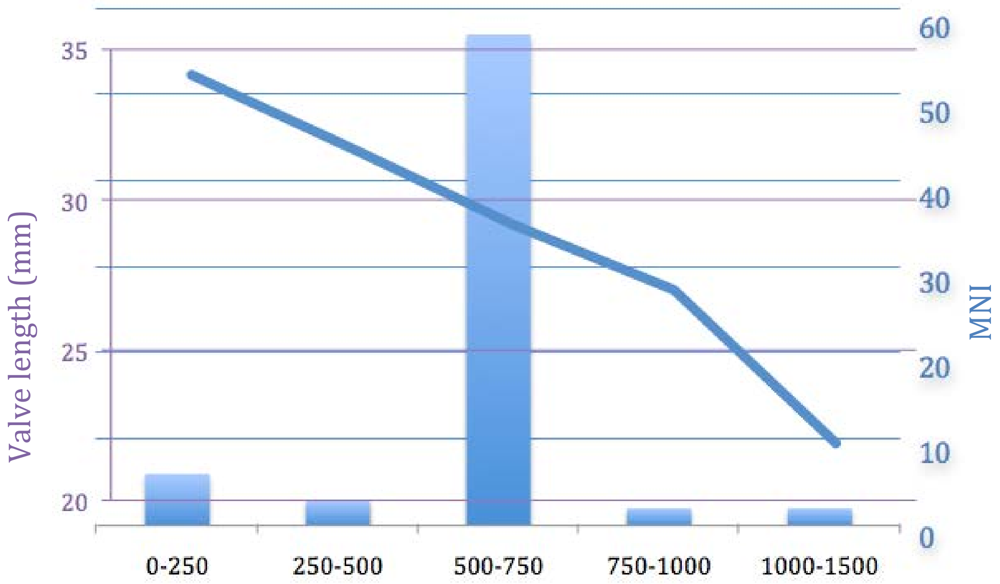


Figure 14.22: Relationship between *M. hiantina* MNI (columns) and mean valve length (mm) per 250-year time period.

14.9 Discussion

The visible *in situ* shell exposures appear only to have low quantities of shell; however fishtraps along the coastline in the vicinity of Jirrkamirndiyarrb suggest regular occupation of the area. Radiocarbon dates also attest to repeated use of the site. Jirrkamirndiyarrb exhibits evidence for low occupation prior to 750 cal BP and again between 0-500 cal BP, with an intensive occupation phase occurring in the 250 years in between 500-750 cal BP where MNI numbers for high-ranked cultural taxa are at their highest.

Occupants of the site consistently exploited three resource zones; resources from Sandy-Mud Flats and Rocky Reefs were preferred over Mangroves and Tidal-Mud Flats, either for the proximity of habitats to the site and/or sociocultural reasons. Mangrove and Tidal-Mud Flat molluscs (i.e. *Cerithidea* sp.) make up a lower proportion of the assemblage throughout all periods except 1500-3500 cal BP. This coincides with a period of coastal development when this habitat was located much closer to Jirrkamirndiyarrb (Moss *et al*. 2015). Although the post-1500 cal BP mangroves are further away from the site, they are still within easy foraging distance, which suggests that dietary preference is more likely to be the reason for low mangrove mollusk numbers rather than difficulty accessing resources. It is unlikely these specimens were selected for food due to their small (<10mm) size.

The diet breadth graph (Figure 14.18) and changes in the patch-use graph (Figure 14.20) indicate that people at Jirrkamirndiyarrb accessed sandy-mud flats more than the other two habitats. The varying proportions of each species collected in different time periods may reflect differential abundance in the environment impacting access to resources (see discussion in section 6.10). Alternatively this assemblage may be the result of specific selection for maximizing dietary energy returns.

Reviewing two of the top five species that are known food species, *M. hiantina* and *Turbo* sp. respectively represent 63% and 7% of the identified assemblage by MNI (Figure 14.18 and Table 14.5). *Marcia hiantina* from the Sandy-Mud Flats habitat were collected consistently throughout time and intensively targeted during the period 500-750 cal BP. *M. hiantina* grows to a length of 20-50mm with a meat:shell ratio of around 0.2 depending on size (personal observation) providing low energy returns of c.800 kcal/kg (Meehan 1977).

At other times of occupation small quantities of *Saccostrea glomerata,* Pinctada *sp., Calliostoma* sp. and *Turbo* sp. were collected from Rocky Reef habitats. *Turbo* sp. take approximately 3-4 years to mature and grow to a length of 35-50mm with a meat:shell ratio of 0.248 providing low energy returns of c.520-606 kcal/kg (Bird and Bleige Bird 2002). Table 14.9 shows comparative data of these two species that can be used to estimate their dietary contribution at Jirrkamirndiyarrb. The fish specimens were likely speared in nearshore shallow waters where they feed around seagrasses and rocks – they may even have ventured into a fish trap like the one shown in Figure 14.6.

Table 14.9: Estimated weights of *M. hiantina* and *Turbo* sp. based on comparative values from TARL reference collection specimens and data from Smith (2011).

Taxon	Comparative meat weights per MNI (g)	MNI	Estimated meat weight of archaeological specimens (g)	Energetic return (kcal/hr)	Estimated energy return (cal)
Marcia hiantina	c.3.5	78	273.0	800	218.4
Turbo sp.	c.4.0	10	40.0	520-606	20.8-24.2

From the figures above we can estimate that based on each taxon's MNI, hiant venus clams contributed c.273.0g of meat, and Turban cats-eye shells contributed c.40.0g of meat. Shellfish compare poorly to fish in terms of net energy returns on a one-to-one basis, although shellfish are generally a more reliable meal and may require less energy expenditure to collect than opportunistically caught fish. Kaiadilt appear to have preferentially foraged *M. hiantina*, from the Sandy-Mud Flats but also supplemented their diet with molluscs and fish from Rocky Reefs.

14.10 Summary

Excavation at Jirrkamirndiyarrb Site 8 revealed a low-density shell deposit consistent with observations of the extensive shell material exposed across the mobile sand dune landscape at Jirrkamirndiyarrb. The restricted range of shellfish taxa and presence of shell artefacts, charcoal, burnt shell and fish remains support a cultural origin for the majority of the deposit. The faunal assemblage results at Jirrkamirndiyarrb are more likely indicative of hunter-gatherer foraging choices rather than a reflection of environmental changes impacting resources.

PART IV SYNTHESIS AND CONCLUSIONS

Chapter 15. Towards a Regional Archaeology of the South Wellesley Archipelago

15.1 Introduction

The recent timing of human settlement of the South Wellesley Islands offers a unique opportunity to investigate Aboriginal impacts on undisturbed Australian ecosystems against a backdrop of climatic and environmental change. A comprehensive suite of 128 radiocarbon dates provides a chronological framework for archaeological sites across the South Wellesley Islands that is used to situate Aboriginal occupation of the archipelago within the broader settlement histories of the Gulf of Carpentaria region. Detailed analysis of the archaeological assemblages from a select group of these sites indicates variation in the resources and habitats that people exploited temporally and spatially.

This chapter synthesises the data presented in the individual site report chapters (7 to 14) and considers it in conjunction with the available ethnographic and palaeoenvironmental information. All data are grouped into chronological units of 250-year intervals, which provide a degree of confidence in temporal accuracy constrained by individual site limitations, such as few radiocarbon dates and/or site integrity (see Table 15.1).

Table 15.1: Assessment of the robustness of site chronologies based on the number of radiocarbon dates obtained.

Site	Number of dates	Robust Model	Moderately Robust Model	Poor Chronological Model
Dangkankuruwuru	5	X		
Thundiy	12	X		
Wirrngaji	5	X		
Nalkurdalayarrb	4	X		
Murdumurdu	2			X
Wardilmiru	3		X	
Banbanbarukeind	2			X
Jirrkamirndiyarrb*	4		X	

* Anomaly in site integrity with three dates inverted.

While the 250-year units offer only a broad temporal resolution that may obscure fine-grained variance in individual datasets, they provide a method for characterising local assemblages in a way that can be compared across the region (e.g. Ulm 2006). Examination of assemblage contents focuses on marine fauna remains (i.e. shell, fish bone, other marine vertebrate and invertebrate remains), in order to better understand the role of marine resources in the local subsistence economies. It is apparent that different variables (e.g. environmental parameters and forager population density) have influenced people's economic choices and decisions and these are reflected in localised assemblage contents.

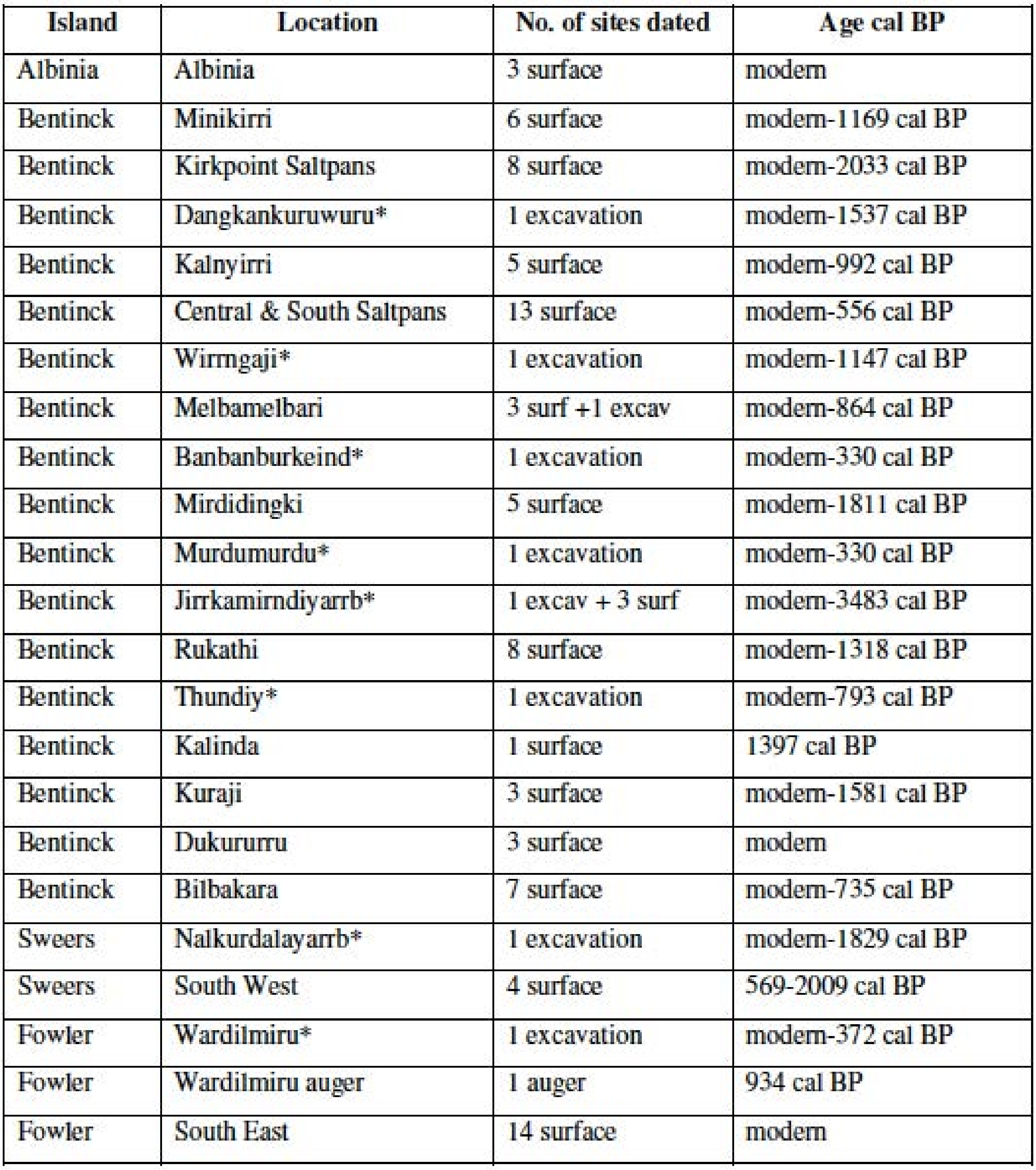
15.2 The South Wellesley Archipelago Archaeological Record

15.2.1 Patterns in site Location and Chronology

One aim of this investigation is to identify and document the Aboriginal archaeological sites in the study area in order to increase regional archaeological knowledge and provide insights into late Holocene cultural changes in tropical Australia. Extensive ground and aerial surveys of the South Wellesley Islands revealed hundreds of archaeological sites that represent some form of Aboriginal occupation. These sites comprise fishtraps, stone quarries, story places, open shell-matrix sites (i.e. middens, mounds and surface scatters) dominated by marine faunal remains and particularly shellfish. A suite of 128 radiocarbon dates have been obtained on shellfish collected from 96 sites distributed across the four largest islands in the archipelago, which provide a framework for use of the archipelago and its resources. Table 15.2 and Figures 15.1 and 15.2 indicate people visited and/or occupied sites within the study area during the late Holocene, ranging from approximately 3500 years BP to the present.

Ethnographic evidence suggests that most occupation sites in the South Wellesley Islands were located along coastlines and fringing the major estuarine waterways. Some occupation sites are more visible due to a prograding landscape preserving the archaeological record, however geomorphological processes (e.g. erosion), varied climate patterns and associated weather events (e.g. seasonal and long-term climate changes, storm surges and cyclones) have greatly impacted the Gulf of Carpentaria and the islands, thereby affecting the representation of archaeological materials (Rowland and Ulm 2012). A significant number of sites located on the shoreline have undoubtedly been destroyed. Tindale (1977:249) reports that the overnight eating and sleeping camps that the majority of people used at most times of the year were placed on sandy beaches just above the high tide mark with day shelters in the half shade of the coastal fringe Casuarina trees (cf. Meehan 1982). In contrast, the majority of sites selected for archaeological sampling in this study are those located further inland that were probably used as central-place eating and sleeping camps in times of inclement weather (see Section 2.3.6). While these sites represent the surviving subset of all sites, for the most part they are still *in situ* and display limited or little taphonomic disturbance.

Table 15.2: South Wellesley Islands locations with dated archaeological sites.



Island	Location	No. of sites dated	Age cal BP
Albinia	Albinia	3 surface	modern
Bentinck	Minikirri	6 surface	modern-1169 cal BP
Bentinck	Kirkpoint Saltpans	8 surface	modern-2033 cal BP
Bentinck	Dangkankuruwuru*	1 excavation	modern-1537 cal BP
Bentinck	Kalnyirri	5 surface	modern-992 cal BP
Bentinck	Central & South Saltpans	13 surface	modern-556 cal BP
Bentinck	Wirrngaji*	1 excavation	modern-1147 cal BP
Bentinck	Melbamelbari	3 surf +1 excav	modern-864 cal BP
Bentinck	Banbanburkeind*	1 excavation	modern-330 cal BP
Bentinck	Mirdidingki	5 surface	modern-1811 cal BP
Bentinck	Murdumurdu*	1 excavation	modern-330 cal BP
Bentinck	Jirrkamirndiyarrb*	1 excav + 3 surf	modern-3483 cal BP
Bentinck	Rukathi	8 surface	modern-1318 cal BP
Bentinck	Thundiy*	1 excavation	modern-793 cal BP
Bentinck	Kalinda	1 surface	1397 cal BP
Bentinck	Kuraji	3 surface	modern-1581 cal BP
Bentinck	Dukururru	3 surface	modern
Bentinck	Bilbakara	7 surface	modern-735 cal BP
Sweers	Nalkurdalayarrb*	1 excavation	modern-1829 cal BP
Sweers	South West	4 surface	569-2009 cal BP
Fowler	Wardilmiru*	1 excavation	modern-372 cal BP
Fowler	Wardilmiru auger	1 auger	934 cal BP
Fowler	South East	14 surface	modern

- Archaeological assemblages recovered from these sites through controlled excavations have been analysed for this thesis.

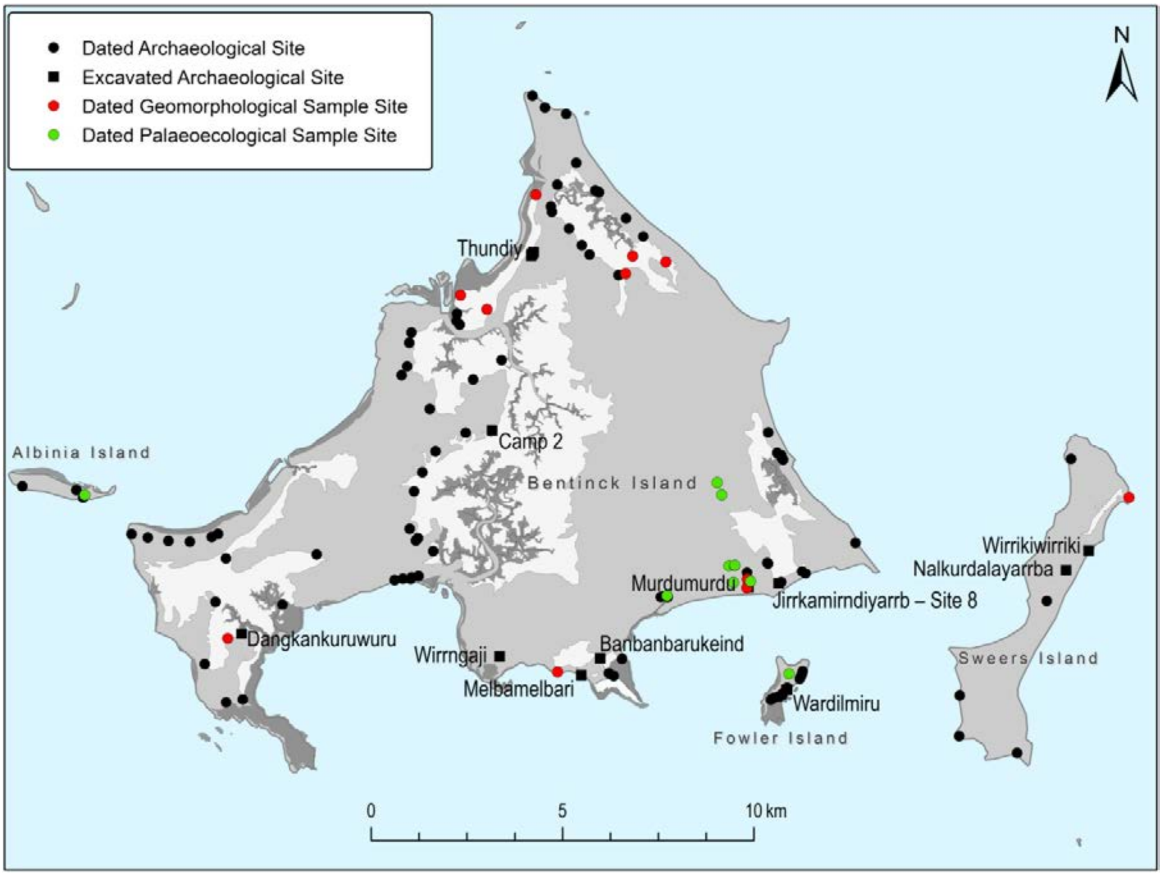


Figure 15.1: Map of South Wellesley Islands showing the locations of dated sites listed in Table 15.2. Excavated sites are named (map prepared by Lincoln Steinberger and Sean Ulm).

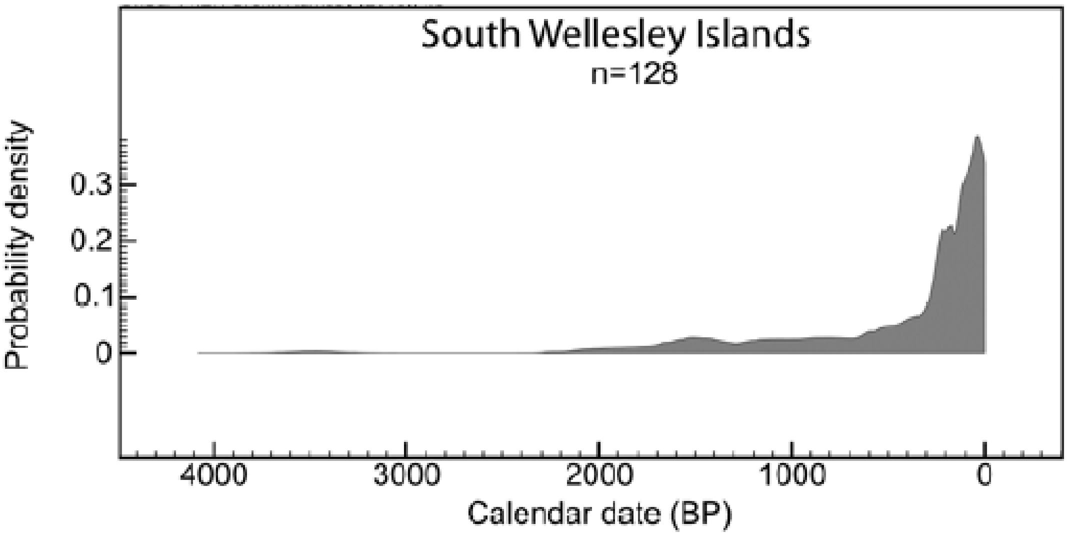


Figure 15.2: The summed probability plot of all calibrated radiocarbon ages (n=128) available for the South Wellesley Islands (Bentinck, Sweers, Fowler and Albinia Islands) (after Memmott *et al.* 2016). Radiocarbon dates were calibrated into calendar years using OxCal (v.4.2.4) (Bronk Ramsey 2013) and the Marine13 calibration dataset (Reimer *et al.* 2013) using a local ΔR of -49±102 (Ulm *et al.* in prep).

An assessment of the patterning of radiocarbon ages synthesised with excavated site assemblage density data indicates three overarching phases of occupation (Figure 15.3).

- ***Phase 1: c.2000-3500 cal BP*** – Exploratory occupation in the South Wellesley Islands during a period exhibiting a very different landscape from today, with sea level +2m until c.2000 cal BP (Moss *et al.* 2015; Sloss *et al.* 2012). Navigating across the vast stretches of open water would have been extremely hazardous on watercraft made of hibiscus logs lashed with grass string (Memmott *et al.* 2016). Few occupation sites from this time are visible with the earliest trace of human presence on Bentinck Island occurring from 3483 cal BP at Jirrkamirndiyarrb.

- ***Phase 2: c.800-2000 cal BP*** – Discontinuous occupation of the islands occurred as people maintained external connections and networks in order to survive in a small island environment with limited resources. On Sweers Island radiocarbon dates of 1829 cal BP and 1699 cal BP, bracketing a relatively dense c.15cm layer of cultural shell and fishbone deposit at Nalkurdalayarrb, indicate use of the site during Phase 2. Dangkankuruwuru and Wirrngaji also exhibit evidence of concentrated occupation during this phase, which continued to within the last c.100 years. A more continuous occupation signal is evident from 1000 cal BP onwards that conforms to the broader northern Australia pattern (Williams *et al.* 2010). Sites that exhibit evidence of occupation during this phase include Nalkurdalayarrb and Wirrngaji.

- ***Phase 3: c.0-800 cal BP*** – Reflects the main phase of intensive occupation and site deposition. Over half the dates from the South Wellesley Islands have median calibrated ages in the last 300 years. During this period all of the analysed sites exhibit greater densities of archaeo-faunal remains linked to diet. The consumption of higher biomass levels was associated with an expansion of diet-breadth to include more fish. Memmot et al. (2016) suggest that as population densities increased their reliance on outside connections decreased and people lived in relative isolation, reflected in linguistic drift. At Thundiy the archaeological and palynological evidence indicates that people commenced using the site c.800 cal BP and continued to occupy the site to within the last century. At some sites (e.g. Thundiy and Dangkankuruwuru) there is a change in the shellfish taxa being collected by foragers around c.500 cal BP, which palynological evidence links to changes in resources availability, most likely due to monsoonal weather events impacting on habitats (see Moss et al. 2014). Radiocarbon dates from Wardilmiru indicate primary site use occurred between c.100-400 cal BP. Cultural use of Murdumurdu is determined to have occured during c.250-500 cal BP.

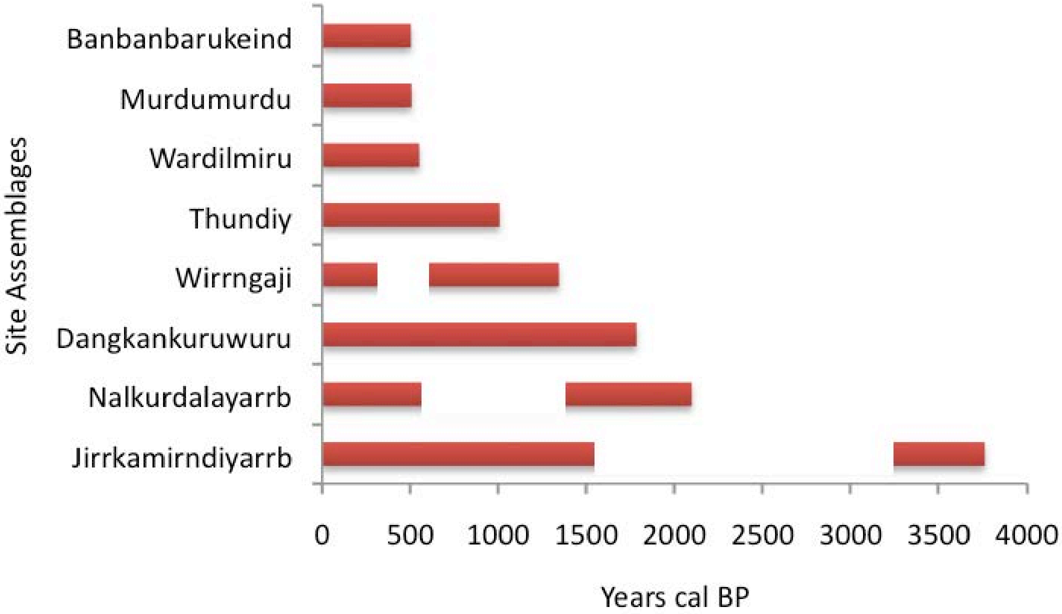


Figure 15.3: Age spans for excavated archaeological site assemblages.

15.2.2 Patterns in Site Contents

Researchers (Attenbrow 2004; Faulkner 2006; Ulm 2006) have previously used quantitative changes in the contents of faunal assemblages as evidence of site use intensity. Eight archaeological sites with *in situ* stratified faunal deposits were selected for fine-grained analysis in this study. A summary of these sites and an overview of their contents are presented in Table 15.3. Site area and volume are used as a proxy to reflect broad trends in patterns in the intensity of occupation and resource use.

Table 15.3: Summary of sampled sites.

Campsite	Approximate Dimensions of Site	Approximate Size of Site (m^3) (Cultural Zone)	Excavated Midden Weight (g)	Retained Midden Weight (g)	Mollusca Weight (g) (% of RMW)	Crustacea Weight (g) (% of RMW)	Osteichthyes Weight (%) (% of RMW)
Dangkankuruwuru	10,500m x 60cm	6,300m^3	586,400g	20,574.2g	11,765.0g (66%)	44.4g (0.2%)	24.48g (0.1%)
Thundiy	600,000m x 40cm	240,000m^3	679,000g	103,141.9g (cultural)	87,786.8g (85%)	187.0g (0.1%)	31.26g (0.03%)
Wirrngaji	25,000m x 66cm	16,500m^3	305,000g	8,822.5g	8,132.4g (92%)	16.4g (0.1%)	1.5g (<0.1%)
Nalkurdalayarrb	10,000m x 40cm	4,000m^3	216,800g	4,563.8g	1,533.8g (34%)	14.7g (0.3%)	3.8g (<0.1%)
Murdumurdu	3,000m x 40cm	1,200m^3	485,200g	6,009.6g	5,276.6g (88%)	16.8g (0.2%)	1.9g (<0.1%)
Wardilmiru	3,000m x 40cm	1,200m^3	407,700g	8,832.3g	5,932.4g (67%)	38.9g (0.4%)	8.0g (<0.1%)
Banbanbarukeind	1,500m x 20cm	300m^3	373,500g	9,041.4g	3,012.1g (33%)	12.6g (0.1%)	4.5g (<0.1%)
Jirrkamirndiyarrb	5,000m x 25cm	1,250m^3	237,500g	1,802.7g	521.1g (29%)	8.45g (0.4%)	0.6g (<0.1%)

Food refuse represents a significant proportion of the contents from the South Wellesley Islands site assemblages, which presents a valuable opportunity to examine not just dietary composition but also long-term patterns in the temporal and spatial availability of subsistence resources. Archaeological evidence from the above eight sites, in addition to information from other surface sites recorded across the archipelago, indicates that marine shellfish, fish and invertebrates made up the majority of Kaiadilt diet.

Shellfish (Mollusca)

Marine molluscs in the assemblage range in size from large mudshell bivalves (*Geloina erosa*) and longbum gastropods (*Telescopium telescopium*) to smaller script venus clams (*Circe scripta*) and topshells (*Calliostoma* sp.). Mollusc quantities (by weight) in the excavated assemblages increase in line with suggested dated phases in Section 15.2.1 (Figure 15.4). Note that deposition patterns in the most recent phase (0-250 cal BP) may be impacted by accelerating European and Southeast Asian incursions since the early eighteenth century.

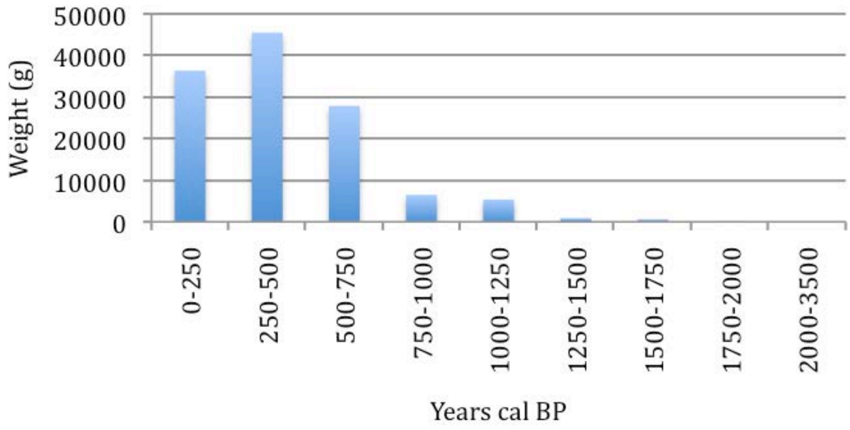


Figure 15.4: Total mollusc weights per 250-year period for combined excavated assemblages.

Some mollusc specimens exhibit high numbers but are small in size and weight (e.g. *Cerithidea* sp., *Rhinoclavis* sp.), and are not thought to have been dietary items (cf. Rowland 1994). It is possible that they may have been collected for another cultural purpose, such as for jewellery making, however it is more likely they entered site matrices via natural processes (e.g. storm surges, wind deposition) or as by-catch attached to larger shellfish. Still, these small shellfish reveal potentially important data about environmental zones exploited and foraging strategies. Table 15.4 shows that the dominant molluscan species based on MNI include *Marcia hiantina, Saccostrea glomerata, Turbo* sp. *Gafrarium pectinatum* and *Telescopium telescopium.*

Table 15.4: Dominant four molluscan taxa based on MNI from each analysed assemblage.

Site	Rank 1 Taxon	Rank 2 Taxon	Rank 3 Taxon	Rank 4 Taxon
Dangkankurwuru	*M. hiantina*	*S. glomerata*	*G. virens*	*Cerithidea* sp.
Thundiy	*Rhinoclavis* sp.	*M. hiantina**	*Cerithidea* sp.	*T. granosa*
Wirrngaji	*M. hiantina*	*S. glomerata*	*Cerithidea* sp.	*T. telescopium*
Nalkurdalayarrb	*S. glomerata*	*Turbo* sp.	*M. hiantina*	*G. pectinatum*
Murdumurdu	*M. hiantina*	*Calliostoma* sp.	*G. pectinatum*	*C. scripta*
Wardilmiru	*Cerithidea* sp.	*Rhinoclavis* sp.	*Clypeomorus* sp.	*M. hiantina**
Banbanbarukeind	*S. glomerata*	*M. hiantina*	*T. telescopium*	*T. sulcata*
Jirrkamirndiyarrb	*M. hiantina*	*Cerithidea* sp.	*Turbo* sp.	*Calliostoma* sp.

*Although *M. hiantina* does not have the highest MNI at Thundiy and Wardilmiru it is still considered the dominant prey taxon collected for food, as there is a high probability that two of the other three species (*Cerithidea* sp., *Rhinoclavis* sp.) did not contribute to the diet.

Marine bivalves of the Veneridae and Ostreidae families provide an important source of protein for coastal populations across tropical northern Australia and throughout the Indo-West Pacific (Poutiers 1998). When undertaking this study it is important to consider possible variables that may contribute to a species vulnerability to over-predation.

Marcia hiantina (Lamarck, 1818) commonly known as the hiant venus clam (Poutiers 1998:334) inhabits sandy and muddy substrates burrowing up to 8cm in the low intertidal and subtidal zones to a depth of 20m (Poutiers 1998:334). The mollusc's preferred locality for habitation just beyond the influences of tides lessens its exposure to fluctuations in salinity, temperature, or extended periods of desiccation (Kithsiri *et al.* 2004). Dense concentrations of seagrasses appear to enhance the biological productivity of *M. hiantina*, reported to be a short-lived, fast-growing species (Kithsiri *et al.* 2000, 2004). Due to the paucity of data about age and size at which sexual maturation occurs, data about other bivalve species with similar 3-year lifespans are used as proxy for *M. hiantina* that indicate growth rates are accelerated to reach maturity within their first year (see Jagadis and Rajagopal 2007a, 2007b). *M. hiantina* grows to a length of 20-50mm and meat makes up around 20-50% of the total clam weight depending on size (personal observation based on live collected specimens; cf. Meehan 1977). To procure the shell people sifted through the sand with their fingers, at times when sand was covered with up to 50cm of water (Meehan 1977:366). The fresh shellfish were stacked umbos up in clean sand and 'a small, fast fire was lit on top and allowed to burn down' (Meehan 1977:366). When cooking large quantities 'shells were cooked in steam ovens which consisted of very hot dead shells, green branches and bark' (Meehan 1977:366).

Saccostrea glomerata (Gould 1815) commonly known as the rock oyster (Poutiers 1998:232; Sydney Fish Market 2015) lives on hard substrates to 3m in sheltered bays and estuaries, most frequently on rocky reefs or mangrove tree roots in the absence of rocks (Ulm 2006; Sydney Fish Market 2015). Although there have been some finds of oyster in mangrove environments in the South Wellesley Islands, for the most part these are collected from rocks in the intertidal zone. The presence of turban snails, top shells, limpets and reef dwelling fishes indicate rocky reefs were being accessed by foragers who would also have collected oysters from this location. In the South Wellesley Islands it is a common taxon found in the archaeological record linked to human diet. People either wade through shallow water to access rocks or wait until low-tide to hand collect oysters. Oysters cement themselves to the rocky substrate, and tools generally need to be used to remove them; sometimes only the top lid of the shell can be prised open and the meat collected (Meehan 1982:2). Tindale (1960:97) describes a functionally dedicated hammerstone and oyster pick used by Kaiadilt people for such a purpose. The presence of *Saccostrea glomerata* in archaeological sites has been reported from sites across Australia (e.g. Faulkner 2006; Morrison 2010, 2013; Rosendahl *et al.* 2014; Sim and Wallis 2008; Ulm *et al.* 2010). The species is available year round. With an average weight of 40-60g (7-9cm length) they are generally smaller than other oysters, although some specimens can grow to 25cm (Sydney Fish Market 2015). Meat makes up around 20% of an oyster’s weight. Ross and Quandamooka Land Council (1996) confirm the importance of *S. glomerata* as a sustainable food resource managed and eaten by the Quandamooka people of the Moreton Bay region in Queensland.

Fishes (Osteichthyses and Elasmobranchii)

Fishbones are found throughout all temporal periods at most sites however they are more prevalent in the upper layers dated to the last 500 years (Figure 15.5). This could mean they were either harvested and/or discarded more frequently only fairly recently; or it could reflect taphonomic influences on sites that have resulted in the deterioration of fishbones over time and/or differential preservation of site types containing fish remains. Despite relatively few fishbones being recovered I am still able to gain some understanding of Kaiadilt fishing practices from the identified fish remains at most sites. Table 15.5 shows all vertebrate taxa identified in the study from faunal remains, and the site locations where specimens were found.

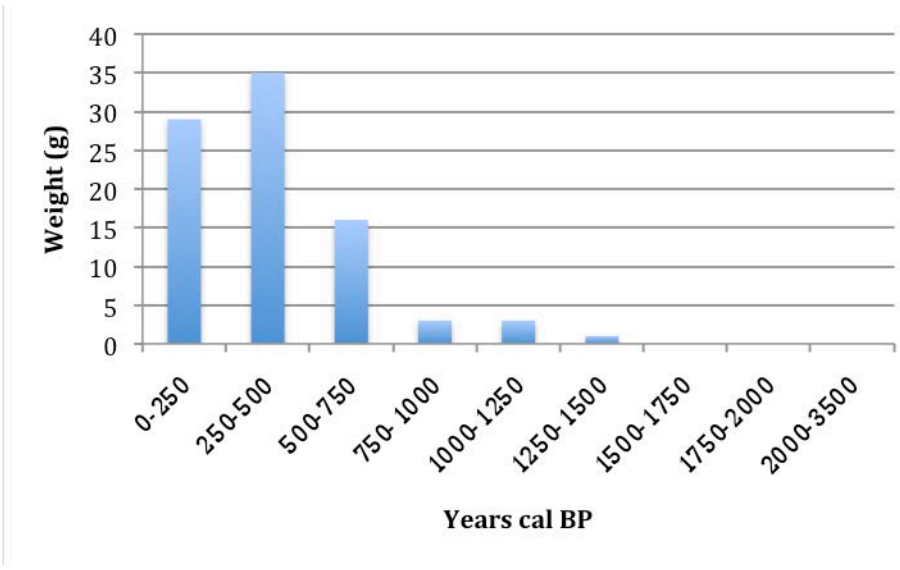


Figure 15.5: Total bone weights for each 250-year period from all excavated assemblages.

Based on known habitats for the specimens identified in archaeological assemblages most of the fish would have been obtained from hunting in nearshore waters, either from around rocky/coral reefs, intertidal mangroves, estuaries or in the constructed stone-walled intertidal fishtraps. Considering the prolific amount of fishtraps found around the study area it is unusual that there is a general paucity of fishbone in the midden assemblages analysed.

Table 15.5: Fish taxa identified from the South Wellesley Islands assemblages.

Taxa	**Trophic level**	**Habitat**	**Feeds on**	**Archaeological Site Representation**
longtom (*Tylosurus gavialoides*)	4.4	Coral reefs, inshore coastal waters, intertidal estuaries (Collette 1999)	small fishes	Dangkankuruwru
wrasse (Labridae, *Choerodon schoenleinii*)	3.6	Shallow waters and rubble areas of reef flats (Randall *et al.* 1990)	molluscs	Thundiy Wirrngaji Nalkurdalayarrb Murdumurdu Wardilmiru
Emperor red snapper (*Lutjanus sebae*)	4.1	Coral, rocky reefs, sand flats, deeper waters too (Allen 1985)	sea urchins, fishes, crustaceans, cephalopods	Nalkurdalayarrb
catfish (Ariidae)	3.6	Brackish estuaries and coastal marine waters (Allen 1989)	arthropods, insects, aquatic plants, molluscs, prawns, crayfish, fishes	Dangkankuruwru Thundiy Wirrngaji
stripey (*Lutjanus carponatus*)	3.9	Coral reefs in sheltered lagoons and outer reef slopes, also in turbid coastal waters (Allen 1985)	crustaceans and fishes	Dangkankuruwru

Taxa	**Trophic level**	**Habitat**	**Feeds on**	**Archaeological Site Representation**
sea mullet (*Mugil cephalus*)	2.5	Adults: coastal waters entering estuaries and lagoons over sand and mud bottoms (Harrison 1995)	Juveniles feed on zooplankton. Adults: micro algae, benthic organisms	Dangkankuruwuru
Russell's snapper *(Lutjanus russellii*)	4.1	Adults: coastal reef waters marine and brackish, 3-80m Juveniles: mangrove estuaries (Allen 1985)	benthic invertebrates and fish	Dangkankuruwru
rockcod (Serranidae, *Epinephelus* sp.)	4.0	Adults: turbid coastal reefs; brackish water over mud and rubble. Juveniles: shallow waters of estuaries (Heemstra and Randall 1993)	small fishes, prawns and crabs	Dangkankurwuru Wirrngaji Wardilmiru
garfish (Hemiramphidae)	3.5	Most species are marine, but some inhabit freshwaters (Collette and Su 1986)	omnivorous, feeds on zooplankton, sea grasses, small fishes, crustaceans	Dangkankuruwuru Nalkurdalayarrb
javelin grunter (*Pomadasys kaakan*)	3.5	Turbid inshore waters sandy to muddy bottoms, enters estuaries (Smith and McKay 1986)	crustaceans and fish	Thundiy
diamond-scale mullet (*Liza vaigiensis*)	2.3	Inshore slow moving coastal waters marine and brackish over muddy substrates with aquatic vegetation (Harrison and Senou 1997)	microalgae, detritus, terrestrial plant material and aquatic insects	Dangkankuruwuru
whiting (*Sillago burrus*)	3.3	Adults: silty-sand or muddy substrates, near gutters and sandbars. Juveniles: seaweed banks and mangrove creeks (McKay 1992)	benthic invertebrates, molluscs, worms, sea urchins	Dangkankuruwru Thundiy
reef shark (Carcharhinidae)	4.1	Shallow and deep waters around coral reefs and sandy flats, also known to enter brackish water (Compagno 1984)	bony fishes, cephalopods, crustaceans, aquatic mammals, sharks	Thundiy Murdumurdu Wardilmiru
bream (*Acanthopagrus* sp.)	3.4	warm shallow and coastal waters, entering river mouths and estuaries (Iwatsuki 2013)	worms, crustaceans, sea urchins, small fish	Wardilmiru

Taxa	**Trophic level**	**Habitat**	**Feeds on**	**Archaeological Site Representation**
Grass snapper (*Lethrinus laticaudis*)	4.5	Adults: inshore coastal waters marine and brackish, reef associated. Juveniles: seagrass beds and mangrove swamps (Carpenter and Allen 1989)	crustaceans and fishes	Wirrngaji Nalkurdalayarrb Murdumurdu
blue-barred parrotfish (Scaridae)	2.1	Adults: inshore lagoons and seaward coral reefs Juveniles: inshore algae reefs (Lieske and Myers 1994)	feed on algae from rocks and corals	Thundiy

Other Marine Invertebrates

Crustacea: Two species of crabs are common in the South Wellesley Islands. Mud crabs (*Scylla serrata*) are known ethnographically to be the most heavily exploited as a food source by past and contemporary people (Bradley *et al.* 2006). This crab grows on average to have a maximum carapace width of 17cm-20cm (500g-1000g) and live for 3-4 years. The other commonly seen crab is Blue-swimmer (*Portunus armatus*) that grows to approximately 200mm and lives for 3-4 years (de Lestange *et al.* 2003). Crustacea remains are present in all sites but due to their highly fragmented nature it is difficult to discern MNI of this class and therefore the relative dietary contribution. Still, the presence of crustacea indicates people were foraging in the muddy mangroves for mudcrabs, in estuaries for blue-swimmer crabs and around rocky reefs, where the barnacles are found.

Other Marine Vertebrates

Dugong: There is no evidence of dugong hunting from the faunal assemblages of the eight sites analysed, despite other sources indicating that dugong and turtle substantially contributed to diet of Aboriginal people in the study area and across northern Australia (Haddon 1912; Johannes and MacFarlane 1991; McNiven *et al.* 2008; Weisler and McNiven 2015). The answer may be found in ethnographic descriptions of dugong butchering and feasting practices that all appear to have taken place at the shoreline (e.g. Tindale 1962a).

Turtle: The only site that exhibits evidence of turtle consumption is Thundiy, which has minor quantities of turtle bone in each of the three squares (18 unidentified bone fragments weighing 21.68g). The bone specimens could represent three separate turtles or the remains from one turtle that was shared between members of a large group. The turtle bone is isolated to a few XUs within 250-750 cal BP. This is also the period that exhibits the most intensive site use with abundant mollusc remains and evidence of fish exploitation. Representation consists of only a few bones that are very fragmented, making them difficult to identify. Although six species are known from the region, green turtles (*Chelonia mydas*) are the most abundant and ethnographically the most often hunted (Bradley *et al.* 2006). This species is found feeding on seagrass and algae along exposed sections of coast and rocky shores and coral reef flats. A large adult turtle can weigh up to 130kg providing a substantial meal for many.

15.3 Understanding Human Foraging Choices

15.3.1 Prey Choice

Every day people living in the South Wellesley Islands were faced with making foraging and hunting choices that would ideally provide for the optimum subsistence outcomes. The average recommended daily calorie intake is 2000 kcal (Meehan 1977) and the majority of people’s daily calorie intake came from marine fauna resources. Archaeological and ethnographic evidence suggest two main types of prey were targeted that required different gathering/hunting approaches. Shellfish, a sessile prey type can regularly be found en-masse in patches, require little or no technology to procure and all members of a group can access the resource, so shellfishing is regarded generally as a low-risk, reliable activity (Erlandson *et al.* 2005; Whitaker 2008; Whitaker and Byrd 2014). The active prey type (e.g. fish, crabs, dugong and turtle) would require the use of technology for capture and most encounters would be dependent on movements of the fauna, therefore making this a more risky and less reliable resource.

Prey Choice Models devised by researchers investigating human behaviour associated with forager-prey relationships are designed around the premise that foragers target prey resources that maximise the return of calories, protein or other benefits in terms of foraging energy expenditure (Charnov 1976; Hawkes and O’Connell 1992; MacArthur and Pianka 1966). Research based on the prey choice model indicates foragers will initially target high-ranked prey and then diversify diet breadth to include lower-ranked resources as high ranked resources reduce (Erlandson and Rick 2010; Erlandson *et al.* 2008; Kaplan and Hill 1992:171). From this model I have created a hypothesis for testing the South Wellesley Islands faunal assemblages using indices of taxa abundance, size and diversity.

Hypothesis: **I can expect that as hunter-gatherer populations expanded in the South Wellesley Islands during the late Holocene, increased human predation pressure on resources will be reflected in initially high abundances of the highest ranked taxa reducing through time and decreased mean sizes. I can also expect more diversified diet-breadth through time as more taxa were added to the diet. This would likely include a broadening of foraging patterns to incorporate different patches or habitats.**

The archaeological assemblages from most of the sites investigated reflect on average an increased rate of cultural material accumulation over time (refer section 15.1). The overall increase in fish and shellfish resource densities is coupled with evidence for foraging intensification of preferred species, seen in increased quantities of high-ranked species in most faunal assemblages (refer Chapters 7-14). This study investigates the impact that foraging predation pressure had on marine resources of the islands assuming that high-ranked prey was sought first (Bettinger 2009; Broughton *et al.* 2011; Charnov 1976). Although some researchers suggest that animal size is a reasonable proxy for prey rank (e.g. Broughton 1994b) ethnographic studies suggest other factors are just as important (e.g. Bird and Bliege Bird 1997; Bird *et al.* 2002; Thomas 2001).

Reflecting on the suite of marine fauna prey types available to foragers, I have presented marine fauna taxa in Table 15.6 with average kcal energy yield for meat. To determine net calorific return we would need to take into account a number of variables (e.g. prey size, habitat location, transport cost and energy utility after procurement and processing costs) (Thomas 2007). Considering all factors it is feasible to suggest that shellfish could be considered a high ranked prey with estimated utility almost equivalent to that of Dugong when collected en-mass, as can be seen in Table 15.6.

Individually mollusc specimens are lower-ranked marine resources, but because they often occur in dense concentrations at predictable locations and can be collected en-mass, their rankings are raised and compare favourably in the overall picture of diet breadth calorie comparison. For this study, because there is limited or no evidence in the archaeological record regarding consumption quantities of vertebrate taxa, the above hypothesis will be tested on the *M. hiantina*, the Rank 1 dominant mollusc based on MNI (see Table 15.4).

Table 15.6: Prey Energy Yields.

Prey	Average meat weight (g) per individual	Estimated Utility (kcal/kg)	Habitat (ease of locating)	Technology (ease of procuring and processing)
Dugong (*Dugong dugon*)	250,000	1940	sheltered inshore shallow waters, seagrass beds	hunted with spear and raft, dragged to beach to be butchered with knife and distributed, ethnographically reported to be eaten at beach
Turtle (*Chelonia mydas*)	130,000	1660	exposed sections of coast, rocky shores, coral reef flats, seagrass beds	hunted with spear and raft, dragged to beach to be butchered with knife and distributed, ethnographically reported to be eaten at beach
Reef Shark (Elasmobranchii)	1,000-14,000	1140	inshore shallow and deep waters, around coral reefs and in estuaries	hunted with spear or net, dragged to beach to be butchered with knife, cooked and eaten at beach or carried to camp
Fish (Osteichthyses)	200-3,000	1170	inshore shallow and deep waters, around coral reefs and in estuaries	hunted with spear or net, eaten at beach or carried to camp
Crustacea (*Scylla serrata*)	200-500	930	shallow waters, tidal-mud flats in mangroves and estuaries	spear, dillies, hand
Mollusca – Sandy Mud Flats *M. hiantina,* *G. pectinatum,* *T. granosa*	1.25 (Average foraging event=2,400)	800 1920	intertidal / subtidal zones in sandy-muds	average foraging event per person 1,920 kcal calculated: 11.5kg gross hand collected / 2 hrs – 1km distance from camp yields 2,400g of meat (Meehan 1977:367)).

Dugong and turtle data from Heinsohn (1972); Heinsohn *et al.* (1976); Nietschmann (1977). Fish and shellfish size data from live-collected specimens; other nutritional data collated from Smith (2004, 2011); Thomas (2001); Bird and Bliege Bird (2002); Meehan (1977) and Vlieg (1988).

In the South Wellesley Islands *M. hiantina* is the most ubiquitous taxon found in the archaeological record that is linked to human diet. The magnitude of its presence in deeply stratified deposits and various sized surface scatters indicates long-term and widespread economic value. The presence of *M. hiantina* in archaeological sites has been reported from across Australia's north and east coasts (e.g. Faulkner 2013; Meehan 1977; Morrison 2003; 2013; Rosendahl *et al.* 2014; Sim and Wallis 2008; Ulm *et al.* 2010). Meehan's observation of the Anbarra people of Arnhem Land confirms the importance of *M. hiantina* year round and especially in wet season diets (Meehan 1982:5). This makes it a good candidate for detailed analyses that investigate potential resource depression resulting from intensified foraging episodes.

The relationship between *M. hiantina* weight and MNI from each site is considered in order to determine if MNI counts offer an accurate reflection of this taxon's relative contribution to each site (Figure 15.6). There is a strong and significant correlation between weight and MNI within each site (Pearson's $r=0.9888$, $r^2=0.9777$, $p<0.001$, $n=14$), indicating that MNI values provide a robust reflection of *M. hiantina* quantities in the assemblages.

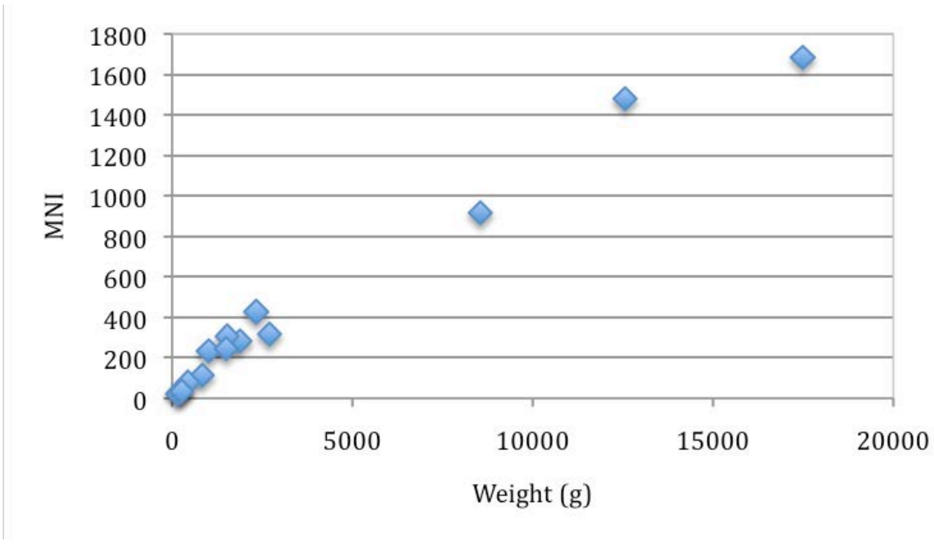


Figure 15.6: The relationship between *M. hiantina* weight and MNI.

I calculated a comparative abundance index (Σ *M. hiantina* / (Σ *M. hiantina* + Σ All other molluscs)) to determine the relationship between *M. hiantina* and other molluscan taxa through time (e.g. Morrison and Cochrane 2008; Nagaoka 2002a, 2002b). Table 15.7 summarises results of the *M. hiantina* abundance index that measures the changing proportions of *M. hiantina* to all other shellfish taxa in the assemblages (e.g. Broughton 1997; Broughton *et al.* 2011; Butler 2000:654; Cannon 2000). If foraging efficiency is weakening, then there should be a reduction in the high-ranked *M. hiantina* relative to other taxa plotted across the temporal periods.

In Table 15.7 the relative proportions of the high-ranked mollusc taxon *M. hiantina* compared to other shellfish densities increase at six of the eight sites (Dangkankuruwuru, Thundiy, Wirrngaji, Murdumurdu, Wardilmiru and Banbanbarukeind). These sites exhibit the highest representation for *M. hiantina* within the last 250 years. For example, at Dangkankuruwuru *M. hiantina* has a relatively low representation in the assemblage during prior periods (11%-28%) but for 0-250 cal BP there is a significant increase (62%) in the proportion of this species. Nalkurdalayarrb and Jirrkamirndiyarb both appear to show evidence for a decrease in *M. hiantina* in the period 0-250 cal BP. At Jirrkamirndiyarrb this species dominated the assemblage during the preceding 1000 years but abundances of all taxa are low in the most recent 250 years. *M. hiantina* makes up a very high proportion of the Murdumurdu and Wardilmiru shellfish assemblages representing 51% and 55% respectively in 250-500 cal BP increasing to 79% and 76% respectively in 0-250 cal BP.

Table 15.7: Abundance index for changes in *M. hiantina* MNIs compared against all shellfish taxa MNIs (Σ *M. hiantina* / (Σ *M. hiantina* + Σ all other molluscan taxa).

Period / Site	**Dangkankuruwuru**	**Wirrngaji**	**Murdumurdu**	**Thundiy**	**Jirrkamirndiyarrb***	**Wardilmiru**	**Nalkurdalayarrb**	**Banbanbarukeind**
0-250	0.62	0.63	0.79	0.51	0.34	0.76	0.13	0.28
250-500	0.28	0.45	0.51	0.49	0.75	0.55	0.14	0.02
500-750	0.22	0.45	0.06	0.16	0.95	0.07	0.24	0.01
750-1000	0.19	0.18	0.02	0.02	0.85		0.24	
1000-1250	0.21	0.23	0.04		0.57		0.24	
1250-1500	0.27				0.26		0.24	
1500-1750	0.11				0.33		0.19	
1750-2000	0.18						0.19	

*Note: At Jirrkamirndiyarrb abundance of shellfish is relatively low compared with other sites.

Foraging efficiency can also be investigated by comparing size means for *M. hiantina* specimens through time (see Chapters 7 to 14 for temporal size means at each site), which is an indicator of the age demographic being targeted and informs on species returns (after Reitz and Wing 2008:235). At all five sites where *M. hiantina* represents the Rank 1 molluscan taxon, the change in size mean through time is trending upward (Figures 15.7 to 15.11).

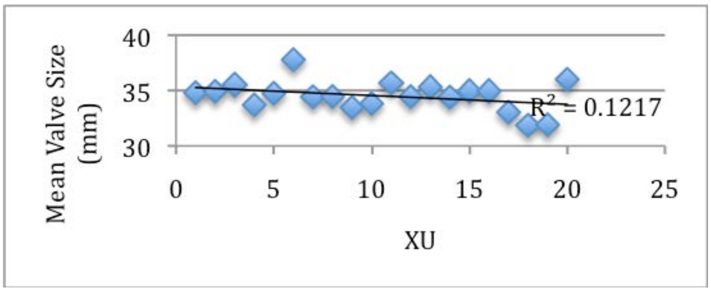


Figure 15.7: ***M. hiantina*** **mean valve size (mm) for each XU at Dangkankuruwuru.**

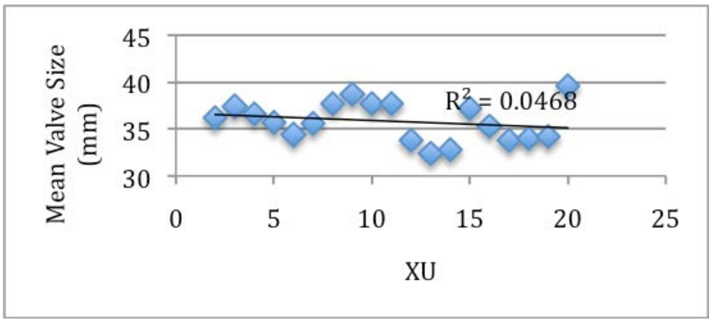


Figure 15.8: ***M. hiantina*** **mean valve size (mm) for each XU at Wirrngaji.**

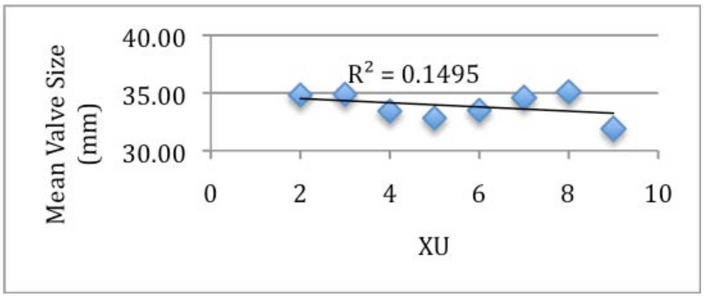


Figure 15.9: ***M. hiantina*** **mean valve size (mm) for each XU at Murdumurdu.**

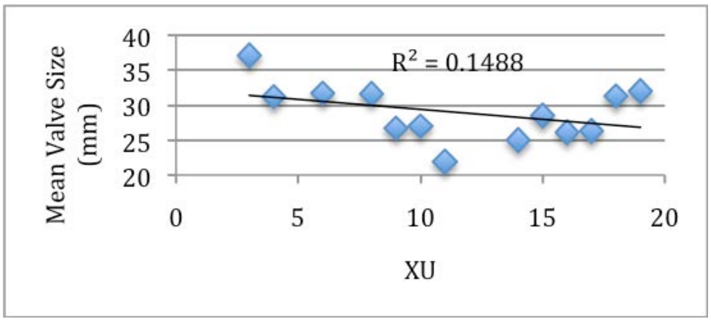


Figure 15.10: ***M. hiantina*** **mean valve size (mm) for each XU at Jirrkamirndiyarrb.**

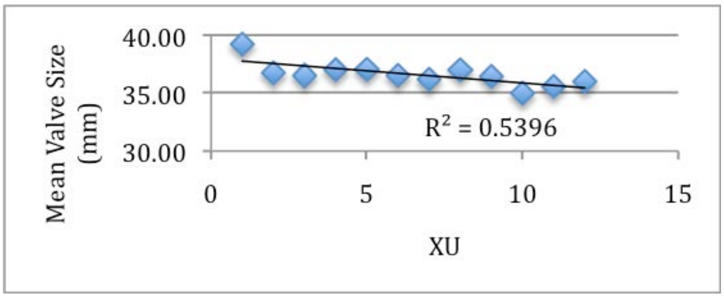


Figure 15.11: ***M. hiantina*** **mean valve size (mm) for each XU at Thundiy.**

In Chapters 7 to 14 the analysis of fine-grained data at the excavation unit level indicated possible evidence of *M. hiantina* overpredation. A pattern emerged where heavy predation (as suggested by elevated abundance levels) was followed by a decrease in mean valve size in the following unit(s) and sometimes coupled with reducing abundance levels. When this data is amalgamated and averaged over the 250-year phases (Table 15.8), the long-term picture does not reflect a case of overpredation. The increased abundance of dominant taxon *M. hiantina* at Dangkankuruwuru is coupled with a slight reduction in specimen mean size, peaking at 36.1mm in 250-500 cal BP but dropping back slightly to 34.74mm in 0-250 cal BP. Overall though the trend for a change in taxon size over time is positive rather than negative. Foragers at Murdumurdu, Wirrngaji, Thundiy and Jirrkamirndiyarrb (in the earlier periods) appear to have progressively collected larger specimens through time. These results are unexpected in view of the above hypothesis that suggests overpredation would result in taxa mean size reductions (but see Giovas *et al.* 2010).

At Nalkurdalayarrb *M. hiantina* and *G. pectinatum* were co-collected in reasonably even proportions during 1000-2000 cal BP. During this time the average size of *G. pectinatum* declined while the average size of *M. hiantina specimens* increased as more numbers were collected. It is possible that *G. pectinatum* populations may have been smaller/fewer in quantity than *M. hiantina* and/or that the species may take longer to mature, therefore population sustainability levels would be exceeded more quickly than *M. hiantina* sustainability levels. Between 0-1000 cal BP, there appears to be a converse relationship between the two species, where *M. hiantina* numbers are high when *G. pectinatum* numbers are low and vice versa in different 250-year temporal periods. During these times both mollusc species exhibited an increase in average size when more numbers were collected. Research by Giovas and colleagues (2010 and 2013) demonstrates that a temporal increase in shell size during times of heavy predation by humans can occur for a number of reasons, beside foragers preferentially selecting larger specimens through time (prey choice model). Evironmental processes, such as favourable water temperature and salinity, can improve shell growth rates (Kithsiri *et al.* 2004). Potentially, the shell size increase could occur because of mollusc population thinning, thereby reducing competion for the species (Giovas et al. 2010). A Pearson's r correlation test used for each site assemblage indicates mean size and abundances only have a weak positive correlation.

The second part of our hypothesis indicates that increased foraging pressure on resources would result in a more diversified diet breadth. Evidence of increasing diet-breadth would include more species in the diet and more even proportions of taxa as foragers sought to offset declining foraging efficiency (Morrison and Cochrane 2008). Tables 15.9 and 15.10 summarise the results of changes in the Shannon Weaver Diversity and Evenness Indices of taxa diversity incorporating both mollusca and vertebrate taxa. If diet breadth is increasing I should see higher diversity levels (on a scale of 0-5) and increasing evenness values approaching one (e.g. Grayson 1984; Grayson and Delpech 1998; Shannon and Weaver 1949).

Table 15.8: Comparison of temporal changes in *M. hiantina* specimen size means (mm).

Period / Site	Dangkankuruwuru	Wirrngaji	Murdumurdu	Jirrkamirndiyarrb	Thundiy	Nalkurdalayarrb	Wardilmiru	Banbanbarukeind
0-250	34.74	36.47	33.91	34.15	37.60	36.37	34.73	34.20
250-500	36.10	34.40	33.50	31.70	36.70	38.51	34.61	
500-750	34.46	36.65	31.90	29.15	36.10	30.89	34.59	
750-1000	33.64	35.51		27.00	36.00	31.00		
1000-1250	34.25	35.68		21.90		42.12		
1250-1500				21.90		38.20		
1500-1750				28.20				
1750-2000								

Table 15.9: Shannon-Weaver's Diversity Index.

Period / Site	Dangkankuruwuru	Nalkurdalayarrb	Jirrkamirndiyarrb	Wirrngaji	Murdumurdu	Thundiy	Wardilmiru	Banbanbarukeind
0-250	2.12	2.13	1.37	1.38	1.23	1.58	1.43	1.95
250-500	2.36	1.92	0.56	1.20	1.16	1.99	1.21	0.38
500-750	2.18	2.01	0.08	1.35	1.43	2.20	0.98	0.32
750-1000	2.22	1.96	0.63	1.49	1.03	2.12	1.23	
1000-1250	2.24	1.63	0.63	1.93	1.40			
1250-1500	2.23	1.43	1.38					
1500-1750	2.31	1.83	1.73					
1750-2000	2.13	2.29	1.73					

Table 15.10: Shannon-Weaver's Evenness Index.

Period / Site	Dangkankuruwuru	Nalkurdalayarrb	Jirrkamirndiyarrb	Wirrngaji	Murdumurdu	Thundiy	Wardilmiru	Banbanbarukeind
0-250	0.59	0.59	0.38	0.38	0.34	0.45	0.40	0.54
250-500	0.65	0.53	0.15	0.33	0.32	0.54	0.34	0.10
500-750	0.62	0.56	0.02	0.37	0.39	0.59	0.27	0.08
750-1000	0.61	0.54	0.17	0.41	0.28	0.58	0.33	
1000-1250	0.62	0.45	0.38	0.53	0.39			
1250-1500	0.62	0.39	0.38					
1500-1750	0.64	0.50	0.48					
1750-2000	0.59	0.63	0.48					

Taxa diversity at Dangkankururwuru and Thundiy is generally higher than at other sites, but proportions of different taxa exploited appear to remain consistent. There is a drop in molluscan taxa diversity for both sites during the most recent period 0-250 cal BP, suggesting foraging progressively focused on fewer species (Grayson and Delpech 1998), however this is also a period that exhibits increased exploitation of fish taxa, both in diversity and biomass. At Nalkurdalayarrb and Wardilmiru diversity and evenness increase through time with highest levels seen in 0-250 cal BP. Notably neither of these sites exhibits intensive foraging of *M. hiantina*. At Jirrkamirndiyarrb, Banbanbarukeind, Wirrngaji and Murdumurdu foragers committed to low diversity and evenness levels. Changes in species richness (NTAXA) over time examined with a Cochrane's test for linear trend (see Chapters 7 to 14) are not considered significant.

15.3.2 Patch Choice

The third part of our hypothesis indicates that broadening foraging patterns to add or substitute new habitats may suggest predation pressure in one patch. Based on the availability of resources within different habitats I assume that foragers could exploit a mix of prey from within a patch where resources are ranked from most to least efficient (Smith 1991:208). The invertebrate marine fauna resources in the South Wellesley Islands can be found in three patches or habitats (Sandy-Mud Flats, Mangroves and Tidal-Mud Flats and Rocky/Coral Reefs).

The predictable and reliable nature of mollusc patches would make them subject to intensified exploitation. Sites where mollusc returns appear to decrease as suggested by reductions in specimen size and an increased diversification in taxa, may suggest changes in the exploitation of marine habitats (e.g. Braje *et al.* 2007; Morrison and Cochrane 2008). The Patch Choice Model postulates that as higher ranked patches become depleted, foragers should add patches to their itinerary in order of decreasing returns (Smith 1983:632). Table 15.11 summarises foragers' preferred habitats during different time periods at each site based on taxa MNIs.

Table 15.11: Primary habitats exploited during each time period based on taxa MNIs. (Sandy-Mud Flats = SMF, Mangroves and Tidal-Mud Flats = MMF and Rocky/Coral Reefs = RCR).

Period / Site	**Dangkankuruwuru**	**Thundiy**	**Murdumurdu**	**Wirrngaji**	**Jirrkamirndiyarrb**	**Banbanbarukeind**	**Nalkurdalayarrb**	**Wardilmiru**
0-250	SMF	SMF	SMF	SMF	SMF	RCR	RCR	MMF
250-500	SMF	SMF	SMF	SMF	SMF	MMF	RCR	MMF
500-750	ALL	SMF/MMF	RCR	RCR/SMF	SMF	MMF	RCR	MMF
750-1000	ALL	MMF	RCR	RCR	RCR		RCR	MMF
1000-1250	ALL			MMF	RCR		RCR	
1250-1500	SMF						RCR	
1500-1750							RCR	
1750-2000							RCR	

Foraging strategies at Dangkankuruwuru appear to be spread across the three habitats. During 0-250 cal BP there is a noticeable rise in taxa contribution from Sandy-Mud Flats. This is likely attributed to the intensification of *M. hiantina* production, as is noted at other sites that experience greatest contribution from the sandy-mud flats habitat in this period (e.g. Thundiy, Wirrngaji, Murdumurdu, Jirrkamirndiyarrb). The chi-square results (see Chapters 7-14) indicate that declines in either mangrove and/or rocky reef species are significantly correlated with anincrease in Sandy-Mud Flats species. The Wardilmiru assemblage is dominated by *Cerithidea* and *Rhinoclavis* species that are determined as being non-cultural introductions to the assemblage. If these were removed from the analysis then *M. hiantina* (Sandy-Mud Flats) would also dominate the assemblage. In contrast Rocky/Coral Reefs taxa dominate the Nalkurdalayarrb assemblage for all times, with minor contributions from the other two habitats occurring in relatively consistent proportions. This is possibly because of the site's close proximity to rocky reefs supporting plentiful molluscan resources (as I noticed when undertaking fieldwork in the vicinity). At Banbanbarukeind the change from Mangrove and Tidal-Mud Flat species to Rocky/Coral Reef species is also significantly correlated.

15.4 Modelling Kaiadilt Responses to Temporal Changes in Resource Availability

Studies illustrate that where resource intensification occurs at a particular location over time there are a number of indicators (e.g. Claassen 1998:45; Mannino and Thomas 2002:458; Mason *et al.* 1998:317; Mason *et al.* 2000:757, 759). For example, the relative abundance and average size of the preferred species will decrease from the bottom of the deposit to the top. Other species that are more difficult to procure and/or process will increase from the base of the deposit to the top (Claassen 1986:130). This would be a predictable pattern if human predation affects the composition of the species population by removing more than can be replaced by natural increase (Botkin 1980:1).

So do the archaeo-faunal assemblages of the South Wellesley Islands reflect declining efficiencies in marine exploitation and human harvest pressure on resources? The South Wellesley Island site assemblages display some of these hallmarks for intensification such as amplified abundance levels of a high-ranked taxon and diversification of diet breadth, reflected through more taxa and different habitats being exploited. But they do not exhibit declines in taxa size through time. Overall there is no definitive archaeological evidence of a pattern of resource depression in the South Wellesley Islands, particularly for our case study shell *M. hiantina*, the highest represented molluscan taxon. Despite Kaiadilt population density being reported as amongst the highest number of people per area of land (Tindale 1962a), shellfish resources appear very abundant and not subject to overly excessive exploitation. Similar interpretations are proposed for patterns of *Anadara (Tegillarca) granosa* exploitation within Darwin Harbour (Bourke 2000:218-20) and Blue Mud Bay NT (Faulkner 2006). Intensification patterns of *M. hiantina* do not follow the resource depression paradigm of diet breadth expansion.

The slight increase in mean size of *M. hiantina* does not match with prediction that increased human predation pressure on resources will be reflected in decreased mean sizes. While some researchers suggest this may be a factor of thinning shellbeds having the effect of amplifying nutrients for remaining specimens that mature more quickly as a result, Pearson's r correlation tests suggests that shell size and abundance measures are only weakly linked. Broadening diet breadth is not necessarily a response to dwindling prey availability. An alternative explanation could be that foraging behaviour was reasonably flexible where people deliberately had a wide diet-breadth of taxa and focused on more than one high-ranked taxon. The continuous exploitation of a number of different habitats and species may be a pattern that equates with ethnographically recorded risk minimisation strategies by groups that include all prey (high- and low-ranked) encountered thereby reducing search time (e.g. Mowat 1995:163; Bird *et al.* 2004; Whitaker and Byrd 2014). This could be what I am seeing at Dangkankuruwuru and Thundiy.

Evidence for dietary expansion to include more fish taxa, I argue, is not because of shrinking foraging returns but because of population growth requiring more food. The increase in fish exploitation may have accompanied a less visible/invisible dugong and turtle production. High-ranked shellfish taxa continue to be exploited in high numbers therefore exploiting lower-ranked species is not a byproduct of decreased abundance of higher ranked taxa. For example, the graph displaying percentage distributions of shellfish remains throughout the Banbanbarukeind deposit (Figure 13.13) indicates an increase in site use through time, with the greatest quantity of shell dating from the period 0-250 cal BP and the upper part of 250-500 cal BP. Six species account for 86% of the assemblage and there is a more diverse diet breadth spread. *Saccostrea glomerata, M. hiantina, Telescopium telescopium, Terebralia sulcata* and *Glauconome virens* all contributed to the diet with an emphasis on *S. glomerata* in the past 250 years. A different scenario of narrowing diet breadth is reflected at Jirrkamirndiyarrb, Banbanbarukeind, Wirrngaji and Murdumurdu. If the forager is confident that resources will be readily available when they need them, then they can afford to focus only on favoured preys.

Despite evidence at some sites of a broadening diet-breadth, the contribution extent of some taxa may not be entirely visible. The presence of *S. glomerata* in most sites indicates this was a popular species. I suggest it is likely that people may have relied even more heavily on this species than is visible in the archaeological record. I consider that the contrast between ethnographic and archaeological evidence can be explained by the premise that shell waste material in the midden may have been differentially transported (see Bird and Bliege Bird 1997). I suggest that due to difficulty with procuring the species (oysters adhere themselves to the rocks and the cemented shells are hard to remove), the assemblages do not reflect a true picture of the importance of this species for subsistence.

15.4.1 Central-Place Forager Model

The Central-Place Forager Model (Bettinger 1991) is useful for interpreting the archaeological record based on understanding human foraging and processing decisions. The model offers the possibility to predict the threshold when it becomes more economical to field-process a prey type or take it back to base (Bettinger *et al.* 1997; Bird and Bliege Bird 1997; Bird *et al.* 2002; Charnov 1976; Metcalf and Barlow 1992; Thomas 2002).

A review of the proximity of all sites to various habitats and resources indicates people would not have to travel far to access resources from any one of the three patches. All sites analysed in this study are located within a 1km radius (range = 0.2km – 0.7km) to the shoreline where resources can be found. It is feasible to suggest that people established their settlement patterns based on the distances to resource zones. Based on evidence from other forager groups (e.g. Braje *et al.* 2007; Jazwa *et al.* 2015) a reasonable foraging radius may be around 2km from the site. Bird and Bliege Bird (1997) observed Meriam people in Torres Strait traveling around 1km from the central site to forage for shellfish, while Meehan (1977) noted Anbarra people camped between 1–3km from shellfish beds. Even though people did not have to travel great distances to collect resources ethnographic research indicates many coastal groups used different areas in their foraging territory as specific activity locales in a semi-sedentary, cyclical settlement pattern (see Kelly 1992; Binford 1980). Sometimes Meehan (1982:112-114, 117) observed people processing *M. hiantina* at temporary dinnertime camps near a site of procurement, prior to returning to central camp, even when central camps are within 1km of shellbeds. Thresholds for travel while carrying large loads of resources have been calculated by Jazwa *et al.* (2015), who found that a one-way travel limit for a 15kg load is about 2.6km (1.5hrs), within which most hunter-gatherers confine their daily foraging (see also Bettinger *et al.* 1997:896; Bird and Bleige Bird 2002).

The results from this mobile style of settlement are midden sites that could be home-base sites, which do not reflect all dietary resources consumed (Meehan 1982). Variability in the taxonomic representations of shellfish remains and vertebrate remains may reflect differences in the extent of processing away from camp rather than relative importance of the resource type in the diet (McNiven 1989:46). Additionally some sites may experience periods of abandonment and re-occupation (Kelly 1992:56). Jazwa *et al.* (2015) did a study incorporating different site types and found that they contained different taxa abundances but together all sites made up a whole subsistence system.

15.4.2 Environmental Changes

For sites where I see a change in habitat exploitation through time I need to consider that environmental events coincide with this shift. Sites located along the southern coastline of Bentinck Island display assemblage contents shifting from rocky reef to sandy mud flat species in the last 500 years. There is palynological evidence from Marralda Swamp that suggests this coastline was perhaps subject to some environmental event that caused landscape change (Moss *et al.* 2015). Mangrove development around c.500 cal BP related to a prograding coastal system, formed an environment protected from wave action with suitable sandy-mud substrates (Moss *et al.* 2015, Grindrod *et al.* 1999, 2002). In the island’s north palynological analysis of Thundiy archaeological deposits also indicate environmental changes over the past 500 years. Previously an open coastal phase landscape, there is a decline in charcoal values and an increase in Casuarinaceae between 250-500 cal BP. This seems to coincide with a period of very high site use. Then between 0-250 cal BP there is an increase in grass and herbaceous taxa and a decline in arboreal taxa. The open forest mangrove system that previously consisted of mixed Avicennia, Ceriops and Rhizophora becomes a contemporary fringe dominated by choking Rhizophora (Moss *et al.* 2014).

This supports the probability that spatial and temporal variances in the relative abundance and distribution of specific molluscan taxa would commonly be reflected in the archaeological record. I see a marked overall decrease in the use of species from Rocky/Coral Reef substrates and an increase in Mangrove, Tidal-Mud Flats and Sandy-Mud Flats habitats. At Thundiy there is evidence for new occurrences of *Tegillarca granosa* and *Placuna placenta* in the diet around c.500 cal BP as mangrove zones and estuarine mudflats developed (see Pathansali and Soong 1958:27). Local environmental changes would have caused some habitats and associated resources to decline while providing optimal conditions for other habitats and associated resources to flourish. Research elsewhere indicates that these environmental changes occurred on a regional scale (e.g. Bourke 2000; Faulkner 2006; Woodroffe *et al.* 1986, 1988).

15.4.3 Taphonomy

The idea of sites not being in continuous use raises questions of taphonomy as rates of foraging cannot accurately be determined from accumulation rates, particularly as the archaeological record is a condensed palimpsest of activity occurring at some stages over hundreds or thousands of years. Variation in accumulation rates can be attributed to more or less intensive harvesting, different discard practices and larger group sizes (Bourke 2000:172). Radiocarbon dates cannot feasibly be obtained for every excavation unit and therefore I cannot accurately account for variations in site formation history (Stein *et al.* 2003:310). Furthermore, the small sample sizes and preservation biases of the archaeological record result in under or over-representation of some taxa (Mannino and Thomas 2002:465).

All zooarchaeological methods have inherent biases; there is no single best way to quantify or interpret a faunal assemblage. However if multiple lines of evidence are in agreement then stronger arguments can be made. The trophic level approach augments other archaeological approaches by providing another way in which zooarchaeological data of the South Wellesley Islands can be interrogated and compared.

15.5 Measuring Kaiadilt Impacts on Resources in the Marine Ecosystem

Fish and mollusc populations have important roles in a marine ecosystem as consumers and prey and a taxon’s position in the food web is depicted by its trophic level. Table 15.12 lists the trophic levels for taxa identified in this study.

Table 15.12: Trophic levels for taxa identified in this study (Pauly *et al.* 2000).

Trophic Level Category	Taxa Recorded (Trophic Level)
4.1 - 5.0 Sharks and Piscivore Fishes	*Lethrinus laticaudis* (4.5) *Tylosurus gavialoides* (4.4) Carcharhinidae (4.1) *Lutjanus russellii* (4.1) *Lutjanus sebae* (4.1)
3.1 – 4.0 Carnivore and Piscivore Fishes	Serranidae (4.0) *Epinephelus* sp. (4.0) *Lutjanus carponatus* (3.9) Ariidae (3.6) Labirdae (3.6) *Choeredon schoellenii* (3.6) Hemiramphidae (3.5) *Pomadasys kaakan* (3.5) *Sillago burrus* (3.3)
2.1 – 3.0 Herbivore Vertebrates, Crustaceans, Molluscs	Molluscs (2.1) *Chelonia mydas* (2.5) *Mugil cephalus* (2.5) *Liza vaigiensis* (2.3)

Trophic levels in aquatic environments range from 1.0 to 5.0 covering from marine plants to top-level carnivores that are predators of marine mammals and large bony fishes (Pauly *et al.* 2000). The trophic level assigned to a taxon is dependent on their diet, size and maturity. For example a juvenile fish that consumes mainly zooplankton will have a TL=2.0 but as the fish matures and grows its diet changes to incorporate small fishes or benthic invertebrates and this increases their trophic level to 3.0 or 4.0.

As humans adapted their foraging strategies in response to major environmental/climatic events and internal social pressures brought on by group populationg growth, is there a corresponding change in the average trophic levels of marine fauna represented in the archaeological assemblages? Because marine resources contributed a large proportion of hunter-gatherers' diet in the South Wellesley Islands, there is the possibility that humans impacted the marine food web, firstly through removal of mature specimens with a high trophic level that played an important role of keeping low-trophic-level taxa in check; and secondly through mass removal of immature individuals that had not yet grown to become adults and reproduce (Pauly 1979). The effects of overfishing removals on ecosystems include a gradual reduction in the abundance of long-lived, high trophic level organisms and an increase in smaller, short-lived fish species and invertebrates (Pauly *et al.* 1998). This triggers a trophic cascade; an imbalance in the natural ecosystem that results in smaller fishes and molluscs depleting the plankton biomass (see Erlandson and Rick 2008:12). Eventually people turn toward exploitation of lower trophic level small fishes (herbivores and omnivores), molluscs and crustacea.

Hypothesis: **As humans adapt their foraging strategies in response to major environmental /climatic events or social pressures brought on by population growth this may result in the overexploitation of a class of taxa. This would be reflected in corresponding changes in the average trophic levels of marine fauna represented in archaeological assemblages and may result in dysfunctional trophic cascades in the local marine ecosystem.**

Pauly *et al.* (1998) documented a decline in the global mean trophic levels of catches of marine fauna based on 40 years of harvesting data from industrial fisheries. In order to assess potential changes over time in the aquatic food web of the study area, I applied trophic level analysis to the archaeological assemblages. Because most archaeological deposits are accumulations of refuse collected over many years it is important to note that some biases are inherent in the data, such that it does not necessarily represent everything that was incorporated into diet. Some variables include the taphonomic effects on surviving remains, site sampling, vagaries of time averaged deposits and identification of taxa. These biases are critiqued by zooarchaeologists (e.g. Butler and Campbell 2004; Fitzpatrick and Anderson 2008; Fitzpatrick and Keegan 2007; Reitz 2004; Reitz and Wing 2008; Wing 2001) but unfortunately they are fundamental to archaeological sites and methods and most cannot be resolved. Braje *et al.* (2007) point out that anthropogenic impacts on ecosystems can also be problematic in distinguishing them from natural (non-cultural) ecological changes. Nevertheless, highlighting any change in the mean trophic level for each 250-year period may indicate potential dysfunction trophic cascades in the local marine ecosystem.

Known trophic level data for each taxon has been incorporated from information published on www.Fishbase.org (Pauly *et al.* 1998). Estimates of body sizes for identified fish have been calculated by comparing archaeological skeletal elements with similar specimens in the TARL Fish Reference Collection using methods outlined in Chapter 5 (see also Tomkins *et al.* 2013). From these data I can evaluate for each taxon its potential meat contribution to diet, the size range caught, feeding habits and habitat preference (i.e. juvenile fish and adult fish tend to live in different locations and eat different organisms). Body size estimates of the identified vertebrate taxa are presented for each assemblage in the previous site report chapters.

The catch biomass has been estimated for each 250-year time period based on the weight of each identified vertebrate species, determined from calculated body size data using an allometric formula (logY = log a+b (logX)) as outlined in Chapter 6. Table 15.13 below presents the estimated biomass and trophic level of taxa identified in the assemblages (note: vertebrate species from Banbanbarukeind and Jirrkamirndiyarrb could not be identified and so no trophic level data are available for vertebrates from these sites). For molluscan taxa both identified and unidentified shell has been used in biomass estimates, which rely on an assumption that shell represents around 70% of the mollusc weight determined from an average of live-collected specimens that are in the TARL Reference Collections.

Table 15.13: Estimated Biomass and Trophic Level of Taxa Identified in Assemblages.

Site	Phase	Taxon	Biomass	Trophic Level
Dangkankurwuru	0-250	*Tylosurus gavialoides*	726	4.4
	0-250	*Tylosurus gavialoides*	432	4.4
	0-250	*Lutjanus russellii*	655	4.1
	0-250	*Lutjanus carponatus*	801	3.9
	0-250	Ariidae	268	3.6
	0-250	Ariidae	292	3.6
	0-250	*Mugil cephalus*	435	2.5
	0-250	*Liza vaigiensis*	439	2.3
	0-250	*Liza vaigiensis*	642	2.3
	0-250	Mollusca	5587	2.1
	250-500	Mollusca	1527	2.1
	250-500	*Sillago burrus*	265	3.3
	500-750	Ariidae	410	3.6
	500-750	Hemiramphidae	54	3.5
	500-750	Mollusca	904	2.1
	750-1000	Ariidae	252	3.6
	750-1000	Serranidae	1098	4.0
	750-1000	Ariidae	316	3.6
	750-1000	Ariidae	252	3.6
	750-1000	Mollusca	1812	2.1
	1000-1250	*Sillago burrus*	210	3.3
	1000-1250	Mollusca	5651	2.1
	1250-1500	Mollusca	1098	2.1
	1250-1500	*Lutjanus carpontus*	308	3.9
	1500-1750	Mollusca	178	2.1
	1750-2000	Mollusca	50	2.1
Thundiy	0-250	Ariidae	315	3.6
	0-250	Mollusca	36213	2.1
	250-500	Ariidae	442	3.6
	250-500	*Sillago burrus*	220	3.3
	250-500	Mollusca	54883	2.1
	500-750	*Pomadasys kaakan*	290	3.5
	500-750	Mollusca	32649	2.1
	750-1000	Mollusca	1662	2.1
Jirrkamirndiyarrb	0-250	Mollusca	59	2.1
	250-500	Mollusca	19	2.1
	500-750	Mollusca	369	2.1
	750-1000	Mollusca	10	2.1

Site	Phase	Taxon	Biomass	Trophic Level
Wirrngaji	0-250	*Lethrinus laticaudis*	250	4.5
	0-250	Ariidae	250	3.6
	0-250	Mollusca	1665	2.1
	250-500	Mollusca	340	2.1
	500-750	Mollusca	2952	2.1
	750-1000	Serranidae	500	4.0
	750-1000	Labridae	1800	3.6
	750-1000	Mollusca	4565	2.1
	1000-1250	Mollusca	1062	2.1
Nalkurdalayarrb	0-250	*Lethrinus laticaudis*	400	4.5
	0-250	Hemiramphidae	112	3.5
	0-250	Mollusca	461	2.1
	250-500	Mollusca	427	2.1
	500-1000	*Lutjanus sebae*	537	4.1
	500-1000	Hemiramphidae	195	3.5
	500-1000	Mollusca	107	2.1
	1000-1500	Mollusca	107	2.1
	1500-1750	Mollusca	294	2.1
	1750-2000	Mollusca	107	2.1
Murdumurdu	0-250	*Lethrinus laticaudis*	450	4.5
	0-250	Labridae	350	3.6
	0-250	Mollusca	1348	2.1
	250-500	Labridae	350	3.6
	250-500	Mollusca	4797	2.1
	500-750	Mollusca	398	2.1
	750-1000	Mollusca	225	2.1
	1000-1250	Mollusca	770	2.1
Wardilmiru	0-250	*Choeredon schoellenii*	2240	3.6
	0-250	Mollusca	2954	2.1
	250-500	Labridae	350	3.6
	250-500	*Epinephelus* sp.	900	4.0
	250-500	Mollusca	2671	2.1
	500-750	Carchahinidae	1000	4.1
	500-750	Mollusca	2012	2.1
	750-1000	Mollusca	831	2.1
Banbanbarukeind	0-250	Mollusca	2508	2.1
	250-500	Mollusca	209	2.1
	500-750	Mollusca	165	2.1

The trophic level formula ($TL_i = \sum TL_{ij} Y_{ij} / \sum Y_{ij}$) was then used to estimate the relative contribution of each trophic level during each time period or the mean trophic level for the collection. Changes in the mean trophic level can indicate potential human induced impacts to the ecosystem. Declining levels imply a gradual reduction in abundance of large, long-lived, high trophic level organisms, which are replaced by smaller, short-lived, low trophic level fish and organisms. Table 15.14 presents the mean trophic level for each 250-year period.

Table 15.14: Mean Trophic Level per 250-year period For Assemblages.

Period / Site	Dangkankuruwuru	Nalkurdalayarrb	Wirrngaji	Murdumurdu	Thundiy	Wardilmiru	Banbanbarukeind	Jirrkamirndiyarrb	Mean per 250-year period
0-250	2.75	3.25	3.40	2.85	2.11	2.76	2.1	2.1	2.66
250-500	2.28	2.10	2.10	2.20	2.12	2.67	2.1	2.1	2.21
500-750	2.60	3.52	2.10	2.10	2.12	2.76	2.1	2.1	2.42
750-1000	2.99	3.70	3.23	2.10	2.10	2.10		2.1	2.61
1000-1250	2.14	2.10	2.10	2.10					2.11
1250-1500	2.49	2.10							2.29
1500-1750	2.10	2.10							2.1
1750-2000	2.10	2.10							2.1

At Wardilmiru and Murdumurdu I see increasing mean trophic levels through time. At Dangkankurwuru, Nalkurdalayarrb and Wirrngaji there is a repeating pattern of the catch reflecting initially low trophic levels, followed by a period of increased trophic levels. This cycle happens twice during the past 2000 years, although terminal (0-250 cal BP) deposits at all sites reflect relatively high mean trophic levels relative to preceding periods.

Do the archaeo-fauna assemblages reflect any dysfunctional trophic cascades in the local marine ecosystem resulting from over-exploitation of particular marine resources? Faunal data demonstrate that people in the South Wellesley Islands targeted primarily low trophic level shellfish during the early periods of occupation, before shifting their economic focus to a more broad-based diet-breadth incorporating more fish, which in turn raised the mean trophic level of all site assemblages. As the mean trophic level at Murdumurdu, Wardilmiru, Wirrngaji and Nalkurdalayarrb increases it is matched with increasing species diversity (see Table 15.15). I equate the increase in diversity not as the result of resource depression but instead to a more broad-based use of the local resources. At Thundiy the mean trophic level remains constant and diversity reduces. At Dangkankuruwuru as the mean trophic level increases diversity reduces. This time diversity is reducing with people intensifying use of fewer molluscan resources and using more fish resources. Molluscan resources (TL2.1) were consistently exploited. Small mullet (TL2.3) were collected between 0-250 cal BP. Fishes with TL3-4 such as bream, wrasse, catfish, garfish and whiting have representation in at least one or more sites over the entire sequence of occupation. Higher trophic level species between TL4-5 include longtom, perch, rockcod, snapper and shark, which were collected during the past 1000 years. There is no pattern that suggests fish were added to the diet because of declining mollusc resources.

Table 15.15: Composite table showing Taxa Diversity Index (TDI) and Mean Trophic Level (MTL) per 250-year period for assemblages.

Site / 250-year period	Dangkankuruwuru (TDI)	Dangkankuruwuru (MTL)	Nalkurdalayarrb (TDI)	Nalkurdalayarrb (MTL)	Jirrkamirndiyarrb (TDI)	Jirrkamirndiyarrb (MTL)	Wirrngaji (TDI)	Wirrngaji (MTL)	Murdumurdu (TDI)	Murdumurdu (MTL)	Thundiy (TDI)	Thundiy (MTL)	Wardilmiru (TDI)	Wardilmiru (MTL)	Banbanbarukeind (TDI)	Banbanbarukeind (MTL)
0-250	2.12	2.8	2.13	3.3	1.37	2.1	1.38	3.4	1.23	2.9	1.58	2.1	1.43	2.8	1.95	2.1
250-500	2.36	2.3	1.92	2.1	0.56	2.1	1.20	2.1	1.16	2.2	1.99	2.1	1.21	2.7	0.38	2.1
500-750	2.18	2.6	2.01	3.5	0.08	2.1	1.35	2.1	1.43	2.1	2.20	2.1	0.98	2.8	0.32	2.1
750-1000	2.22	3	1.96	3.7	0.63	2.1	1.49	3.2	1.03	2.1	2.12	2.1	1.23	2.1		
1000-1250	2.24	2.1	1.63	2.1	0.63		1.93	2.1	1.40	2.1						
1250-1500	2.23	2.5	1.43	2.1	1.38											
1500-1750	2.31	2.1	1.83	2.1	1.73											
1750-2000	2.13	2.1	2.29	2.1	1.73											

15.6 Summary

Aboriginal lifeways in northern Australia are connected to seasonal and longer-term cycles of climate change, reflected in changing resource distributions and subsistence strategies. Such traditional Aboriginal lifeways continued on Bentinck and satellite islands from c.2000 years ago until 1948 when Kaiadilt people were forcibly removed to Mornington Island (Ulm *et al.* 2010). Although some islands in the western Torres Strait, Vanderlin Island and northwest Kimberley coast exhibit evidence for use during the marine transgression (Barker 1991; David *et al.* 2004; McDonald and Berry 2016; O'Connor 1999a; Sim and Wallis 2008; Wright 2011; Veth *et al.* 2007, 2016) most islands show evidence for a post-marine transgression occupation. It was not until landscape and sea-level stabilisation and climate amelioration after 2500 years ago that permanent settlement is archaeologically visible.

Analysis of the archaeological deposits from the South Wellesley Islands has identified evidence of human subsistence strategies, in particular the diversity of marine species types exploited and patterns of habitat exploitation through time. The research has also characterised temporal changes in biomass contribution and population structure of *M. hiantina* through development of taxa size/age profiles. Although some parts of the main hypotheses appear to be supported by zooarchaeological evidence at a fine-scale resolution this is not always clear at broader scales. In Chapters 7 to 14 the analysis of fine-grained data at the excavation unit level indicated possible evidence of *M. hiantina* overpredation. A pattern emerged where heavy predation (as suggested by elevated abundance levels) was followed by a decrease in mean valve size in the subsequent excavation unit(s) and sometimes coupled with reducing abundance levels. When these data are amalgamated and averaged over the 250-year blocks (Table 15.7), the long-term picture does not reflect a case of overpredation. I need to consider other possible causes for the signatures seen in the record.

Instead I offer the following explanation for the patterns observed in the South Wellesley Islands assemblages. The archaeological assemblage is not a true reflection of the entire subsistence system. Different site types within a localised area are all part of the whole subsistence system. The hunter-gatherers in this study did not live a sedentary lifestyle nor were all meals consumed in one place. They traveled around their country accessing and utilising resources, at times stopping and eating at the place of resource procurement or nearby; at other times transporting their resource collection (or part thereof) back to a central location to share it amongst others in their group. The lower numbers of some high-ranked resource taxa are very likely the result of differential processing and transport methods. Ethnographically dugong and turtle were butchered on the beach at the place where these animals were brought ashore. There they were divided and shared amongst members of the group. The unwanted remains were then cast back into the water leaving little to no evidence that the consumption event had even occurred. Shellfish resources collected from rocky reef were at times difficult to procure. For example, oysters cement themselves to the rocks and are very difficult to remove intact. People would have eaten the oyster meat as they were collecting it or placed it in a container to bring back to a central place to share. The oyster shell in many cases would be left on the rocks or discarded in the water. Similarly, recent ethnoarchaeological observations show Kaiadilt women removing the meat from the heavy-shelled large estuarine bivalve *Geloina erosa* for transport (Sean Ulm, pers comm. 2015). While it appears that *M. hiantina* was the dominant taxon consumed it is wrong to assume that other taxa were not as highly favoured based solely on the archaeological evidence. Instead it is considered to be only a part of a more diverse diet breadth that incorporated a mix of high ranked taxa and low ranked taxa.

Besides human-induced pressures I also need to consider variables such as the potential impacts of environmental events as demonstrated by zooarchaeological evidence of diet-breadth and habitat changes c.500 cal BP coinciding with palynological evidence for an altered environment (Moss *et al.* 2014, 2015; Braje *et al.* 2007; Hawkes *et al.* 1982; Madsen and Schmitt 1998). Local environmental changes would have caused some habitats and associated resources to decline while providing optimal conditions for other habitats and associated resources to flourish. Research elsewhere indicates that these environmental changes occurred on a regional scale (e.g. Bourke 2000; Faulkner 2006; Woodroffe *et al.* 1986, 1988).

There is no evidence for a decline in higher trophic level species for low ones and conversely no evidence for a decline in lower trophic level species for higher ones, either by prey diet or prey size. There is also no evidence for any trophic cascades reflected by the zooarchaeological assemblages. This indicates that human predation on marine fauna did not heavily impact the environment. Instead I see the long-term stability of mollusc resource bases and a general continuity in the major species exploited through time. Similar findings are reported for research conducted in South East Asia (e.g. Wickler 2001). Often the most common taxa represented in Lapita shell middens are also the highest biomass intertidal mollusc species in the adjacent environments (Szabó 2009). There is also little active selection for particular size classes within populations with juvenile and sub-adult shells often forming a reasonable proportion of assemblages (Szabó 2009). Similarly in California, Jones et al. (2016:106) found no evidence for depression of the prehistoric fishery, instead noting that a highly productive but under-exploited fishery was sustainably fished by the low human populations.

Environmental (e.g. seasonal and long-term fluctuations) and social factors (e.g. group population sizes, territoriality, mobility, settlement systems) influenced decisions about what resources to collect and when to collect them. The archaeological evidence from the South Wellesley Islands does not conclusively match with that of 'fishing down the food web' (Pauly *et al.* 1998:860; see also Reitz 2004, Wing 2001) or with the alternative 'fishing up the food web' (e.g. Braje *et al.* 2007, Erlandson *et al.* 2004, 2005, 2008, 2009). Instead it seems that in the last 500 years in response to environmental and social factors people continued to exploit increasing quantities of molluscs as well as targetting finfish.

Chapter 16. Archaeological Evidence for Human Adaptation and the Effects on Resources from Environmental Change and Prehistoric Foraging Activities.

16.1 Introduction

This chapter amalgamates all findings and considers them in the context of local, regional and global issues in human subsistence practices and prehistoric foraging impacts on resources. It presents the key findings of the study as well as a restating the research aims and outlining the objectives achieved. Methodological limitations and directions for future research are also discussed.

Investigations into the use of marine ecosystems have generally relied on historical records, limiting studies in most areas of Australasia to the last few hundred years. Through the high-resolution analysis of archaeological marine fauna assemblages with secure chronologies, this study provides a valuable longer-term perspective on the nature of past marine ecosystems and the history of anthropogenic impacts on marine fisheries in the South Wellesley Islands.

The pattern of Aboriginal settlement and island use in the South Wellesley Islands during the late Holocene fits with the broader-scale trend identified for northern Australia. The combination of resource intensification, more new sites and increasing use of remote locations may reflect increasing population densities fissioning into smaller groups (McNiven 1999), with groups becoming more mobile and adopting a risk minimisation strategy by accessing more resources (Hiscock 2008).

The hallmarks of hunter-gatherer resource intensification support broader trends along some lines, but overall the data does not support evolutionary ecology expectations for resource intensification whereby foraging efficiency decreases as production increases (Broughton 1994b:501). Moreover, it is also possible that intensification was occuring in the South Wellesley Islands in the socioeconomic context put forward by Lourandos (1983), where Kaiadilt people efficiently managed resources by regulating resource yields and managing resource regeneration.

Erlandson and Rick (2008:11) identify four key ways in which archaeologists can empirically measure human impacts on marine ecosystems by identifying and quantifying: (1) resource depletion and depression; (2) temporal changes in the size or age distributions of particular populations; (3) reductions in the geographic ranges of marine species; and (4) changes in marine trophic levels and trophic cascades. This thesis has addressed the first three of these key ways within an evolutionary ecology framework, through application of evolutionary ecology models of diet-breadth, optimal foraging and resource intensification to archaeological marine-fauna data. Radiocarbon dates provided the framework for grouping the data into 250-year age periods for analysing chronological changes in hunter-gatherers foraging patterns. The fourth key way; trophic level analysis was used to establish the average trophic level for each 250-year period's marine biomass catch. Reviewing temporal changes in the mean trophic level of resources exploited by hunter-gatherers in the South Wellesley Islands indicates that people had limited long-term impacts on shellfish.

16.2 Key Findings

- A three-phase cultural chronology is proposed for the study area. The earliest radiocarbon ages indicate cultural activity c.3500 cal BP based on dated burnt fish remains at Jirrkamirndiyarrb. But the paucity of dates from between c.2000-3500 cal BP suggests only occasional visitation. At this time the South Wellesley Islands would have been considerably further offshore than they are today with landform development and stabilisation occurring post-3000 cal BP and sea-levels +2m until c.2000 cal BP (Moss *et al.* 2015, Lewis *et al.* 2013; O'Connor 2016; Sloss *et al.* 2012). A comprehensive suite of dates on cultural marine shell indicates more frequent visits and more permanent occupation between 2000-800 cal BP. After 800 cal BP there is a dramatic rise in the creation and continuous occupation of sites, accelerating in the last 300 years.

- Rosendahl (2012) has established that archaeological deposits at the Yiinkin Embayment indicate cultural use of resources on Mornington Island by c.3300 cal BP. It is possible that these Proto-Tangkic people who occupied Mornington Island may have fissioned from the mainland earlier and could be linked with people who travelled to the South Wellesley Islands around this time. Memmott *et al.* (2016) suggest that the first Tangkic population fission occurred c.2000 cal BP from Mornington Island south to the mainland and South Wellesley Islands leading to colonisation. Between 800 and 400 cal BP climatic instability may have caused people to return to the mainland for refuge (Memmott *et al.* 2016). When people returned to Bentinck Island after this time of fusion with Eastern Tangkic speakers, the Kayardild language had time to evolve in relative isolation. The trajectory of hunter-gatherer settlement in the South Wellesley Islands appears to be that of regionalisation (McNiven 1999:157) whereby social groups fissioned into smaller localised groups that carried out economic activities on their country.

- A total of 124.36kg of marine faunal remains from 8 stratified coastal middens (located between 200m to 800m from the present-day shoreline) were examined for this study. I suggest these sites are representative of repeatedly-used/occupied central place camps where members of a hunting-foraging group came together to share food and materials accumulated over time. A minimum 15 species of fish, 1 species of shark and 1 species of turtle were identified from skeletal remains. There is also consistent evidence of crustacea being collected. The majority of faunal remains are mollusc shells (99.6% by weight) indicating people placed heavy reliance on this protein source. There were 62 molluscan taxa identified in the study. Hiant venus clam (*Marcia hiantina*), rock oyster (*Saccostrea glomerata*), Turban snails (*Turbo* sp., *Lunella cinerea*), tumid venus clam (*Gafrarium pectinatum*) and longbums (*Telescopium telescopium*) were the main shells consumed. Some other species (e.g. *Rhinoclavis* sp. and *Cerithidea* sp.) have a very high representation in the assemblages but all these specimens are less than 10mm in size and were either introduced to the sites by natural processes, entered the site attached to other molluscs or collected by humans for another purpose (cf. Rowland 1994). Based on known habitats for the specimens identified in archaeological assemblages most of the marine fauna were obtained from foraging in nearshore waters, either from around rocky/coral reefs, sandy-mud flats, intertidal mangroves, estuaries or in the constructed intertidal fishtraps.

- Diet-breadth/Prey choice models were used to investigate foraging strategies reflected by the archaeological record. These models have successfully contributed to our understanding of peoples' prey and habitat preferences. They have also been useful in highlighting variance in patterns of intensive exploitation. Overall there is no definitive archaeological evidence of a pattern of resource depression in the South Wellesley Islands, particularly for our case study shell *M. hiantina*, the highest represented molluscan taxon. Although *M. hiantina* specimens exhibit some short-term reductions in mean size during seasonal episodes of intensive foraging, temporal patterns indicate that foraging efficiency was not compromised in the long-term.

- Patch choice models show that hunter-gatherers continued to exploit a diverse range of taxa from different habitats on their country. At most sites the highest percentage of shellfish comes from sandy-Mud Flat habitats, although people also collected molluscs from Rocky/Coral Reefs and Mangroves and Tidal-Mud Flats. The emphasis on different habitats occurred in different time periods, which could reflect changing cultural preferences and/or changing environments affecting resource availability.

- The low quantities of fish and other vertebrate bones identified in the analysed materials, intimate that these types of marine animals did not contribute significantly to diet. However this does not equate with the plethora of fishtraps found throughout the islands and ethnographic accounts that report fish, turtle and dugong were important for subsistence. There are several possible explanations that may explain this disparity. First, Central Place Foraging Models, which contend it is likely fish and other large marine vertebrate fauna were processed and eaten closer to the location of procurement may account for the paucity of vertebrate remains. Second, only a small portion of each site was excavated due to the archaeological sampling methods employed, so it is possible that fish remains could be found in greater abundance in other areas of the site.

- Application of trophic level analyses not previously utilised in Australian archaeological studies, has demonstrated the benefit of this method as an adjunct OFT tool. Faunal data suggest that people in the South Wellesley Islands targeted primarily low trophic level shellfish during the early periods of occupation, before shifting economic focus to a more broad-based diet-breadth incorporating more fish, which in turn raised the mean trophic level of all site assemblages. However these changes are generally of a slight magnitude. Despite reputedly having amongst the highest population densities, zooarchaeological data in this study show no long-term anthropogenic impact on a key marine resource.

- This case-study contributes to the growing literature concerning hunter-gatherer resource intensification (eg. Broughton 1994a, 1994b; Broughton et al. 2007; Jerardino 2010; Kennett 2005; Nagaoka 2001, 2002a, 2002b; Stiner et al. 2000), with hallmarks supporting broader trends along some lines (e.g. amplified abundance levels of high-ranked taxon and diversification of diet breadth, reflected through more taxa and different habitats being exploited. But overall the data does not support evolutionary ecology expectations for resource intensification whereby foraging efficiency decreases as production increases (Broughton 1994b:501) or there are signs of resource depression such as declines in taxa size through time (but see Thakar 2011). Efficiency might have been maintained because of the high predictability and reliability of shellfish compared with relatively low costs involved in its search and processing (Waselkov 1987; Kennett 2005). Moreover, it is also possible that intensification was occuring in the South Wellesley Islands in the socioeconomic context put forward by Lourandos (1983). It appears that Kaiadilt people efficiently managed resources by regulating resource yields and managing the regeneration of resources (e.g. through broad-based foraging strategies collecting different resources from different habitats and by alternating exploitation of dominant shellfish species at different times).

- At a local level this archaeological research undertaken in collaboration with the Kaiadilt Aboriginal community has resulted in the recording of cultural places on their lands and provides traditional owners with information to help make management decisions about their lands and waters. Community engagement continues to be an integral part of this research project and will ultimately contribute to the success of the project.

- At a regional level this thesis contributes to the northern Australia cultural chronology for the late Holocene. The project provides a large regional dataset similar to those of other studies conducted internationally, and is therefore able to contribute additional evidence to research based within an ecological theory framework.

16.3 Aims and Objectives Achieved

1. A primary aim of identifying and recording Aboriginal archaeological sites in the study area has been achieved through extensive surveys of the South Wellesley Islands, which revealed hundreds of sites reflecting hunter-gatherer settlement and subsistence activities over the past c.3500 years.

A detailed chronology of Aboriginal site patterns indicates subsistence and settlement focused around the four largest islands in the South Wellesley Archipelago at varying levels of intensity both spatially and temporally. Sites vary in size, shape and contents that reflect details about the activities that were carried out at each location. Many stratified sites that were used as central place camps provide evidence of several marine fauna taxa being consumed indicating Aboriginal subsistence centred on marine fauna for thousands of years. Reconstructed chronologies indicate these sites have accumulated over time at varying density rates and represent an unknown number of meals, where people in hunting-foraging groups came together to share food. There are numerous other smaller discrete sites recorded that exhibit a lower intensity of discard and fewer taxa that were likely used as dinner-time camps or eating stops for only some members the group (see Meehan 1982). The assessment of site contents, from large stratified middens containing many taxa and smaller sites with a single taxa, helps to secure the idea of a settlement pattern including sites used for different subsistence purposes such as a dinner time camps, central place camps and resource processing sites. This pattern of settlement guided by subsistence is visible throughout the islands. This identified pattern supports interpretations by other researchers in the region (e.g. Bourke 2005; Morrison 2003) that all site types are parts of the overall economic structure of the area (Bailey 1999).

2. The Prey Choice, Patch Choice and Central Place Forager Models informed by underlying ecological theory are effectively used for understanding and interpreting archaeological evidence of human foraging behaviour. This study has been able to provide an explanation of changes in foragers' prey selection choices and habitat exploitation patterns through time.

The Prey and Patch Choice Models have established that localised economies around the islands were specialised marine economies akin to those documented in the ethnohistoric record. Kaiadilt foraging strategies were broad-based in terms of both range of habitats accessed and diversity of species collected. At times there is intensified collection of one, two or even three main shellfish species, supplemented by a wider range of taxa. At stratified sites with evidence of repeated use over time I see evidence for a long-term trend in changing habitat preferences. At Thundiy palaynological evidence suggests that this change c.500 cal BP was likely the result of an environmental event impacting mangrove habitat and therefore changing taxa abundances available for exploitation. Taxa representation in sequences recovered along the southern coastline over the last 250 years appear to reflect the creation and/or expansion of extensive sandy-mud flat systems.

The Central Place Forager Model has been used to explain disparity between ethnographic reports of fishing and hunting activities and the low quantities of fish and vertebrate bones identified in the analysed materials from excavated sequences. Employment of this model has also enabled us to better understand how the patterning of archaeological sites reflects economic systems. Mobile forager groups moved around their country accessing all littoral and marine habitats in varying levels to collect food in varying densities, perhaps as a risk minimising strategy (Hiscock 2008).

3. The study has characterised temporal changes in the population structure of *M. hiantina* shellfish species through development of taxa size/age profiles and biomass contribution of marine catches.

Detailed examinations of *M. hiantina*, in particular documenting changing densities and sizes through time, have informed discussions about potential resource depletion and depression. The study has established that foragers' strategies included short-term periods of intensified exploitation that had minimal impact on the resource in the long-term. As discussed above, these findings are not in line with evolutionary ecology expectations for resource intensification whereby foraging efficiency decreases as production increases (Broughton 1994b:501) or there are signs of resource depression, such as declines in taxa size through time (but see Thakar 2011). Rather intensification seems more in line with Lourandos (1983) and it is suggested that because foragers appear to have been highly mobile, alternating collection of resources from different areas of their country, coupled with the *M. hiantina* species general resilience to overpredation, the shellfish beds had time to naturally restock.

4. Marine trophic level analysis has effectively been applied for the first time on an Australian archaeological dataset, in order to determine anthropogenic impacts on local ecologies.

Trophic level analysis was used to establish the average trophic level for each 250-year period's marine biomass catch. Reviewing temporal changes in the mean trophic level of resources exploited by hunter-gatherers in the South Wellesley Islands indicates that people had limited long-term impacts on the mollusc fishery.

16.4 Methodological Limitations

Through this study I have been able to construct reasonably secure chronologies of Aboriginal settlement patterns in the islands based on detailed controlled excavations and the large suite of radiocarbon dates obtained combined with variances in site stratigraphies. However the 250-year timeframe scale reported could be tightened and the overall project could benefit from a more detailed finer-scale chronology that can only be achieved through collecting more dates. At some archaeological sites like Murdumurdu, only one radiocarbon age per square was obtained in order to date the commencement of cultural activity. Potential gaps in the temporal data may result in over-interpretation, which could be a problem aleviated by collecting more dates. A better understanding of the length of site use and rate of accumulation could therefore benefit from collecting further dates to inform termination of cultural use. Larger sample sizes may also increase the understanding of intra-site variability, however the costs of undertaking more extensive excavations would need to be considered. It would be desirable if the sample also included the types of vertebrate fauna that are necessary to undertake more detailed trophic analyses, however these do not appear to be a part of the archaeological record. A related problem is the wide error estimates available for local ΔR correction values (Ulm et al. in prep) on specimens live-collected in the nineteenth century and the absence of information about how ΔR in the southern Gulf of Carpentaria night have varied over the mid-to-late Holocene.

A significant problem when investigating anthropogenic impacts on ecosystems is differentiating them from non-cultural ecological changes. Some natural events such as cyclones, storm surges and long-term climatically driven environmental changes will affect habitats and therefore taxa abundances. A prime example of this occurring is evidenced in the Thundiy assemblage, where there is a change in habitat exploitation through time that coincides with an environmental event. Cyclonic activity that impacted mangrove forests was responsible for the decline in resources from this habitat rather than human induced causes.

It is also noted that these naturally occurring events also have an impact on the visibility and survivorship of the archaeological record, particularly in these coastal sites. Some site types (e.g. overnight camping and eating places along the shoreline) are extremely unlikely to be preserved. Other taphonomic intrusions also need to be accounted for when considering integrity of sites. In all but one case Jirrkamirndiyarrb that exhibits evidence of site disturbance in the upper layers, the sites analysed had intact stratification and generally well-preserved materials with not much disturbance.

Again, although very detailed examinations were conducted on archaeological assemblages recovered, the sampling strategy adopted only enabled a small portion of each site to be excavated. This means that some archaeological evidence (e.g. fish and other vertebrate remains) may have been undetected, therefore impacting the interpretations drawn from analyses. Additional archaeological evidence, which more broadly characterises the full subsistence record, is needed to fully illustrate the benefit of trophic level analysis in this type of study.

16.5 Recommendations for Future Research

- Additional radiocarbon dating to enhance a finer-scale chronology for informing on site use and settlement patterns, and strengthen the interpretation of the data.
- Larger excavation samples at really extensive and deeply stratified sites such as Thundiy.
- Data from the palaeoecological and geomorphological research currently being undertaken in the islands by Patrick Moss, Lynda Petherick, Craig Sloss, Lydia Mackenzie, Alison Sternes and Shoshannah O’Connor will need to be reviewed once completed so that event signatures can be considered against interpretations of significant changes reported in this study.
- More detailed analysis of foraminiferas from sites could help to differentiate cultural from natural materials. This was done at Thundiy and confirmed the idea formed from the suite of radiocarbon dates that materials below a certain depth were undoubtedly

naturally deposited beach ridge materials (Nagel *et al.* 2016). This helped to secure a timeframe for landscape formation in the local area.

- Knowledge about the antiquity and use of fishtraps in the economic structure of the area is also required. The fishtraps have a large presence on the study area's landscape and I would expect that the returns would be high from such an investment measured in human energetic output costs. However the expected high returns from these structures is not reflected in the site contents analysed for this study. It would be very useful to have more knowledge about these structures, which appear from observation to have varying levels of effectiveness for collecting fish. Some observations made in the field are that some traps depending on location tend to work better than others for retaining fish between tides and it is suggested that some traps may have only had seasonal use (Kreij *et al.* 2015). Anna Kreij and colleagues (2015) have recently commenced investigations on these South Wellesley Island fishtraps that that may shed light on unanswered questions.

16.6 Conclusion

This research forms a component of the ARC-funded 'Naïve Island Landscapes: People and Environmental Change in Tropical Sclerophyll Landscapes' (DP120103179) project. It provides models of human-environment interaction during the late Holocene that contribute to the overarching aim of the ARC project, that is, to identify and measure the impacts of human arrivals on the Australian environment.

The study has provided a greater understanding of Aboriginal subsistence practices and settlement patterns for the South Wellesley Islands and thereby augmented interpretations of other locations in the Gulf of Carpentaria region. Kaiadilt populations were specialised marine hunters and gatherers akin to those documented in the ethnohistoric record (e.g. Tindale 1962a, 1962b). Environmental (e.g. seasonal and long-term fluctuations) and social factors (e.g. group population sizes, territoriality, mobility, settlement systems) influenced decisions about what resources to collect and when to collect them.

REFERENCES CITED

Abbott, R.T. and S.P. Dance 1998 *Compendium of Seashells: A Full Color Guide to more than 4,200 of the Worlds Marine Shells*, 6th ed. Hong Kong: Odyssey Publishing.

Aird, S., A. Fitzpatrick, H. Tomkins, and S. Ulm. 2013 Through a Vertebral Lens: Estimation of Fish Size from a Late Holocene Midden Assemblage on Bentinck Island, Gulf of Carpentaria. Poster presented to Australian Archaeological Association Annual Conference, Coffs Harbour, 1-4 December.

Allen, G.R. 1985 FAO Species Catalogue. Vol. 6. Snappers of the world: An annotated and illustrated catalogue of Lutjanid species known to date. *FAO Fisheries Synopsis* 125(6). Rome: Food and Agricultural Organisation of the United Nations.

Allen, G.R. 1989 *Freshwater Fishes of Australia*. Neptune City: T.F.H. Publications Inc.

Allen, M. 2004 Bet-hedging strategies, agricultural change and unpredictable environments: historical development of dryland agriculture in Kona, Hawaii. *Journal of Anthropological Archaeology* 23:196-224.

Alvard, M. 1998 Evolutionary ecology and resource conservation. *Evolutionary Anthropology* 7:62-74.

Anderson, A.J. 1983 Faunal depletion and subsistence change in the early prehistory of southern New Zealand. *Archaeology in Oceania* 18(1):1-10.

Anderson, A.J. 1989 *Prodigious Birds: Moas and Moa-Hunting in Prehistoric New Zealand*. Cambridge: Cambridge University Press.

Anderson, A.J. 1997 Prehistoric Polynesian impact on the New Zealand environment: Te whenua hou. In P.V. Kirch and T.L. Hunt (eds), *Historical Ecology in the Pacific Islands*, pp.271-283. New Haven: Yale University Press.

Anderson, A.J. 2001 No meat on that beautiful shore: The prehistoric abandonment of subtropical Polynesian islands. *International Journal of Osteoarchaeology* 11:14-23.

Anderson, A.J. 2008 Short and sometimes sharp: Human impacts on marine resources in the archaeology and history of South Polynesia. In T.C. Rick and J.M. Erlandson (eds), *Human Impacts on Ancient Marine Ecosystems: A Global Perspective*, pp.21-42. Berkeley: University of California Press.

Andrew, N.L. 1994 Survival of kelp adjacent to areas grazed by sea urchins in New South Wales, Australia. *Australian Journal of Ecology* 19:466-472.

Arkush, E. 2006 Collapse, conflict, conquest: The transformation of warfare in the late prehispanic Andean highlands. In E. Arkush and M. Allen (eds), *The Archaeology of Warfare: Prehistories of Raiding and Conquest*, pp.286-335. Gainesville: University Press of Florida.

Arkush, E. 2008 War, chronology, and causality in the Titicaca Basin. *Latin American Antiquity* 19:339-373.

Atlas of Living Australia: Sharing Biodiversity Knowledge. Retrieved 10 January 2015 from http://www.ala.org.au/.

Attenbrow, V. 2004 *What's Changing: Population Size or Land-Use Patterns? The Archaeology of Upper Mangrove Creek, Sydney Basin*. Terra Australis 21. Canberra: Research School of Pacific and Asian Studies, The Australian National University.

Avery, G. 1976 Discussion on the age and use of tidal fish-traps (Visvywers). *South African Archaeological Bulletin* 30:105-113.

Bailey, G.N. 1977 Shell mounds, shell middens, and raised beaches in the Cape York Peninsula. *Mankind* 11:132-143.

Bailey, G.N. 1983 Problems of site formation and the interpretation of spatial and temporal discontinuities in the distribution of coastal middens. In P.M. Masters and N.C. Flemming (eds), *Quaternary Coastlines and Marine Archaeology*, pp.558-582. London: Academic Press.

Bailey, G.N. 1994 The Weipa shell mounds: Natural or cultural? In M. Sullivan, S. Brockwell and A. Webb (eds), *Archaeology in the North: Proceedings of the 1993 Australian Archaeological Association Conference*, pp.107-129. Darwin: The North Australian Research Unit, Australian National University.

Bailey, G.N. 1999 Shell mounds and coastal archaeology in northern Queensland. In J. Hall and I.J McNiven (eds), *Australian Coastal Archeology*, pp.105-112. Research Papers in Archaeology and Natural History 31. Canberra: Archaeology and Natural History Publications, Research School of Pacific and Asian Studies, Australian National University.

Bailey, G.N., J. Chappell and R. Cribb 1994 The origin of *Anadara* shell mounds at Weipa, north Queensland Australia. *Archaeology in Oceania* 29(2):69-80.

Bailey, G.N. and A.S. Craighead 2003 Late Pleistocene and Holocene coastal palaeoeconomies: A reconsideration of the molluscan evidence from northern Spain. *Geoarchaeology: An International Journal* 18(2):175-204.

Barham, A.J. 2000 Late Holocene maritime societies in the Torres Strait Islands, northern Australia-cultural arrival or cultural emergence. In S. O'Connor and P. Veth (eds), *East of Wallace's Line: Studies of Past and Present Maritime Cultures of the Indo-Pacific Region*, pp.223-314. Rotterdam: AA Balkema.

Barham, A.J., S. O'Connor and S. Fallon 2008 Coastal Archaeology, Climate Change and Proxy Records in Australia: An Indigenous Cultural Partnership Approach, using Geoarchives of Prehistoric Coastal Occupation to Calibrate, Manage and Guide Future Policy on Climate Change. Paper presented in the Archaeology and Climate Change session at World Archaeological Congress Conference in Dublin, Ireland, 29 June – 4 July.

Barker, B. 1989 Nara Inlet 1: A Holocene sequence from the Whitsunday Islands, central Queensland coast. *Queensland Archaeological Research* 6:53-76.

Barker, B. 1991 Nara Inlet 1: Coastal resource use and the Holocene marine transgression in the Whitsunday Islands, central Queensland. *Archaeology in Oceania* 26(3):102-109.

Barker, B.C. 1992 An Assessment of the Heritage Sites in the Whitsunday Region as Part of the Whitsunday Regional Management Plan. Unpublished report to the Queensland Department of Environment and Heritage, Brisbane.

Barker, B. 1996 Maritime hunter-gatherers on the tropical coast: A social model for change. In S. Ulm, I. Lilley and A. Ross (eds), *Australian Archaeology '95: Proceedings of the 1995 Australian Archaeological Association Annual Conference*, pp.31-44. Tempus 6. Brisbane: Anthropology Museum, The University of Queensland.

Barker, B. 2004 *The Sea People: Late Holocene Maritime Specialisation in the Whitsunday Islands, Central Queensland*. Terra Australis 20. Canberra: Pandanus Books.

Beaton, J. 1985 Evidence for a coastal occupation time-lag at Princess Charlotte Bay (north Queensland) and implications for coastal colonisation and population growth theories for Aboriginal Australia. *Archaeology in Oceania* 20(1):1-20.

Beck, C., A.K. Taylor, G.T. Jones, C.M. Fadem, C.R. Cook and S.A. Millward 2002 Rocks are heavy: Transport costs and Paleoarchaic quarry behaviour in the Great Basin. *Journal of Anthropological Archaeology* 21:481-507.

Belcher, Rev. D. Mornington Island Mission Diaries, 1950-1969. Unpublished document, Mornington Island, Queensland.

Belgrano, A., U. Scharler, J.A. Dunne and R.E. Ulanowicz.2005 *Aquatic Food Webs: An Ecosystem Approach*. London: Oxford University Press.

Best, A. 2012 The Aboriginal material culture of the Wellesley Islands and adjacent mainland coast, Gulf of Carpentaria: Social and environmental factors affecting variations in style. *Queensland Archaeological Research* 15:1-46.

Bettinger, R.L. 1991 *Hunter-Gatherers: Archaeological and Evolutionary Theory*. New York: Plenum Press.

Bettinger, R.L. 2009 *Hunter-Gatherer Foraging: Five Simple Models*. New York: Eliot Werner Publications.

Bettinger, R.L., R. Malhi and H. McCarthy 1997 Central place models of acorn and mussel processing. *Journal of Archaeological Science* 24:887-899.

Betts, M.W. and T.M. Frieson 2004 Quantifying hunter-gather intensification: A zooarchaeological case study from Arctic Canada. *Journal of Anthropological Archaeology* 23:357-384.

Binford, L.R. 1980 Willow smoke and dogs' tails: Hunter-gatherer settlement systems and archaeological site formation. *American Antiquity* 45(1):4-20.

Bird C.F.M. and D. Frankel 1991 Chronology and explanation in western Victoria and south-east South Australia. *Archaeology in Oceania* 26(1):1-16.

Bird, D.W. and R. Bliege Bird 1997 Contemporary shellfish gathering strategies among the Meriam of the Torres Strait Islands, Australia: Testing predictions of a central place foraging model. *Journal of Archaeological Science* 24:39-63.

Bird, D.W. and R. Bliege Bird 2000 The ethnoarchaeology of juvenile foragers: Shellfishing strategies among Meriam children. *Journal of Anthropological Archaeology* 19:461-476.

Bird, D.W. and R. Bliege Bird 2002 Children on the reef. *Human Nature* 13:269-297.

Bird, D.W., R. Bliege Bird and B.F. Codding 2009 In pursuit of mobile prey: Martu hunting strategies and archaeofaunal interpretation. *American Antiquity* 74(1):3-29.

Bird, D.W., R. Bliege Bird and J.L. Richardson 2004 Meriam ethnoarchaeology: Shellfishing and shell middens. *Memoirs of the Queensland Museum, Cultural Heritage Series* 3(1):183-197.

Bird, D., J.L. Richardson, P.M. Veth and A.J. Barham 2002 Explaining shellfish variability in middens on the Meriam Islands, Torres Strait, Australia. *Journal of Archaeological Science* 29:457-469.

Bird, M.K. 1992 The impact of tropical cyclones on the archaeological record: An Australian example. Archaeology in Oceania 27(2):75-86.

Bird, M.K. 1994 Cultural Heritage Assessment of the Proposed Port Hinchinbrook Resort Development Site, Oyster Point, North Queensland. Unpublished report to Queensland Department of Environment and Heritage, Brisbane.

Bird, M. 1995 Coastal morphodynamics and the archaeological record: Further evidence from Upstart Bay, north Queensland. *Australian Archaeology* 40:57-58.

Bird, M. 1996 Report on the Cultural Heritage Assessment of a Proposed Radio Communications Development Site, Bentinck Island, Southern Gulf of Carpentaria. Unpublished report to Telstra prepared by Northern Archaeology Consultancies, Queensland.

Boone, J.L. and E.A. Smith 1998 Is it evolution yet? A critique of evolutionary archaeology. *Current Anthropology* 39:141-157.

Botkin, S. 1980 Effects of human predation on shellfish populations at Malibu Creek, California. In T.K. Earle and A.L. Christenson (eds), *Modeling Change in Prehistoric Subsistence Economies*, pp.121-139. New York: Academic Press.

Bourke, P. 2000 Late Holocene Indigenous Economies of the Tropical Australian Coast: An Archaeological Study of the Darwin Region. Unpublished PhD thesis, Northern Territory University, Darwin.

Bourke, P. 2005 Archaeology of shell mounds of the Darwin coast: Totems of an ancestral landscape. In P. Bourke, S. Brockwell and C. Fredericksen (eds), *Darwin Archaeology: Aboriginal, Asian and European Heritage of Australia's Top End*, pp.29-49. Darwin: Charles Darwin University Press.

Bourke, P., S. Brockwell, P. Faulkner and B. Meehan 2007 Climate variability in the mid to late Holocene Arnhem Land Region, North Australia: Archaeological archives of environmental and cultural change. *Archaeology in Oceania* 42(3):91-101.

Bourque, B.J., B.J. Johnson and R.S. Steneck 2008 Possible prehistoric fishing effects on coastal marine food webs in the Gulf of Maine. In T.C. Rick and J.M. Erlandson (eds), *Human Impacts on Ancient Marine Ecosystems: A Global Perspective*, pp.165-185. Berkeley: University of California Press.

Bowdler, S. 1977 The coastal colonisation of Australia. In J.Allen, J. Golson and R. Jones (eds), *Sunda and Sahul*, pp.203-246. London: Academic Press.

Bowdler, S. 1981 Hunters in the highlands: Aboriginal adaptations in the eastern Australian uplands. *Archaeology in Oceania* 16(2):99-111.

Bowdler, S. 1995 Sieving seashells: Midden analysis in Australian archaeology. In G. Connah (ed.), *Australian Field Archaeology: A Guide to Techniques*, pp.135-144. Canberra: Australian Institute of Aboriginal Studies.

Bradley, J. 1988 *Yanyuwa Country: The Yanyuwa People of Borroloola Tell the History of their Land*. Richmond: Greenhouse Publications.

Bradley, J., M. Holmes, D.N. Marrngawi, A.I. Karrakayn, J.M. Wuwarlu and I. Niganga 2006 *Yumbulyumbulmantha ki-Awarawu All Kinds of Things from Country: Yanyuwa Ethnobiological Classification*. ATSISU Report Series 6. Brisbane: Aboriginal and Torres Strait Islander Studies Unit, The University of Queensland.

Braje T.J, D.J. Kennett, J.M. Erlandson and B. Culleton 2007 Human impacts on nearshore shellfish taxa: A 7000-year record from Santa Rosa Island, California. *American Antiquity* 72:735-756.

Brockwell, S., P. Faulkner, P. Bourke, A. Clarke, C. Crassweller, D. Guse, B. Meehan and R. Sim 2009 Radiocarbon dates from the Top End: a cultural chronology for the Northern Territory coastal plains. *Australian Aboriginal Studies* 1:54-76.

Broeker, W., A. Mix, M. Andree and H. Oeschger 1984 Radiocarbon measurements on coexisting benthic and planktic foraminifera shells: Potential for reconstructing ocean ventilation times over the past 20 000 years. *Nuclear Measurements and Methods in Physics Research* B5:331-339.

Bronk Ramsey, C. 2009 Bayesian analysis of radiocarbon dates. *Radiocarbon* 51(1):337-360.

Broughton, J.M. 1994a Declines in foraging efficiency during the late Holocene: The archaeological mammal evidence from San Francisco Bay, California. *Journal of Anthropological Archaeology* 13:371-401.

Broughton, J.M. 1994b Late Holocene resource intensification in the Sacramento Valley, California: The vertebrate evidence. *Journal of Archaeological Science* 21:501-514.

Broughton, J.M. 1997 Widening diet breadth, declining foraging efficiency, and prehistoric harvest pressure: Ichthyofaunal evidence from the Emeryville Shellmound, California. *Antiquity* 71:845-862.

Broughton, J.M. 2002 Prey spatial structure and behavior affect archaeological tests of optimal foraging models: Examples from the Emeryville shellmound vertebrate fauna. *World Archaeology* 34:60-83.

Broughton, J.M., M.D. Cannon, F.E. Bayham and D.A. Byers 2011 Prey body size and ranking in zooarchaeology: Theory, empirical evidence, and applications. *American Antiquity* 76(3):403-428.

Broughton, J.M. and D.K. Grayson 1993 Diet breadth, adaptive change, and the White Mountains faunas. *Journal of Archaeological Science* 20:331-336.

Broughton, J.M. and J.F. O'Connell 1999 On evolutionary ecology, selectionist archaeology, and behavioral archaeology. *American Antiquity* 64:153-165.

Bruinsma, C. and S. Duncan 2000 *Queensland Coastal Wetland Resources: The Northern Territory Border to Flinders River*. Brisbane: Department of Primary Industries Queensland.

Bureau of Meteorology (BOM) 2014a Monthly Climatic Statistics for Mornington Island, Queensland. Retrieved 14 June 2014 from http://www.bom.gov.au/climate/averages/tables/cw_029039.shtml.

Bureau of Meteorology (BOM) 2014b Historical Impacts in the Gulf of Carpentaria. Retrieved 2 July 2014 from http://www.bom.gov.au/cyclone/history/gulf.shtml.

Burney, D.A. 1997 Tropical islands as palaeoecological laboratories: Gauging the consequences of human arrival. *Human Ecology* 25(3):437-457.

Butler, V. 1994 Fish feeding behaviour and fish capture: The case for variation in Lapita fishing strategies. *Archaeology in Oceania* 29(2):81-90.

Butler, V. 2000 Resource depression on the northwest coast of North America. *Antiquity* 74:649-661.

Butler, V. 2001 Changing fish use on Mangaia, Southern Cook Islands: Resource depression and the prey choice model. *International Journal of Osteoarchaeology* 11:88-100.

Butler, V. and S.K. Campbell 2004 Resource intensification and resource depression in the Pacific Northwest of North America: A zooarchaeological review. *Journal of World Prehistory* 18:327-405.

Cannon, M.D. 2000 Large mammal relative abundance in pithouse and Pueblo period archaeofaunas from southwestern New Mexico: Resource depression among the Mimbres–Mogollon? *Journal of Anthropological Archaeology* 19:317-347.

Caraco, T. 1979a Time budgeting and group size: A theory. *Ecology* 60:617-617.

Caraco, T. 1979b Time budgeting and group size: A test of theory. *Ecology* 60:618-627.

Caraco, T., S. Martindale and T.S. Whittam 1980 An empirical demonstration of risk sensitive foraging preferences. *Animal Behaviour* 28:820-830.

Carpenter, K.E. and G.R. Allen 1989 Emperor fishes and large-eye breams of the world (family Lethrinidae). An annotated and illustrated catalogue of lethrinid species known to date. *FAO Fisheries Synopsis* 125(9):118. Rome: Food and Agricultural Organisation of United Nations.

Carpenter, K.E. and V.H. Niem (eds) 1998 *FAO Species Identification Guide for Fishery Purposes.The Living Marine Resources of the Western Central Pacific. Volume 1. Seaweeds, Corals, Bivalves and Gastropods*, pp.1-686. Rome: Food and Agricultural Organisation of the United Nations.

Cashden, E. 1992 Spatial organization and habitat use. In B. Winterhalder (ed.), *Evolutionary Ecology and Human Behaviour*, pp.237-268. New York: Aldine de Gruyter.

Casteel, R. 1972 A method for estimation of live weight of fish from the size of skeletal elements. *American Antiquity* 39(2):194-198.

Casteel, R. 1976 *Fish Remains in Archaeology and Paleo-Environmental Studies*. New York: Academic Press.

Catterall, C.P. and I.R. Poiner 1987 The potential impact of human gathering on shellfish populations, with reference to some NE Australian intertidal flats. *Oikos* 50(1):114-122.

Chappell, J., E.G. Rhodes, B.G. Thom and E. Wallensky 1982 Hydro-isostasy and sea-level isobase of 5500 B.P. in north Queensland, Australia. *Marine Geology* 49:81-90.

Charnov E.L. 1976 Optimal foraging: The marginal value theorem. *Theoretical Population Biology* 9:129-136.

Charnov, E.L. and G.H. Orians 1973 *Optimal Foraging: Some Theoretical Explorations*. Salt Lake City: Department of Biology, University of Utah.

Charnov, E.L., G.H. Orians and K. Hyatt 1976 Ecological implications of resource depression. *American Naturalist* 110:247-259.

Chivas, A.R., A. Garcia, S. Van Der Kaars, M.J.J. Couapel, S. Holt, J.M. Reeves, D.J. Wheeler, A.D. Switzer, C.V. Murray-Wallace and D. Banerjee 2001 Sea-level and environmental changes since the last interglacial in the Gulf of Carpentaria, Australia: An overview. *Quaternary International* 83-85:19-46.

Christensen, V. S. Guenette, J.J. Heymans, C. Walters, D. Zeller and D. Pauly 2003 Hundred-year decline of North Atlantic predatory fish. *Fish and Fisheries* 4:1-24.

Claassen, C. 1986 Shellfishing seasons in the prehistoric Southeastern United States. *American Antiquity* 51(1):21-37.

Claassen, C.L. 1998 *Shells*. Cambridge: Cambridge University Press.

Claassen, C. 2000 Quantifying shell: Comments on Mason, Peterson, and Tiffany. *American Antiquity* 65(2):415-418.

Clarke, A. 1994 Winds of Change: An Archaeology of Contact in the Groote Eylandt Archipelago, Northern Australia. Unpublished PhD thesis, Australian National University, Canberra.

Clarke, A. 2002 The ideal and the real: Cultural and personal transformations of archaeological research on Groote Eylandt, Northern Australia. *World Archaeology* 34(2):249-264.

Clarkson, C. 2004 Technological Provisioning and Assemblage Variation in the Eastern Victoria River Region, Northern Australia: A Darwinian Approach. Unpublished PhD thesis, Australian National University, Canberra.

Clarkson, C. 2006 Explaining point variability in the eastern Victoria River region, Northern Territory. *Archaeology in Oceania* 41(3):97-106.

Codding, B.F., D.W. Bird and R. Bliege Bird 2010 Interpreting abundance indices: Some zooarchaeological implications of Martu foraging. *Journal of Archaeological Science* 37:3200-3210.

Cohen, J.E., F. Briand and C.M. Newman 1990 *Community Food Webs: Data and Theory*. Berlin: Springer.

Collette, B.B. 1999 Belonidae. Needlefishes. In K.E. Carpenter and V.H. Niem (eds), *FAO Species Identification Guide for Fishery Purposes: The Living Marine Resources of the Western Central Pacific*. Volume 4. Bony Fishes Part 2 (Mugilidae to Carangidae), pp.2151-2161. Rome: Food and Agricultural Organisation of United Nations.

Collette, B.B. and J. Su 1986 The halfbeaks (Pisces, Beloniformes,Hemiramphidae) of the Far East. *Proceedings of the Academy of Natural Science Philadelphia* 138(1):250-301.

Colley, S.M. 1990 The analysis and interpretation of archaeological fish remains. In M.B. Schiffer (ed.), *Archaeological Method and Theory 2*, pp.207-253. Tuscon: University of Arizona Press.

Colley, S. and R. Jones 1987 New fish bone data from Rocky Cape, north west Tasmania. *Archaeology in Oceania* 22(2):67-71.

Compagno, L.J.V. 1984 FAO Species Catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 2 - Carcharhiniformes. *FAO Fisheries Synopsis* 125(4/2):251-655. Rome: Food and Agricultural Organisation of United Nations.

Cosgrove, R. J. Field and A. Ferrier 2007 The archaeology of the Australia's tropical rainforests. *Palaeogeography, Palaeoclimatology. Palaeoecology* 251(1):150-173.

Curtain, C., N. Tindale and R. Simmons 1966 Genetically determined blood protein factors in Australian Aborigines of Bentinck, Mornington, and Forsyth Islands and the mainland, Gulf of Carpentaria. *Archaeology and Physical Anthropology in Oceania* 1:74-80.

Curtain, C., E. van Loghem, H.H. Fudenberg, N.R. Tindale, R.T. Simmons, R.L. Dogherty and G. Vos 1977 Distribution of the immunoglobulin markers at the IgG1, IgG2, IgG3, IgA2, and Kchain loci in Australian Aborigines: Comparison with New Guinea populations. *American Journal of Human Genetics* 24:145-155.

Dalley, C. and P. Memmott 2010 Domains and the intercultural: Understanding Aboriginal and missionary engagement at the Mornington Island Mission, Gulf of Carpentaria, Australia from 1914 to 1942. *International Journal of Historical Archaeology* 14:112-135.

David, B. 2002 *Landscapes, Rock Art and the Dreaming: An Archaeology of Preunderstanding*. London: Leicester University Press.

David, B. and H. Lourandos 1998 Rock art and socio-demography in northeastern Australian prehistory. *World Archaeology* 30:193-219.

David, B. and H. Lourandos 1999 Landscape as mind: Land use, cultural space and change in north Queensland prehistory. *Quaternary International* 59:107-123.

David, B. and I.J. McNiven 2004 Western Torres Strait cultural history project: Research design and initial results. In I.J. McNiven and M. Quinnell (eds), *Torres Strait Archaeology and Material Culture*, pp.199-208. Memoirs of the Queensland Museum, Cultural Heritage Series 3. Brisbane: Queensland Museum.

David, B., I. McNiven, R. Mitchell, M. Orr, S. Haberle, L. Brady and J. Crouch 2004 Badu 15 and the Papuan-Austronesian settlement of Torres Strait. *Archaeology in Oceania* 39(2):65-78.

David, B. and M. Wilson 1999 Re-reading the landscape: Place and identity in NE Australia during the late Holocene. *Cambridge Archaeological Journal* 9(2):163-188.

Davidson D.S. 1935 The chronology of Australian watercraft, *Journal of the Polynesian Society* 44:137-152.

Dayton, P.K., M.J. Tegner, P.B. Edwards and K.L. Riser 1998 Sliding baselines, ghosts, and reduced expectations in kelp forest communities. *Ecological Applications* 8(2):309-322.

De Deckker, P., A.R. Chivas, J.M.G. Shelley and T. Torgersen 1988 Ostracod shell chemistry: A new palaeoenvironmental indicator applied to a regressive/transgressive record from the Gulf of Carpentaria, Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 66(3-4):231-241.

de Lestange, S., N.G. Hall and I.C. Potter 2003 Reproductive biology of the Blue Swimmer Crab, *Portunus pelagicus* (Decapoda: Portunidae) in five water bodies on the west coast of Australia. *Fishery Bulletin* 101:745-757.

Donders, T.H., S.G. Haberle, G. Hope, F. Wagner and H. Visscher 2007 Pollen evidence for the transition of the eastern Australian climate system from the post-glacial to the present-day ENSO mode. *Quaternary Science Reviews* 26:1621-1637.

Dortch, J., C. Dortch and R. Reynolds 2006 Test excavation at the Oyster Harbour stone traps, King George Sand, Western Australia. An investigation aimed at determining the construction method and maximum age of the structures. *Australian Archaeology* 62:38-43.

Dunne, J.A., R.J. Williams and M.D. Martinez 2002 Network structure and biodiversity loss in food webs: Robustness increases with connectance. *Ecology Letters* 5:558-567.

Dunnell, R.C. 1980 Evolutionary theory and archaeology. In M.B. Schiffer (ed.), *Advances in Method and Theory*, pp.35-99. New York: Academic Press.

Dunnell, R.C. 1982 Science, social science, and common sense: The agonizing dilemma of modern archaeology. *Journal of Anthropological Research* 38:1-25.

Dunnell, R.C. 1992 Archaeology and evolutionary science. In L. Wandsnider (ed.), *Quandaries and Quests: Visions of Archaeologys Future,* pp.209-224. Occasional Paper 20. Carbondale: Centre for Archaeological Investigations, Southern Illinois University.

Elton, C.S. 2001 (1927) *Animal Ecology*. Chicago: University of Chicago Press.

Emery, J. 1973 *The Discovery of Australia: Including the Mandated Territory of New Guinea; A chronological summary of voyages of discovery up till the foundation of Australia (1576-1788).* Hamlyn Guides, Australia.

Erlandson, J.M. and T.C. Rick 2008 Archaeology, marine ecology, and human impacts on marine ecosystems. In T.C. Rick and J.M. Erlandson (eds), *Human Impacts on Ancient Marine Ecosystems: A Global Perspective*, pp.1-19. Berkeley: University of California Press.

Erlandson, J.M. and T.C. Rick 2010 Archaeology meets marine ecology: The antiquity of maritime cultures and human impacts on marine fisheries and ecosystems. *Annual Review of Marine Science* 2:231-251.

Erlandson, J.M., T.C. Rick and T.J. Braje 2009 Fishing up the food web?: 12,000 years of maritime subsistence and adaptive adjustments on California's Channel Islands. *Pacific Science* 63:711-724.

Erlandson, J.M., T.C. Rick, T.J. Braje, A. Steinberg and R.L. Vellanoweth 2008 Human impacts on ancient shellfish: A 10,000 year record from San Miguel Island, California. *Journal of Archaeological Science* 35:2144-2152.

Erlandson J.M., T.C. Rick, J.A. Estes, M.H. Graham, T.J. Braje and R.L. Vellanoweth 2005 Sea otters, shellfish, and humans: A 10,000 year record from San Miguel Island, California. In D.K. Garcelon and C.A. Schwemm (eds), *Proceedings of the VI California Islands Symposium*, pp.9-21. National Park Service Technical Publication CHIS-05-01. Arcata: Institute for Wildlife Studies.

Erlandson J.M., T.C. Rick and R.L. Vellanoweth 2004 Human impacts on ancient environments: A case study from California's Northern Channel Islands. In S.M. Fitzpatrick (ed.), *Voyages of Discovery: The Archaeology of Islands*, pp.51-83. New York: Praeger.

Estes, J.A. and D.O. Duggins 1995 Sea otters and kelp forests in Alaska: Generality and variation in a community ecological paradigm. *Ecological Monographs* 65:75-100.

Evans, N. 1985 *Kaiadilt: The Language of the Bentinck Islanders of North West Queensland*. Canberra: Australian National University.

Evans, N. 1995 *A Grammar of Kayardild*. Berlin: Mouton de Gruyter.

Evans, N. 1998 Wellesley Islands Sea Claim: the Kaiadilt Group, Andrew Chalk and Associates, Solicitors, Sydney. [Native Title submission filed in Federal Court]

Evans, N. 2005 East across a narrow sea: Micro-colonization and synthetic prehistory in the Wellesley Islands, northern Australia. In O. Toshiki (ed.), *Linguistics, Archaeology and the Human Past*, pp.9-39. Occasional Paper 1. Kyoto: Research Institute for Humanity and Nature.

Fanning, P. and S. Holdaway 2001 Temporal limits to the archaeological record in arid western NSW, Australia: Lessons from OSL and radiocarbon dating of hearths and sediments. In M. Jones and P. Sheppard (eds), *Australasian Connections and New Directions: Proceedings of the 7th Australasian Archaeometry Conference*, pp.85-104. Auckland: Department of Anthropology, University of Auckland.

Faulkner, P. 2006 The Ebb and Flow: An Archeological Investigation of Late Holocene Economic Variability on the Coastal Margin of Blue Mud Bay, Northern Australia. Unpublished PhD thesis, Australian National University, Canberra.

Faulkner, P. 2008 Patterns of chronological variability in occupation on the coastal margin of Blue Mud Bay. *Archaeology in Oceania* 43(2):81-88.

Faulkner, P. 2009 Focused, intense and long-term: Evidence for granular ark (*Anadara granosa*) exploitation from the late Holocene shell mounds of Blue Mud Bay, northern Australia. *Journal of Archaeological Science* 36:821-834.

Faulkner, P. 2011a Late Holocene mollusc exploitation and changing near-shore environments: A case study from the coastal margin of Blue Mud Bay, Northern Australia. *Environmental Archaeology* 16(2):137-150.

Faulkner, P. 2011b Quantifying shell weight loss in archaeological deposits. *Archaeology in Oceania* 46(3):118-129.

Faulkner, P. 2013 *Life on the Margins: An Archaeological Investigation of Late Holocene Economic Variability, Blue Mud Bay, Northern Australia*. Terra Australis 38. Canberra: ANU E Press.

Faulkner, P. and A. Clarke 2004 Late-Holocene occupation and coastal economy in Blue Mud Bay, northeast Arnhem Land: Preliminary archaeological findings. *Australian Archaeology* 59:23-30.

Fitzpatrick, S.M. and T.J. Donaldson 2007 Anthropogenic impacts to coral reefs in Palau, Western Micronesia during the Late Holocene. *Coral Reefs* 26:915-930.

Fitzpatrick, S.M., and W.F. Keegan 2007 Human adaptations and impacts in the Caribbean: An historical ecology approach. *Earth and Environmental Sciences*, *Transactions of the Royal Society of Edinburgh* 98:29-45.

Flannery, K.V. 1969 Origins and ecological effects of early domestication. In P.J. Ucko and G.W. Dimbleby (eds), *Iran and the Near East: The Domestication and Exploitation of Plants and Animals*, pp.73-100. Chicago: Aldine Publishing Co.

Flannery, K.V. 1986 *Guila Naquitz: Archaic Foraging and Early Agriculture in Oaxaca, Mexico*. New York: Academic Press.

Flinders, M. 1814 *A Voyage to Terra Australis*, 2 vols. London: G. and W. Nichol.

Flood, J. 1999 *Archaeology of the Dreamtime: The Story of Prehistoric Australia and its People*, 3rd ed. Sydney: Angus and Robertson.

Forbes, A.M.G. and J.A. Church 1983 Circulation in the Gulf of Carpentaria II: Residual currents and mean sea level. *Australian Journal of Marine and Freshwater Research* 34(1):11-22.

Gagan, M.K., E.J. Hendy, S.G. Haberle and W.S. Hantoro 2004 Post-glacial evolution of the Indo-Pacific Warm Pool and El Niño-Southern Oscillation. *Quaternary International* 118-119:127-143.

Gale, S.J. and Y.R. Carden 2005 The archaeology of native wells: Aboriginal wells on Sweers Island in the Gulf of Carpentaria of northern Australia. In J.W. Johson and A.C. Gill (eds), *Gulf of Carpentaria Scientific Study Report*, pp.181-200. Geography Monograph Series 10. Brisbane: Royal Geographic Society of Queensland.

Gillieson, D. 2005 Coastal geomorphology and historic change in the Pennefather River area, Cape York. In J.W. Johson and A.C. Gill (eds), *Gulf of Carpentaria Scientific Study Report*, pp.201-214. Geography Monograph Series 10. Brisbane: Royal Geographic Society of Queensland.

Giovas, C.M., S.M. Fitzpatrick, M. Clark and M. Abed 2010 Evidence for size increase in an exploited mollusc: humped conch (*Strombus gibberulus*) at Chelechol ra Orrak, Palau from ca. 3000-0 BP. *Journal of Archaeological Science* 37:2788-2798.

Giovas, C.M., M. Clark, S.M. Fitzpatrick and J. Stone 2013 Intensifying collection and size increase of the tessellated nerite snail (*Nerita tessellata*) at the Coconut Walk site, Nevis, northern Lesser Antilles, AD 890-1440. *Journal of Archaeological Science* 40:4024-4038.

Glassow, M. 2000 Weighing vs. counting shellfish remains: A comment on Mason, Peterson, and Tiffany. *American Antiquity* 65:407-414.

Glassow, M.A. and L.R. Wilcoxon 1988 Coastal adaptations near Point Conception, California, with particular regard to shellfish exploitation. *American Antiquity* 53:35-51.

Goodwin, I.D., T. van Ommen, M. Curran and P.A. Mayewski 2004 Mid latitude climate variability in the south Indian and south-west Pacific regions since1300 AD from the Law Dome ice core record. *Climate Dynamics* 22:783-794.

Gould, R.A. 1991 Arid-land foraging as seen from Australia: Adaptive models and behavioural realities. *Oceania* 62:12-33.

Gould, R.A. 1996 Faunal reduction at Puntutjarpa Rockshelter, Warburton Ranges, Western Australia. *Archaeology in Oceania* 31(2):72-86.

Grant, E.M. 2004 *Grant's guide to fishes*. 10th edn. Scarborough, E.M. Grant Pty. Ltd.

Grayson, D.K. 1984 *Quantitative Zooarchaeology*. New York: Academic Press.

Grayson D.K. 2001 The archaeological record of human impact on animal populations. *Journal of World Prehistory* 15:1-68.

Grayson, D.K. and F. Delpech 1998 Changing diet breadth in the Early Upper Palaeolithic of Southwestern France. *Journal of Archaeological Science* 25:1119-1130.

Gremillion, K.J. 1996 Diffusion and adoption of crops in evolutionary perspective. *Journal of Anthropological Archaeology* 15:183-204.

Grimes, K.G. 1979 *Mornington-Cape Van Dieman Queensland: 1:250,000 Geological Series Explanatory Notes*. Canberra: Australian Government Publishing Service.

Grimes, K.G. and I.P. Sweet 1979 *Westmoreland Queensland: 1:250,000 Geological Series Explanatory Notes*. Canberra: Australian Government Publishing Service.

Grindrod, J., P.T. Moss and S. van der Kaars 1999 Late Quaternary cycles of mangrove development and decline on the north Australian continental shelf. *Journal of Quaternary Science* 14:465-470.

Grindrod, J., P.T. Moss and S. van der Kaars 2002 Late Quaternary mangrove pollen records from the continental shelf and deep ocean cores in the north Australian region. In A.P. Kershaw, B. David, T. Tapper, D. Penny and J. Brown (eds), *Bridging Wallace's Lines – The Environmental and Cultural History and Dynamics of the SE-Asian-Australian Region*, pp.119-146. Advances in Geoecology 34. Reiskirchen, Germany: Cantena Verl.

Haberle, S. 2000 Vegetation response to climate variability: A palaeoecological perspective in the ENSO phenomenon. In R.H. Grove and J. Chappell (eds), *El Nino – History and Crisis: Studies from the Asia-Pacific Region*, pp.66-78. Cambridge: The White Horse Press.

Haberle, S., J. Stevenson and M. Prebble (eds) 2010 *Altered Ecologies: Fire, Climate and Human Influence on Terrestrial Landscapes*. Terra Australis 32. Canberra: ANU E Press.

Haddon A.C. 1912 *Reports on the Cambridge Anthropological expedition to Torres Straits. Volume 4 Arts and Crafts*. Cambridge: Cambridge University Press.

Hall, J. 1982 Sitting on the crop of the bay: An historical and archaeological sketch of Aboriginal settlement and subsistence in Moreton Bay, Southeast Queensland. In S. Bowdler (ed.), *Coastal Archaeology in Eastern Australia*, pp.79-95. Canberra, Department of Prehistory, Research School of Pacific Studies, Australian National University.

Hall, J. and I. Lilley 1987 Excavation at the New Brisbane Airport Site (LB:C69): Evidence for early mid-Holocene coastal occupation in Moreton Bay, Queensland. *Queensland Archaeological Research* 4:54-79.

Hames, R. 1992 Time allocation. In E.N. Wilmsen (ed.), *Evolutionary Ecology and Human Behaviour*, pp.203-236. New York: Aldine de Gruyer.

Hames, R. and W. Vickers 1982 Optimal foraging theory as a model to explain variability in Amazonian hunting. *American Ethnologist* 9:358-378.

Harrison, I.J., 1995 Mugilidae. Lisas. In K.E. Carpenter and V.H. Niem (eds), *FAO Species Identification Guide for Fishery Purposes: The Living Marine Resources of the Western Central Pacific*, pp.1293-1298. Vol 4. Bony fishes Part 3. Rome: Food and Agricultural Organisation of United Nations.

Harrison, I.J. and H. Senou, 1997 Order Mugiliformes. Mugilidae. Mullets. In K.E. Carpenter and V.H. Niem (eds), *FAO Species Identification Guide for Fishery Purposes: The Living Marine Resources of the Western Central Pacific*, pp.2069-2108. Volume 4. Bony Fishes Part 2 (Mugilidae to Carangidae). Rome: Food and Agricultural Organisation of United Nations.

Harvey, J.T., T.R. Loughlin, M.A. Perez and D.S. Oxman 2000 Relationship between fish size and otolith length for 63 species of fishes from the eastern North Pacific Ocean. *NOAA Technical Report NMFS* 150:1-36. Seattle: Department of Commerce.

Hawkes, K. 1991 Showing off: Tests of an explanatory hypothesis about mens foraging goals. *Ethnology and Sociobiology* 12:29-54.

Hawkes, K. and R. Bliege Bird 2002 Showing off, handicap signalling, and the evolution of mens work. *Evolutionary Anthropology* 11:58-67.

Hawkes, K., K. Hill and J.F. O'Connell 1982 Why hunters gather: Optimal foraging and the Ache of Eastern Paraguay. *American Ethnologist* 9:379-398.

Hawkes, K. and J.F. O’Connell 1992 On optimal foraging models and subsistence transitions. *Current Anthropology* 33:63-66.

Heemstra, P.C. and J.E. Randall 1993 FAO Species Catalogue. Vol. 16. Groupers of the world (family Serranidae, subfamily Epinephelinae). An annotated and illustrated catalogue of the grouper, rockcod, hind, coral grouper and lyretail species known to date. *FAO Fisheries Synopsis* 125(16):382. Rome: Food and Agricultural Organisation of United Nations.

Heemstra, P.C. and J.E. Randall 1999 Serranidae. Groupers and sea basses (also, soapfishes, anthiines, etc.). In K.E. Carpenter and V. Niem (eds), *FAO Species Identification Guide for Fishery Purposes: The Living Marine Resources of the Western Central Pacific. Volume 4. Bony fishes part 2 (Mugilidae to Carangidae).* Rome: Food and Agricultural Organisation of United Nations.

Heinsohn, G.E. 1972 A study of dugongs (*Dugong dugon*) in northern Queensland, Australia. *Biological Conservation* 4:205-213.

Heinsohn, G.E., A.V. Spain and P.K. Anderson 1976 Populations of dugong (Mammalia: Sirenia): aerial survey of the inshore waters of tropical Australia. *Biological Conservation* 9:21-23.

Hendy, E.J., M.K. Gagan, C.A. Alibert, M.T. McCulloch, J.M. Lough and P.J. Isdale 2002 Abrupt decrease in tropical Pacific sea surface salinity at end of Little Ice Age. *Science* 295:1511-1514.

Hine, P., J. Sealy, D. Halkett and T. Hart 2010 Antiquity of stone-walled tidal fish traps on the Cape Coast, South Africa. *The South African Archaeological Bulletin* 65(191):35-44.

Hiscock, P. 1999 Holocene coastal occupation of western Arnhem Land. In J. Hall and I. McNiven (eds), *Australian Coastal Archaeology*, pp.91-103. Canberra: Archaeology and Natural History Publications, Research School of Pacific and Asian Studies, Australian National University.

Hiscock, P. 2008 *Archaeology of Ancient Australia*. New York: Routledge.

Hiscock, P. and P. Faulkner 2006 Dating the dreaming? Creation of myths and rituals for mounds along the northern Australian coastline. *Cambridge Archaeological Journal* 16:209-222.

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

Hoffman, E.J. 2011 Adopting a Geoarchaeological Approach to Understanding Shell Mound Formation in Weipa, Cape York, Australia. Unpublished Honours thesis, University of Auckland, Auckland.

Holdaway, S., P.C. Fanning, M. Jones, J. Shiner, D.C. Witter and G. Nicholls 2002 Variability in the chronology of late Holocene Aboriginal occupation on the arid margin of southeastern Australia. *Journal of Archaeological Science* 29:351-363.

Holdaway, S.J., P.C. Fanning and J. Littleton 2009 Assessing the frequency distribution of radiocarbon determinations from the archaeological record of the late Holocene in western NSW, Australia. In A. Fairbairn, S. O'Connor and B. Marwick (eds), *New Directions in Archaeological Science*, pp.1-11. Terra Australis 28. Canberra: ANU E Press.

Holdaway, S., P. Fanning and E. Rhodes 2008 Challenging intensification: Human-environment interactions in the Holocene geoarchaeological record from western New South Wales, Australia. *Holocene* 18:411-420.

Holdaway, S., D. Witter, P. Fanning, R. Musgrave, G. Cochrane, T. Doelman, S. Greenwood, D. Pigdon and J. Reeves 1998 New approaches to open site spatial archaeology in Sturt National Park, New South Wales, Australia. *Archaeology in Oceania* 33(1):1-19.

Hope, G. and K. Aplin 2005 Environment change in the Aru Islands. In S. O'Connor, M. Spriggs and P. Veth (eds), *The Archaeology of the Aru Islands*, pp.24-40. Terra Australis 23. Canberra: Pandanus Books.

Hopley, D. 1974 Coastal changes produced by tropical Cyclone Althea in Queensland; December 1971. *The Australian Geographer* 12:445-456.

Iwatsuki, Y. 2013 Review of the *Acanthopagrus latus* complex (Perciformes: Sparidae) with descriptions of three new species from the Indo-West Pacific Ocean. *Journal of Fish Biology* 83:64-95.

Jackson, J.B., M.X. Kirby, W.H. Berger, K.A. Bjorndal, L.W. Botsford, B.J. Bourque, R.H. Bradbury, R. Cooke, J. Erlandson, J.A. Estes, T.P. Hughes, S. Kidwel, C.B. Lange, H.S. Lenihan, J.M. Pandolfi, C.H. Peterson, R.S. Steneck, M.J. Tegner and R.R. Warner 2001 Historical overfishing and the recent collapse of coastal ecosystems. *Science* 293:629-637.

Jagadis, I. and S. Rajagopal 2007a Age and growth of the Venus Clam *Gafrarium tumidum* (Roding) from south-east coast of India. *Indonesian Journal of Fish* 54(4):351-356.

Jagadis, I. and S. Rajagopal 2007b Reproductive biology of Venus Clam *Gafrarium tumidum* (Roding, 1798) from south-east coast of India. *Aquaculture Research* 38:1117-1122.

Jazwa, C.S., T.J. Braje, J.M. Erlandson and D.J. Kennett 2015 Central place foraging and shellfish processing on California's Channel Islands. *Journal of Anthropological Archaeology* 40:33-47.

Jennings, S. and J.L. Blanchard 2004 Fish abundance with nofishing: Predictions based on macroecological theory. *Journal of Animal Ecology* 73:632-642.

Jennings, S., E.M. Grandcourt and N.V. Polunin 1995 The effects of fishing on the diversity, biomass and trophic structure of Seychelles' reef fish communities. *Coral Reefs* 14:225-235.

Jennings S. and N.V. Polunin 1996 Effects of fishing effort and catch rate upon the structure and biomass of Fijian reef fish communities. *Journal of Applied Ecology* 33:400-412.

Jerardino, A. and R. Navarro 2008 Shell morphometry of seven limpet species from coastal shell middens in southern Africa. *Journal of Archaeological Science* 35:1023-1029.

Johannes R.E. and J.W. MacFarlane 1991 *Traditional Fishing in the Torres Strait Islands*. Hobart: CSIRO Division of Fisheries.

Johnson, J.W. and A.C. Gill (eds) 2005 *Gulf of Carpentaria Scientific Study Report*. Geography Monograph Series 10. Brisbane: Royal Geographic Society of Queensland.

Jones, K.T. and D.B. Madsen 1989 Calculating the cost of resource transportation: A Great Basin example. *Current Anthropology* 30:529-534.

Jones, R. 1990 Hunters of the Dreaming: Some ideational, economic and ecological parameters of the Australian Aboriginal productive system. In D.E. Yen and J.M.J. Mummery (eds), *Pacific Production Systems: Approaches to Economic Prehistory*, pp.25-53. Occasional Papers in Prehistory 18. Canberra: Department of Prehistory, Research School of Pacific Studies, Australian National University.

Jones, S. 2007 Human impacts on ancient marine environments of Fiji's Lau group: Current ethnoarchaeological and archaeological research. *Journal of Island and Coastal Archaeology* 2:239-244.

Jones S. 2009 A long-term perspective on biodiversity and marine resource exploitation in Fiji's Lau group. *Pacific Science* 63(4):617-648.

Jones, T.L., K.W. Gobalet and B.F. Codding 2016 The archaeology of fish and fishing on the central coast of California: The case for an under-exploited resource. *Journal of Anthropological Archaeology* 41:88-108.

Kaplan, H. and K. Hill 1992 The evolutionary ecology of food acquisition. In B. Winterhalder (ed.), *Evolutionary Ecology and Human Behaviour*, pp.167-202. New York: Aldine De Gruyter.

Keen, S. 1983 Yukulta. In R. Dixon (ed.), *Handbook of Australian Languages*, pp.191-304. Canberra: Australian National University.

Kelly, R. and N. Evans 1985 The McKenzie Massacre on Bentinck Island. *Aboriginal History* 9(1):44-52.

Kelly, R.L. 1992 Mobility/sedentism: Concepts, archaeological measures and effects. *Annual Review of Anthropology* 21:43-66.

Kelly, R.L. 1995 *The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways*. Washington: Smithsonian Institution Press.

Kenady, S. in prep. A Geophysical ExploraKon of Archaeological Shell Matrix Deposits: Comparing Geophysical Techniques in Mapping the Boundaries, Internal Structure, and Features of Shell Matrix Sites. Unpublished PhD thesis, James Cook University, Cairns.

Kennett, D.J. 2005 *The Island Chumash: Behavioral Ecology of a Maritime Society*. Berkeley: University of California Press.

Kennett, D.J. and R.A. Clifford 2004 Flexible strategies for resource defense on the Northern Channel Islands of California: An agent-based model. In. S.M. Fitzpatrick (ed.), *Voyages of Discovery: The Archaeology of Islands*, pp.21-50. New York: Praeger.

Kennett, D.J. and J.P. Kennett 2000 Competitive and cooperative responses to climatic instability in coastal southern California. *American Antiquity* 65:379-395.

Kent, B.W. 1992 *Making Dead Oysters Talk: Techniques for Analyzing Oysters from Archaeological Sites*. Crownsville, Maryland: Maryland Historical Trust.

Kirch, P.V. 1997 Microsmic histories: Island perspective on ‘global’ change. *American Anthropologist* 99:30-42.

Kirch, P.V. and T.L. Hunt 1997 *Historical Ecology in the Pacific Islands*. New Haven: Yale University Press.

Kithsiri, H.M.P., M.J.S. Wijeyaratne and U.S. Amarasinghe 2000 Influence of some environmental factors on the abundance of three commercially important bivalve species (Family: Veneridae) in the Puttalam lagoon and Dutch bay, Sri Lanka. *Sri Lanka Journal of Aquatic Sciences* 5:27-37.

Kithsiri, H.M.P., M.J.S. Wijeyaratne and U.S. Amarasinghe 2004 Population dynamics of three commercially importand bivalve species (Family: Veneridae) in Puttalam lagoon and Dutch bay, Sri Lanka. *Sri Lanka Journal of Aquatic Sciences* 9:13-29.

Krebs, J.R. and N.B. Davies (eds) 1978 *Behavioural Ecology: An Evolutionary Approach.* 1st ed. Oxford: Blackwell

Krebs, J.R. and N.B. Davies (eds) 1997 *Behavioural Ecology: An Evolutionary Approach*, 4th ed. Oxford: Blackwell.

Lamprell, K. and J. Healy 1998 *Bivalves of Australia,* Volume 2. Leiden: Backhuys Publishers.

Lamprell, K. and T. Whitehead 1992 *Bivalves of Australia,* Volume 1. Bathurst: Crawford House Press.

Larson, H., N.Gribble, J. Salini, R. Pillans and S. Peverell 2004 Sharks and Rays. . In National Oceans Office (ed.), *Description of Key Species Groups in the Northern Planning Area*, pp.59-74. Hobart: National Oceans Office.

Lewis, S.E., C.R. Sloss, C.V. Murray-Wallace, C.D. Woodroffe and S.G. Smithers 2013 Post-glacial sea-level changes around the Australian margin: A review. *Quaternary Science Reviews* 74:115-138.

Lieske, E. and R. Myers 1994 *Collins Pocket Guide. Coral Reef Fishes. Indo-Pacific and Caribbean including the Red Sea*. Melbourne: Harper Collins Publishers.

Limpus, C. and R. Chatto 2004 Marine turtles. In National Oceans Office (ed.), *Description of Key Species Groups in the Northern Planning Area*, pp.113-136. Hobart: National Oceans Office.

Lindeman, R.L. 1942 The trophic-dynamic aspect of ecology. *Ecology* 23(4):399-418.

Lourandos, H. 1980 Change or stability?: Hydraulics, hunter-gatherers and population in temperate Australia. *World Archaeology* 11(3):245-264.

Lourandos, H. 1983 Intensification: A late Pleistocene-Holocene archaeological sequence from southwestern Victoria. *Archaeology in Oceania* 18(2):81-94.

Lourandos, H. 1985 Intensification and Australian prehistory. In T.D. Price and J.A. Brown (eds), *Prehistoric Hunter-Gatherers: The Emergence of Cultural Complexity*, pp.385-423. Orlando: Academic Press.

Lourandos, H. 1988 Palaeopolitics: Resource intensification in Aboriginal Australia and Papua New Guinea. In T. Ingold, D. Riches and J. Woodburn (eds), *Hunters and Gatherers 1: History, Evolution and Social Change*, pp.148-160. Vol. 1. New York: Berg.

Lourandos, H. 1993 Hunter-gatherer cultural dynamics: Long- and short-term trends in Australian prehistory. *Journal of Archaeological Research* 1(1):67-88.

Lourandos, H. 1997 *Continent of Hunter-Gatherers: New Perspectives in Australian Prehistory*. Cambridge: Cambridge University Press.

Lourandos, H. and A. Ross 1994 The great ‘intensification debate’: Its history and place in Australian archaeology. *Australian Archaeology* 39:54-63.

Lupo, K.D. and D.N. Schmitt 2002 Upper Paleolithic net-hunting, small prey exploitation and women’s work effort: A view from the ethnographic and ethnoarchaeological record of the Congo basin. *Journal of Archaeological Method and Theory* 9:147-179.

Lupo, K.D. and D.N. Schmitt 2005 Small prey hunting technology and zooarchaeological measures of taxonomic diversity and abundance: Ethnoarchaeological evidence from Central African forest foragers. *Journal of Anthropological Archaeology* 24:335-353.

Lyman, R.L. 1994 *Vertebrate Taphonomy*. Cambridge: Cambridge University Press.

Lyman, R.L. and K.P. Cannon (eds) 2004 *Zooarchaeology and Conservation Biology*. Salt Lake City: University of Utah Press.

MacArthur, R.H. and E.R. Pianka 1966 On optimal use of a patchy environment. *American Naturalist* 100:603-609.

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

Mackenzie, L. in prep. Holocene Environments and Human Occupation of the South Wellesley Islands, Tropical Northern Australia. Unpublished PhD thesis, School of Geography, Planning and Environmental Management, The University of Queensland, Brisbane.

Madsen, D.B. and D.N. Schmitt 1998 Mass collecting and the diet breadth model: A Great Basin example. *Journal of Archaeological Science* 25:445-455.

Malcolm, H. 1998 Reef Fish Community and Incidental Observations: Wellesley Islands - Gulf of Carpentaria. Unpublished Report for Queensland Department of Environment.

Mannino, M.A. and K.D. Thomas 2002 Depletion of a resource? The impact of prehistoric human foraging on intertidal mollusc communities and its significance for human settlement, mobility and dispersal. *World Archaeology* 33(3):452-474.

Markgraf, V. and H.F. Diaz 2000 The past ENSO record: A synthesis. In H.F. Diaz and V. Markgraf (eds), *El Niño and The Southern Oscillation: Multiscale Variability and Global and Regional Impacts*, pp.465-488. Cambridge: Cambridge University Press.

Marston, J.M. 2011 Archaeological markers of agricultural risk management. *Journal of Anthropological Archaeology* 30:190–205.

Martin, P.S. 2002 Prehistoric extinctions: In the shadow of man. In C.E. Kay and R.T. Simmons (eds), *Wilderness Political Ecology: Aboriginal Influences and the Original State of Nature*, pp. 1-27. Salt Lake City: University of Utah Press.

Martin, S. 1988 Eyre Peninsula and West Coast Aboriginal Fish Trap Survey. Unpublished manuscript of South Australia Department of Environment and Planning, Adelaide.

Mason, R.D., M.L. Peterson and J.A. Tiffany 1998 Weighing vs. counting: Measurement reliability and the California School of midden analysis. *American Antiquity* 63(2):303-324.

Mason, R.D., M.L. Peterson and J.A. Tiffany 2000 Weighing and counting shell: A response to Glassow and Claassen. *American Antiquity* 65:757-761.

McDonald, J. and M. Berry 2016 Murujuga, Northwestern Australia: When Arid Hunter-Gatherers Became Coastal Foragers. *The Journal of Island and Coastal Archaeology* DOI:10.1080/15564894.2015.1125971

McKay, R.J. 1992 Sillaginid fishes of the world (family Sillaginidae). An annotated and illustrated catalogue of the sillago, smelt or Indo-Pacific whiting species known to date. *Fisheries Synopsis* 125(14):87. Rome: Food and Agricultural Organisation of the United Nations.

McKnight, D. 1979 Lardil: Mornington Island. *Family of Man* 63:1742-1743.

McKnight, D. 1986 Kaiadilt: Australia. *Family of Man* 4(53):1468-1471.

McKnight, D. 1995 *Lardil: Keepers of the Dreamtime*. San Francisco: Chronical Books.

McKnight, D. 1999 *Peoples, Countries, and the Rainbow Serpent: Systems of Classification among the Lardil of Mornington Island*. Oxford: Oxford University Press.

McNiven, I.J. 1989 Aboriginal shell middens at the mouth of the Maroochy River, southeast Queensland. *Queensland Archaeological Research* 6:28-52.

McNiven, I.J. 1999 Fissioning and regionalisation: The social dimensions of changes in Aboriginal use of the Great Sandy Region, southeast Queensland. In J. Hall and I.J. McNiven (eds), *Australian Coastal Archaeology*, pp.157-168. Research Papers in Archaeology and Natural History 31. Canberra: Archaeology and Natural History Publications, Research School of Pacific and Asian Studies, Australian National University.

McNiven, I. 2003 Saltwater people: Spiritscapes, maritime rituals and the archaeology of Australian indigenous seascapes. *World Archaeology* 35(3):329-349.

McNiven, I.J., J. Crouch, M. Weisler, N. Kemp, L. Clayton Martínez, J. Stanisic, M. Orr, L. Brady, S. Hocknull and W. Boles 2008 Tigershark rockshelter (Baidamau Mudh): Seascape and settlement reconfigurations on the sacred islet of Pulu, western Zendah Kes (Torres Strait). *Australian Archaeology* 66:15-32.

McNiven, I.J. and R. Feldman 2003 Ritually orchestrated seascapes: Hunting magic and dugong bone mounds in Torres Strait, NE Australia. *Cambridge Archaeological Journal* 13(2):169-194.

McNiven, I.J. and G. Hitchcock 2004 Torres Strait marine subsistence specialization and terrestrial animal translocation. In I.J. McNiven and M. Quinnell (eds), *Torres Strait Archaeology and Material Culture*, pp.105-162. Memoirs of the Queensland Museum Cultural Heritage Series 3(1). Brisbane: Queensland Museum.

Meehan, B. 1977 Man does not live by calories alone: The role of shellfish in a coastal cuisine. In J. Allen, J. Golson and R. Jones (eds), *Sunda and Sahul: Prehistoric Studies in South-East Asia, Melanesia and Australia*, pp.493-531. London: Academic Press.

Meehan, B. 1982 *Shell Bed to Shell Midden*. Canberra: Australian Institute of Aboriginal Studies.

Memmott, P.C. 1979 Lardil Properties of Place: An Ethnological Study in Man-Environment Relations. Unpublished PhD thesis, The University of Queensland, Brisbane.

Memmott, P. 1982 The South Wellesley Islands and the Kaiadilt: A History and an Analysis of the Significance of the Land and its People. Unpublished manuscript, Aboriginal Data Archive, Brisbane: Department of Architecture, The University of Queensland.

Memmott, P. 2010 *Material Culture of the North Wellesley Islands*. Research Report Series 8. Brisbane: Aboriginal and Torres Strait Islander Studies Unit, The University of Queensland.

Memmott, P. and G. Channells 2004 Living on Saltwater Country: Southern Gulf of Carpentaria Sea Country Mangement, Needs and Issues. Consultation Report prepared on behalf of Carpentaria Land Council Aboriginal Corporation. Hobart: National Oceans Office.

Memmott, P., N. Evans, R. Robins and I. Lilley 2006 Understanding isolation and change in island human populations through a study of Indigenous cultural patterns in the Gulf of Carpentaria. *Transactions of the Royal Society of South Australia* 130(1):29-47.

Memmott, P., R. Robins and E. Stock 2008 What exactly is a fish trap? Methodological issues for the study of Aboriginal intertidal rock wall fish traps, Wellesley Islands region, Gulf of Carpentaria, Australia. In J. Conolly and M. Campbell (eds), *Comparative Island Achaeologies*, pp.47-67. BAR International Series S1829. Oxford: Archaeopress.

Memmott, P., E. Round, D. Rosendahl and S. Ulm 2016 Fission, fusion and syncretism: Linguistic and environmental changes amongst the Tangkic people of the southern Gulf of Carpentaria, northern Australia. In J-C. Verstraete and D. Hafner (eds), *Land and Language in Cape York Peninsula and the Gulf Country*, pp.105-136. Culture and Language Use 18. Amsterdam: John Benjamins Bublishing Company.

Memmott, P. and D. Trigger 1998 Marine tenure in the Wellesley Islands region, Gulf of Carpentaria. In N. Peterson and B. Rigsby (eds), *Customary Marine Tenure in Australia*, pp.110-124. Oceania Monograph 48. Sydney: Oceania Publications.

Metcalfe, D. and K.R. Barlow 1992 A model for exploring the optimal trade-off between field processing and transport. *American Anthropologist* 94:340-356.

Minagawa, M. and E. Wada 1984 Stepwise enrichment of δ^{15}N along food chains: Further evidence and the relation between δ^{15}N and animal age. *Geochimica et Cosmochimica Acta* 48:1135-1140.

Mithen, S.J. 1990 *Thoughtful Foragers: A Study of Prehistoric Decision Making*. Cambridge: Cambridge University Press.

Morales, A. and E. Rosello 2004 Fishing down the food web in Iberian prehistory? A new look at the fishes from Cueva de Nerja (Malaga, Spain). In J. Brigal and J. Desse (eds), *Pettis Animaux et Societes Humaines du Complement Alimentaire aux Resources Utilitaires XXIV*, pp.111-123. Antibes: APDCA.

Morrison, A.E and E.E. Cochrane 2008 Investigating shellfish deposition and landscape history at the Natia Beach Site, Fiji. *Journal of Archaeological Science* 35:2387-2399.

Morrison, A.E. and T.L. Hunt 2007 Human impacts on the nearshore environment: An archaeological case study from Kaua'i, Hawaiian Islands. *Pacific Science* 61:325-345.

Morrison, M. 2003 Old boundaries and new horizons: The Weipa shell mounds reconsidered. *Archaeology in Oceania* 38(1):1-8.

Morrison, M. 2010 The Shell Mounds of Albatross Bay: An Archaeological Investigation of Late Holocene Production Strategies Near Weipa, North Eastern Australia. Unpublished PhD thesis, Flinders University, Adelaide.

Morrison, M. 2013 Niche production strategies and shell matrix site variability at Albatross Bay, Cape York Peninsula. *Archaeology in Oceania* 48(2):78-91.

Morwood, M. 1987 The archaeology of social complexity in south-east Queensland. *Proceedings of the Prehistoric Society* 53:337-350.

Moss, M.L. and A. Cannon (eds) 2011 *The Archaeology of North Pacific Fisheries*. Fairbanks: University of Alaska Press.

Moss, M.L. 2012 Understanding variability in northwest coast faunal assemblages: Beyond economic intensification and cultural complexity. *Journal of Island and Coastal Archaeology* 7:1-22.

Moss, P., L. Mackenzie, S. Ulm, C. Sloss, D. Rosendahl, L. Petherick, L. Steinberger, L. Wallis, H. Heijins, F. Petchey and G. Jacobsen 2015 Environmental context for late Holocene human occupation of the South Wellesley Archipelago, Gulf of Carpentaria, northern Australia. *Quaternary International* 385:136-144.

Moss, P., L. Petherick and D. Neil 2011 Environmental change at Myora Springs, North Stradbroke Island over the last millennium. *Proceedings of the Royal Society of Queensland* 117:133-140.

Moss, P., S. Ulm, T. Nagel, D. Rosendahl, L. Wallis and C. Sloss 2014 Pollen Analysis of an Archaeological Midden Site: Thundiy, Bentinck Island, Gulf of Carpentaria. Poster presented at the Australian Archaeological Association and Australasian Society for Historical Archaeology combined Conference, Cairns, 1-3 December.

Mowat, F.M. 1995 Variability in Western Arnhem Land Shell Midden Deposits, Unpublished MA thesis, Northern Territory University, Darwin.

Mulvaney, K. 1969 *The Prehistory of Australia*. London: Thames and Hudson.

Murray-Wallace, C.V. and A.P. Belperio 1991 The last interglacial shoreline in Australia - A review. *Quaternary Science Reviews* 10(5):441-461.

Nagaoka, L. 2001 Using diversity indices to measure changes in prey choice at the Shag River Mouth Site, Southern New Zealand. *International Journal of Osteoarchaeology* 11:101-111.

Nagaoka, L. 2002a The effects of resource depression on foraging efficiency, diet breadth, and patch use in southern New Zealand. *Journal of Anthropological Archaeology* 21:419-442.

Nagaoka, L. 2002b Explaining subsistence change in southern New Zealand using foraging theory models. *World Archaeology* 34(1):84-102.

Nagaoka, L. 2005a Differential recovery of Pacific Island fish remains. *Journal of Archaeological Science* 32:941-955.

Nagaoka, L. 2005b Declining foraging efficiency and Moa carcass exploitation in southern New Zealand. *Journal of Archaeological Science* 32:1328-1338.

Nagel, T., D. Rosendahl, Q. Hua, P. Moss, C. Sloss, F. Petchey and S. Ulm 2016 Extended residence times for foraminifera in a marine-influenced terrestrial archaeological deposit and implications for palaeoenvironmental reconstruction. *Journal of Archaeological Science: Reports* 5:25-34.

Nakada, M. and K. Lambeck 1989 Late Pleistocene and Holocene sea-level change in the Australian region and mantle rheology. *Geophysical Journal International* 96:497-517.

Nanson, G.C., D.M. Price, S.A. Short, R.W. Young and B.G. Jones 1991 Comparative uranium-thorium and thermoluminescence dating of weathered Quaternary alluvium in the tropics of northern Australia. *Quaternary Research* 35(3):347-366.

National Native Title Tribunal Maps. Retrieved 21 January 2015 from www.nntt.gov.au.

Nettle, D. and R.I.M. Dunbar 1997 Social markers and the evolution of reciprocal exchange. *Current Anthropology* 38:93-99.

Nichol, R.K. and C.J. Wild 1984 Numbers of individuals in faunal analysis: The decay of fish bone in archaeological sites. *Journal of Archaeological Science* 11:35-51.

Nietschmann, B. 1977 Torres Strait Islander Hunters and Environment. Work-in-Progress Seminar Paper presented 23 Feb 1977. Canberra: Department of Human Geography, Research School of Pacific Studies, Australian National University.

Nietschmann, B. 1984 Hunting and ecology of dugongs and green turtles in Torres Strait. *National Geographic Society Research Reports* 17:625-651.

Nott, J. 1997 Extremely high-energy wave deposits inside the Great Barrier Reef, Australia: Determining the cause--Tsunami or tropical cyclone. *Marine Geology* 141(1-4):193-207.

Nott, J. 2006 Tropical cyclones and the evolution of the sedimentary coast of northern Australia. *Journal of Coastal Research* 22(1):49-62.

Nott, J., J. Goff, C. Change-Goff, C. Sloss and N. Riggs 2013 Anatomy of sand beach ridges: Evidence from severe Tropical Cyclone Yasi and its predecessors, northeast Queensland, Australia. *Journal of Geophysical Research: Earth Surface* 118:1-10.

Nott, J. and M. Hayne 2001 High frequency of 'super-cyclones' along the Great Barrier Reef over the past 5,000 years. *Nature* 413:508-512.

Nott J., S. Smithers, K. Walsh and E. Rhodes 2009 Sand beach ridges record 6000 year history of extreme tropical cyclone activity in northeastern Australia. *Quaternary Science Review* 28:1511-1520.

O'Connell, J.F. and K. Hawkes 1984 Food choice and foraging sites among the Alyawara. *Journal of Anthropological Research* 40:504-535.

O'Connell, J.F., K. Hawkes and N.G. Blurton Jones 1988 Hadza hunting, butchering, and bone transport and their archaeological implications. *Journal of Anthropological Research* 44:113-161.

O'Connor, S. 1996a Where are the middens? – An overview of the archaeological evidence for shellfish exploitation along the northwestern Australian coastline. *Indo Pacific Prehistory Association Bulletin* 15(2):165-180.

O'Connor, S. 1996b Thirty thousand years in the Kimberley: Results of excavation on three rockshelters in the coastal west Kimberley, W.A. In P. Veth and P. Hiscock (eds), *Archaeology of Northern Australia*, pp.26-49. Tempus 4. Brisbane: Anthropology Museum, The University of Queensland.

O'Connor, S. 1999a *30,000 Years of Aboriginal Occupation*. Terra Australis 14. Canberra: Department of Archaeology and Natural History and Centre for Archaeological Research.

O'Connor, S. 1999b A diversity of coastal economies: Shell mounds in the Kimberley region in the Holocene. In J. Hall and I.J, McNiven (eds*), Australian Coastal Archaeology*, pp.37-50. Canberra: Archaeology and Natural History Publications, Research School of Pacific and Asian Studies, Australian National University.

O'Connor, S., M. Spriggs and P. Veth (eds) 2005 *The Archaeology of the Aru Islands, Eastern Indonesia*. Terra Australis 32. Canberra: Pandanus Books.

O'Connor, S. and M. Sullivan 1994a Distinguishing middens and cheniers: A case study from the southern Kimberley, Western Australia. *Archaeology in Oceania* 29:16-28.

O'Connor, S. and M. Sullivan 1994b Coastal archaeology in Australia; developments and new directions. *Australian Archaeology* 39:87-96.

Odum, W.E. and E.J. Heald.1972 Trophic analyses of an estuarine mangrove community. *Bulletin of Marine Science* 22:671-737.

Oertle, A., M. Leavesley, S. Ulm, G. Mate and D. Rosendahl 2014 At the margins: Archaeological evidence for Macassan activities in the South Wellesley Islands, Gulf of Carpentaria. *Australasian Historical Archaeology* 32:64-71.

Ogden, A. 1941 *The California Sea Otter Trade*. Berkeley: University of California Press.

O'Grady, G.N., C.F. Voegelin and F.M. Voegelin 1966 Languages of the World: Indo-Pacific Fascicle Six. *Anthropological Linguistics* 8(2):1-197.

Orians, G.H. and N.E. Pearson 1979 On the theory of central place foraging. In G.R. Stairs (ed.), *Analysis of Ecological Systems*, pp.154-177. Columbus: Ohia State University.

Pace, M.L. J.J. Cole, S.R. Carpenter and J.F. Kitchell 1999 Trophic cascades revealed in diverse ecosystems. *Trends in Ecology and Evolution* 14:483-488.

Pathansali, D. and M.K. Soong 1958 Some aspects of cockle (*Anadara granosa* L.) culture in Malaya. *Proceedings of the Indo-Pacific Fisheries Council* 8(2):26-31.

Paul, P., N. Loogatha, A. Loogatha, E. Thomas, D. Loogatha, B. Evans, N. Evans, H. Tomkins, D. Rosendahl, S. Ulm, E. Round and P. Memmott 2009 Kayardilt Fish Names: Spoken by the Kaiadilt of Bentinck Island. Gununa, QLD: Mirndiyan Gununa Aboriginal Corporation.

Pauly, D. 1979 Theory and management of tropical multispecies stocks: A review with emphasis on the southeast Asian demersal fisheries. ICLARM Studies Review 1. Manila: International Center for Living Aquatic Resources Management.

Pauly, D. 1995 Anecdotes and the shifting baseline syndrome in fisheries. *Trends in Ecology and Evolution* 10:430.

Pauly D., V. Christensen, J. Dalsgaard, R. Froese and F. Torres Jr. 1998 Fishing down marine food webs. *Science* 279:860-863.

Pauly, D., V. Christensen, R. Froese and M.L.D. Palomares 2000. Fishing down aquatic food webs. *American Scientist* 88:46-51.

Peacock, E. 2000 Assessing bias in archaeological shell assemblages. *Journal of Field Archaeology* 27:183-196.

Pinnegar, J.K. and G.H. Engelhard 2008 The 'shifting baseline' phenomenon: A global perspective. *Reviews in Fish Biology and Fisheries* 18:1-16.

Poiner, I.R., D.J. Staples and R. Kenyon 1987 Seagrass communities of the Gulf of Carpentaria. *Australian Journal of Marine and Fresh Water Research* 38:121-131.

Polis, G.A., A.L.W. Sears, G.R. Huxel, D.R. Strong and J. Maron 2000 When is a trophic cascade a trophic cascade? *Trends in Ecology and Evolution* 15(11):473-475.

Poutiers, J.M. 1998 Bivalves (Acephala, Lamellibranchia, Pelecypoda). In K.E. Carpenter and V.H. Niem (eds), *The Living Marine Resources of the Western Central Pacific: Volume 1. Seaweeds, Corals, Bivalves and Gastropods, FAO Species Identification Guide for Fishery Purposes*. Rome: Food and Agricultural Organisation of United Nations.

Prebble, M., R. Sim, J. Finn and D. Fink 2005 A Holocene pollen and diatom record from Vanderlin Island, Gulf of Carpentaria, lowland tropical Australia. *Quaternary Research* 64(3):357-371.

Proske, U. and S.G. Haberle 2012 Island ecosystem and biodiversity dynamics in northeastern Australia during the Holocene: Unravelling short-term impacts and long-term drivers. *The Holocene* 22(10):1097-1111.

Queensland Government Wildlife Online database. Retrieved 1 March 2015 from https://www.qld.gov.au/environment/ plants-animals/species-list/.

Quitmyer, I.R. and E.J. Reitz 2006 Marine trophic levels targeted between AD 300 and 1500 on the Georgia coast, USA. *Journal of Archaeological Science* 33:806-822.

Rainbird, P. 2002 A message for our future? The Rapa Nui (Easter Island) ecodisaster and Pacific Island environments. *World Archaeology* 33:436-451.

Randall, J.E., G.R. Allen and R.C. Steene 1990 *Fishes of the Great Barrier Reef and Coral Sea*. Honolulu: University of Hawaii Press.

Reeves, J.M., H.C. Bostock, L.K. Ayliffe, T.T. Barrows, P. De Decckker, L.S. Devriendt, G.B. Dunbar, R.N. Drysdale, K.E. Fitzsimmons, M.K. Gagan, M.L. Griffiths, S.G. Haberle, J.D. Jansen, C. Krause, S. Lewis, H.V. McGregor, S.D. Mooney, P. Moss, G.C. Nanson, A. Purcell and S. van der Kaars 2013 Palaeoenvironmental change in tropical Australasia over the last 30,000 years – A synthesis by the OZ-INTIMATE group. *Quaternary Science Reviews* 74:97-114.

Reeves, J.M., A.R. Chivas, A. Garcia, S. Holt, M.J.J. Couapel and B.G. Jones 2006 The Sedimentary Record of Palaeoenvironments of the Gulf of Carpentaria, Australia through the Last Glacial Cycle. Wollongong: GeoQuEST Research Centre, School of Earth and Environmental Sciences, University of Wollongong.

Reeves, J.M., A.R. Chivas, A. Garcia and P. De Deckker 2007 Palaeoenvironmental change in the Gulf of Carpentaria (Australia) since the last interglacial based on Ostracoda. *Palaeogeography, Palaeoclimatology, Palaeoecology* 246:163-187.

Reeves J.M., A.R. Chivas, A. Garcia, S. Holt, M.J.J. Couapel, B.G. Jones, D.I. Cendon and D. Fink 2008 The sedimentary record of palaeoenvironments and sea-level change in the Gulf of Carpentaria, Australia, through the last glacial cycle. *Quaternary International* 183:3-22.

Reimer, P. J., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P. G., Bronk Ramsey, C., Grootes, P. M., Guilderson, T. P., Haflidason, H., Hajdas, I., Hattz, C., Heaton, T. J., Hoffmann, D. L., Hogg, A. G., Hughen, K. A., Kaiser, K. F., Kromer, B., Manning, S. W., Niu, M., Reimer, R. W., Richards, D. A., Scott, E. M., Southon, J. R., Staff, R. A., Turney, C. S. M., & J. van der Plicht 2013 IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0-50,000 Years cal BP. *Radiocarbon* 55(4):1869-1887.

Reitz, E.J. 2004 'Fishing down the food web': A case study from St. Augustine, Florida, USA. *American Antiquity* 69:63-83.

Reitz, E.J. and E.S Wing 2008 *Zooarchaeology*. 2nd ed. Cambridge: Cambridge University Press.

Reitz, E.J., I.R. Quitmyer, H.S. Hale, S.J. Scudder and E.S. Wing 1987 Application of allometry to zooarchaeology. *American Antiquity* 52:304-317.

Reitz, E.J., I.R. Quitmyer and R.A. Marrinan 2009 What are we measuring in the zooarchaeological record of Prehispanic fishing strategies in the Georgia Bight, USA? *Journal of Island and Coastal Archaeology* 4:2-36.

Rhodes, E.G. 1982 Depositional model for a chenier plain, Gulf of Carpentaria, Australia. *Sedimentology* 29:201-221.

Rhodes, E.G., H.A. Polach, B.G. Thom and S.R. Wilson 1980 Age structure of Holocene coastal sediments: Gulf of Carpentaria, Australia. *Radiocarbon* 22:718-727.

Rick, T.C. and J.M. Erlandson 2008 *Human Impacts on Ancient Marine Ecosystems: A Global Perspective*. Berkeley: University of California Press.

Rick T.C., J.M. Erlandson, T.J. Braje, J.A. Estes, M.H. Graham and R.L. Vellanoweth 2008 Historical ecology and human impacts on coastal ecosystems of the Santa Barbara Channel region, California. In T.C. Rick and J.M. Erlandson (eds), *Human Impacts on Ancient Marine Ecosystems: A Global Perspective*, pp.77-102. Berkeley: University of California Press.

Rick, T.C., J.M. Erlandson, R.L. Vellanoweth and T.J. Braje 2005 From Pleistocene mariners to complex hunter-gatherers: The archaeology of the California Channel Islands. *Journal of World Prehistory* 19:169-228.

Rigler, F.H. 1975 The concept of energy flows and nutrients flows between trophic levels. In U.W. van Dobben and R.H. Lowe-McConnell (eds), *Unifying Concepts in Ecology*, pp.27-43. The Hague: Dr W Junk B.V. Publishers.

Robins, R.P., E.C. Stock and D.S. Trigger 1998 Saltwater people, saltwater country: Geomorphological, anthropological and archaeological investigations of the coastal lands in the southern Gulf Country of Queensland. *Memoirs of the Queensland Museum Cultural Heritage Series* 1(1):75-125.

Rosendahl, D. 2012 The Way it Changes Like the Shoreline and the Sea: The Archaeology of the Sandalwood River, Mornington Island, Southeast Gulf of Carpentaria, Australia. Unpublished PhD thesis, The University of Queensland, Brisbane.

Rosendahl, D., S. Ulm, H. Tomkins, L. Wallis and P. Memmott 2014 Late Holocene changes in shellfishing behaviors from the Gulf of Carpentaria, Northern Australia. The *Journal of Island and Coastal Archaeology* 9:253-267.

Ross, A. and R. Duffy 2000 Fine Mesh Screening of Midden Material and the Recovery of Fish Bone: The Development of Flotation and Deflocculation Techniques for an Effcient and Effective Procedure. *Geoarchaeology: An International Journal* 15(1):21-41.

Ross, A. and Quandamooka Land Council 1996a Aboriginal approaches to cultural heritage management: A Quandamooka case study. In S. Ulm, I. Lilley and A. Ross (eds), *Australian Archaeology '95: Proceedings of 1995 Australian Archaeological Association Annual Conference*, pp.107-112. Tempus 6. Brisbane: Anthropology Museum, The University of Queensland.

Ross, A. and H. Tomkins 2011 Fishing for data—The value of fine-mesh screening for fish-bone recovery: A case study from Peel Island, Moreton Bay, Queensland. In J. Specht and R. Torrence (eds), *Changing perspectives in Australian archaeology, Papers in Honour of Val Attenbrow. Technical Reports of the Australian Museum, Online* 23(9):133–151.

Ross, P.J. 2009 Ngarrindjeri Fish Traps of the Lower Murray Lakes and Northern Cooroy Estuary, South Australia. Unpublished Master of Maritime Archaeology thesis, Flinders University, Adelaide.

Roth, W.E. 1901 Carpentaria Blacks 1: The Wellesley Islands. *The Brisbane Courier*, 24 August, p.13.

Roth, W.E. 1903 Dr Roth’s Visit to the Wellesley Islands: Report to the Under Secretary, Department of Public Lands. Office of the Northern Protector of Aboriginals.

Roth, W.E. 1908 The natives of the ‘Never Never’. *The World Wide Magazine* 22:556-565.

Rowland, M.J. 1983 Aborigines and environment in Holocene Australia: Changing paradigms. *Australian Aboriginal Studies* 2:62-77.

Rowland, M.J. 1989 Population increase, intensification or a result of preservation?: Explaining site distribution patterns on the coast of Queensland. *Australian Aboriginal Studies* 2:32-41.

Rowland, M.J. 1992 Climate change, sea-level rise and the archaeological record. *Australian Archaeology* 34:29-33.

Rowland, M. 1994 Size isn’t everything: Shells in mounds, middens and natural deposits. *Australian Archaeology* 39:118-124.

Rowland M.J. 1999a The Keppel Islands - A ‘3000 year’ event revisited. In J. Hall and I.J. McNiven (eds), *Australian Coastal Archaeology*, pp.141-156. Research Papers in Archaeology and Natural History 31. Canberra: Archaeology and Natural History Publications, Research School of Pacific and Asian Studies, Australian National University.

Rowland, M.J. 1999b Holocene environmental variability: Have its impacts been underestimated in Australian pre-history? *The Artefact* 22:11-48.

Rowland, M.J. 2008 Saving the past from the future. *Historic Environment* 21:19-29.

Rowland, M.J. and S. Ulm 2011 Indigenous fish traps and weirs of Queensland. *Queensland Archaeological Research* 14:1-58.

Rowland, M.J. and S. Ulm 2012 Key issues in the conservation of the Australian coastal archaeological record: Natural and human impacts. *Journal of Coastal Conservation* 16:159-171.

Roy, K., A.G. Collins, B.J. Becker, E. Begovic and J.M. Engle 2003 Anthropogenic impacts and historical decline in body size of rocky intertidal gastropods in southern California. *Ecology Letters* 6:205-211.

Saalfeld, K. and H. Marsh 2004 Dugong. In National Oceans Office (ed.), *Description of Key Species Groups in the Northern Planning Area*, pp.93-112. Hobart: National Oceans Office.

Saenger, P. 2005 Sweers Island: Changes over two hundred years since Flinders' visit. In J.W. Johnson and A.C. Gill (eds), *Gulf of Carpentaria Scientific Study Report*, pp.1-23. Geography Monograph Series 10. Brisbane: Royal Geographic Society of Queensland.

Sahlins, M.D. 1972 *Stone Age Economics*. Chicago: Aldine.

Schiel, D.R. 1990 Macroalgal assemblages in New Zealand: Structure, interactions and demography. *Hydrobiologia* 192:59-76.

Schiffer, M.B. 1972 Archaeological context and systemic context. *American Antiquity* 37(2):156-165.

Schiffer, M.B. 1983 Toward the identification of formation processes. *American Antiquity* 48:675-706.

Schmidt-Nielsen, K. 1984 *Scaling: Why is Animal Size so Important*. New York: Cambridge University Press.

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

Shannon, C.E. and W. Weaver 1949 *A Mathematical Model of Communication*. Urbana, IL: University of Illinois Press.

Sheppard, C. 1995 The shifting baseline syndrome (editorial). *Marine Pollution Bulletin* 30:766–767.

Shulmeister, J. 1999 Australasian evidence for mid-Holocene climate change implies precessional control of Walker Circulation in the Pacific. *Quaternary International* 57-58:81-91.

Shulmeister, J. and J. Head 1993 Aspects of the emplacement, evolution and ^{14}C chronology of ridges on a coastal spit, Groote Eylandt, Northern Australia. *Marine Geology* 111(1-2):159-169.

Shulmeister, J. and B.G. Lees 1995 Pollen evidence from tropical Australia for the onset of an ENSO-dominated climate at c.4000 BP. *The Holocene* 5:10-18.

Shulmeister, J. and B.G. Lees 1992 Morphology and chronostratigraphy of a coastal dunefield; Groote Eylandt, northern Australia. *Geomorphology* 5(6):521-534.

Sim, R. 1999 Why the Tasmanians stopped eating fish: Evidence for late Holocene expansion in resource exploitation strategies. In J. Hall and I.J. McNiven (eds), *Australian Coastal Archaeology*, pp.263-270. Research Papers in Archaeology and Natural History 31. Canberra: Archaeology and Natural History Publications, Research School of Pacific and Asian Studies, Australian National University.

Sim, R. 2002 Preliminary Results from the Sir Edward Pellew Islands Archaeological Project, Gulf of Carpentaria, 2000-2001, Unpublished report to the Australian Institute of Aboriginal and Torres Strait Islander Studies, Canberra.

Sim, R. and L.A. Wallis 2008 Northern Australian offshore island use during the Holocene: The archaeology of Vanderlin Island, Sir Edward Pellew Group, Gulf of Carpentaria. *Australian Archaeology* 67:95-106.

Simmons, R., J. Graydon and N. Tindale 1964 Further blood group genetical studies on Australian Aborigines of Bentinck, Mornington and Forsyth Islands and mainland, Gulf of Carpentaria, together with frequencies for natives of the Western Desert, Western Australia. *Oceania* 35:66-80.

Simmons, R., N. Tindale and J. Birdsell 1962 A blood group genetical survey in Australian Aborigines of Bentinck, Mornington and Forsyth Islands, Gulf of Carpentaria. *American Journal of Physical Anthropology* 20:303-320.

Sloss, C. R., L. Nothdurft, L. Petherick, A. Sternes, S. Ulm and P. Moss 2012 Holocene sea-level change in the South Wellesley Islands, Gulf of Carpentaria, Australia: A pilot study. INQUA Congress, Bern, Switzerland. *Quaternary International* 279:454.

Smit, N., N. Gribble, W. Sumpton and B. Hill 2004 Crabs. In National Oceans Office (ed.), *Description of Key Species Groups in the Northern Planning Area*, pp.249-258. Hobart: National Oceans Office.

Smith, E.A. 1983 Anthropological applications of optimal foraging theory: A critical review. *Current Anthropology* 24:625-651.

Smith, E.A. 1991 *Inujjuamiut Foraging Strategies*. New York: de Gruyter.

Smith, E.A. and B. Winterhalder 1992 *Evolutionary Ecology and Human Behavior*. New York: Aldine de Gruyter.

Smith, I.W.G. 2004 Nutritional perspectives on prehistoric marine fishing in New Zealand. *New Zealand Journal of Archaeology* 24:5-31.

Smith, I. 2011 Meat *Weight, Nutritional and Energy Yield Values for New Zealand Archaeofauna. Otago Archaeological Laboratory Report 8*. Otago: Anthropology Department, University of Otago.

Smith, K. 1996 *Environmental Hazards: Assessing Risk and Reducing Disaster*. London: Routledge.

Smith, M.M. and R.J. McKay 1986 Haemulidae. In M.M. Smith and P.C. Heemstra (eds), *Smiths' Sea Fishes*, pp.564-571. Berlin: Springer-Verlag.

Sobel, E. and G. Bettles 2000 Winter hunger, winter myths: Subsistence risk and mythology among the Klamath and Modoc. *Journal of Anthropological Archaeology* 19:276-316.

Specht, R.L. and F.D. McCarthy 2005 The ‘Snake Woman Story’ of Hemple Bay, Groote Eylandt: An Enindilyyakwa legend of a tsunami in the Gulf of Carpentaria. *Proceedings of the Royal Society of Queensland* 112:77-82.

Spenneman, D.H.R. 1987 Availability of shellfish resources on prehistoric Tongatapu, Tonga: Effects of human predation and changing environment. *Archaeology in Oceania* 22(3):81-96.

Steadman, D.W. 1989 Extinctions of birds in eastern Polynesia: A review of the record and comparisons with other Pacific island groups. *Journal of Archaeological Science* 16:177-205.

Steadman, D.W. 1995 Prehistoric extinctions of Pacific island birds: Biodiversity meets zooarchaeology. *Science* 267:1123-1131.

Steadman, D.W. 2006 *Extinction and Biogeography of Tropical Pacific Birds*. Chicago: University of Chicago Press.

Stein, J.K. 1992 Sediment analysis of the British camp shell midden. In J.K. Stein (ed.), *Deciphering a Shell Midden*, pp.135-162. San Diego: Academic Press.

Stein, J.K., J.N. Deo and L.S. Phillips 2003 Big sites - short time: Accumulation rates in archaeological sites. *Journal of Archaeological Science* 30:297-316.

Steneck, R.S., M.H. Graham, B.J. Bourque, D. Corbett, J.M. Erlandson, J.A. Estes and M.J. Tegner 2002 Kelp forest ecosystems: Biodiversity, stability, resilience, and future. *Environmental Conservation* 29(4):436-459.

Stephens, D.W. and J.R. Krebs 1986 *Foraging Theory*. Princeton: Princeton University Press.

Stiner, M.C., and N.D. Munro 2002 Approaches to prehistoric diet breadth, demography and prey ranking systems in time and space. *Journal of Archaeological Method and Theory* 9:181-214.

Stiner, M.C., N.D. Munro and T.A. Surovell 2000 The tortoise and the hare: Smallgame use, the broad spectrum revolution and paleolithic demography. *Current Anthropology* 42:39-73.

Stiner, M.C., N.D. Munro, T.A. Surovell, E. Tchernov and O. Bar-Yosef 1999 Paleolithic population growth pulses evidenced by small animal exploitation. *Science* 283:190-194.

Stock, E. 2008 Report on Geology of Eengan (Yinhkan) Embayment. Unpublished manuscript held on file. Brisbane: Aboriginal Environments Research Centre, University of Queensland.

Stockton, J. 1982 Stone wall fish-traps in Tasmania. *Australian Archaeology* 14:107-114.

Sullivan, M.E. 1987 The recent prehistoric exploitation of edible mussel in Aboriginal shell middens in New South Wales. *Archaeology in Oceania* 22(3):97-106.

Sullivan, G.M. 1993 Post-Depositional Leaching of Shell in Two Northwest Coast Shell Middens. Unpublished MA thesis, University of Washington, Washington.

Sydney Fish Market 2015 Oyster Species Fact Sheet. Retrieved 1 April 2012 from www.sydneyfishmarket.com.au

Szabó, K. 2009 Molluscan remains from Fiji. In G. Clark and A. Anderson (eds), *The Early Prehistory of Fiji*, pp.183-211. Terra Australis 31. Canberra: ANU E Press.

Tegner, M.J. and P.K. Dayton 1991 Sea urchins, El Ninos, and the long term stability of southern California kelp forest communities. *Marine Ecology Progress Series* 77:49-63.

Tegner, M.J. and P.K. Dayton 2000 Ecosystem effects of fishing in kelp forest communities. *ICES Journal of Marine Science* 57:576-589.

Thomas F.R. 2001 Mollusk habitats and fisheries in Kiribati: An assessment from the Gilbert Islands. *Pacific Science* 55:77–97.

Thomas, F.R. 2002 An evaluation of central-place foraging among mollusk gatherers in western Kiribati, Micronesia: Linking behavioral ecology with ethnoarchaeology. *World Archaeology* 34:182-208.

Thomas, F.R. 2007a The behavioral ecology of shellfish gathering in western Kiribati, Micronesia. 1: Prey choice. *Human Ecology* 35:179-194.

Thomas, F.R. 2007b The behavioral ecology of shellfish gathering in western Kiribati, Micronesia. 2: Patch choice, patch sampling, and risk. *Human Ecology* 35:515-526.

Thomas, F.R. 2009 Historical ecology in Kiribati: Linking past with present. *Pacific Science* 63(4):567-600.

Thompson, R.M., M. Hemberg, B.M. Starzomski and J.B. Shurin 2007 Trophic levels and trophic tangles: The prevalence of omnivory in real food webs. *Ecology* 88(3):612-617.

Tindale, N.B. 1960 Field Journal of a Visit to Bentinck and Mornington Islands, Queensland. Adelaide: South Australian Museum Archives.

Tindale, N.B. 1962a Geographic knowledge of the Kaiadilt people of Bentinck island, Queensland. *Records of the South Australian Museum* 14:259-296.

Tindale, N.B. 1962b Some population changes among the Kaiadilt people of Bentinck Island, Queensland. *Records of the South Australian Museum* 14:297-318.

Tindale, N.B. 1977 Further report on the Kaiadilt people of Bentinck Island, Gulf of Carpentaria, Queensland. In J. Allen, J. Golson and R. Jones (eds), *Sunda and Sahul: Prehistoric Studies in Southeast Asia, Melanesia and Australia,* pp.247-273. London: Academic Press.

Titcomb, M. 1952 *Native Use of Fish in Hawaii*. Wellington: Polynesian Society Press.

Tomkins, H., D. Rosendahl and S. Ulm 2013 Tropical Archaeology Research Laboratory comparative fish reference collection: Developing a resource for identifying marine fish remains in archaeological deposits in tropical Australasia. *Queensland Archaeological Research* 16:1-14.

Torgersen, T., M.F. Hutchinson, D.E. Searle and H.A. Nix 1983 General bathymetry of the Gulf of Carpentaria and the Quaternary physiography of Lake Carpentaria. *Palaeogeography, Palaeoclimatology, Palaeoecology* 41(3-4):207-225.

Torgersen, T., M.R. Jones, A.W. Stephens, D.E. Searle and W.J. Ullman 1985 Late Quaternary hydrological changes in the Gulf of Carpentaria. *Nature* 313(28):785-787.

Torgersen, T., J. Luly, P. De Deckker, M.R. Jones, D.E. Searle, A.R. Chivas and W.J. Ullman 1988 Late Quaternary environments of the Carpentaria Basin, Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 67(3-4):245-261.

Trigger, D.S. 1987 Inland, coast and islands: Traditional Aboriginal society and material culture in a region of the southern Gulf of Carpentaria. *Records of the South Australian Museum* 21(2):69-84.

Ulm, S. 2002 Reassessing marine fishery intensification in southeast Queensland. *Queensland Archaeological Research* 13:79-96.

Ulm, S. 2006 *Coastal Themes: An Archaeology of the Southern Curtis Coast, Queensland*. Terra Australis 24. Canberra: ANU E Press.

Ulm, S. 2011 Coastal foragers on southern shores: Marine resource use in northeast Australia since the late Pleistocene. In N.F. Bicho, J.A. Haws and L.G. Davis (eds), *Trekking the Shore: Changing Coastlines and the Antiquity of Coastal Settlement*, pp.441-461. Interdisciplinary Contributions to Archaeology. New York: Springer.

Ulm, S. 2013 'Complexity' and the Australian continental narrative: Themes in the archaeology of Holocene Australia. *Quaternary International* 285:182-192.

Ulm, S., G. Jacobsen, P. Memmott, R. Robins and I. Lilley 2010 Marine Carbon Reservoir Variability in the Southern Gulf of Carpentaria: Progress Report for AINGRA09025. Retrieved 29 July 2015 from http://ainse.edu.au/__data /assets/pdf_file/0011/48638/r_09025.pdf

Ulm, S., N. Evans, D. Rosendahl, P. Memmott and F. Petchey 2010 Radiocarbon and linguistic dates for occupation of the South Wellesley Islands, northern Australia. *Archaeology in Oceania* 45(1):39-43.

Ulm, S. and J. Hall 1996 Radiocarbon and cultural chronologies in southeast Queensland prehistory. In S. Ulm, I. Lilley and A. Ross (eds), *Australian Archaeology '95: Proceedings of the 1995 Australian Archaeological Association Annual Conference*, pp.45-62. Tempus 6. Brisbane: Anthropology Museum, University of Queensland.

Ulm, S. and J. Reid 2000 Index of dates from archaeological sites in Queensland. *Queensland Archaeological Research* 12:1-129.

Ulm, S. and D. Vale 2006 The antiquity of marine fishing in southeast Queensland: New evidence for pre-2000 BP fishing from three sites on the southern Curtis Coast. In S. Ulm and I. Lilley (eds.), *An Archaeological Life: Papers in Honour of Jay Hall*, pp.161-176. Research Report Series 7. Brisbane: Aboriginal and Torres Strait Islander Studies Unit, University of Queensland.

Vale, D. and R.H. Gargett 2002 Size matters: 3-mm sieves do not increase richness in a fishbone assemblage from Arrawarra I, an Aboriginal Australian shell midden on the mid-north coast of New South Wales, Australia. *Journal of Archaeological Science* 29(1):57-63.

Vallance, T.G., D.T. Moore and E.W. Groves 2001 *Nature's Investigator: The Diary of Robert Brown in Australia, 1801-1805*. Canberra: ABRS.

van Holst Pellekaan, S.M., M. Ingman, J. Roberts-Thomson and R. M. Harding 2006 Mitochondrial genomics identifies major haplogroups in Aboriginal Australians. *American Journal of Physical Anthropology* 131(2):282-294.

Van Neer, W., A. Ervynck, L. Bolle, R.S. Millner and A.D. Rijnsdorp 2002 Fish otoliths and their relevance to archaeology: An analysis of medieval, post-medieval and recent material of plaice, cod and haddock from the North Sea. *Environmental Archaeology* 7:61-76.

Veth, P., K. Aplin, L. Wallis, T. Manne, T. Pulsford, E. White and A. Chappell 2007 *The Archaeology of Montebello Islands, North-West Australia: Late Quaternary Foragers on an Arid Coastline*. BAR International Series S1668. Oxford: Archaeopress.

Veth, P., I. Ward and T. Manne 2016 Coastal Feasts: A Pleistocene Antiquity for Resource Abundance in the Maritime Deserts of North West Australia? *The Journal of Island and Coastal Archaeology* DOI:10.1080/15564894.2015.113279

Vlieg, P. 1988 *Proximate Composition of New Zealand Marine Finfish and Shellfish*. Palmerston North: Biotechnology Division, Department of Scientific and Industrial Research.

Walker, T. 1991 The Wellesley Islands, Gulf of Carpentaria. Report to the Queensland Environmental Protection Agency.

Walters, I. 1989 Intensified fishery production at Moreton Bay, southeast Queensland, in the late Holocene. *Antiquity* 63:215-224.

Walters, I. 1992 Seasonality of fishing in south-east Queensland. *Queensland Archaeological Research* 9:29-34.

Wanner, H., J. Beer, J. Butikofer, T.J. Crowley, U. Cubasch, J. Fluckiger, H. Goosse, M. Grosjean, F. Joos, J.O. Kaplan, M. Kuttel, S.A. Muller, I.C. Prentice, O. Solomina, T.F. Stocker, P. Tarasov, M. Wagner and M. Widmann 2008 Mid- to late Holocene climate change: An overview. *Quaternary Science Reviews* 27(19-20):1791-1828.

Waselkov, G.A. 1987 Shellfish gathering and shell midden archaeology. *Advances in Archaeological Method and Theory* 10:93-210.

Weisler, M.I. 1993 The importance of fish otoliths in Pacific island archaeofaunal analysis. *New Zealand Journal of Archaeology* 15:131-159.

Weisler, M.I. and I.J. McNiven 2015 Four thousand years of western Torres Strait fishing in the Pacific-wide context. *Journal of Archaeological Science: Reports*.

Weissner, P. 1977 Hxaro: A Regional System of Reciprocity for Reducing Risk Among the !Kung San. Unpublished PhD thesis, University of Michigan, Ann Arbor.

Weissner, P. 1982 Beyond willow smoke and dogs' tails: A comment on Binford's analysis of hunter-gatherer settlement systems. *American Antiquity* 47:171-178.

Whitaker, A.R. 2008 Incipient aquaculture in prehistoric California?: Long-term productivity and sustainability vs. immediate returns for the harvest of marine invertebrates. *Journal of Archaeological Science* 35(4):1114-1123.

Whitaker, A.R. and B.F. Byrd 2014 Social circumscription, territoriality, and the late Holocene intensification of small-bodied shellfish along the California coast. *Journal of Island and Coastal Archaeology* 9(2):150-168.

White, E. 2011 Heiltsuk stone fish traps on the central coast of British Columbia. In M.L. Moss and A. Cannon (eds), *The Archaeology of North Pacific Fisheries*, pp.75-90. Fairbanks: University of Alaska Press.

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

White, T.E. 1953 A method of calculating the dietary percentage of various food animals utilized by Aboriginal peoples. *American Antiquity* 18(4):396-398.

Wickler, S. 2001 *The Prehistory of Buka: A Stepping Stone Island in the Northern Solomons.* Terra Australis 16. Canberra: Department of Archaeology and Natural History and Centre for Archaeological Research, Australian National University.

Wightman, G., K. Danaher, M. Dunning, J. Beumer and M. Michie 2004 Mangroves. In National Oceans Office (ed.), *Description of Key Species Groups in the Northern Planning Area*, pp.23-34. Hobart: National Oceans Office.

Willan, R.C. 2013 A key to the potamidid snails (longbums, mudcreepers and treecreepers) of northern Australia. *Northern Territory Naturalist* 24:68-80.

Willan, R. and M. Dredge 2004 Molluscs. In National Oceans Office (ed.), *Description of Key Species Groups in the Northern Planning Area*, pp.201-216. Hobart: National Oceans Office.

Williams, A., G. Begg, R. Marriott, R. Garrett, G. McPherson, W. Sumpton, H. Larson, S. Griffiths and J. Lloyd 2004 Snappers and emperors. In National Oceans Office (ed.), *Description of Key Species Groups in the Northern Planning Area,* pp.157-170. Hobart: National Oceans Office.

Williams, A.N., S. Ulm, I.D. Goodwin and M. Smith 2010 Hunter-gatherer response to late Holocene climatic variability in northern and central Australia. *Journal of Quaternary Science* 25(6):831-838.

Williams, A.N., P. Veth, W. Steffen, S. Ulm, C. Turney, J. Reeves, S.J. Phipps and M. Smith 2015 A continental narrative: Human settlement patterns and Australian climate change over the last 35,000 Years. *Quaternary Science Reviews* 123:91-112.

Williams A.N., S. Ulm, C.S.M. Turney, D. Rohde and G. White 2015 Holocene Demographic Changes and the Emergence of Complex Societies in Prehistoric Australia. *PLoS ONE* 10(6):e0128661. Available online at doi:10.1371/journal.pone.0128661

Williams, R.J. and N.D. Martinez 2000 Simple rules yield complex food webs. *Nature* 404:180-183.

Williams, R.J. and N.D. Martinez 2008 Success and its limits among structural models of complex food webs. *Journal of Animal Ecology* 77:512-519.

Wing, E.S. 2001 The sustainability of resources used by Native Americans on four Caribbean islands. *International Journal of Osteoarchaeology* 11:112-126.

Winterhalder, B. 1981 Optimal foraging strategies and hunter-gatherer research in anthropology: Theory and models. In B. Winterhalder and E.A. Smith (eds), *Hunter-Gatherer Foraging Strategies: Ethnographic and Archaeological Analyses*, pp.13-35. Chicago: The University of Chicago Press.

Winterhalder, B. and D.J. Kennett 2006 Behavioral ecology and the transition from hunting and gathering to agriculture. In D.J. Kennett and B. Winterhalder (eds), *Behavioral Ecology and the Transition to Agriculture*, pp.1-21. Berkeley: University of California Press.

Winterhalder, B. and D.J. Kennett 2009 Four neglected concepts with a role to play in explaining the origins of agriculture. *Current Anthropology* 50(5):645-648.

Winterhalder, B., F. Lu and B. Tucker 1999 Risk-sensitive adaptive tactics: Models and evidence from subsistence studies in biology and anthropology. *Journal of Archaeological Research* 7:301-348.

Winterhalder, B. and E.A. Smith 1992 Evolutionary ecology and the social sciences. In E.A. Smith and B. Winterhalder (eds), *Evolutionary Ecology and Human Behavior*, pp.3-23. New York: Aldine de Gruyter.

Winterhalder, B. and E.A Smith 2000 Analyzing adaptive strategies: Human behavioural ecology at twenty-five. *Evolutionary Anthropology* 9:51-72.

Woodroffe, C.D. 1988 Changing mangrove and wetland habitats over the last 8000 years, northern Australia and South-East Asia, In D. Wade-Marshall and P. Loveday (eds), *Floodplains Research. Northern Australia: Progress and Prospects,* pp.1-33. Volume 2. Darwin: North Australian Research Unit, The Australian National University, Darwin.

Woodroffe, C.D. and J. Chappell 1993 Holocene emergence and evolution of the McArthur River delta, southwestern Gulf of Carpentaria, Australia. *Sedimentary Geology* 83(3-4):303-317.

Woodroffe, C.D., J.M. Chappell and B.G. Thom 1988 Shell middens in the context of estuarine development, South Alligator River, Northern Territory. *Archaeology in Oceania* 23(3):95-103.

Woodroffe, C.D., J. Chappell, B.G. Thom and E. Wallensky 1986 *Geomorphological Dynamics and Evolution of the South Alligator Tidal River and Plains, Northern Territory*. Mangrove Monograph 3. Darwin: The Australian National University, North Australian Research Unit.

Woodroffe, C.D. and D. Grime 1999 Storm impact and evolution of a mangrove-fringed chenier plain, Shoal Bay, Darwin. Australia. *Marine Geology* 159:303-321.

Woodroffe, C.D., D.M. Kennedy, D. Hopley, C.E. Rasmussen and S.G. Smithers 2000 Holocene reef growth in Torres Strait. *Marine Geology* 170(3-4):331-346.

WoRMS Editorial Board 2016 World Register of Marine Species. Retrieved on 21 January 2015 from http://www.marinespecies.org at VLIZ.

Wright, D. 2011 Mid Holocene maritime economy in the western Torres Strait. *Archaeology in Oceania* 46(1):23-27.

Yearsley, G.K., P.R. Last and R.D. Ward 2001 *Australian Seafood Handbook: An Identification Guide to Domestic Species*. Hobart: CSIRO Division of Marine Research.

Zeder, M.A. 2012 The Broad Spectrum Revolution at 40: Resource diversity, intensification, and an alternative to optimal foraging explanations. *Journal of Anthropological Archaeology* 31(3):241-264.

Zori, C. and E. Brant 2012 Managing the risk of climatic variability in late prehistoric northern Chile. *Journal of Anthropological Archaeology* 31(3):403-421.

Appendix 1. Fish and Vertebrate Species Recorded for the South Wellesley Islands.

[based on observational surveys undertaken by Malcolm (1998) and Johnson and Gill (2005)]

Family	Species	Common Name	Kayardild Name (Evans 1992:282-284, Paul et al. 2009)	Abundance of sightings common = 10-100 records of sightings or catches; abundant = 100+ records
Carcharhinidae	*Carcharhinus amblyrhynchoides*	grey reef shark	wirningathi	common
Ginglymostomatidae	*Nebrius ferrugineus*	tawny shark	wirningathi	rare
Clupeidae	*Herklotsichthys lippa*	pilchards	balila	abundant
Clupeidae	*Herklotsichthys quadrimaculatus*	gold-spot herring	wurubarra	abundant
Clupeidae	*Spratelloides deicatulus*	northern blue sprat	yirrbi	common
Clupeidae	*Nematalosa come*	hairback herring	yukanja	rare
Engraulidae	*Stolephorus carpentariae*	Carpentaria anchovy	miburalngka	common
Chanidae	*Chanos chanos*	milkfish	?	uncommon
Ariidae	*Arius graeffei*	sea catfish	bambalt	common
Plotosidae	*Paraplotosus albilabris*	white-lipped catfish eel	kulirra	common
Synodontidae	*Synodus sp.*	reef grinner	kulutha	common
Batrachoididae	*Batrachomoeus trispinosus*	threespine frogfish	thungalngumuwuru	rare
Batrachoididae	*Halophryne diemensis*	banded frogfish	thungalngumuwuru	uncommon
Hemiramphidae	*Hyporhamphus dussumieri*	slender garfish	bidaralkuru	abundant
Hemiramphidae	*Arrhamphus sclerolepsis*	snubnose garfish	jarrjarrp	common
Belonidae	*Tylosurus gavialoides*	stout longtom	karrmuku	common
Atherinidae	*Atherinomorus endrachtensis*	hardyhead	?	abundant

Atherinidae	*Craterocephalus mugiloides*	freshwater hardyhead	?	abundant
Holocentridae	*Sargocentron rbrum*	red squirrelfish	kamarrmadinda	common
Syngnathidae	*Choeroichthys brachysoma*	Pacific shortbody pipefish	?	common
Syngnathidae	*Halicampus dunckeri*	ridgenose pipefish	?	rare
Syngnathidae	*Lissocampus fatiloquus*	prophet's pipefish	?	rare
Scorpaenidae	*Parascorpaena picta*	painted scorpionfish	?	common
Centrogenyiidae	*Centrogenys waigiensis*	false scorpionfish	?	common
Platycephalidae	*Platycephalus arenarius*	sand flathead	burruth	common
Platycephalidae	*Platycephalus endrachtensis*	yellowtail flathead	miburjuluru	abundant
Platycephalidae	*Cymbacephalus nematophthalmus*	fringe-eyed flathead	miburjuluru	common
Platycephalidae	*Cymbacephalus bosschei*	smalleye flathead	miburjuluru	uncommon
Platycephalidae	*Cymbacephalus staigeri*	northern rock flathead	miburjuluru	uncommon
Latidae	*Psammoperca waigiensis*	sand bass	burbada	common
Latidae	*Lates calcarifer*	barramundi	kurndawurnda	uncommon
Serranidae	*Epinephelus coiodes*	estuary cod	duju	abundant
Serranidae	*Epinephelus coralicola*	coral rockcod	kirdi	common
Serranidae	*Epinephelus fuscoguttatus*	flowery cod	dibidibi	common
Serranidae	*Epinephelus polyphekadion*	bluetailed cod	kambu	common
Serranidae	*Epinephelus quoyanus*	longfin cod	kirrmurndu	common
Serranidae	*Plectropomus maculatus*	bar cheeked trout	darurrka	common
Serranidae	*Epinephelus fasciatus*	blacktip rockcod	kambu	rare
Serranidae	*Epinephelus lanceolatus*	Queensland groper	duju	rare
Serranidae	*Cephalopholis boenack*	brownbarred rockcod	kambu	uncommon
Pseudochromidae	*Pseudochromis wilsoni*	dottyback	?	abundant

Pseudochromidae	*Congrogadus subducens*	dottyback	?	common
Terapontidae	*Amniataba caudavittatus*	yellowtail perch / trumpeter	barduwardu, warukarra	common
Terapontidae	*Pelates sexlineatus*	eastern striped grunter	barduwardu, warukarra	common
Terapontidae	*Pelates quadrilineatus*	trumpeter	barduwardu, wankarra	common
Apogoniidae	*Apogon pallidofasciatus*	palestriped cardinalfish	?	abundant
Apogoniidae	*Apogon doederleini*	fourline cardinalfish	?	common
Apogoniidae	*Apogon ruppellii*	western gobbleguts	?	common
Apogoniidae	*Fowleria variegata*	variegated cardinalfish	?	common
Apogoniidae	*Pseudamia nigra*	estuary cardinalfish	?	rare
Apogoniidae	*Apogon brevicaudatus*	manyband cardinalfish	?	uncommon
Sillaginidae	*Sillago snslid*	golden lined whiting	rukuruku	abundant
Sillaginidae	*Sillago burrus*	trumpeter whiting	rukuruku	abundant
Carangidae	*Caranx bucculentus*	bluespotted trevally	ngarrawuru	common
Carangidae	*Caranx ignobilis*	giant trevally	waradawuru	common
Carangidae	*Gnathanodon speciosus*	golden trevally	ngarrawuru	common
Carangidae	*Caranx papuensis*	brassy trevally	thardawukarr	common
Carangidae	*Scomberoides commersonianus*	tang queenfish	karwarrk	common
Carangidae	*Alepes vari*	herring scad	yarinyarra	uncommon
Rachycentridae	*Rachycentron canadus*	cobia / kingfish	murrkurdi	rare
Leiognathidae	*Leiognathus decorus*	ornate ponyfish	bardabarda	common
Leiognathidae	*Leiognathus spledens*	blacktip ponyfish	bardabarda	common
Lutjanidae	*Lutjanus carponotatus*	stripey	thakund	common
Lutjanidae	*Lutjanus johnii*	fingermark	karnarnurru	common
Lutjanidae	*Lutjanus malabaricus*	red jew / nannygai	burbarda	common

Lutjanidae	*Lutjanus russelli*	moses perch	burbarda	common
Lutjanidae	*Lutjanus sebae*	red emperor	karndukarndu	common
Caesionidae	*Caesio cuning*	red-bellied fusilier	kangkuru	common
Nemipteridae	*Scaevius milii*	coral monacle bream	marndawanda yakuri	abundant
Nemipteridae	*Pentapodus paradiseus*	paradise threadfin bream	marndawanda yakuri	uncommon
Nemipteridae	*Scolopsis monogramma*	rainbow monocle bream	marndawanda yakuri	uncommon
Gerreidae	*Gerres subfasciatus*	common silver-belly / -biddy	waribanda	abundant
Gerreidae	*Gerres oyena*	black tip silver biddy	waribanda	common
Gerreidae	*Gerres filamentosus*	threadfin silver biddy	waribanda	uncommon
Haemulidae	*Plectorhynchus multivittatum*	many line sweetlips	mirri	abundant
Haemulidae	*Plectorhynchus gibbosus*	brown sweetlips / blubberlips	mirri	common
Haemulidae	*Plectorhynchus albovittatus*	giant two-striped sweetlips	mirri	rare
Haemulidae	*Diagramma pictum*	painted sweetlips / morwong	damulurra	uncommon
Lethrinidae	*Lethrinus laticaudis*	grass emperor	karnurruru	abundant
Sparidae	*Acanthopagrus latus*	yellowfin bream	kurrangk	common
Sciaenidae	*Protonibea diacanthus*	black jewfish	dubunda	common
Mullidae	*Upeneus tragula*	bar tailed goatfish	teraglin	common
Pempheridae	*Pempheris ypsilychnus*	sweeper	?	common
Ephippidae	*Platax teira*	roundface batfish	bungkal-balanda	rare
Ephippidae	*Zabidius novemaculeatus*	shortfin batfish	kurrbangka	rare
Chaetodontidae	*Chelmon marginalis*	margined coralfish	marndawanda yakuri	abundant
Chaetodontidae	*Chelmon muelleri*	black-fin coralfish	marndawanda yakuri	common
Chaetodontidae	*Parachaetodon ocellatus*	ocellate butterflyfish	marndawanda yakuri	rare
Pomacanthidae	*Chaetodontoplus duboulayi*	scribbled angelfish	kamarmadinda	uncommon

Pomacentridae	*Pomacentrus littoralis*	damselfish	kamarmadinda	abundant
Pomacentridae	*Pomacentrus milleri*	millers damsel	kamarmadinda	abundant
Pomacentridae	*Abudefduf bengalensis*	bengel sergeant	kamarmadinda	common
Pomacentridae	*Stegastes obreptus*	western gregory	kamarmadinda	common
Mugilidae	*Liza vaigiensis*	diamond-scale mullet	duburrk	common
Mugilidae	*Valamugil georgii*	fantail mullet	bininya	common
Mugilidae	*Valamugil seheli*	blue-tailed mullet	warndaa	common
Sphyraenidae	*Sphyraena flavicauda*	barracuda	ralkaralka	uncommon
Sphyraenidae	*Sphyraena obtusata*	striped barracuda	balamarra	uncommon
Labridae	*Choerodon cyanodus*	blue tuskfish	ngarrawurn	abundant
Labridae	*Choerodon schoenleinii*	blackspot tuskfish	walarrawu	abundant
Labridae	*Halichoeres nigrescens*	rainbowfish	marndawanda yakuri	abundant
Labridae	*Choerodon cephalotes*	purple tuskfish	burrurri	common
Scaridae	*Scarus ghobban*	blue barred parrot	karakara	common
Blenniidae	*Omobranchus rotundiceps*	rotund blenny	?	abundant
Blenniidae	*Laiphognathus multimaculatus*	manyspot blenny	?	common
Blenniidae	*Omobranchus germaini*	Germain's blenny	?	common
Blenniidae	*Omobranchus punctatus*	muzzled blenny	?	common
Blenniidae	*Omobranchus lineolatus*	roundhead blenny	?	uncommon
Tripterygiidae	*Enneapterygius gracilis*	three-fin blenny	?	abundant
Gobiidae	*Amblygobius bynoensis*	shrimp goby	kambulukambulu	abundant
Gobiidae	*Bathygobius laddi*	Ladd's frill goby	kambulukambulu	abundant
Gobiidae	*Drombus triangularis*	brown drombus	kambulukambulu	abundant
Gobiidae	*Eviota quenslandica*	Queensland eviota	kambulukambulu	abundant

Gobiidae	*Bathygobius fuscus*	dusky frill goby	kambulukambulu	common
Gobiidae	*Cryptocentrus leptocephalus*	pinkspot shrimp goby	kambulukambulu	common
Gobiidae	*Cryptocentrus strigiliceps*	target shrimp goby	kambulukambulu	common
Gobiidae	*Eviota zebrina*	zebra eviota	kambulukambulu	common
Gobiidae	*Istigobius nigrocellatus*	blackspotted sand goby	kambulukambulu	common
Gobiidae	*Priolepis nuchifastciatus*	threadfin reef goby	kambulukambulu	common
Gobiidae	*Silhouettea evanidae*	vanishing silhoutte goby	kambulukambulu	common
Gobiidae	*Yongeichthys nebulosus*	shadow goby	kambulukambulu	common
Gobiidae	*Valenciennea alleni*	aliens goby	kambulukambulu	common
Gobiidae	*Periophthalmus argentilineatus*	silverlined mudskipper	kambulukambulu	common
Gobiidae	*Gobiopsis aporia*	poreless barbel goby	kambulukambulu	uncommon
Acanthuridae	*Acanthurus grammoptilus*	inshore surgeonfish	marndawanda yakuri	common
Siganidae	*Siganus fuscescens*	dusky rabbitfish	jardiyardi	abundant
Siganidae	*Siganus lineatus*	goldlined rabbitfish	miyarlda	uncommon
Scombridae	*Scomberomorus commerson*	spanish mackeral	karwarrk	common
Scombridae	*Scomberomorus semifasciatus*	grey mackeral	karwarrk	common
Scombridae	*Thunnus tonggoi*	longtail tuna	duluka	common
Bothidae	*Engyprosopon grandisquama*	spottail wide-eyed flounder	burrutha	common
Paralichthyidae	*Pseudorhombus arsius*	large-toothed flounder	burrutha	common
Paralichthyidae	*Pseudorhombus quinquocellatus*	five-eye flounder	burrutha	rare
Soleidae	*Aseraggodes* sp.	sole	jabarda	rare
Cynoglossidae	*Paraplagusia bilineata*	lemon tongue sole	murimuri	rare
Monacanthidae	*Monacanthus chinesis*	fan-bellied leatherjacket	thuwalka	common
Tetraodontidae	*Torquigener whitleyi*	Whitley's toadfish	thungalngumuwuru	rare

Diodontidae	*Diodon hystrix*	spotted porcupinefish	juluru	rare
Cheloniidae	*Chelonia mydas*	green turtle		common
Cheloniidae	*Natator depressus*	Flatback turtle		rare
Cheloniidae	*Carreta carreta*	Loggerhead turtle		rare
Cheloniidae	*Eretmochelys imbricata*	Hawksbill turtle		rare
Cheloniidae	*Dermochelys coriacea*	Leatherback turtle		rare
Dugongidae	*Dugong dugon*	Dugong		common

Appendix 2. Molluscan Species Recorded for the South Wellesley Islands.

[based on personal observational surveys and presence in archaeological sites]

TAXON	FAMILY	DANGKANKURUWURU	THUNDIY	WIRRNGAJI	NALKURDALAYARRB	MURDUMURDU	WARDILMIRU	BANBANBARUKEIND	JIRRKAMIRNDIYARRB	RESOURCE PATCH	Description of Habitat
Acrosterigma reeveanum	Cardiidae									Sandy-Mud Flats	coral sands and muddy sands in sheltered areas
Anadara antiquata	Arcidae									Sandy-Mud Flats	intertidal sandy-muds
Anadara rufescens	Arcidae									Sandy-Mud Flats	intertidal sandy-muds
Arca sp.	Arcidae		X							Rocky and Coral Reefs	bysally attached on rocks, corals
Asaphis violascens	Psammobidae	X	X	X	X	X		X		Sandy-Mud Flats	deeply buried littoral sand, coarse gravelly bottoms
Barbatia sp.	Arcidae	X	X	X			X			Rocky and Coral Reefs	rock/debris in littoral area, coral reefs
Beguina semiobiculata	Carditidae		X	X	X	X		X		Rocky and Coral Reefs	coral, rock or shell debris
Calliostoma sp.	Calliostomatidae	X	X	X		X	X	X		Rocky and Coral Reefs	rocky seaweed

Cardiidae	Cardiidae	X	X			X				Sandy-Mud Flats	intertidal sand and mud littoral
Cerithidea anticipata	Potamididae									Mangroves and Mud Flats	mangrove muds
Cerithidea cingulata	Potamididae	X	X			X	X			Mangroves and Mud Flats	mud flats near mangroves and estuaries
Cerithidea largillierti	Potamididae		X							Mangroves and Mud Flats	high intertidal in mangroves
Cerithidea sp.	Cerithiidae	X	X	X		X	X	X	X	Mangroves and Mud Flats	mangrove roots (*Avicennia, Bruguiera*) shallow mud
Cerithium coralium	Chamidae	x	X							Mangroves and Mud Flats	midtidal mud flats of estuarine and mangrove areas
Chama sp.	Veneridae	X	X			X				Rocky and Coral Reefs	Coral, Rock or Shell debris
Circe scripta	Cerithiidae	X	X		X	X	X	X		Sandy-Mud Flats	intertidal sand and mud littoral
Clypeomorus sp.	Cardiidae	X	X			X	X	X		Sandy-Mud Flats	sandy bottoms of reef flats and intertidal
Codakia tigerina	Lucinidae		X							Sandy-Mud Flats	sandy bottoms of reef flats and intertidal
Corbula fortisulcata	Corbulidae	X	X	X		X	X			Sandy-Mud Flats	intertidal sand and mud littoral
Cypraea sp.	Cypraeaidae		X							Rocky and Coral Reefs	rock/debris in littoral area, coral reefs
Ellobium sp.	Ellobiidae		X							Mangroves and Mud Flats	mangroves
Euchelus atratus	Chilodontidae		X							Rocky and Coral Reefs	rocky reefs

Gafrarium pectinatum	Veneridae	X	X	X	X	X	X	X	X	Sandy-Mud Flats	Littoral Sandy-mud
Geloina erosa	Corbiculidae	X	X					X	X	Mangroves and Mud Flats	coastal rivers, estuaries, mangroves
Glauconome virens	Glauconomidae	X	X			X		X		Mangroves and Mud Flats	mud flats near mangroves and estuaries
Irus sp.	Veneridae	X			X					Rocky and Coral Reefs	rocky reefs
Isognomon isognomon	Isognomonidae	X	X	X	X		X	X	X	Mangroves and Mud Flats	mangroves
Littoraria scabra	Littorinidae		X				X			Mangroves and Mud Flats	tree roots mangroves
Lunulicardia hemicardium	Cardiidae	X	X			X			X	Sandy-Mud Flats	intertidal sand and mud littoral
Lunella cinerea	Turbinidae	X	X		X		X			Rocky and Coral Reefs	rocky reef
Mactra sp.	Mactridae	X	X			X				Sandy-Mud Flats	littoral sand
Mactra dissimilis	Mactridae				X					Sandy-Mud Flats	sandy bottoms sublittoral
Marcia hiantina	Veneridae	X	X	X	X	X	X	X	X	Sandy-Mud Flats	littoral sand
Melo amphora	Volutidae	X	X	X	X		X		X	Sandy-Mud Flats	lower intertidal and sib-tidal sandy mud
Mitra sp.	Mitridae	X								Sandy-Mud Flats	sandy bottoms of reef flats and intertidal
Mitrella scripta	Collumbellidae		X			X	X			Rocky and Coral Reefs	coral reefs and rocky shores, low intertidal

Mytilidae	Mytilidae	x	X	X	X	X	X	X		Rocky and Coral Reefs	rocky reefs
Nassarius coronatus	Nassariidae		X							Sandy-Mud Flats	clean sandy bottoms
Nassarius sp.	Nassariidae		X			X				Sandy-Mud Flats	clean sandy bottoms
Neotrapezium sublaevigatum	Trapezidae		X							Rocky and Coral Reefs	byssally attached on rocks, corals
Nerita balteata	Neritidae	X	X					X		Mangroves and Mud Flats	intertidal mud and rock bottoms in mangrove areas
Nerita planospira	Neritidae		X							Mangroves and Mud Flats	intertidal mud and rock bottoms in mangrove areas
Nerita sp.	Neritidae	X	X	X					X	Mangroves and Mud Flats	mangrove roots / rocks
Nerita undata	Neritidae		X							Rocky and Coral Reefs	intertidal rocks
Oliva lignaria	Olividae									Sandy-Mud Flats	sandy intertidal and subtidal
Patellidae	Patellidae	X	X	X	X	X	X	X	X	Rocky and Coral Reefs	rocks
Pinctada sp.	Pteridae				X	X			X	Rocky and Coral Reefs	attached to substrate in intertidal subtidal areas
Pinnidae	Pinnidae									Rocky and Coral Reefs	sand and mud around rocks and corals
Pitar pellucidus	Veneridae		X			X				Sandy-Mud Flats	fine sandy bottoms intertidal and shallow sublittoral
Placamen retroversum	Veneridae	X	X			X				Sandy-Mud Flats	littoral sand

Placuna placenta	Placunidae		X			X				Mangroves and Mud Flats	surface of mud near mangroves
Planaxis sulcatus	Planaxidae	X	X				X	X		Rocky and Coral Reefs	upper rocks intertidal
Polinices sp.	Naticidae		X	X						Sandy-Mud Flats	sandy bottoms sublittoral
Saccostrea glomerata	Ostreidae	X	X	X	X	X	X	X	X	Rocky and Coral Reefs	rocks
Pyrene sp.	Collumbellidae	X								Rocky and Coral Reefs	coral reefs and rocky shores, low intertidal
Rhinoclavis sp.	Cerithidae	X	X	X		X	X	X		Sandy-Mud Flats	sandy bottoms sublittoral
Semele sinensis	Semelidae	X	X			X	X	X		Mangroves and Mud Flats	mud flats near mangroves and estuaries
Solen sp.	Solenidae									Sandy-Mud Flats	littoral sandy-mud
Strombus sp.	Strombidae				X			X		Sandy-Mud Flats	sandy bottoms of reef flats and intertidal
Tegillarca granosa	Arcidae		X							Mangroves and Mud Flats	mud flats near mangroves and estuaries
Telescopium telescopium	Potamididae	X	X	X			X	X		Mangroves and Mud Flats	mangroves (*Rhizophora*)
Tellina sp.	Tellinidae		X			X	X	X		Sandy-Mud Flats	littoral sandy-mud
Terebralia palustris	Potamididae									Mangroves and Mud Flats	littoral sandy-mud
Terebralia sulcata	Potamididae	X	X	X	X		X	X	X	Mangroves and Mud Flats	mangroves (*Avicennia*, *Bruguiera*, *Ceriops*)

Trisidos tortuosa	Arcidae		X							Mangroves and Mud Flats	sand and mud in shallow water
Trochus sp.	Trochidae		X	X	X				X	Rocky and Coral Reefs	coral reefs and rocky shores, low intertidal
Turbo sp.	Turbinidae	X	X	X	X	X			X	Rocky and Coral Reefs	shallow water rocks
Turitella terebra	Turitellidae									Sandy-Mud Flats	subtidal soft sandy-muds
Volegalea cochlidium	Melongenidae	X	X	X		X				Mangroves and Mud Flats	sand and mud in shallow water