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exploitation during the earliest period of human occupation of Western (Koroa) settlement, southwest Viti Levu, Fiji
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July 2004

EF
CHANGES IN PATTERNS OF MARINE-RESOURCE (SHELLFISH) EXPLOITATION DURING THE EARLIEST PERIOD OF HUMAN OCCUPATION (1200/1100 BC TO 700/600 BC) OF BOUREWA (LAPITA) SETTLEMENT, SOUTHWEST VITI LEvu ISLAND, FIJI.

by

Tony Ahikau Heorake

A thesis submitted in fulfillment of the requirement for the degree of Master of Science in Environmental Science

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Division of Geography
School of Islands and Oceans
Faculty of Science, Technology and Environment
The University of the South Pacific

December, 2009
DECLARATION

I, Tony Ahikau Heorake declare that this thesis is the product entirely of my own work except where due acknowledgement is made in the text. It has not been submitted for a higher degree at any other academic institution.

Signature .................................. Date .............. 4-12-2009 ..............

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The research in this thesis was performed under my supervision and to my knowledge is the sole work of Mr. Tony Ahikau Heorake.

Signature .................................. Date .............. 3.12.04 ..............

Name: Professor Patrick D. Nunn

Designation: Pro Vice-Chancellor (Research and Innovation) and Supervisor
Dedication

This thesis is dedicated in honour and memory of Diana Su’uliseuha’akenitaoha-Heorake for her inspiration.

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Abstract

This thesis examines the changes in patterns of marine-resources (shellfish) exploitation during the earliest period of human occupation (1200/1100 BC to 700/600 BC) of Bourewa (Lapita) settlement, southwest Viti Levu Island, Fiji. The goal of this thesis is to analyse and report on the shellfish exploitation at the Bourewa site and explain the composition of the shell assemblage and factors that influence change over time. Shellfish quantification methods like NISP, MNI, Weight and Size have been utilised to address the composition and structure of the shell midden. Radiocarbon dates were obtained from four (4) shallow marine shells of Pits X2 and X3, while additional dates were taken during other field seasons. Optimal foraging theory models are also used to assess variability in shellfish abundance and foraging efficiency throughout the sites occupation. The data analysis has revealed some small but important shifts in shellfish variability from bottom to top of the midden. There is an apparent reduction in the shell size of most common bivalves and an increase in the exploitation of smaller shellfish species which indicate a shift in shellfish and habitat use over time – from Shoreline Sandy/Muddy species to Intertidal/Coral Reef species. Other shellfish species like *Tridacna gigas* and *Hippopus hippopus* were present during Lapita times but are now extirpated in Fiji. The sustained predation on the shellfish population at Bourewa also resulted in a broadening of the resource base (diet breadth) as large abundant species are preferentially exploited and adversely impacted. The changes in shellfish species and habitats also reflect changing sea level after the mid-Holocene and the expansion of the reef area. The findings of this study will be useful for people studying Pacific marine resource use in general and in particular those interested in the utilisation of shellfish resources (species and habitats) during the Lapita era.
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Chapter 1. Introduction

1.1 Introduction

This thesis examines the changes in patterns of marine-resource (shellfish) exploitation during the earliest period of human occupation (1200/1100 BC to 700/600 BC) of Bourewa settlement, southwest Viti Levu Island, Fiji (Figures 1.1 and 1.2).

It reports on the mid-2005 geoarchaeological excavations, sampling and dating of shells from Pits X1, X2, X3, X5 and X6 at the Bourewa site. An analysis of the shellfish species and habitats exploited during the Lapita occupation of Bourewa is also discussed and presented here. This thesis is part of a larger research project directed by Professor Patrick Nunn of the University of the South Pacific (USP), Roselyn Kumar of the Institute of Applied Sciences (IAS), USP, and Sepeti Matararaba of the Fiji Museum.

The Bourewa site was first discovered in December 2003 by a team of researchers from the University of the South Pacific and the Fiji Museum (Kumar and Nunn, 2003; Kumar et al., 2004; Nunn et al., 2004). It is located on the former Vusama Island, now known as the Rove Peninsula. Since its discovery, Bourewa has been the subject of numerous geoarchaeological excavations and publications by various collaborators. At least six field seasons have been conducted at the Bourewa site involving local, regional and international archaeologists, scientists, students and volunteers.

Other Lapita-era sites discovered along the Rove Peninsula over the recent past are Waikereira, Tomato Patch, Jugendar’s Farm, Rove and Qoqo Island, though they appear to post-date Bourewa. These sites have provided significant clues to the Lapita colonisation and settlement of the Rove Peninsula and the Fiji Islands. It is expected that through this study the impact of both human and environmental factors on shellfish species and habitats will be examined, analysed and discussed.
This particular report is based on the mid-2005 geoarchaeological excavations and sampling of shells from Pits X1, X2, X3, X5 and X6 at Bourewa. It examines the composition (structure) and abundance of shellfish species from different environmental habitats along the Rove Peninsula. It presents the results and analysis of shells excavated at Bourewa and the radiocarbon ages of shallow marine shells sampled from different stratigraphic layers in Pits X2 and X3. A discussion on the nature of shellfish exploitation and the impact of environmental change on the subsistence strategies of the Bourewa Lapita people is also presented here. This study also highlights the implications of prehistoric subsistence (impacts) practices for modern resource management of shellfish resources for Fiji including other tropical Pacific islands.

Sections 1.2, 1.3 and 1.4 describe the geography, prehistory and Lapita settlement of the Fiji Islands. The aims and objectives of this thesis are outlined in section 1.5, while the various abbreviations for time used here are explained in section 1.6. Section 1.7 explains the organisation and scope of this thesis.

1.2 The Fiji Islands

The Fiji Islands are located in the southwestern Pacific, northeast of Australia, west of Tonga and east of Vanuatu (Figure 1.1). Fiji straddles the latitude 18°S and longitude 179°E with the International Dateline passing through its central-islands group. The Fiji Archipelago comprises more than 300 islands with a land area of about 18,270 km². Rotuma Island which lies far north of the main island groups is politically part of Fiji.

As illustrated in Figures 1.2 and 1.3, the two largest islands - Viti Levu and Vanua Levu, are surrounded by subgroups of volcanic islands in the west (Yasawa group), centre (Lomaiviti group), and south (Kadavu and Yasayasamoala groups). The scattered Lau group of eastern Fiji comprises mostly smaller limestone islands. Other higher volcanic islands include Taveuni, Gau and Ovalau - where the former capital of Fiji – Levuka is located.
Fiji has a tropical marine climate with seasonal temperature variations. A cool dry season between the months of May and October and a hot wet (cyclone) season between November and April. Fiji’s physical environment also varies from wet and dry sides on the larger islands generally influenced by the southeast trade winds and island topography.

The Fiji Islands were initially inhabited about three millennia ago by the Lapita people. The first European explorers made contact with Fiji only recently during the seventeenth century. In 1874, Fiji came under British colonial rule but gained political independence in 1970. Although Fiji still has a large subsistence-based sector, its economy is dependent on income from tourism, export of sugar, garments, timber, fish, gold including coconut oil, and overseas remittances (from Fiji nationals working and residing overseas).
The major ethnic groups in Fiji include, indigenous Fijians and Indo-Fijians. Indigenous Fijians (predominantly Melanesians with a Polynesian admixture) comprise more than half of the population followed by Indo-Fijians and others (Europeans, other Pacific Islanders and Chinese). The major religions in Fiji include Christianity, Hinduism, Islam and other sects and creeds.

1.3 Prehistoric settlement of the Fiji Islands

The Fiji Islands were initially colonised by the Lapita people around as early as 1220 BC or 1100 BC with the settlement of the Bourewa site (Figures 1.3 and 1.4) (Nunn et al., 2004; Nunn, 2007a). According to Nunn and others, Bourewa is the “probable founder” settlement site in the Fiji Islands since it was occupied much earlier than any other dated settlement sites in Fiji (Nunn et al., 2005a).

The Lapita people were the first people to colonise and inhabit the islands of the western tropical Pacific, east of the Reef/Santa Cruz group and Vanuatu. Their colonisation of Fiji occurred after an arduous journey that crossed the largest ocean gap in the Lapita world - between the Reef/Santa Cruz group and Fiji. They probably sailed to Fiji on large bamboo rafts or “double-hulled” canoes. After making initial contact with the islands in western Fiji, they traveled along the extensive barrier reef system on southwestern Viti Levu Island and eventually landed at Bourewa where they established their settlement (Nunn et al., 2005a; Nunn 2007a).

The Bourewa settlement was founded on offshore Vusama Island during Lapita times (Nunn et al., 2004; Nunn, 2005) when sea-level was much higher than today (Nunn and Peltier, 2001). The settlement was established on a 70-80 m sand spit that partially enclosed a small tidal inlet (embayment). Based on the distribution of dentate-stamped potsherds found on the site, its area could be at least 12,500 m² (Nunn, 2007a). Sometime after the end of the Lapita period in Fiji as sea-level continued to fall, the Tuva Estuary became shallower and narrower gradually causing Vusama Island to be joined with mainland Viti Levu (Nunn, 2005).
Until the discovery of the Bourewa site (Figures 1.3 and 1.4) in 2003, there was much contention about where and when the initial colonisers of the Fiji Islands settled, how they lived and interacted with the environment, and their impact on natural resources including shellfish. It is still unclear if the first Lapita people in Fiji
also brought with them edible plant tubers and crops and domesticated animals besides their human cargo although the recent study by Horrocks and Nunn (2007) has demonstrated evidence for horticulture/agriculture practice most probably by a subsequent group of Lapita people at the Bourewa settlement. The recent excavation of non-human bones like dogs, pigs, chickens and birds at Bourewa site (USP News, 2008) may also provide important clues to their life ways.

Undoubtedly the earliest colonisers of Bourewa settlement site had optimal access to an extensive marine-rich coral reef ecosystem where they subsisted on a wide range of marine resources including shellfish. The Bourewa settlers perhaps consumed other foods like taro and yam and vegetables suggesting they might have had a mixed-subsistence economy. It is also plausible to assume that they probably ate algae, sea weeds and other soft-bodied marine organisms like sea urchins although to date no evidences of remains of such food sources had been found (Nunn 2007b). As the human population of Bourewa increased due to later influx of new migrants, it is inevitable that they continued to exploit the available natural resources, cultivated food crops and perhaps domesticated more animals and expanded their influence along the Rove Peninsula.

1.4 Lapita in Fiji

According to Sand and others, the term Lapita was named after a site in New Caledonia (Site 13 on La Grande Terre) where their distinct and intricately decorated pottery was first recognised (Sand et al., 2002). Lapita pottery is a special feature of the Lapita people and culture. It is distinguished from other forms of pottery by its characteristic dentate-stamped (toothed) designs and motifs and its prominence encompassed a period of about 500-600 years before it was transformed into other simpler designs and motifs (Kirch, 1997).

The first Lapita potsherds were initially recognised by a Catholic Priest in 1909 on Watom Island, north of New Britain Island in the Bismarck Archipelago of Papua New Guinea. But, at that time they were not yet known as Lapita pottery. In the 1920’s Lapita pottery were also discovered in the Tonga Isles. Almost half a century had elapsed after the first sightings of Lapita potsherds before Mr Shutler and others
excavated large quantities of decorated (dentate-stamped) potsherds in New Caledonia where the collection was named Lapita pottery (Chino, 2002).

While it is plausible that the Fiji Islands were colonised by people who originated from either the Bismarcks or Santa Cruz/Reef Group or Vanuatu, various colonisation models have been proposed to describe the nature of Lapita settlement in Fiji. For example Clark and Anderson (2001) broadly characterised two major migration phases which included the initial settlement of western Fiji, followed by the expansion and occupation of eastern Fiji. Kumar (2004) also postulated at least four colonisation routes that were followed by the Lapita people as they settled the Fiji Islands.

According to Kumar’s model, the first route involved the settlement of the southwest Viti Levu Island via the Bligh Waters. The second group traveled northeast and perhaps settled on Vanua Levu Island, (though this is conjectural), or they settled on northern Viti Levu Island and/or central Fiji (Lomaiviti group). Another group, which perhaps originated from Bourewa settlement sailed southwards and colonised the southern group of islands like Beqa and Kadavu, while the fourth group (which originated from either central Fiji or Viti Levu Island) settled the eastern part of the Fiji Islands mostly in the Lau group (Figure 2.5) (Kumar, 2004).

The Bourewa settlement was subsequently abandoned after 500-600 years of continuous occupation. By the end of the Lapita period, the Bourewa settlers migrated and colonised other locations along the Rove Peninsula and/or settled in other places along southwest Viti Levu Island or other islands of Fiji (Kumar, 2004; Nunn et al., 2004, 2005b; Nunn, 2007a).

There are no available evidences (or clues yet) to suggest any post-Lapita occupation of the Bourewa settlement, but preliminary dates (post-Lapita) obtained from human burials excavated during the mid-2005 field season (Nunn, 2007a) suggest that the site may have had some post-Lapita cultural significance. Perhaps the site was later used for burial although it is uncertain if it was a cemetery associated with any ritualistic practices as in other Lapita sites like Teouma, on north Efate Island, Vanuatu (Shing et al., 2005). There are indications though that the site could be a
significant place for the post-Lapita settlers of the Rove Peninsula but the extent to which this is so, is yet to be determined and analysis of the human remains is still in progress.

Almost a century ago Indo-Fijian farmers leased the land where the Bourewa settlement was founded and planted sugar cane crops. During the mid-2005 field season the Bourewa site was part of a sugar cane farm formerly cultivated by Mr Ram Lal and family. Today the land on which the Bourewa settlement is located is owned by the Shangri-La group of companies.

1.5 Aims and objectives of this thesis

The analysis of shellfish remains from archaeological sites has been conducted on most Pacific Islands in the recent past to understand many aspects of prehistoric settlement and subsistence behaviour including human and non-human impacts on shellfish resources. In Fiji, several studies have demonstrated the impact of human predation on shellfish resources while inferring that environmental change may have been important as well (Morrison and Cochrane, 2008; Nunn et al., 2006; Thomas et al., 2004). This study attempts to understand particularly the impact of both human-induced pressures and environmental change on the availability and abundance of shellfish resources over space (different environmental habitats/ecosystems) and time (phases of occupation) by analysing the shells sampled from the Bourewa settlement’s shell midden.

Since Bourewa was colonised against a backdrop of both climatic and sea-level changes during and after the mid-Holocene, an understanding of the interplay between human and environmental factors is important (Nunn, 2005) for interpreting shellfish abundance and variability. The analysis of the Bourewa shells will enable a better understanding of the way early humans (Lapita people) in Fiji interacted and impacted shellfish species and habitats and how environmental factors (sea-level fall) influenced their choices and actions, their preferences and subsistence behaviour over time. An understanding of this interrelationship will also be useful for informing
resource managers, policy makers and resource owners with management scenarios to manage the exploitation of marine resources especially shellfish species and habitats.

The character and composition (structure) of the shell midden at Bourewa settlement can inform us about the variability of shellfish species and habitats targeted by foragers and types of shellfish they preferred, collected and consumed. The shellfish analysis should allow us to examine their subsistence strategies and how they were able to alter their behaviour due to changes in shellfish resources.

1.5.1 Primary aim

Shellfish resources were an integral part of the initial Lapita colonisers of both Near and Remote Oceania (Davidson and Leach, 2001; Nunn, 2007b). By conducting an analysis of the shells sampled from the Bourewa shell midden during the mid-2005 field season this study aims to determine the nature of shellfish exploitation during the Lapita era in Fiji especially during the 500-600 years of settlement at Bourewa. As in most faunal (shellfish) analysis, this study employed methods such as MNI, NISP, weight and size to quantify and analyse the shellfish species sampled from Pits X1, X2, X3, X5 and X6. This analysis intends to understand the subsistence strategies of the Lapita people on the shellfish species and habitats along the Rove Peninsula and trace their changes through time as well.

1.5.2 Secondary aim

The impact of environmental change particularly sea-level fall on shellfish resources in the Pacific is well documented (Amesbury, 2007; Kirch and Yen, 1982; Morrison and Cochrane, 2008; Spennemann, 1987). As suggested by Nunn et al., (2004, 2005a) and Nunn (2007a), the Bourewa settlement was occupied during a period when environmental conditions were also changing especially after the mid-Holocene sea-level maxima, so this study also aims to understand the nature of sea-level and its impact on available marine resources and human behaviour during Lapita times.
Although isolating the human and non-human factors will be challenging, a review of the literature citing several examples illustrating the impact of sea-level change on shellfish resources on different tropical Pacific Islands will be outlined and described to provide a backdrop for understanding the impact of sea-level change on the Bourewa shells. Based on the case studies and a recent palaeogreographic reconstruction of the Rove Peninsula (Nunn, 2005) and shellfish analysis of Qoqo Lapita site Nunn et al., (2006), inferences will also be made regarding the possible impact of sea-level change on certain shellfish species and habitats along the Rove Peninsula.

1.5.3 Objectives

Since the first geoarchaeological dig at the Bourewa settlement site, many significant finds have been analysed and published by various collaborators. Examples include Dickinson (2005), Horrocks and Nunn (2007), Nunn (2005), Nunn et al., (2004, 2005a, 2005b), Nunn (2007a) and Szabó (2006). The foregoing publications have been important for understanding the presence of prehistoric people in southwest Viti Levu Island though a comprehensive shellfish study is required to understand the nature of human impact on shellfish species and habitats along the Rove Peninsula particularly during the Lapita period.

This thesis proposes to specifically,

(i) examine and understand the nature and pattern of marine-resources (shellfish) exploitation from the period of initial human (Lapita) occupation of Bourewa until 600 years later – from 1200/1100 BCE to 700/600 BCE,

(ii) understand the nature of subsistence strategies of the Bourewa settlers,

(iii) explain the nature of environmental change during the period of human occupation of Bourewa (e.g. sea-level change),

(iv) link marine-resource (shellfish) exploitation by the early human (Lapita) settlers of Bourewa to environmental change, and,

(v) understand particularly in terms of modern resource management, the interrelationship between human (resources) exploitation and environmental change.
1.6 Notes on how time is explained in this thesis

The following abbreviations of time are used throughout this thesis to explain various references to time.

- AD – Anno domini (indicate the number of years after the traditional date of Christ’s birth).
- BC – Before Christ (indicate the time before the Christian era).
- BCE – Before Common Era (indicate the time before the Christian era, used particularly by non-Christians).
- cal yr BP (or cal BP) – calibrated years before present (before present = 1950).
- years BP (or BP) – years before present (before present = 1950).
- ka – thousand years ago.
- Ma – million years ago.

1.7 Organisation and scope of this thesis

This thesis is divided into eight chapters. Each chapter outlines, describes, explains, and discusses the major themes of the thesis.

The second chapter outlines the prehistoric settlement of the Pacific Islands including Fiji (section 2.2). It discusses the colonization of Pacific Islands, presents the debate over human colonisation of Near and Remote Oceania, outlines the nature of Lapita settlement in Oceania, and describes the recent settlement of the Pacific during the last millennium (subsections 2.2.1 to 2.2.5). Lapita in the context of Fiji (section 2.3) including their colonisation route and settlement patterns in the Fiji Islands are also described here (subsections 2.3.1 and 2.3.2).

Chapter three reviews the major prehistoric subsistence trends in ancient times, discusses human-environmental interactions in the Pacific including the Fiji Islands, and describes three important foraging models that are important for understanding the shellfish analysis at Bourewa. The objective of section 3.2 is to outline the perspectives on prehistoric subsistence in the Pacific Basin in ancient times. Section
3.3 reviews Lapita subsistence in Oceania, outlines the current debate relating to subsistence practices in the Pacific, and explains some of the recent advances in reconstructing subsistence economies in Oceania (subsections 3.3.1 to 3.3.3). Section 3.4 reviews human-environmental interactions in pre-modern (Pacific) societies and previous shellfish studies in Fiji, while optimal foraging theory models which explain human predation patterns are outlined in section 3.5.

Chapter four describes the methodology and outlines a theoretical overview of underlying concepts and terms in zooarchaeology that are used in this thesis. A review of some important terminologies and quantification methods commonly used in faunal analysis and theories associated with the study of faunal remains including invertebrate marine shellfish is provided here as well.

While the quantification methods are critically examined, the overall objective of this chapter is to ground the shellfish analysis in anthropological and archaeological practice. The methods used to quantify shells in this thesis include NISP (number of individual specimens) (subsections 4.2.1 to 4.2.3), MNI (minimum number of individuals) (subsections 4.2.4 to 4.2.6), Weight (subsections 4.2.7 to 4.2.9), and Size (subsections 4.2.10 to 4.2.12). These quantification methods have been selected because of their appropriateness for this particular shellfish analysis.

Chapter five describes the study site, major excavation phases, and the field and laboratory methods employed to sample the shells for quantification and analysis. Section 5.2 briefly outlines the geotectonic history and development of the Fiji Islands providing a backdrop for understanding the geography and palaeogeography of the Rove Peninsula and the Bourewa site. Section 5.3 outlines the history of excavations conducted along the Rove Peninsula and describes the major phases of fieldwork carried out from 2003 to 2005. Post-2005 field excavations are briefly described here as well. Sections 5.4 and 5.5 briefly explain the field and laboratory methods employed by the research team and the author to recover, sample and quantify the shellfish species excavated during the mid-2005 field season at the Bourewa settlement site.
Chapter six presents the results and analysis of the Bourewa shell assemblage. Section 6.2 describes the excavation profiles of Pits X1, X2, X3, X5 and X6 and the radiocarbon dates obtained for the different levels of each pit. Section 6.3 outlines the radiocarbon chronology and dating of Pits X2 and X3. The objective of these sections is to illustrate the various stratigraphic layers and provide an overview of the general composition and context of the pits, the palaeogeography, and the occupation levels of the Bourewa Lapita site. Section 6.4 presents the analysis of MNI, NISP, weight quantification, and size measurements for the Bourewa shells. The analytical zones delineated for the shell assemblage and their analysis are presented in section 6.5. Section 6.6 presents the analysis of shellfish species and habitats using foraging theory models and the analysis of shellfish species diversity and relative abundances is presented in section 6.7.

Chapter seven provides the interpretation and discussion of the results and analysis presented in chapter six and relates them to the aims and objectives of this thesis. Section 7.1 interprets the shellfish analysis. Subsection 7.1.1 interprets the stratigraphy and radiocarbon ages of the pits sampled at the Bourewa site. Subsections 7.1.2 to 7.1.4 interpret and discuss the MNI, NISP, weight, and size analyses. Section 7.2 interprets the shellfish habitat usage at Bourewa including foraging in the Shoreline Sandy/Muddy and Intertidal/Coral Reef Habitats and shellfish diversity and abundance. Section 7.3 discusses the implications of archaeological shellfish studies like the Bourewa shellfish analysis for marine resources management in general and in particular Fiji.

Finally, chapter eight provides a summary of the results and analysis and outlines both human and non-human impacts on shellfish species and habitats as indicated by the Bourewa shellfish data.
Chapter 2. Settlement history of the southwest Pacific and the Fiji Islands

2.1 Introduction

This chapter outlines the human settlement history of the Pacific Islands and Fiji. It traces the migration of the early colonisers of the Pacific region (section 2.2) and describes the nature of Lapita settlement in the Fiji Islands (section 2.3).

According to Dalzell, “the Pacific Islands were among the last parts of the world to be settled by humans, settlement in most having occurred within the last two or three millennia” (Dalzell, 1998:238). Due to the nature of the Pacific region, many scholars are fascinated by the colonisation of the Pacific Islands given the vast ocean-distances that were crossed by humans from Southeast Asia and the Bismarcks to as far as Easter Island in eastern Polynesia (Hurles et al., 2003).

2.2 Prehistoric settlement of the Pacific Islands

Several works have outlined the prehistoric settlement of the Pacific Islands. These include Spriggs (1997) who traced the prehistoric settlement of “Island Melanesia” by people who originated from Asia and Kirch (1997) who described the expansion of the Lapita phenomena into both Near and Remote Oceania particularly during the mid-Holocene period. Roger Green also proposed the concept of Lapita Cultural Complex (LCC) (Green, 1979, 1982), to describe Lapita and its associated trappings and intrusion into the Pacific region, while Kirch (2003) provided a concise summary of the human colonisation of the Pacific Islands. Bellwood (1980) and Irwin (1992) also outlined a chronology of the prehistoric settlement of the Pacific Islands.

Based on these works, at least three major pulses of human migration into the Pacific Islands have been broadly recognised. These are referred to here as - the Pre-Lapita, Lapita, and Post-Lapita Phases. These migration phases spanned the late Pleistocene to the late Holocene and were generally characterised by an eastward trend which originated from somewhere in the Southeast Asian region.
The first migration phase (pre-Lapita) was marked by the settlement of both Sahul (Australia and New Guinea) and parts of Island Melanesia during the late-Pleistocene by mainly Papuan-language speaking people of continental Asia or Island Southeast Asian (ISA) origin (Spriggs, 1997). The second migration phase (Lapita) saw the wholesale migration of Roger Green’s Lapita Cultural Complex from the Bismarck Archipelago, into the Solomon Islands, Vanuatu, New Caledonia, Fiji, Tonga and Samoa beginning sometime around 4000-3500 years ago. This episode also included the settlement of the central and eastern regions of Micronesia (Kirch, 1997, 2003). Around the turn of the last millennium, the third migration phase (post-Lapita) undertaken by descendents of the Lapita people occurred. This stage is characterised by the settlement and colonisation of most of the eastern, northern, central, and southern Polynesia and possibly the colonisation by Pacific Islanders of the Panama region of Central America (Nunn, 1999; Nunn and Britton, 2001) (Figure 2.1).

2.2.1 Early human colonisation of the Pacific Islands (Pre-Lapita Phase)

Archaeological evidence demonstrates that modern humans (Homo sapiens) first appeared in the fossil record in Southeast Asia about 40,000 BP (Shutler and Shutler, 1975). While recent controversial evidence from Australia suggests even older dates for the presence of modern humans in Australia, Tasmania and New Guinea (or Greater Australia) (O’Connell and Allen, 1998), the initial colonisation of parts of Island Melanesia and the Bismarcks occurred sometime between 35,000 and 29,000 years ago (Kirch, 2003; Spriggs, 1997) and by 29,000 BP people had already colonised the Bismarcks and possibly certain parts of the western Solomon Islands (Hurles et al., 2003).

The first phase of human movement into the western Pacific region occurred during the Pleistocene epoch; a period characterised by cooler global temperatures, increased glaciers, and lower sea levels. Besides others, these conditions rendered the sea gaps between most continents and islands narrower than present and had significant implications for human migration and technological and cultural exchange.
During this time, sea-level in most parts of the world was substantially lower and certain regions which are now separated by expansive seawater gap were once connected. For instance, mainland New Guinea was once joined with Australia (and Tasmania) forming a super-continent called Sahul (Nunn, 1999). The continental shelves of Sunda (Greater Southeast Asia) were also exposed and the sea gap between the islands of Bali and Lambok was narrower which might have enabled modern humans to cross from Sunda to Sahul relatively easily (Rapaport, 2006). During this time the islands of Buka, Bougainville, the Shortlands, Choiseul, Santa Isabel, and Ngella were also joined together when sea-level was lower forming a larger landmass which Spriggs referred to as “Greater Bougainville” (Leavesley, 2006:190).

Although the fall in sea level to about 150 m below present during the Pleistocene period was responsible for significant increase in landmasses and migration of people and certain fauna across land bridges, the continental shelves of Sunda and Sahul were never connected (O’Connell and Allen, 1998). Due to lower sea levels during the Pleistocene period, anatomically modern humans were able to cross the Wallace Line from Island Southeast Asia into mainland New Guinea (O’Connell and Allen, 1998; Rapaport, 2006). Their subsequent crossing into Island Melanesia implied they
probably had appropriate seafaring knowledge and skills, though sailing technology was not yet invented until the mid-Holocene. So it is plausible to assume that they could have utilised simple boats or bamboo rafts to cross the narrow water gaps between Southeast Asia and mainland New Guinea or Island Melanesia (Irwin, 1992).

The early human colonists of the Pacific Islands were mostly hunter-gatherers (Kirch, 2003; Nunn, 1999; Spriggs, 1997) and they exploited resources from the tropical rainforests and inshore marine habitats and established extensive communication and exchange networks that linked different island communities together (Kirch, 1997; Leavesley, 2006).

In his investigations of economies, technological and social complexities in the Bismarck Archipelago, Leavesley (2006) examined evidences of human colonisation and behaviour from several New Ireland Pleistocene sites. By synthesising the archaeological data and settlement dates, Leavesley was able to identify six pulses of human deposition that are important for understanding the late-Pleistocene and Holocene colonisation of the Bismarcks and Solomon Islands. He demonstrated that the initial settlement of the Bismarcks occurred around 39,500 BP followed by the settlement of Manus at least about 20,000 BP. There was a settlement hiatus after the Last Glacial Maximum (LGM) and by 15,000 BP people re-occupied most sites in central and southern New Ireland including the initial occupation of northern New Ireland sites. The settlement of western New Britain and Buka occurred slightly later, while all of the New Ireland sites were occupied around 12,000 to 10,000 BP. By about 8000 BP people had apparently abandoned all the sites on New Ireland. These inland sites were abandoned probably due to migration of people to the coastal regions where there would be abundant resources that can sustain the islands expanding populations.

The Holocene period (last 10,000 years of Earth history), was marked by a warmer period and rising sea level around most parts of the world including the Pacific region (Nunn, 1997, 1999). This period also witnessed significant cultural changes occurring in certain places within Near Oceania. For example, Pavlides (2006) who examined a site on West New Britain Island (dating between 10,000 and 3600 years
ago) revealed several important cultural processes and social changes in Oceania’s prehistory and amongst these were gradual changes in the way people interacted with the environment, with more intensive resource management occurring in the mid-Holocene period.

According to Nunn (1997, 1999), the mid-Holocene period is marked by cooler conditions, increased precipitation, lowering sea level, increased sedimentation of foreshore areas, and vegetation change on some Pacific Islands. This period also saw the advent of the Lapita people in the central, eastern Pacific and parts of the northern Pacific. The arrival of humans into the Oceania region has been associated with the introduction of fire, exotic biota, and vegetation change on most islands, although climatogenic factors maybe have had significant impact on island environments resulting in the development of certain physical landscapes like grasslands on certain islands.

David Roe (1993) who re-examined and analysed a 6000-year long cultural sequence from the Vatuluma Posovi (Poha) Cave on northwest Guadalcanal Island, highlighted the sites association with pre-Lapita population occupation and intrusion of this region of the central Solomon Islands. During the same study, Roe also identified a 3000-year old cultural sequence coinciding with the Lapita colonisation of Oceania. But, as Kirch (1997) highlighted extensive fieldwork and research are required throughout the main Solomon chain to ascertain a much clearer and finer settlement pattern and chronology for this region including the period immediately before the Lapita colonisation of Oceania because as Pavlides states, “the mid-Holocene is perhaps the most elusive phase in Melanesian prehistory” (Pavlides, 2006:207).

2.2.2 Human settlement of Near and Remote Oceania (Lapita Phase)

The second phase of human colonisation of the Pacific region is characterised by the intrusion of Roger Green’s Lapita Cultural Complex into Oceania. It also marked the initial settlement of parts of Oceania which were perhaps devoid of human inhabitants prior to the advent of the Lapita people (Figure 2.1 and 2.3) (Kirch, 1997).
About 3300 BP the Lapita people expanded into the southeast Solomon Islands from the Bismarcks. Based on archaeological evidence, the colonisation of Vanuatu, New Caledonia and/or other more remote archipelagoes, did not occur until after 3300 BP because they reached the Fiji Islands about 3050 BP, and by 2900 BP Tonga was colonised (Horrocks and Nunn, 2007).

When the Lapita people migrated into the western Pacific about four or three and a half millennia ago, they encountered a range of island types, sizes, habitats and ecosystems (Nunn, 2005). Due to the nature and character of the different islands, the initial colonisers of most tropical Pacific Islands had to adjust to a range of conditions in order to adapt to the different island environments. In many instances the interaction between humans and the islands has lead to changes in both human behaviour as well as the environments of the islands that were colonised (Kirch, 1997; Nunn, 2005).

In the early 1990s, Roger Green delineated the southwest Pacific region (excluding Australia) into two sub-regions - Near Oceania and Remote Oceania (Green, 1991a) (Figure 2.2). Besides aiming to discourage the use by scholars of Oceanic culture history of the classical terms - Melanesia and Polynesia, Green attempted to highlight the distinct nature and character of these sub-regions including their island environments and their potential impact on human colonisation and behaviour. Today, this concept is widely used by Oceanic archaeologists because it seems to accurately “convey a more meaningful historical division of Oceanic island geography than that implied by the classical terminologies” such as Melanesia, Polynesia or even Micronesia (Walter and Sheppard, 2006:137).

The ecological differences between the islands of Near and Remote Oceania are paramount for understanding human colonisation of the Pacific Islands and their interactions with island environments. In terms of island ecology and biogeography, Near and Remote Oceania exhibit distinct environmental characters. For example Near Oceania (Papua New Guinea and the archipelagoes of the Bismarcks and Solomon Islands) comprise relatively larger landmasses and narrow water gaps, so the inter-visible islands would not hinder migration by potential human colonists like
the Lapita people and the dispersal and translocation of diverse flora and fauna from island to island (Kirch, 1997).

In contrast, Remote Oceania which includes all islands north, east and southeast of the main Solomon chain as farther east as the Fiji-Samoa-Tonga triangle, is mostly separated by huge expanses of seawater. For instance, according to Kirch (1997) the sea gap between the Reef/Santa Cruz group and the Fiji Islands spans over 850 km rendering it to be the largest ocean-distance in the Lapita world. The Lapita people marked the first colonisers to have crossed this uninterrupted ocean gap and settled the islands of the eastern and southern Lapita provinces of Remote Oceania.

The Near Oceania region is biogeographically and ecologically richer than Remote Oceania with a decline in the diversity of native flora and fauna from western to eastern Pacific. The larger islands of the Bismarcks and Solomons for example hosted a wide range of indigenous and endemic species of mammals, reptiles,
avifauna, and abundant marine resources. All these protein sources in addition to tubers, seeds, fruits and nuts had contributed to the diet of the early humans who colonised Near Oceania (Kirch, 1997).

By comparison, the ecosystems of the region beyond the main Solomon Islands are generally impoverished and the richness of indigenous flora and fauna decreased markedly (Kirch, 1997). Thus Remote Oceania “lacks natural populations of most cultivated Oceanic plants and their close relatives” which were important for sustaining human settlement and the growth of large populations (Horrocks and Nunn, 2007:740). Despite being environmentally poor, Remote Oceania contained a host of bird taxa and its seas and coral reefs were bountiful with marine resources almost similar to Near Oceania. So the early hunter-gatherers of the Oceania region developed a system of food production and relied on the exploitation of marine resources (Kirch, 1997).

According to Nunn (2007b) and Nunn and Heorake (2009), when the Lapita people encountered island environments in Remote Oceania their subsistence options were significantly less than they are today. For instance, there were fewer reefs and those that existed at the ocean surface probably hosted less diverse ecosystems. Coastal lowland landscapes were also less extensive, offering fewer options for horticulture/agriculture. Despite these limiting factors, several case studies from different parts of the tropical Pacific that indicated that the Lapita people clearly made sense of their world by optimising access to desired albeit scarce food resources. Thus, throughout the Lapita world as we see it today, smaller-island settlements were more common than those on larger islands.

Some examples of Lapita settlements that were established on smaller islands during Lapita times include Malo on Temotu Neo Island, Temotu group, southeast Solomon Islands, Bourewa on southwest Viti Levu Island, Fiji, and northern Tongatapu Island around the Fanga ’Uta lagoon. These sites were chosen because of their proximity to expanding coral reefs particularly after the mid-Holocene sea-level maxima and for security against potential attackers and disease-carrying insects. Perhaps these people also allowed their commensal animals to run free on these islands because they would be comparatively easy to catch again when needed. Besides the general
preference of the Lapita people for occupying smaller islands they also settled on tombolos and sand spits. Although they appear today as vulnerable locations, these locations were deliberately selected by the Lapita people because they provided optimal access to marine and intertidal food resources (Nunn, 2007b; Nunn and Heorake, 2009).

2.2.3 Lapita colonisation of Oceania: Express Train to Polynesia (ETP) and Indigenous Melanesian Origins (IMO) models

According to Spriggs, by the first millennium BC Island Melanesia became bigger, larger, and expanded as it had received its next group of human settlers – the Lapita people who belonged within a new cultural tradition, used pottery, and practiced agriculture/horticulture. This second colonisation pulse saw the intrusion of the Lapita Cultural Complex into both Near and Remote Oceania and cultural exchanges between Lapita and older Island Melanesian cultures (Spriggs, 1997).

Figure 2.3 shows the locations of some of the islands in the southwest Pacific where evidence of Lapita-era settlement sites has been found. The extent of the Lapita colonisation of Oceania stretched from the Mussau group of islands in the Bismarck Archipelago of Papua New Guinea in western Melanesia, through to the Solomon Islands, Vanuatu, New Caledonia, Fiji, Tonga and Samoa (Terrell, 1997; Spriggs, 1997) and extends even to ‘Uvea, Futuna and probably Rotuma (Kirch, 1997).

Though we now have a much clearer idea about the distribution of the Lapita settlement sites within Oceania, Bedford (2006) noted that in the 1970s Lapita origins and its associated trappings were widely debated by researchers and archaeologists. As a result of this contention many theories and models of Lapita colonisation were developed and postulated. For our purpose, two opposing models for explaining the Lapita colonisation of Oceania are useful. These models are discussed below.

First is the “Express Train to Polynesia” (ETP) theory and second, the “Indigenous Melanesian Origins” (IMO) theory (Bedford, 2006; Kirch, 1997; Summerhayes, 2001). As highlighted by Bedford (2006) these models attempt to explain the origins
of the Lapita people and describe the nature of their migration, technology, and culture as they expanded into both Near and Remote Oceania.

The ETP model proposes a significant and very rapid population intrusion (wholesale migration) of Austronesian-speaking peoples with their domesticated animals, elements of material culture, and technology, and pottery into the Bismarck region from somewhere in Southeast Asia. It assumes that subsequent changes in the pottery style are due to subsequent isolation of populations over long periods of time (Summerhayes, 2001) and perhaps cessation of constant contact and trade between island populations (Kirch and Yen, 1982).

According to the ETP model, the migrating Austronesians passed through Melanesia en route to Polynesia in the mid-late second millennium BC. It is regarded as the fast train model because the colonisation of the Bismarcks preceded Fiji about 3000 km away to the east by only about a century, thus persuading proponents of this model to suggest that the rate of colonisation was very rapid. But according to Kirch, the “express train” concept is somewhat misleading because such a train would have made several stops in Melanesia dropping off “boxcars full of colonists” suggesting cultural exchange and perhaps intermarrying with the inhabitants of Near Oceania before proceeding eastward into Remote Oceania (Kirch 1997:45).

In contrast the IMO model postulates that key aspects of the Lapita culture were largely developed within the Bismarck Archipelago without any input from outside the Near Oceania region (or from the Southeast Asian region). Essentially, advocates of the Melanesian indigenist model argue that “Lapita is wholly an indigenous development out of earlier social and economic configurations in the Bismarcks, with the acquisition of pottery being the only contribution from the west” (Kirch, 1997:46). Apparently, the model assumes that the Lapita culture arose from internal social and economic developments of the previous 35,000 or so years of occupation of Island Melanesia (Summerhayes, 2001). Additionally extreme variants of the indigenist theory refute the concept of a Lapita Cultural Complex as proposed by Roger Green and stressed that the dentate-stamped pottery was only a “trade ware” which the Lapita people utilised in trade or exchange networks between island communities (Kirch, 1997).
As noted by Bedford *et al.*, (2006), over the years archaeologists have taken sides on the issue of Lapita origins and development. So, whether or not it was largely an indigenous development in the Bismarck region with limited contact with Island Southeast Asia or, if it was primarily a Southeast Asian intrusion or, something in between, is still a matter of contention. As a consequence of the ongoing debate several research projects were established by archaeologists to re-examine and address issues associated the origin, settlement pattern, subsistence economy and other important aspects of the Lapita phenomena.

A case in point is the “Lapita Homeland Project” established during the 1980s in the Bismarck Archipelago, Papua New Guinea by Patrick Kirch and others (Bedford, 2006). Despite being very significant and useful for understanding many aspects of Lapita, the project fell short of completely resolving the origin question, but it did encourage some modifications of the opposing views and the development and proposition of other theories like the “Slow Train Model” which is a variant of the “Express Train Model” (Summerhayes, 2001) and Roger Green’s “Triple-I” model of “Intrusion/Innovation/Integration” (Green, 1991b:298).

According to Kirch (1997:46), Roger Green’s model “recognizes that some aspects of Lapita must be accounted for by intrusion, the movement of people and their cultures into the Bismarck Archipelago where existing populations were then integrated into a new cultural pattern which itself underwent certain innovations”. Bedford (2006) states that although the “Triple-I” model at least provides an outline for potential processes, Spriggs (1997) suggests that a shortened time line is required to accommodate for the integration component. Both the Express Train and Slow Train models suggest that the Lapita Cultural Complex developed in the Bismarck Archipelago before colonising groups migrated to Remote Oceania (Summerhayes, 2001).

In Kirch’s literary model of “the beach”, a holistic approach is posited where various aspects of the Lapita Cultural Complex like, new settlement patterns, economic systems, and regional exchange plus linguistic and biological patterns in Near and Remote Oceania must be considered and not just the elaborate pottery (Kirch, 1997).
Other Lapita origin theories have been proposed by scholars including, the “Entangled Bank” and “Slow Boat” models (Hurles et al., 2003).

2.2.4 Nature of Lapita settlement in Oceania

The other talking point amongst many archaeologists is the rate of Lapita expansion into Oceania. As such Clark and Anderson noted the emergence of two hypotheses for explaining the nature of Lapita dispersal. Firstly, “Lapita settlement was restricted to the Bismarcks for 200-300 years before an explosive phase of eastward expansion which occurred so rapidly that no chronological gradient can be discerned in the radiocarbon record”. Secondly, “Lapita movement was incremental, occurring as a series of colonisation fronts” as it advanced eastward into the central Pacific (Clark and Anderson, 2001:77).

While Kirch (1997) proposed a slightly longer time span of 300-500 years, Terrell (1997) suggested a slightly lesser span. Terrell posited that since Lapita pottery showed up in the archaeological record of New Caledonia, Vanuatu, Fiji, Tonga, and Samoa soon after it appeared in western Melanesia, it must have taken less than 100-200 years for Lapita to spread from the Bismarcks to the Fiji-Tonga-Samoa region. Kirch also calculated an average rate of dispersal in the order of 9-15 kilometers per year (Kirch, 1997:62). Thus Bedford and others suggested that, “if this is the case then the posited 3300 BP date for Lapita settlement in the Bismarcks leaves only a very short time interval before people set out to explore, discover and colonise the western parts of Remote Oceania” (Bedford et al., 2006:824). Based on their demographic simulation of Lapita dispersal, Di Piazza and Peartree (1999) summarised the rate of Lapita colonisation of the Pacific Islands as perhaps the fastest human migration in prehistory.

The Lapita people migrated from the Bismarcks and into the main Solomon chain around 3500-3200 BP (Di Piazza and Peartree, 1999; Spriggs, 1997). Kirch (1997) noted that the early Lapita settlement of the Bismarck Archipelago may have occurred between 1550-1400 BC (3500-3350 cal BP) while the settlement of the Reef/Santa Cruz group occurred around 1100 BC (3050 cal BP). The Lapita people
then expanded southwards through Vanuatu and New Caledonia establishing settlements there around 1000 BC (2950 cal BP) although recent archaeological data from the Teouma site in Vanuatu has pegged the initial human colonisation to around 3200-3000 cal BP (Bedford et al., 2006). During this same period, perhaps slightly later the Lapita people must have crossed the open-ocean gap between the Reef/Santa Cruz group of eastern Solomon Islands and the Fiji Islands while Tonga and Samoa were colonised possibly from Fiji a few centuries later.

Kirch (1997) who provided a comprehensive account of the Lapita people described their character, origin, history, settlement patterns, ceramics, technology, artifacts, livelihoods, subsistence and colonisation of the Pacific Islands and stated that the Lapita people were the common ancestors of the Austronesian-speaking Melanesians, the Polynesians and some Micronesians. The term “Lapita” is derived from Site 13 in Kone, New Caledonia (the site of Lapita itself) where their distinctly-decorated pottery was initially recognised (Sand et al., 2002). Today the term has come to represent more than just the pottery itself. For example, Kirch (1997:10) noted that “Green saw the Lapita Cultural Complex as based on a sophisticated horticultural-fishing economy, with fairly large villages occupying beaches and offshore islets, and using a broad range of distinctive material culture including various kinds of stone, shell, and bone implements”.

The Lapita people initially lived along the coast as transient hunter-gatherers and horticulturists/agriculturalists. They gathered, collected and gleaned shellfish from the near-shore marine environment including coral reefs, fished and depended on the land for food and other materials. They were skilled potters, toolmakers and craftsmen. They cultivated fruit trees, food gardens and harvested roots, tubers, fruits and leaves from crops and trees they planted and probably kept animals such as pigs, chicken and dogs (Kirch, 1997).

Although Anderson and O’Connor (2008) highlighted reservations regarding the “out of Taiwan” model, re-evaluations of data from Island Southeast Asia has compelled Nunn to contend that the Lapita people originated from somewhere in southern China and Taiwan possibly direct descendants of the present-day aboriginal people of Taiwan. Genetic (DNA) evidence also lends support to this proposition. So, as
Nunn suggested that the Lapita people migrated through Halmahera Island in the Molucca Sea and the Bismarck Archipelago in northeast Papua New Guinea between 2000-1500 BC (3950-3450 cal BP). They later colonised the Solomons, Vanuatu, New Caledonia, Fiji, Tonga and Samoa including parts of Micronesia (Nunn, 1999).

Evidence from settlement sites, tools, and the characteristic dentate-stamped Lapita pottery, testify to the development and history of the Lapita people (Kirch, 1997) and a general eastward colonisation trend (Nunn, 1999). The early Lapita sites generally comprise hamlets or villages where houses were constructed and elevated on posts or stilts situated over tidal reef flats or along shorelines. Plant and animal remains excavated from these sites indicate a mixed-subsistence economy with horticulture/agriculture and marine resource exploitation. Exchange networks were established where substantial quantities of exotic materials like obsidian, chert, shell artifacts, ornaments, pottery and other materials were traded between communities (Kirch, 1997).

The ability of the Lapita people to traverse vast ocean-distances in boats, canoes and rafts to migrate to new lands around three thousand years ago indicate that they had appropriate skills and technology. Leavesley (2006) stated that the late Pleistocene colonists of Near Oceania also possessed comparative skills and watercrafts. Similarly Pavlides (2006:205) also noted that the “main elements of social and economic organisation more usually associated with later Lapita settlement were already in place by about 4000 years ago” in Near Oceania.

But Nunn (1999) suggested that the early inhabitants of Papua New Guinea and Solomon Islands were probably constrained by their inability to voyage over great ocean distances though their later relatives - the Lapita people, possessed advanced navigational skills and were equipped with suitable vessels. These attributes probably enabled them to successfully navigate open ocean-distances in search of other islands in the South Pacific although to date no trace or evidence of their boats, canoes or rafts had been found.

After the Lapita people colonised the islands beyond the main Solomons chain, their migration eastward was very rapid (Kirch, 1997). For example their settlement of the
southeast Solomons, Vanuatu, New Caledonia, Fiji, Samoa and Tonga occurred only within a few hundred years and in many places the Lapita era was somewhat short-lived lasting only for 200-300 years (Anderson and Clark, 1999; Bedford, 2003) before it was either replaced or integrated into other post-Lapita cultures. But, at the Bourewa site, Fiji Islands, the Lapita settlement period was much longer spanning some 500-600 years (Nunn, 2007a).

While the issue of what compelled or motivated the Lapita people to migrate to other islands and/or search for new homelands is still unclear, there are several important considerations that may explain the reasons for the Lapita diaspora. These include, push factors like, population pressure and preference for marine resource-rich offshore islets/islands motivated them to colonise new lands, while trading opportunities for new resources to exploit and the social organisation of the Lapita people were important pull factors (Kirch, 1997).

In his work along the Sepik coast of New Guinea, John Terrell suggested that by the second millennium BC newly formed lagoons along New Guinea's northern coastline and elsewhere probably fueled prehistoric cultural change in the southwestern Pacific. The naturally increasing abundance of certain wild resources encouraged growth of human populations along the Sepik coast following the expansion of these lagoonal systems. This subsequently extended human social and economic horizons in all directions including eastward toward the Solomons and westward toward Island Southeast Asia (Terrell, 1997). Nunn recently pointed out (in support of Kirch) that, perhaps the major motivating factor for the migration and colonisation of the Pacific Islands by the Lapita people was marine-food resource availability perhaps due to high sea level and the expansion and development of marine-rich coral reefs on many islands in the Pacific (Nunn, 2007b).

It has been suggested that environmental change may have been an important pull factor in encouraging people to move to other islands as well. For example, Nunn and Heorake (2009) noted that during the past few thousand years, the tropical Pacific had become much drier and this aridity might have been the driver of cross-ocean exploration and migration. Nunn also suggested that climatic conditions then were relatively cooler than today and were associated with increased frequency of El
Niño events (Nunn, 2007b). During an El Niño onset, a westerly wind event in the far western Pacific pushes the West Pacific Warm Pool (an area of convergence in the western Pacific) towards the east. Once the warm pool gradually drains to the east, the convection now draws winds from both east and west and that pushes the warm pool further east. This results in cooler, drier conditions in the western Pacific while the east experiences much warmer, wetter conditions (Kessler, 2009). The occurrence of persistent westerly winds during an El Niño event may have been utilised by the Lapita people to migrate from west (Bismarck Archipelago) to east (Samoa-Tonga region). Recently Anderson et al. (2006) proposed the idea that an El Niño event or several of them, may have facilitated the exploration of the Pacific in what is generally regarded as an “against-the-wind migration” where movement was eastward against the trade winds.

2.2.5 Settlement of the Pacific during the last millennium (Post-Lapita Phase).

In Table 2.1, the settlement dates for selected islands in Melanesia, Polynesia and Micronesia are provided. The dates from Table 2.1 and “from the archaeological evidence, there appears to be a pause of 500 to 1000 years before permanent settlement of the eastern-most islands of Polynesia” (Hurles et al., 2003: 533). In Nunn’s (1999) synthesis of the earliest known settlement sites and dates for selected Pacific islands a generalised settlement trend suggest that older settlement sites were founded in Melanesia and parts of Micronesia whilst Polynesia comprised mostly younger sites.

The settlement of most parts of Polynesia as illustrated Figure 2.1 and Table 2.1 occurred only within the last millennium, marking the third wave of human migration into the Pacific. This phase of human settlement is characterised by the occupation of the islands farther east, south, and north of the Samoa-Tonga region mostly by the descendants of the Lapita people. They settled the Marquesas (~1650 BP), Hawaii (~1300 BP), Easter Island (~1180 ± 230 BP), Society Islands (<1200 BP), and Cook Islands (~1140 BP). New Zealand, Henderson Islands and Mangareva were settled between 900-700 BP (Nunn, 1999). According to Nunn and Britton (2001) Pacific Islanders probably migrated farther east of Easter Island and possibly
established settlements in parts of Central America like the Panama region sometime around AD 1514 (Figure 2.1).

Table 2.1. Radiocarbon dates for some of the older settlement sites for selected islands in Melanesia, Polynesia and Micronesia.

<table>
<thead>
<tr>
<th>Island (group)</th>
<th>Site</th>
<th>Date (years BP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melanesia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Ireland</td>
<td>Matenkuipum cave</td>
<td>32,700 ± 1,550</td>
</tr>
<tr>
<td>Buka</td>
<td>Killu</td>
<td>~ 28,000</td>
</tr>
<tr>
<td>New Britain</td>
<td>Masati cave</td>
<td>11,400 ± 1,200</td>
</tr>
<tr>
<td>Fiji</td>
<td>Natunuku, Viti Levu</td>
<td>3,240 ± 100</td>
</tr>
<tr>
<td></td>
<td>Boyrewa, Viti Levu*</td>
<td>3,170 (1,220 BC)</td>
</tr>
<tr>
<td></td>
<td>Nakoa, Motunui*</td>
<td>2,850 (800 BC)</td>
</tr>
<tr>
<td></td>
<td>Nasa</td>
<td>3,165 ± 120</td>
</tr>
<tr>
<td></td>
<td>Mala</td>
<td>3,150 ± 70</td>
</tr>
<tr>
<td></td>
<td>Teouma, Etete*</td>
<td>3,200-2,800</td>
</tr>
<tr>
<td>Polynesia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tonga</td>
<td>Tongatapu</td>
<td>3,540 ± 70</td>
</tr>
<tr>
<td>Samoa</td>
<td>Ferry Berth, Upolu</td>
<td>3,251 ± 155</td>
</tr>
<tr>
<td>Marquesas</td>
<td>Hane, Ua Huka</td>
<td>~ 1,650</td>
</tr>
<tr>
<td>Hawaiʻi</td>
<td>Waialuku, Hawaiʻi</td>
<td>~ 1300</td>
</tr>
<tr>
<td>Easter Island</td>
<td>Rano Kao</td>
<td>1,130 ± 230</td>
</tr>
<tr>
<td>Society Islands</td>
<td>Huhuhine</td>
<td>~ 1,200</td>
</tr>
<tr>
<td>Cook Islands</td>
<td>Ureia, Atutaki</td>
<td>~ 1,140</td>
</tr>
<tr>
<td>New Zealand</td>
<td>Waikawo Bar, North Island</td>
<td>~ 825</td>
</tr>
<tr>
<td>Henderson Island</td>
<td></td>
<td>790 ± 110</td>
</tr>
<tr>
<td>Mangareva</td>
<td></td>
<td>760 ± 80</td>
</tr>
<tr>
<td>Micronesia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mariana Islands</td>
<td>Chalan Pai, Saipan</td>
<td>3,479 ± 300</td>
</tr>
<tr>
<td>Caroline Islands</td>
<td>Bokor, Lamotrek</td>
<td>3,310 ± 85</td>
</tr>
</tbody>
</table>

Source: Nunn (1999:198) label#2.2. *Radiocarbon dates from Fiji (Boyrewa – Nunn et al., 2004; Nunn, 2007a; Motunui – Nunn et al., 2007) and Vanuatu (Teouma – Bedford et al., 2008) are included.

In summary, based on the available information and radiocarbon dates obtained from different sites, some parts of Island Melanesia were initially settled during the Pleistocene and most of the Holocene period while other parts were settled by the Lapita people particularly after the mid-Holocene. The Lapita period marked the time of rapid human settlement in both Near and Remote Oceania. During the past one thousand years, descendants of the Lapita people migrated farther south, north, and east and settled the region we now refer to as Polynesia and even as far as the west coast of Central America (Nunn and Britton, 2001).
While Anderson and Clark (1999) did not record any evidences for Lapita in Fiji that predates 2900 cal BP (950 BCE), recent evidences from Bourewa settlement point to even earlier period of human occupation for the Fiji Islands. The recent Fiji dates from Nunn and others’ work along the Rove Peninsula has provided strong support for a contemporaneously early Lapita settlement between the Reef/Santa Cruz-Vanuatu region and the Fiji Islands (Nunn et al., 2004). While Bedford et al. (2006) confirmed that Vanuatu was settled slightly earlier than Fiji, Nunn et al., (2004) suggested that the Lapita settlement at Bourewa was established sometime between 1220-970 BCE (3170-2920 cal BP).

Research work for example by Clark and Anderson (2001), Kumar (2004) and Nunn et al. (2004) have also provided additional dates to the scheme proposed by Anderson and Clark (1999) and most of these sites were settled prior to 2900 cal BP (850 BC). These include; Naitabale (Moturiki Island) (1220-540 BC), Ugaga (Bega) (1150-850 BC), Qoqo Island (1000-800 BC), Yanuca (950-800 BC), Naigani (900-750 BC), Lakeba (900 BC), Mago (850-650 BC) and Waya (850-450 BC). Other important Lapita settlement sites on Viti Levu Island include the famous Sigatoka Dunes (750-550 BC), Rove Beach site (750-550 BC) and Natunuku (> 550 BC) (Nunn et al., 2004, 2006; Nunn, 2005). There is also a possible Lapita presence at Navutulevu village on south Viti Levu Island (Figure 1.3).

The founder site of Nukuleka on Tongatatapu Island, Tonga dates to about 950 BC (2900 cal BP) (Burley and Dickinson, 2001) while the Mulifanua site on Upolu Island, Samoa contains dentate-stamped pottery sherds with Early Eastern Lapita motifs (Green and Davidson, 1974). Apparently, the islands in the Fiji-Tonga-Samoa region were devoid of human inhabitants prior the Lapita colonisation of Remote Oceania so the Lapita people were undoubtedly the first settlers of this part of the Lapita world three millennia ago (Kirch, 1997; Nunn, 1999).

The Lapita people also expanded into eastern and central Micronesia in the last few centuries of the first millennium BC. Of particular significance is the historical,
linguistic and archaeological evidence confirming the existence of two distinct regions within Micronesia. The first (western Micronesia), had links with people who may have originated from the Philippines and moved through Palau and the Marianas. The second suggests initial settlement of the central and eastern Micronesia region contemporaneous with the Lapita people who settled the Bismarck Archipelago and the Solomon Islands (Kirch, 1997). Based on the presence of red-slipped pottery, some decorated with lime-filled, impressed designs and well radiocarbon-dated sites, Kirch (2003) argued that humans settled the Marianas and Palau no later than 1500 BC (3450 cal BP) or possibly as early as 2000 BC (3950 cal BP).

Despite our current understanding of the Lapita occupation of Oceania and the contention over Lapita settlement patterns and why people settled where they did, the Lapita people first arrived in Fiji sometime about 3170 cal BP (1220 BC) (Nunn et al., 2004). As reported by Nunn (1999) and Kirch (2000), the Lapita people arrived in Fiji most probably from the Bismarck Archipelago and/or eastern Solomon Islands or Vanuatu (Bedford and Spriggs, 2008; Nunn, 2005, 2007a).

Their journey crossed an ocean-distance of some 850 km between the Reef/Santa Cruz group and the Fiji Islands about three millennia ago (Kirch, 1997). According to Clark and Anderson (2001:84) this episode marked a voyage that traversed “the longest uninterrupted sea passage in the Lapita world”. They probably encountered uninhabited islands in the Fiji group and were able to occupy a range of island types and sizes (Nunn, 2005). They initially settled on coastal open sites and sometimes later moved inland and occupied sites like caves and rockshelters (Kumar et al., 2004). There were also no earlier colonists with whom they needed to compete for land and resources (Lepofsky, 1988) so it was assumed they exploited a range of sea foods and ate well (Nunn, 2007b).

Based on the types of motifs and designs drawn on a range of potsherds excavated at various sites in Fiji, researchers like Gifford (1951) and Green (1963) were able to reconstruct a ceramic sequence for the Fiji Island. Although certain improvements and
additions have been made since, their scheme is still widely relevant today. Kumar (2007:67) reported that Simon Best (1984) also divided the Fijian ceramic sequence into four major chronological phases. According to Kumar, these are,

- Sigatoka Phase – 2850 -2500 cal yr BP (this is the Lapita ceramic complex period characterised by both dentate stamped pottery and Lapita incised ware),
- Navatu Phase – 2100-950 cal yr BP (is characterised by carved paddle impressed pots usually linked with Level 2 ceramics from the Sigatoka Sand Dune site),
- Vuda Phase - 950-250 cal yr BP (featuring mostly plain pots become while decorated pots are rare with some incising and appliqué), and,
- Ra Phase - 250-100 cal yr BP (are commonly associated with incised pots and a marked increase in the use of appliqué).

The foregoing chronological sequence is useful for understanding the transformation in the forms of pots and the types of designs and motifs associated with different prehistoric settlement intervals, but the issue of when and where the early colonists first settled in the Fiji Islands is still contentious.

A generalised settlement scheme proposed by Clark and Anderson (2001) revealed despite limited radiocarbon dates, a general pattern of west to east colonisation trend for the Lapita settlement of Fiji dating back to around 2900 cal BP (850 BC) (Anderson and Clark, 1999). Based on their model it appears that the Lapita people initially settled in the western and/or southwest part of Viti Levu Island before exploring and/or expanding into the northern, central and eastern regions of Fiji. Linguistic evidence (e.g. Geraghty, 1983) also lends support to this assertion. These two regions have distinctive languages, where eastern Fiji for example, has languages similar to the Tonga-Samoa region including the commonly spoken Bauan dialect.

2.3.1 Possible (Lapita) colonisation route of the Fiji Islands

The dichotomous colonisation model proposed by Clark and Anderson (2001) for the Fiji Islands has been useful but, the migratory trends of the Lapita people based on
recent studies are more complex. According to Kumar (2004), at least four pathways were followed by the Lapita people when they encountered the Fiji Islands.

Based on Kumar’s hypothesis, and as illustrated in Figure 2.5, the first group of colonisers entered Fiji through the sea gap between northern Yasawas and Vanua Levu Island and probably travelled southward along the leeward coasts of Viti Levu Island. They sailed along the extensive reef system off western Viti levu Island and met land and eventually founded their settlement at Bourewa on Vusama Island (Nunn, *et al.*, 2004). Most probably another group went north-eastward and settled on Vanua Levu Island. Although no radiocarbon dates were obtained from coastal and inland sites on Vanua Levu, Parke (2000) recorded evidences of a Lapita presence on the second largest island in the Fiji group. The radiocarbon dates for the Matanamuani site on Naigani Island might signify a slightly earlier Lapita presence or thrust into northern Fiji suggesting population movement through the Bligh Waters (Anderson and Clark, 1999) which may lend support to presence of this second group in this area. The recent dates for the Naitabale site on Moturiki Island also suggest a contemporaneous colonisation route via northern Fiji (Nunn *et al.*, 2005b), perhaps reaffirming previous suggestions by Anderson and Clark (1999).

Kumar (2004) suggested that from Bourewa, a third group sailed along southwest Viti Levu Island before expanding to the east via Beqa and Kadavu. The islands of Mago and Lakeba in the Lau group were probably settled by a later (fourth) group that originated from Moturiki and/or Naigani. Totoya was perhaps colonised by people from Viti Levu possibly around the same time that the other islands in the Lau group were settled. Although the model by Kumar (2004) proposed the colonisation of the Lau group of islands of Eastern Fiji by people who originated from either the central or southern Fiji, Burley and Clark (2003) contended that since the Tongan Archipelago were settled prior to Eastern Fiji, it is plausible to assume that perhaps some islands of the Lau group may have been colonised by people who originated from Tonga.

### 2.3.2 Lapita settlement pattern in Fiji

The pattern of Lapita settlement in the Fiji Islands is such that there was no apparent preference for any particular size of island. As postulated by Nunn (2005), the nature
of Lapita colonisation in the Fiji Islands indicates that both large and small islands were colonised by the Lapita people, unlike in Near Oceania where most early Lapita sites were established on smaller islands. As shown in Figures 2.4 and 2.5, the Lapita people settled on both Viti Levu and Vanua Levu Islands as well as other medium and smaller-sized islands during various times of the Lapita era.

In a proposed model describing the pattern of earliest human settlement in Fiji based on investigations of four Lapita sites on Viti Levu Island, Kumar et al. (2004) demonstrated that early Lapita settlements were exclusively established on open coasts like tombolos and sand spits, while later ones were founded farther inland and mostly associated with caves and rockshelters. On Vanua Levu Island for example, Parke (2000) also confirmed a similar settlement pattern.

This settlement pattern observed for the Fiji Islands is also mirrored elsewhere in both Near Oceania and Remote Oceania. It has been argued that access to abundant marine resources was an important factor in site selection and establishment, particularly during the earliest stages of settlement. The initial colonists deliberately settled coastal regions for optimal access to important food sources (Nunn, 2007b). Nunn argued that the availability of abundant marine foods was an important consideration when selecting settlement sites rather than access by water craft, proximity to fresh water, and land suitable for horticulture which Lepofsky (1988) noted as were the major considerations for the selection of settlement sites on other Pacific Islands.

Nunn (2005) also demonstrated that in Fiji both open and closed sites were occupied during the Lapita period. Open Lapita sites were mostly located on smaller offshore islands (e.g. Bourewa, Rove and Qoqo), tombolos (e.g. Qoqo, Matanamuani and Natunuku) and sand spits (e.g. Bourewa, Naitabale, Yadua and Navutulevu). These sites were all strategically located to optimise access to the available marine resources adjacent to these sites.
This settlement trend has been observed elsewhere in the Pacific where most Lapita sites were founded close to abundant marine resources. For example, the Malû (SZ-23) and Bianga-Mepala (SZ-45) sites in the Reef/Santa Cruz group, southeast Solomon Islands, the site of Lapita itself (sites 13, 13A, 13B and 14) in New Caledonia, the Lapita cemetery site of Teouma on Efate Island, Vanuatu, and Northern Tongatapu Island, Tonga. It appears the motivating factor for the initial establishment of Lapita settlements on coastal regions and offshore islands in Fiji as elsewhere was perhaps to optimise access to a broad fringing coral reef where a range of marine resources can be optimally exploited (Nunn 2005, 2007a, b; Nunn and Heorake, 2009).
Rockshelters and caves characterise the closed, inland settlements sites in Fiji. According to Kumar and others, factors that were influential in the founding of inland settlements in Fiji include increasing population pressures, susceptibility of coastal regions to frequent natural disasters and storms, cross-island trading networks and, the intentional exploitation of inland resources (Kumar et al., 2004). Nunn and Kumar (2004) also noted the transient movement of humans after initial arrival in Fiji into the interior of Viti Levu Island along the upper Sigatoka Valley. They suggested that during their explorations for inland resources early humans might have lit fires along the Yaloku Creek, though it is possible that the fires could have been the result of a Pacific-wide drought period that also affected Fiji at that time.

Although no radiocarbon dates were obtained, archaeological investigations conducted in northern Fiji had led to significant discoveries including the first reported Lapita site on Vanua Levu Island - an inland site at Vaturekuka and identification of an early site characterised by pot covers with phallus-shaped vertical handles (Parke, 2000). Parke also suggested that the Lapita people explored inland areas for a number of reasons. These include exploitation of inland fauna such as birds and lizards, search for fine-grained source rocks for manufacturing stone tools like adzes, and for agriculture/horticulture activities along the fertile valley floor of major river systems.
3.1 Introduction

This review chapter is divided into three parts. The first part (sections 3.2 and 3.3) describes the nature of prehistoric subsistence practices in the Pacific basin and outlines the main features of these subsistence patterns. Part two (section 3.4) discusses human-environment interactions in pre-modern (Pacific) societies and the third part (section 3.5) explains the different foraging theories that are useful for understanding human predation on the shellfish species and habitats along the Rove Peninsula.

The objectives of this chapter are to,

- outline the major trends in prehistoric subsistence in the Pacific basin,
- explain the nature of subsistence practices during Lapita times in Oceania,
- describe human-environment interactions in the tropical Pacific in pre-modern times, and
- explain the foraging theory models that are important for understanding and interpreting faunal assemblages including shellfish species and habitats.

3.2 Perspectives on prehistoric subsistence in the Pacific Basin

The interaction between humans and resources in pre-modern times has revealed several trends in human subsistence practices particularly in relation to the proportion of marine resources exploited for sustenance by humans. According to Nunn, archaeological studies have revealed three major subsistence trends. Firstly, during the early Pleistocene – late Pleistocene humans exhibited low dependence on the marine environment where they consumed minimal amount of marine foods. Secondly, during the late Pleistocene – mid-Holocene they incorporated relatively more marine food into
their diet and thirdly after the mid-Holocene, most coastal settlements were increasingly dependent on marine food resources (Nunn, 2007b).

In general, throughout human prehistory the relative proportion of marine foods consumed by humans appear to have gradually increased over time. When the Lapita people expanded into both Near and Remote Oceania about three thousand years ago they had adopted a mixed subsistence economy where they consumed relatively high proportions of terrestrial food as well to supplement their predominantly marine diet (Davidson and Leach, 2001).

3.2.1 Subsistence during early Pleistocene to late Pleistocene

Although modern humans (*Homo sapiens*) did not appear in the fossil record before about 50,000 years ago in the Pacific Basin, a 300,000 year-old ‘hominid site’ in France called *Terra Amata* and a 130,000 year-old site in South Africa exemplify two of the earliest known sites for marine resource utilisation particularly shellfish consumption (Szabó, 2002). Szabó explained that these deposits of shells and fish bones, fishhooks and shell artefacts show that *Neanderthals* occasionally consumed marine resources despite a major portion of their diet comprising terrestrial foods. Szabó also noted that within the Australasia region, Vietnam, Australia and the Bismarck Archipelago of Papua New Guinea represent some early sites containing evidence for both marine and freshwater molluscs exploitation. These sites date from about 35,000 to 11,000 years ago. Apparently modern humans, unlike their hominid cousins, had a relatively broader diet because they consumed more marine foods and exploited a wider range of food sources.

Several factors are important in order to understand the nature of subsistence practices during the Pleistocene in the Pacific region. Firstly, the Pleistocene period is generally marked by lower sea levels and cooler temperatures. As such Nunn (1999) noted that lower sea levels and cooler global temperatures associated with the Last Glacial Maximum (LGM) were major limiting factors because cooling of most of the worlds’ oceans had affected marine resources availability. Coral reef growth for most parts of the Pacific was also affected by cooler temperatures thereby influencing other marine
organisms that inhabited and depended on coral reefs for food and survival (including protection against predators).

Secondly, lack of secure sites and archaeological data that date back to the Pleistocene are also limiting factors. Since many sites in the Sunda Shelf comprised low archaeological sampling and depaupeate faunal record, possible earlier or older sites or phases are yet to be discovered and securely analysed. So, detailed identifications and analyses of the assemblages are limiting attempts to understand the nature of human subsistence during this period particularly regarding the exploitation of marine resources (Anderson and O’Conner, 2008).

Due to the absence of sufficient archaeological data for the late Pleistocene period, Kirch (1997) cautioned that it can be tempting to speculate on the life ways of early colonists of Near Oceania (the islands of New Guinea, the Bismarcks, and the Solomon Islands). But, recent data from the New Guinea highlands indicate that the early settlers of this area had adapted to non-coastal environments by at least 25,000 years BP, while New Ireland coastal sites contained faunal remains of extinct forest birds. Evidence from the Matenkupkum site on New Ireland also indicates some utilisation of low-level fishing skills and technology with shellfish and echinoderms mostly targeted by hunter-gatherers (Leavesley, 2006). Thus Leavesley suggested that perhaps soon after their arrival in the archipelagos of the Bismarcks and Solomons, these early colonists may have also utilised the available coastal marine resources, though their diet comprised relatively more terrestrial foods.

3.2.2 Subsistence during late Pleistocene to mid-Holocene

After more than ten millennia of human settlement in Near Oceania several important environmental and cultural changes were taking place. Amongst these were changes in sea level after the Last Glacial Maximum (LGM) and an increase in the number of sites with shell midden deposits. Szabó (2002) noted that as sea-level rose after the last ice age, favourable environmental conditions for expansion of shellfish and fish populations were created thus attracting prehistoric people to the coastal regions on both continents and islands. The huge shell mounds found for example in coastal sites in the United States, Australia and parts of Europe indicate that the people who
occupied these sites probably depended heavily on shellfish as a food source. Kirch (1997) also suggested that the rapid rise in sea level due to melting of land ice masses resulted in inundation of coastal regions causing certain settlements to be established inland while encouraging coral reef development and rich marine life, thus triggering a change in subsistence strategies for exploiting marine resources.

Besides changes in settlement patterns and subsistence strategies, Near Oceania also witnessed other significant developments during this period. For instance, the appearance of obsidian flakes from New Britain in New Ireland archaeological sites, bones of the Gray Cuscus (*Phalanger orientalis*) in the Bismarck Archipelago sites at about 18-20,000 years ago, and the marsupial (*Thylogale brunii*) in the Balof cave sequence, New Ireland about 7000 years ago. It is plausible to assume that these volcanic rocks and animals could only have reached these islands had people carried them there (translocation). Thus, these developments meant huge implications for exchange networks between island groups and communities, perhaps increased voyaging by people across different islands and the change in peoples’ attitudes towards the environment (Kirch, 1997). As Gosden (1993) noted, perhaps these data represent a shift from people moving about the landscape to ensuring that resources were brought to them or their settlements. A cultural transformation that Gosden described as, changing from nomadism to sedentism.

Around the Pleistocene - Holocene boundary, Kirch (1997) pointed out some notable innovations towards plant domestication and crop cultivation within Near Oceania. Amongst these were important domesticated crops such as sugar cane, banana, *Pueraria lobata*, and *Cordyline fruticosum* in the New Guinea region. Kirch also noted that the Kuk Swamp record (highlands region of New Guinea) demonstrates that taro (*Colocasia esculenta*) cultivation had already occurred about 9000 cal BP, but Fullagar *et al.* (2006), argued for an even earlier date for processing of taro (*Colocasia esculenta*) and yam (*Dioscorea* sp.) which dates back to around 10,200 cal BP.

By the beginning of the Holocene period, people within mainland New Guinea were already cultivating trees, root and tuber crops including taro, yam and other plants especially in the wetlands of the New Guinea highlands (Fullager *et al.*, 2006). Hurles *et al.* (2003) also noted that around 9000 cal BP, cultivation of tree crops and
other plants was already in place in certain parts of Near Oceania. Archaeological evidence too has demonstrated that horticultural practices were already established in the New Guinea highlands region during the Holocene, establishing it as one of the global centers for horticultural development (Kirch, 2000, 2003). Kirch (1997) suggested that aroids like *Cyrtosperma chamisonis* and *Alocasia macrorrhiza*, were also cultivated and there is ample evidence for the domestication of a number of fruit and nut-bearing trees like coconut, breadfruit, and the hard-shelled nut *Canarium* almond. Although the mid-Holocene archaeological record in Near Oceania remains sketchy due to changes in settlement patterns and scarcity of data, it appears there was a hiatus in settlement after most sites were abandoned around 8000 cal BP (Leavesley, 2006) only to be re-occupied within the last 2000 years (Kirch, 1997).

Of the few sites that yielded significant archaeological data prior to the appearance of the Lapita people in Near Oceania, Kirch (1997) noted the Dongan Village site (northern New Guinea) dating to about 5800 years BP, Matthew Spriggs’ Nissan Island (Halika Phase) site and David Roe’s 6000-year-old Vatuluma Posovi (Poha Cave) and Vatuluma Tavuro sites (Guadalcanal Island, Solomon Islands). Some of these sites contain well-preserved fossils of important tree crops, nut and fruit crops including the sago palm which implies the presence of an agricultural-dominated economy.

There is also evidence for hunting of a range of terrestrial fauna while fishing and shellfish gathering contributed a large proportion of their diet with indications of the use of some form of sophisticated fishing technologies. It is apparent that the people who occupied these sites employed a mixed-subistence strategy incorporating both terrestrial and marine food resources into their diet. Hence as Kirch (1997:41-42) stated the “millennia of familiarity with coasts, reefs, and lagoons also led to increased knowledge of the sea’s resources and of how to capture these”.

Generally the beginning of the Holocene period witnessed increased number of settlements and the establishment of exchange networks between different island communities. There was also evidence for crop cultivation and plant domestication and
the availability of a range of resources which people can exploit. Despite these cultural developments and marine innovations, Kirch suggested that the overall orientation of Old Melanesia during this period appears to have been still more towards the land rather than the sea (Kirch, 1997).

3.2.3 Subsistence after the mid-Holocene

From the Bismarcks to the southeastern Solomon Islands, Vanuatu, New Caledonia, Fiji, Tonga and Samoa, numerous evidences of the variety of flora and fauna exploited by the Lapita people testify to their culture, skills, technology and impact on the environment (or resources). The colonising populations of both Near and Remote Oceania initially lived along the coast as transient hunter-gatherers and horticulturists/agriculturalists who subsisted on wild foods and animals present on the islands they inhabited. They consumed animals such as marsupials, reptiles, sea birds, fruit bats, and rats, while wild forest plant foods also provided staples (Kirch, 1997; Leavesley, 2006).

The Lapita people also ate fish, shellfish and other invertebrates mostly derived from mangrove swamps, inshore coral reefs, and lagoons. They also exploited and supplemented their diet with tubers, seeds, fruits and nuts of wild plants. Fruit trees and food gardens were cultivated and they also domesticated animals (Kirch, 1997). Kirch noted that certain animals and plants were purposely domesticated and transported by the Lapita people to different Pacific Islands as an essential part of their strategy for settling new islands and as a basis for food production. Several examples of animals that were domesticated and transported by the Lapita people as part of the colonisation strategy include dogs, pigs and chickens (Kirch, 1984, 1997).

Despite the persuasion of current evidence suggesting that the Lapita people may have employed a mix subsistence economy which means they depended on both the terrestrial and marine environments for their subsistence, there is still contention over the subsistence strategies of the Lapita people who colonised Oceania (Davidson and Leach, 2001).
3.3 Subsistence during Lapita times in Oceania - Oceanic Strandloopers versus Horticulture/Agriculture

The objectives of this section are to,

- outline the debate over Lapita subsistence economies and the recent advances in reconstructing subsistence economies of the Lapita people,
- explain the concept of Oceanic Strandloopers and Horticulture/Agriculture by providing the context for understanding the apparent trends in subsistence practices in Remote Oceania, and
- describe some of the important subsistence studies from different parts of Oceania where the Lapita people had colonised.

Since the first excavations of Lapita settlement sites in Oceania, archaeologists have continuously debated whether or not the Lapita people were primarily hunter-gatherers or if they also practiced horticulture/agriculture. Davidson and Leach (2001) who reviewed the debate on Lapita subsistence practices ably provided an overview of the nature of subsistence economies of colonising populations in the Pacific Islands. Other researchers who have enhanced our understanding of the life ways of the Lapita people through their work include, Anderson (2003); Burley et al. (2001); Crowther (2005); Green (1979); Groube (1971); Horrocks and Bedford (2004); Horrocks and Nunn (2007); Leach et al. (2000, 2003); Nagaoka (1988) and Swadling (1986).

One of the major factors fueling the subsistence debate has been the lack of plant food remains in the archaeological record for most Lapita sites in Oceania (Horrocks and Bedford, 2004; Horrocks and Nunn, 2007). Consequently, issues of Lapita subsistence have divided archaeologists into two opposing camps that continue to advance their views, despite Nagaoka’s (1988:131) caution that, “Lapita economies will not fit a simple dichotomy between strandlooper and horticultural” models. Hence, while the debate continues, recent evidences suggest that there is sufficient support for some form of a mixed-subsistence economy which echoes similar views as those posited by Nagaoka (1988) and Davidson and Leach (2001).
3.3.1 Oceanic Strandloopers

The Oceanic Strandlooper model was first proposed by Groube in the 1970s to explain subsistence practices by the Lapita people based on evidences recorded in the Tonga Isles (Groube, 1971). The model is premised on three factors – lack of evidence of domesticated plant materials, absence of pig bones, and the presence of rich shell middens at most Lapita sites. According to Kirch, Groube’s Oceanic Strandlooper model, “was influenced by the rich shell middens associated with Early Eastern Lapita pottery in Tonga and by the apparent absence of pig bone from these sites” (Kirch, 1997:194). A similar observation was recorded by Burley (1998) in the Ha’apai faunal collections. In particular Burley noted the marginal evidence for the presence of pig and dog bones and suggested that agriculture (or animal domestication) played only a secondary role in the early Tongans subsistence economies implying that the early colonists may not have brought with them such commensal animals.

The argument by some archaeologists (e.g. Anderson, 2003; Burley et al., 2001; Groube, 1971) that the lack of domesticated plant materials in the archaeological record means that the early Lapita people were mostly “Oceanic Strandloopers” who subsisted primarily on marine food resources as they settled on the islands they inhabited is very persuasive. Anderson (1996) also lend support to this proposition by stating that while resource availability is the main driver for Pacific colonisation, the role of agriculture and/or horticulture during post-initial settlement was either secondary or limited.

As such, the Lapita people apparently had a “restricted maritime, lagoonal economy” and subsequently developed horticulture or agriculture which later on enabled them to colonise islands in Fiji, Tonga and the rest of the Pacific (Davidson and Leach, 2001; Horrocks and Bedford, 2004; Horrocks and Nunn, 2007).

The main point of contention of the Strandlooper model is that, the early colonists of Remote Oceania obtained their food resources largely by fishing and shellfishing (Davidson and Leach, 2001) and probably only “shifted from reef exploitation to agriculture in the later half of the first millennium BC” (Swadling, 1986:145). Thus
horticulture/agriculture or the cultivation and domestication of certain plants and animals were not significant components of the initial Eastern Lapita subsistence economy. But, recent findings from older Lapita sites like Bourewa in Fiji (Horrocks and Nunn, 2007) may be contesting the reliability and consistency of the Strandlooper model for Remote Oceania.

3.3.2 Horticulturalists/Agriculturalists

In contrast to the Oceanic Strandlooper model, some archaeologists strongly maintain that the Lapita economy had always included a major horticultural/agricultural component. For instance, Green (1979) questioned the Strandlooper model based on his work in the Reef/Santa Cruz group, southeast Solomon Islands. In his synthesis Green cited important cultural developments like the location of Lapita sites, settlement size, pits (used for food storage), cooking ovens, pottery cooking vessels, adzes, vegetable scrapers and peelers and other tools which he argued point to some degree of horticultural practice by the Lapita people of Remote Oceania. In support of Green, Kirch (1997) stated that such indirect evidences strongly implied horticultural practices and therefore may have weakened the Oceanic Strandlooper concept.

In fact archaeological evidences collated from various places within Oceania have allowed Kirch (1997:192-255) to reconstruct subsistence economies of the Lapita people and showed that they had wide ranging diets and cuisines. Davidson and Leach (2001:118) are also convinced “that people cannot live satisfactorily on a diet that consists largely of fish and shellfish” implying that the Lapita diet might have also included a certain portion of plant foods that obviously supplemented their marine foods.

In their comparison of the faunal remains from archaeological sites in Remote Oceania, Davidson and Leach (2001:116) noted some major distinctions and queried Patrick Kirch’s “transported landscape” concept. They questioned the idea of whether or not the early colonisers of the Pacific Islands and their crops “arrived everywhere with the first canoes rather than progressively over a longer period” or if
agricultural (domesticated) crops were also introduced by subsequent migrants over time.

A case in point is the recent Bourewa pollen data reported by Horrocks and Nunn (2007). According to Horrocks and Nunn it appears that the evidence for horticultural practices at Bourewa coincided with the same period when Eastern Lapita motifs became prominent at the site, thus, begging the idea whether they were contemporaneous. The initial colonisers of Bourewa may not be directly responsible for the introduction of taro and yam to that area (though it is possible), but, it was perhaps the later Lapita migrants who brought these cultivars to Bourewa settlement.

Despite the persuasive nature of both the Oceanic Strandlooper and Horticulture/Agriculture models, the debate over Lapita subsistence economies particularly in Remote Oceania is far from being resolved. A comparative and detailed quantitative assessment of the available archaeological data and faunal abundances from within both Near and Remote Oceania is important to provide a comprehensive picture of Lapita subsistence economies. This is especially required in order to shift away from the dichotomous and simplistic nature of the contentions and advance a much more refined and reliable scheme for understanding subsistence practices based on recent evidences and data (Nagaoka, 1988).

3.3.3 Recent advances in reconstructing subsistence economies in Oceania

It is common for archaeologists studying shell middens to often observe a very productive lagoon or coral reef nearby and immediately assume that prehistoric people just had to consume sea food to get their nutritional requirements due to their proximity with the ocean. Often it is difficult to appreciate that the lack of arable land for crop cultivation does not necessarily imply there was no horticulture/agriculture being practiced but, actually root and tree crops like taro, yam, and breadfruit, may comprise a significant component of most Pacific Islanders diet as well.

It is plausible to assume that prehistoric people may have also consumed far more terrestrial food than they ate fish and shellfish. So, to properly understand Lapita diet, analysing and quantifying fish bones and shells is not sufficient. For shell or fishbone
studies, a comparative collection is required to identify and analyse the site’s composition. For full dietary reconstruction the composition of different kinds of foods and how this gets into peoples’ bones and hair and can be examined to analyse the proportion of food acquired from the sea and/or the land.

Despite our current knowledge of the different types of food resources consumed by the Lapita people (Kirch, 1997) and the debate over the types of food they ate, determining what proportion of food types (terrestrial or marine) comprised the diet of prehistoric people has been subjected to much conjecture and recent research (Janet Davidson pers. comm., 2007). In recent years, particular scientific methods used in analysing stable isotopes in human tissues for example has provided very useful empirical data for better understanding of the diet of the Lapita people and their descendants.

Szabó (2002) noted that recent advances in scientific techniques have enabled the assessment of the relative proportions of marine and terrestrial food sources in prehistoric human diet. For instance, the use of Multiple Isotope Signatures ($\delta^{13}$C, $\delta^{15}$N and $\delta^{34}$S) is being utilised in reconstructing prehistoric (Lapita) human diet from archaeological bone (Leach et al., 2000, 2003). Other methods include the direct identification of fossil plant starch residues, pollen and phytoliths in soil sediments, pottery, and tools and artifacts (Crowther, 2005; Horrocks and Bedford, 2004; Horrocks and Nunn, 2007). These techniques have enhanced the assessment of Lapita diets in both Near and Remote Oceania and have proved very useful for refining our understanding of the nature of subsistence practices by the Lapita people.

While humans survived in Near Oceania by hunting and gathering for thousands of years, there is now direct evidence for the use of economic and/or domesticated plants by the Lapita people (Kirch, 1997). The Watom study by Leach et al. (2000) demonstrated where plant and seafood fits into the overall scheme of Lapita diet at Watom, New Britain Island, Papua New Guinea. For example, stable Isotope analysis of human bone from six individuals from the Reber-Rakival Lapita burial site on Watom Island recorded the relative contribution of both plant and marine food sources in the Watom prehistoric diet. The Watom diet consisted of fish and
land herbivores as the main protein sources, while plant foods contributed most of the energy requirements. The study by Leach *et al.* (2000:149), therefore shows that “approximately 64% of the diet at Watom came from land-based food and 36% from the sea”.

Through the technique of light microscopy, Crowther (2005) also demonstrated the presence of starch residues preserved on undecorated pottery sherds from Anir, on New Ireland, Papua New Guinea. The study by Crowther has identified microbotanical starch residues and raphides belonging to the aroid *Colocasia esculenta* (taro) and presented a strong case for plant-food processing that particularly involved undecorated Lapita pottery and the general association of pottery with cooking or boiling of starchy food for consumption.

In their study of the Naitabale site, Moturiki Island, Fiji, Nunn *et al.* (2007) also demonstrated that terrestrial plants were an important component of the diet at Naitabale contributing relatively more than marine species. But that the woman named *Mana* had a mixed marine-terrestrial diet, where marine species such as shellfish and fish were dominant protein sources. The analysis of non-human bones at the Naitabale site also supports this conclusion.

Another plant-fossil evidence that lends support to horticultural practice during the Lapita era in Remote Oceania comes from Vanuatu. Based on an examination by Horrocks and Bedford (2004) of plant microfossils in 14 coralline soil and potsherd samples from a 2700 BP (750 BC) Lapita site on Uripiv Island, they have identified starch grains, calcium oxalate crystals and xylem of introduced aroid (non-*Colocasia*). According to Horrocks and Bedford the Uripiv data represents the first direct evidence of Lapita horticulture in Remote Oceania. It demonstrates that introduced *Araceae* grew on Uripiv during Lapita times or people had utilised it for horticulture or food preparation. These data also support plant evidence from Lapita sites in the Bismarcks and add to the indirect evidences from Near and Remote Oceania which confirm that horticulture was an integral component of the Lapita economy.
Although the Naitabale site study has been informative, we may never know for certain what foods the people who first settled at Bourewa consumed, how they lived and impacted the natural environment (resources), and how the environment influenced their behaviour (actions). But, the best possible answers to these questions may be obtained from studying and understanding the plant (fossil) and faunal (shellfish) evidences from the Bourewa settlement.

During the June-July 2005 field season at the Bourewa site, soil samples obtained for plant microfossil analysis yielded significant results. The preliminary soil analysis of the Bourewa Lapita-era site has revealed the presence of both *Colocasia esculenta* (introduced taro) and *Dioscorea esculenta* (lesser yam). This is perhaps the first for the Fiji Islands (Horrocks and Nunn, 2007). It is most likely that if such analysis is conducted on a range of other older sites within the Fiji Archipelago the chances of verifying the widespread consumption of plant foods during Lapita times will be enhanced.

The Uripix and Bourewa data though provide very compelling evidence for Lapita horticulture/agriculture practices in Remote Oceania. Like the Uripix data of Horrocks and Bedford (2004), the Bourewa results suggest that horticulture was an important component of the Lapita subsistence economy and especially the domestication of root crops by Eastern Lapita populations. Horrocks and Nunn (2007) suggested that, since the extent of natural distribution of terrestrial aroids in Oceania extends east only as far as Vanuatu, the Bourewa finds, besides providing evidence of food processing horticulture/agriculture, are undoubtedly anthropogenic introductions. These root crops were definitely introduced into the Fiji Islands by the Lapita people during the second phase of occupation at Bourewa settlement (Nunn, 2007a).

The Bourewa data also demonstrate that the colonising populations of Remote Oceania and Fiji in particular had a mixed-subsistence economy where they incorporated plant foods, fish and shellfish in their diet. New data generated from recent research both in Vanuatu and Fiji are challenging some of the old subsistence theories, in particular the Oceanic Strandlooper concept and its relevance certainly to parts of Remote Oceania.
The evidence for horticulture/agriculture in Vanuatu and Fiji also lends further support to previous research on Lapita subsistence in the Bismarcks and the Reef/Santa Cruz Group that highlighted the importance of aroids like taro and yam to early Pacific peoples (e.g. Kirch, 1997). In their reconstruction of the subsistence economy of pre-European Maori who lived on the shores of Cook Strait, central New Zealand, Davidson and Leach (2001) also concluded that the first Maori settlers had consumed both cultivated plant food and fat while essential caloric energy was derived from sea mammals as they established their gardens, which essentially implied they had a mixed-subsistence economy. So, it may only be plausible to suggest that perhaps sooner more evidence for horticulture/agriculture practices will be uncovered in the Fiji-Tonga-Samoa region which up to now has proved quite elusive.

3.4 Human-environment interactions in pre-modern (Pacific) societies

This section outlines the nature of prehistoric interactions between humans and the environment in the Pacific Islands. It describes human-environment interactions in Fiji as a backdrop for understanding human predation pressures on resources including the shellfish at the Borewa Lapita site.

Human and non-human causations of environmental change in island environments have been the subject of much interest and study in Fiji recently (e.g. Field, 2004; Morrison and Cochrane, 2008; Nunn, 2003). In most instances prehistoric populations have been portrayed as principally responsible for resource depression and/or extirpation and extinction of certain flora and fauna on islands while minimal attention has been given to the impact of environmental change on resources and human behaviour over time (Nunn, 2003). Drawing on recent studies, the cases presented here largely strive to illustrate the interplay between humans and the environment in the earliest period of human settlement on selected parts of the world and the Pacific Islands.
3.4.1 Human impact on resources

The impact of prehistoric populations on the natural environment and its resources is well documented. Recent studies have demonstrated that humans were responsible for the decline and demise of certain flora and fauna on most continents and islands (Allen, 1992; Athens, 1997; Butler, 2000; Grayson, 2001; Hunt and Kirch, 1997; Kirch, 1982; Nagaoka, 2001, 2002; Simone and Navarro, 2002).

Studies done in both North and South America have indicated that several factors have been important contributors to the decline in certain resources by humans. Butler (2000) for example, noted the impact of changing demography and human predation pressure on mammal and fish resources from eight sites on the Columbia River (Oregon, USA). Simone and Navarro (2002) also reported on the impact of steady hunting pressure by hunter-gatherers from the mid-Holocene on local marine resources like sea birds at Chan Chan site, southern Chile. They explained that due to the diversity of the coastal resources, hunter-gatherers who occupied this area developed appropriate technology to exploit these resources.

In the Bismarck Archipelago island of New Ireland, Papua New Guinea, Steadman and others have documented at least 50 bird species that once lived there are now extinct including at least 12 which were not previously recorded. New Ireland was settled from about 35,000 years ago and, since the avian bones date from 15,000 to 6000 years old, they suspected that the avian extinctions were most probably due primarily to humans (Steadman et al., 1999).

Other parts of the Pacific region where human impact on the environment had apparently led to vegetation change and extinction or extirpation of terrestrial resources are also outlined here. For example, in New Caledonia, Stevenson (1999, 2004) reported a late-Holocene vegetation record for the southwest coast of the main island, La Grande Terre. Through pollen analysis, charcoal analysis, radiocarbon dating and stratigraphic analysis, significant changes were found in the sedimentary history of the Lac Saint Louis swamp. Between 6000-5500 BP the sediment record indicates rapid floodplain development associated with postglacial sea-level rise. The pollen record from 5500-3000 BP reflects certain vegetation changes to the coastal
landscape associated with the stabilisation of sea level. These landscape changes particularly around 3000 BP have been associated with the advent of humans in New Caledonia. By around 2000 BP the yam terraces surrounding the Lac Saint Louis area may have been constructed and used. The archaeological records for Lac Saint Louis and Plum sites indicate that forest cover was extensive prior to human arrival and that charcoal accumulation increased significantly after 3000 BP and 2500 BP respectively.

Although climatic fluctuations could be important in environmental change since New Caledonia was first settled (around 3000 years ago), the data show that since the Lapita period, humans have been the principal perpetrators of environmental change, a pattern that is believed to be widespread across the region and farther east. As reported by Stevenson et al. (2001), the impact of the initial colonisers of New Caledonia on the environment is significant. Humans were principally responsible for altering the vegetation of the valleys to savannas and converting the lowland forest to stunted woodland species.

In Tonga, Steadman’s (1999) study on bird extinction and the impact of early-human settlers on the Tongan environment highlighted that the rate and degree of vertebrate extinction on Pacific Islands were influenced by both human and nonhuman factors. The Lapita occupation of Tonga occurred some time after 3000 years BP and the Lapita sites that Steadman examined have yielded abundant bones of bird species that are now extinct so it is plausible to assume that human factors were important in the demise of these bird species.

According to Dalzell (1998), the interaction of prehistoric human populations with their natural (island) environment based on archaeological studies in the Pacific show that human predation has caused resource depletion on several sites in islands like Matenupkum (New Ireland, PNG), Mussau (Papua New Guinea), Tikopia (Solomon Islands), Tongatapu (Tonga), Aitutaki (Cook Islands), Mangaia (Cook Islands) and Kapingamarangi and Nukuoro (Federated States of Micronesia). In Dalzell’s synthesis the archaeological record of anthropogenic impact particularly on Pacific coastal fisheries resources, also reveal a long-term subsistence exploitation pattern of fish and invertebrates from nearshore coral reefs and lagoons and
underscores the importance of molluscs as a food source for early colonists of the Pacific Islands. Dalzell also stated that perhaps the decline in the abundance of molluscs through harvest pressure and environmental effect had subsequently led to a greater reliance on finfish capture and the development of agriculture.

Other examples of human impact on resources include Swadling (1986) who documented the impact of early colonisers of the Reef/Santa Cruz Group (Solomon Islands) on certain marine shellfish species. In Tonga, Spennemann (1987) documented the impact of initial human settlers on Tongatapu Island on shellfish size and availability within the Fanga ‘Uta Lagoon. Nunn and others also pointed out that intense exploitation of wild resources is characteristic of most colonising populations on island environments and the archaeological (shellfish) data from both the Naitabale site and Qoqo Island (Fiji Islands) also lend support to increased human predation pattern on shellfish resources (Nunn et al., 2006, 2007).

3.4.2 Prehistoric (human) interactions in the Fiji Islands

Both human-induced resource stress and environmental impact on resources have been demonstrated throughout Fiji’s prehistory. While humans have had significant impacts on certain terrestrial fauna (e.g. Worthy et al., 1999), environmental change (associated sea-level fall) had also influenced the abundance of both terrestrial and marine resources over time. In some instances environmental impact on resources was responsible for causing societal change, increased competition, and conflicts in most parts of Fiji in the recent (post-Lapita) past (e.g. Field, 2004; Nunn, 2003; Morrison and Cochrane, 2008). The impact of early humans on some of Fiji’s vertebrate fauna in prehistory had resulted in the demise of certain species. For example, the study by Worthy et al. (1999) of the Volivoli and Qara-ni-vokai Caves in the lower Sigatoka area exemplify a case of possible prehistoric human impact on a range of megafauna on Viti Levu Island, Fiji. The Fiji Islands are generally regarded as a land without mammals, but the fossil remains of some megafauna recorded by Worthy and others comprising a frog, an iguana, a terrestrial crocodile, a possible tortoise, a dodo-sized pigeon, a megapode, and numerous birds indicate that various vertebrate species of Amphibia,
Reptilia and Aves were present prior to the initial human colonisation of the Fiji Islands but these are now locally extinct. According to Worthy *et al.*, the disappearance of these species coincided with the arrival of humans in the Sigatoka area.

Worthy *et al.* (1999) also stated that since there was no evidence of major climate change during the last 6000 years of Fijian prehistory, the probability of this extinction (or extirpation) being due to natural forces is insignificant. Therefore, it is plausible to assume that when people first arrived in Fiji about 3000 years ago and especially around the Sigatoka area and began influencing the environment, some of these ancient Fijian endemics became early casualties of human contact (actions). Continuous and perhaps widespread clearance of forests and increased utilisation of the natural resources may have contributed to the extinction/extirpation of the other megafaunal species as well. The degree of human impact on other islands within the Fiji group is difficult to ascertain but this particular study provides invaluable insights into the impact of early humans on the environment and its implication for other parts of the Pacific Islands.

Through an interdisciplinary study, Dickinson *et al.* (1998) also hypothesised a role for humans in the exacerbation and enhanced development of the sand dunes at the mouth of the Sigatoka River after initial human (Lapita) settlement of the area. They suggested that when humans first occupied this area, dune formation was minimal but deforestation (presumably by humans) in the upper regions of the Sigatoka Valley became an important contributing factor in dune development.

Although the degree of early human impact on inland vegetation in the Sigatoka area (and particular flora) is debatable, Nunn and Kumar (2004) demonstrated the probable and/or intentional use of fire by the Lapita people along the Yaloku Creek in the upper Sigatoka Valley. They proposed that the use of land fires can cause death and destruction to both plants and animals, and exposed soils to rain rendering them prone to soil erosion. The eroded soils entered the river system and were transported downstream and into the Pacific Ocean. Ocean currents and waves carried the sediments ashore and were then blown onland by the southeast trade winds and eventually accumulated as dunes near the Sigatoka River mouth.
According to Clark and others, when humans arrived on Totoya Island (southeast Fiji), the landscape was different from today. Sea level was relatively higher than present and the coast was exposed with less land area. The shrub - *cibicibi* (*Cynometra insularis*) dominated the forest flora on Totoya Island. But as human activity like forest clearance increased, soil accumulation in lowland areas led to the natural progradation of the coastal plains and the expansion of mangroves. The use of fire as an agricultural tool was also widespread on the island and this contributed to the expansion of existing grassland vegetation at that time. Totoya Island exemplifies human impact as the principal agent of environmental change on the landscape and vegetation of a small island although natural factors may also have been important. Hence, when considering environmental change during the initial stage of human colonisation and settlement on small islands like Totoya, the role of humans may have been very significant (Clark *et al.*, 1999).

Although no ethnographic data on shellfishing currently exists for the Rove Peninsula, shellfishing and fin fishing in Fiji is done collectively and exclusively by women (Randy Thaman *pers. comm.*, 2005). During shellfishing trips and, as observed along the Rove Peninsula during the mid-2005 field season, the women of Bourewa would walk at low tide along the reef flat and mudflat or into the adjacent lagoon towards the reef edge to pick up or dig out shellfish from the sand and mud, or under rock boulders and/or collect those shellfish that are embedded in rock crevices or grazing on the reef flat. Sometimes they would wade into the Tuva River to pick out freshwater mussels and other shellfish species from the river bed (Tai Dido and Laisani *pers. comm.*, 2005).

### 3.4.3 Previous shellfish studies in Fiji

The analysis shellfish species recovered from different archaeological sites in the Fiji Islands are not uncommon. In her review of Lapita shellfishing within the Pacific region, Swadling (1986) highlighted some of the earliest shellfish analysis conducted in the Fiji Islands. These investigations include Gifford (1951) who examined coastal sites on Viti Levu Island - two near Narewa village, one at the base of Navatu rock and the other on the left bank of the Vuda River, all on Viti Levu Island. Groube (1971) also investigated the shell middens at Natunuku and Yanuca, and Birks and
Birks (1967) excavated at the Sigatoka Dunes, southwest Viti Levu Island, where they noted that no bone or shells had survived.

Nagaoka (1988) also summarised the results of other shellfish studies conducted on smaller offshore islands in central and eastern Fiji. These studies are among the earliest to examine marine resource use in the Fiji Islands. Examples include Best (1981) and Kay (1984) - site VL 21/5 on Naigani island, Hunt (1980) - site VL 16/81 on Yanuca, and Best (1984) - sites 101/7/196 and 101/7/197 on Lakeba island.

There was a hiatus in mollusc studies associated with prehistoric settlement sites in Fiji until most recently. For instance in 2004, Thomas and others published their analysis of the shellfish remains excavated from the Qaranilaca Cave, Vanuabalavu Island (Thomas et al., 2004), while Katherine Szabó also analysed shellfish remains from the Kulu site, Beqa Island (Katherine Szabó pers. comm., 2005). Morrison and Cochrane were also involved in shellfish studies in the Yasawa group of islands, western Fiji where they studied and analysed the shellfish assemblage from the Natia Beach site (Morrison and Cochrane, 2008).

The University of the South Pacific in collaboration with the Fiji Museum also conducted excavations at several early to late/post-Lapita sites within Fiji and analysed their faunal remains including shellfish. These include the recently discovered sites on Moturiki Island namely Naitabale (Nunn et al., 2007) and the Lapita-era sites along the Rove Peninsula, southwest Viti Levu Island like Qoqo Island and Bourewa settlement (Nunn et al., 2004, 2005a, 2006; Nunn, 2007a).

In their analysis of the shellfish remains from the Qaranilaca Cave site, Thomas et al. (2004) recorded several important observations. Although the Qaranilaca Cave sequence is not Lapita in age (only covering the last 1000 years), in general, the shellfish species recovered from the site indicate that they were collected from various marine habitats on the island. Thomas et al. attributed the reduction in the size of Anadara antiquata to both human predation and environmental change due to sea-level fall, while noting that the association between shell size reduction and environmental change is only weakly supported by actual data. They also suggested that shellfish use at the Qaranilaca Cave may reflect both availability of a range of
shellfish resources and the preferences of the cave users while environmental change may have been an important factor in influencing shellfish abundance as well.

Archaeological evidence from two Lapita-era sites in Fiji - namely Naitabale (Moturiki Island) and Qqo Island, (southwest Viti Levu Island) that were settled sometime between 1000-650 BC has revealed the importance of marine food resources to their early colonists. The analyses of both shell assemblages indicated that shellfish utilisation was intense during the initial period of human settlement and gradually declined towards its later stages presumably because other food resources were increasingly being exploited over time (Nunn *et al.*, 2006, 2007). At Naitabale for instance, Nunn *et al.* (2007) reported that gastropods were the dominant shellfish taxa while at Qqo Island bivalves accounted for about 89% of the total shellfish by weight (Nunn *et al.*, 2006).  

The contrasting scenarios between these two sites may in fact reflect the different types of environment associated with each site and especially the impact of sea-level change on the availability of certain shellfish resources. For example, while the Naitabale site was located close to an extensive coral reef system where foragers were expected to encounter reef-dwelling shells like gastropods (Nunn *et al.*, 2007), Qqo Island’s proximity to a river estuary dictated that mostly bivalves were collected from the estuarine habitats nearby (Nunn *et al.*, 2006). So it is obvious from their archaeological records that the different environmental settings were important determining factors in the availability and the types of shellfish taxa that were present at both locations. Additionally Thomas *et al.*, (2004) also noted that preference may be important in the selection of shellfish species thus influencing the composition of the shell assemblage.  

At the Naitabale site, Nunn *et al.* (2007) also recovered evidence of a range of marine inshore fish species and large quantities of shellfish. They suggested that these inshore fish species were either caught with baited hook or captured with nets or spears. Although they recorded the presence of pig, dog, chicken, and turtle bones in the assemblage, these were scattered throughout the site and might not have been associated with the earliest period of Lapita occupation. Other important faunal remains found at Naitabale include the Pacific rat (*Rattus exulans*) and possibly a
fruit bat (*Pteropus* sp.). Based on their analysis of shell weight, Nunn *et al.* concluded that shellfish utilisation was intense during the early occupation phase of the island but decreased later on signifying the role of humans on the shellfish resources.

The shell weight density analysis of the shells excavated from six pits at the Naitabale site also demonstrated that the pits situated inland relative to the modern beach yielded much higher densities, while pits closest to the modern shoreline had the lowest shell density. According to Nunn *et al.*, those pits with low shell density signify the later occupation of the site while those with high densities indicate the earlier occupation phase of the site where it was assumed shellfish utilisation was relatively intense.

For Qoqo Island, the shellfish analysis by Nunn *et al.* (2006) showed that large marine species such as *Trochus niloticus* and *Tridacna* sp. decreased in abundance from lower to upper levels over time. A similar pattern emerges when smaller-sized species like *Anadara antiquata*, *Gafarium pectinatum* and *Codakia punctata* were considered. They concluded that the predation pattern for Qoqo Island is essentially the same as in most early settlement sites across the Pacific where large-sized bivalves were mostly targeted by the early colonists (Swadling, 1986; Spennemann, 1987).

In addition, Nunn *et al.* (2006) also reported the presence of the freshwater mussel *Batissa violacea* and its decline towards the present as marking the transformation of the Qoqo area from an open-coast to a mangrove environment as a result of sea-level fall and shoaling of the Tuva Estuary. This observation suggests that, although human predation may be important, the impact of environmental change especially sea-level fall on the shellfish habitats and availability of *Batissa violacea* and other shellfish species should not be underestimated. It may imply that environmental change may have been an important factor in the decline of this particular freshwater bivalve.

An example of a situation where both human and non-human factors played equally significant roles in the abundance of shellfish resources is illustrated by the Natia
Beach study, Fiji (Morrison and Cochrane, 2008). Although the Natia Beach site is post-Lapita, Morrison and Cochrane had demonstrated that during Fiji’s prehistory both human and non-human factors were important in influencing shellfish abundance and availability. The variations observed in the shellfish accumulated at the Natia site during the different periods of its occupation, indicate that while human predation was important, environmental change associated with climate variability and sea-level fall also altered regional and local environmental conditions thereby affecting certain marine shellfish resources.

At Natia Beach, Morrison and Cochrane (2008) demonstrated that, although shellfish utilisation remained stable for approximately 1600 years after initial colonisation, by around 650 BP there was a marked change coinciding with environmental change associated with the transition between the Little Climatic Optimum (LCO) and Little Ice Age (LIA). During this transition period (also named the “AD 1300 Event”) sea level and temperature fell abruptly, resulting in a decline in marine-resource availability and death for most of the reef-dwelling species that humans depended on for subsistence. These environmental changes resulted in increased human-induced pressures on the scarce and limited marine resources thereby triggering societal disharmony and conflicts within the Fiji archipelago (Nunn, 2000; Field, 2004; Morrison and Cochrane, 2008).

3.4.4 Impact of environmental change on resources

Although the foregoing cases are widely believed to demonstrate human impact on resources and island environments, the issue of whether humans alone were solely responsible for resource depression on most Pacific Islands has been debated for many years. For example, Nunn (2003) noted that while some researchers have argued that humans have been solely responsible for resource depression, and extinction and/or extirpation of certain fauna and flora on many Pacific Islands, others have maintained that non-human agents are equally important. So, although resource depression is commonly associated with human actions, Nunn cautioned that such environmental changes may occur even without human presence and can influence the abundance of certain resources.
Nunn (2003) also stated that certain changes in the environment may largely be determined by both the nature of island environments and the intentions of humans who colonised different islands. But more long-lasting environmental changes due to fluctuations in sea level and climatic conditions have been more pronounced than the “marginal disruptions” caused by forest clearance and species introduction to island biota. Therefore, although archaeological studies have highlighted the role and impact of colonising populations on natural resources, Nunn (2003:219) has argued that “the character of early interactions was decided by both the nature of a particular environment and the intentions of the human settlers”.

Currently our understanding of the impact of environmental change on marine ecosystems is somewhat limited but recent analyses of a range of data from archaeological sites within Oceania have highlighted the significant impact of sea-level change during the Holocene period on the adaptations of prehistoric peoples. For instance, Nunn (1994) discussed the interaction between environmental change and the early human settlers of the Pacific Islands, Dickinson and others investigated the impact of sea-level change on archaeological sites in Tonga (Dickinson et al., 1994), and Gosden and Webb (1994) studied the importance of archaeological and geomorphological evidence in the creation of landscapes in Papua New Guinea.

Other studies that have also reported the impact of environmental change on natural (marine) resources in the Pacific Islands include Kirch and Yen (1982) and Spennemann (1987). In her analysis of shifts in mollusc-collecting strategies and environmental change during the Prehistoric Period in the Mariana Islands Amesbury (1999, 2007) has demonstrated the impact of sea-level change on the demise of mangrove habitat and mangrove-associated shellfish (Anadara antiquata), the increase in favourable habitats for Strombus sp., and the consequent shift in shellfish-collecting strategies from mangroves to coral reefs.

The impact of environmental changes particularly the “AD 1300 Event” on food resources in the Fiji Islands is also demonstrated by Field (2004), Morrison and Cochrane (2008) and Nunn (2000, 2003). These researchers have recorded that significant environmental disruptions due to sudden changes in sea level and climatic
conditions have led to scarcity of marine and terrestrial food resources and in turn caused societal conflicts, disharmony, and settlement change.

3.5 Optimal Foraging Theory Models

For faunal remains like shells, material traces can be examined by archaeologists through the application of formal evolutionary ecology models which can trace declines in foraging efficiency and changes in habitat use (Stephens and Krebs, 1986).

These foraging models predict the types of species and habitats likely to be affected by human predation and the conditions that can influence subsistence shifts. Archaeologists also utilise a particular set of data to reconstruct the past and account for what is being reconstructed. In general these models adopt certain principles derived from such fields as Behavioural Ecology (BE) and apply them to human subsistence behaviour (Bird and O’Connell, 2006). An example of a theoretical framework that is often used by archaeologists to understand human foraging behaviour is the Optimal Foraging Theory (OFT) (Stephens and Krebs, 1986).

According to Smith (1983), Optimal Foraging Theory is drawn from human Behavioral Ecology which derived its principles from neo-Darwinian evolution. Human behavioral ecology (or evolutionary ecology as it is sometimes known) examines the variations in human behaviour through the application of evolutionary biological models. Bird and O’Connell (2006:146) noted that despite foraging theory being grounded in a set of assumptions it specifically “assumes that foraging behavior has been ‘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”.

Since Optimal Foraging Theory models are usually applied to faunal data for analysing prehistoric human foraging strategies, the models premised on maximising the rate of nutrient intake to enhance fitness and free up time to pursue other fitness-related activities (Bird and O’Connell, 2006). Smith (1983) also noted that foraging models are applicable and appropriate to a broad range of animal species yet robust
and accurate to explain the behaviour of foragers. In Gremillion (2002), some of the methodological problems and solutions associated with foraging theory and hypothesis testing in archaeology were explored. Despite the many advances in the application and understanding of the Optimal Foraging Theory, a major critique is it being regarded as a form of “ecological determinism” because of its neo-Darwinian origins (Smith, 1983:626).

The following Optimal Foraging Theory models - Prey Choice Model (Diet Breadth), Patch Choice Model, and Central Place Theory are used in thesis since they are most applicable and appropriate to the Bourewa shellfish analysis. In general these models pose pertinent questions regarding subsistence strategies such as what people consumed, where and how long they foraged and where they lived or processed their food.

### 3.5.1 Prey Choice Model

The \textit{prey choice model} is applied to examine changes in foraging efficiency and measure the net (energy) return rate per unit time (Morrison and Cochrane, 2008; Nagaoka, 2002). Since one of the goals of foraging is to maximise the rate of nutrients (energy) obtained from the prey item, the model predicts that foragers usually select the largest prey upon encounter to optimise energy return (gain). Thus the predator's strategy is to take the highest-ranked prey when encountered. Now if foragers encounter large prey items they will most likely be taken, while smaller ones will be bypassed (Butler, 2000). Normally prey body size is used as a proxy for prey rank so large-bodied taxa are regarded as high-ranked resources, while small-bodied taxa are lower ranked. The \textit{prey choice model} also assumes that low-ranked prey items will only be captured and/or incorporated into the diet if there is a significant decline in high-ranked prey items and foraging efficiency (Bird and O’Connell, 2006; Butler, 2001; Morrison and Cochrane, 2008; Nagaoka, 2002).

Since the relative abundance of high-ranked taxa influences dietary choices, the \textit{prey choice model} can be employed to track changes in high-ranked species in the environment. If there is a decline in foraging efficiency, the ratio of large-bodied
prey to smaller prey will decrease over time and the diet breadth of the foragers will also expand, resulting in increased species diversity (richness) (Nagaoka, 2002).

### 3.5.2 Patch Choice Model

The *patch choice model* examines how foragers decide which environmental habitats to forage in and how long they should remain in a particular area. Thus the *patch choice model* predicts that high-ranked prey tends to be susceptible to resource depression and the habitats exploited will increase while the time allocated to a particular habitat will change only if foraging efficiency falls across all habitats. The *patch choice model* also assumes that, if the energy return rate of high-ranked habitats declines, foragers will shift their attention to lower-ranked habitats (Nagaoka, 2002).

Additionally when high-ranked prey abundance decreases, foragers tend to select younger, smaller individuals leading to decrease in the overall size of the target species (Morrison and Cochrane, 2008). Now, since the types of habitats are ranked on the basis of the size of the resources that are found within them, a habitat which contains abundant high-ranked, larger prey items is generally regarded as a productive habitat, while a less productive habitat usually comprises low-ranked, smaller prey items (Bedford, 2006). Any shifts in the habitats being exploited can be traced by the ratio of taxa between more productive and less productive habitats (Morrison and Cochrane, 2008).

### 3.5.3 Central Place Model

The main assumption of the *central place model* is that most of the prey items collected will be returned to a central location or place like a base camp or settlement site for preparation and consumption. The *central place model* predicts that those resources closer to the central place will be initially targeted and depleted while resources further away will be exploited and/or added to the diet as energy return rates decline (Nagaoka, 2001, 2002). In such a case, the distance from the camp site to the resources is insignificant and is usually ignored during the analysis (Bedford, 2006). But there are situations where the prey items may be large, heavy or bulky for
the forager(s) to transport to the base camp or settlement site so the items would be processed where they were found and only their edible parts taken to the base camp (Bird et al., 2002). So in most cases shell remains of large animals may not end up in the midden deposit.

Essentially shellfish foraging usually fits an optimal foraging model and the collection strategies employed by foragers to seek prey within different habitats are generally aimed at maximising the net energy gained per unit of energy expended (Bedford, 2006). But not all foraging models can be applied to the study of shellfish due to their sedentary nature and generally no substantial energy expenditure is involved in the process of foraging. Examples of several archaeological studies that have applied foraging models are known (Allen, 2003; Allen et al., 2001; Cannon, 2003; Grayson, 2001; Jerardino, 1997; Jones, 2004; Mannino and Thomas, 2002; Morrison and Hunt, 2007, Morrison and Cochrane, 2008; Nagaoka, 2000, 2001, 2002).

Bedford (2006) also applied two models of the Optimal Foraging Theory to shell assemblages from various sites in the Vanuatu Archipelago and suggested that, while factors such as cultural preferences can influence collection strategy, foraging theory models have been useful in predicting the shellfish collecting behaviour of early Ni-Vanuatuans. Morrison and Cochrane (2008), who examined the shellfish remains at Natia Beach, Nacula Island, Fiji, also applied the foraging models to their shellfish analysis. Their study demonstrates that foraging models are very useful in understanding both the roles of human predation and environment change on the inshore shellfish species and habitats at Natia Beach.

Several ethnographic and ethnoarchaeological studies have also applied models as developed in foraging theory to measure foraging efficiency, transport, and compare subsistence patterns based on ethnographic and archaeological shellfish data. Some examples are known (Bird and Bird, 2000, 2002; Bird et al., 2002; Thomas, 2002). Smith (1983) and Winterhalder and Smith (2000) also provided a critical review of the Optimal Foraging Theory and its anthropological application.
These three foraging theory models described above (*prey choice*, *patch choice* and *central place*) are used in this thesis to analyse and interpret the Bourewa shellfish species and habitats and understand subsistence strategies of the Bourewa Lapita people. The analysis and interpretation of the Bourewa shellfish data is presented in chapters six and seven respectively.
4.1 Introduction

Over many years archaeologists have been studying past human behavior and culture by examining and analysing their material consequences. They routinely study refuse and have developed an array of methods for understanding many aspects of what they examined. In the process they developed theories, procedures and generated information that assist in linking the material remains with aspects of past (human) behavior (Bird and O’Connell, 2006).

This chapter defines and critically examines the four main methods employed to quantify and analyse the shellfish taxa sampled from the Bourewa site (Pits X1, X2, X3, X5 and X6). These are minimum number of individuals (MNI), number of identifiable specimens (NISP), weight and size. Each of the subsections (4.2.1 to 4.2.12) defines and explains the limitations and strengths of each quantification method and their appropriateness to this study.

4.2 Methodology

According to Nanfro (2004), the methodology of zooarchaeology starts with an understanding of the terms and concepts that are important in quantifying and comparing faunal remains. The term methodology as commonly used in any research or fieldwork generally refers to the methods or approaches used in a particular field to investigate, examine the finds of the study (or research). In this case it refers to the methods commonly applied to quantifying zooarchaeological faunal remains. It involves the different strategies and/or approaches employed by the researcher(s) to collect, sample and record the required information and data for purposes of analysis and testing various hypotheses.

In Lyman’s (1994b) review of quantitative units, three important concepts are distinguished - measurements, terms and units. Lyman defined measurements as results of observations made on phenomena with a scale based on set rules where
symbols are assigned to each observation per phenomenon. The name or label given to a quantitative unit is regarded as a term. Quantitative units are of different levels or scales of mathematical power of which there are two distinct types - observational units and analytical units. Observational units are physical properties of a phenomenon that can be directly measured using one’s senses while analytical units consist of modified observational units that may be used to indirectly observe and infer the property of the phenomena being studied.

Although Lyman (1994b) further categorised analytical units into derived and interpretive units, for purposes of this paper the basic distinction of quantitative units into observational and analytical units is sufficient. The quantitative units employed in this study include minimum number of individuals (MNI), number of identifiable specimens (NISP), weight and size.

In any zooarchaeological study three major stages (identification, analysis, and interpretation) are important for characterising faunal data and understanding the environment (habitats) and the animals represented (Reitz and Wing, 1999). According to Clason (1972) the identification stage is concerned with obtaining, collecting primary data and the analytical stage with deriving and extrapolating secondary data.

Reitz and Wing (1999) described primary data as any information obtained during the identification stage by the researcher(s) through measurements like elements represented, taxonomic identification, specimen count, modifications and pathologies, anatomical features of age and sex measurements, and specimen weight. Secondary data is derived from primary data by means of indices and other quantification techniques such as relative frequencies of taxa, sex ratios, age classes, dietary contributions and procurement strategies.

Lyman (1994a) also described primary data as observational units and secondary data as analytical products. While primary data is objective and subsequent investigators can replicate similar results, secondary data is subjective, has an interpretive element and future researchers should be able to extrapolate secondary data from primary data (Reitz and Wing, 1999). The proper recording and quantification of primary data
during the identification stage is important because secondary data and subsequent analyses may be at fault or suspect if primary data are not accurately recorded.

The four key methods employed here to identify, quantify and compare shellfish data to form the basis of the primary data have been selected because of their appropriateness and interpretive capacities to the research goals of this study. These are minimum number of individuals (MNI), number of identifiable specimens (NISP), weight and size. Each of the methods is defined and critically evaluated based on its potential for contributing to the understanding of the structure and composition of the Bourewa shell assemblage and taphonomic issues associated with the site and its environs. Secondary (analytical) data is derived from these raw data and then interpreted and discussed in chapter seven of this thesis.

4.2.1 Definition of NISP

NISP is defined as the number of identified specimens per taxon. As is used here “identified” means identified to taxon or genus/species level. NISP is a count approach, which is the primary basis for quantifying data for both vertebrates and invertebrates (also see Reitz and Wing, 1999; Mason et al., 1998). A specimen is regarded here as an isolated shell. A taxon refers to a subspecies, species, genus, family or higher taxonomic category. NISP as an observational unit can be directly counted or measured and whose quantification depends on recognition, use of comparative specimens, and the most reasonable taxonomic assignment Lyman (1994b).

Numerous faunal studies have utilised NISP counts in their analysis including some regional and local studies of shellfish assemblages excavated from archaeological sites or through ethnographic studies. For example, at Qaranilaca Cave, Vanuabalavu Island and Naitabale site, Moturiki Island, NISP quantification was also employed by researchers to understand the impact of human predation on shellfish species from these coastal sites in Fiji (Thomas et al., 2004; Nunn et al., 2007). Thomas (2002), in his evaluation of shellfish collection strategies in Western Kiribati employed NISP, MNI and weight quantification methods to assess the appropriateness of foraging models as they apply to the Kiribati shellfish data.
In her preliminary analysis of the Qoqo Island (southwest Viti Levu, Fiji) shell midden, Yuen (2005:6) describes NISP as “the sum of left and right valves and fragments for all identifiable bivalve shells, or the total count of apices, spires or columellas and fragments for all identifiable gastropods”. Hence, in such a context, NISP is a count of the total of all shells and fragments of an identified taxon from a given stratigraphic context. For the present study the sum of identifiable shells (including fragments) for each species or genus by spit is quantified as NISP and recorded in the appropriate category. Any unidentifiable shell taxon is quantified in an additional category – referred to here as “unidentified/miscellaneous”. All other shell fragments not counted as MNI (see below) have been quantified as NISP.

4.2.2 Limitations of NISP

In his “Quantitative Zooarchaeology”, Grayson (1984:20-24) explained 11 classical criticisms of the NISP method. Although his critique specifically targeted NISP counting as is used in vertebrate analysis, most of the issues he raised are equally appropriate and applicable for invertebrate quantification. Effectively these criticisms addressed issues relating to three major areas. These are “potential interdependence” of the units being quantified (criticisms 3, 5, 6 and 11), decisions/choices, competencies/skills of analysts examining the faunal assemblages or remains (criticisms 2 and 7), and its failure to not address “substantial issues” (criticisms 8 and 10).

Nagaoka (1988) also noted that overestimation of the number of bones or individuals in an assemblage is inevitable when fragments from a single bone or individual are counted separately. The number of diagnostic skeletal elements for a particular taxon may also affect NISP count because most taxa have only one or two diagnostic bones resulting in certain taxon being underrepresented. When applied to shellfish quantification, overestimation can be an issue when diagnostic elements of shells are missing thereby creating room for fragments of the same shell specimen to be quantified more than once, thus often exaggerating the numbers.

Lyman (1994b) contended that NISP does not account for intertaxonomic variations, and it can be biased due to taphonomic processes, and the uncertainty with what NISP
actually measures. Lyman also highlighted the issue of whether NISP truly measures variables like, “the relative abundances of taxa that were walking around the landscape, the abundance of taxa that were killed by human hunters, or the abundances of taxa recovered from an excavation” Grayson (1984:18) noted that in her classic examination of Tabûn and Wad caves using NISP count, Bate (1937) inappropriately assumed that changes in taxonomic frequencies reflected changes in frequencies of the animals in the surrounding environment. Due to the numerous criticisms leveled at the use of NISP as a quantification method, Grayson also stressed that it is now common practice in most faunal studies to combine both counts of number of identified specimens (NISP) with minimum number of individuals (MNI), as is the case in this study.

4.2.3 Strengths of NISP

NISP is an observational unit can be empirically observed (Lyman, 1994b), is reliable (Mason et al., 1998), can be commonly used to estimate relative frequencies of taxa (Reitz and Wing, 1999), and has become a frequently used quantification tool to address most research questions in archaeological faunal studies (Lyman, 1994b).

NISP has been commonly used in many studies to complement MNI count (Mason et al., 1998). For example, if a shell specimen has lost its countable part due to fragmentation, it may not be counted as MNI but will be estimated as NISP (fragments). NISP count can be utilised especially where it is difficult to distinguish the right or left or top or bottom valves of fragmented symmetrical and asymmetrical bivalves respectively.

In addition, as is used here, shell fragments of the same taxon are counted and recorded separately to avoid inflating NISP counts. So, as suggested by Katherine Szabó (pers. comm., 2006), where there is a fragment of a known shell taxa, like Anadara or Saccostrea species, but it is not the portion chosen to be quantified, it would not be counted as ‘1’ for MNI purposes because the countable bit may be in the next spit. It would be recorded as ‘p’ (for present) in the MNI column and then assigned a value of ‘1’ (or whatever it is) in the NISP fragment count column. In this manner the NISP approach is appropriate for quantifying shells when and where MNI is not applicable.
or adequate, especially where the degree of shell fragmentation is high (Mason et al.,
1998), which is not the case for the Lapita shell midden at Bourewa.

4.2.4 Definition of MNI

MNI refers to the minimum number of individual animals necessary to account for a set of identified faunal remains (Lyman, 1994b). As is used in this analysis, MNI is a measure of the minimum number of individual shellfish based on the number of diagnostic elements or non-repetitive elements (NREs) identified for a particular shellfish taxon in the assemblage. The selection and counting of NREs for various shellfish taxa establishes the MNI count. According to Mason et al. (1998:307), NRE is “any hard shell skeletal element that is diagnostic of a single species or genus and can only be counted a limited and set number of time for one individual to have been present”. Some commonly selected NREs for shellfish include spires, aperture or columella for certain gastropods, and hinges or umbos (beaks) for most bivalves.

As an example, for all species of Turbo that are highly fragmented, the columella side of the aperture that takes in the umbilicus is usually counted, otherwise spires are sufficient. As used in this study, MNI counts for gastropods were determined by the presence of >50% of the columella (eg. Turbo spp.), >50% of the top whorl (eg. Strombus spp.), >50% of the entire specimen (eg. Trochus spp.), >50% of the canal termination (eg. Cypraea spp.) and the valve suture (eg. Lambis lambis) (Bird et al., 2002).

For bivalves, hinges and umbos are usually counted. So for cockle-shaped bivalves like, Veneridae, Cardiidae and Lucinidae, their hinges and umbos tend to face in towards each other. The left valves have their umbos and hinges slanting in towards the right and the right valves have their umbos and hinges slanting left (Katherine Szabó pers. comm., 2006). All MNIs for bivalves were therefore estimated by the presence of more than fifty percent of the umbos and/or hinges. All left and right valves for each shellfish species were paired and scored as single individuals. Extra valves without a complement were then counted as individuals (Bird et al., 2002).
4.2.5 Limitations of MNI

In recent years, proponents of the use of MNI approach in shellfish quantification, for example Mason *et al.* (1998), persuasively argued for the analysis of shellfish count using MNI rather than weight, but there are associated weaknesses with quantifying shellfish using MNI alone. Glassow for instance, highlighted some important factors that can restrict the utilisation of NREs in quantifying shellfish data. He noted some major problems in defining and using shellfish MNI. These include, “NREs are often difficult to define, are differentially preserved, and tend to bias samples toward taxa with larger more durable shells as well as larger individuals within taxon” (Glassow, 2000:410).

Claassen (1998) also cited two reasons that can cause MNI count to be weak. Firstly, that MNI is best derived by the side of the creature with the highest NRE count (or the largest count of umbos or from the apex) but in most sites not all NREs have survived to count them. It is also rare for all surviving shells to be excavated and be quantified in the laboratory. Secondly, that one hundred percent of the surviving sample is available to the investigator, but it is impossible for all the surviving shells to be recovered during excavation and be counted. Practically, in most studies only a sample of the set of shellfish in the entire assemblage for example is recovered and considered for analytical purposes (Grayson, 1984).

Notwithstanding the use of MNI calculations to avoid the impact of fragmentation on NISP count, intense shell fragmentation can also affect NREs and that may result in underestimation of the shellfish abundance. Where shells are highly fragmented, NREs like spires and apertures are often useless because spires tend to be less diagnostic than other parts of the shell and apertures are frequently broken so a more reliable part of the gastropod aperture is usually preferred for quantification purposes. The countable bit(s) may vary from species to species though in general the most robust or most distinctive part(s) are usually quantified (Katherine Szabó, *pers. comm.*, 2006). Grayson (1984) noted that MNI count could be affected by aggregation, whether it is by different spits or arbitrary levels or strata, so care must be taken when counting shells from various spits that are combined to form analytical units particularly when quantifying bivalves.
4.2.6 Strengths of MNI

Although the MNI approach has been criticised, Mason et al. (1998) are adamant that MNI is the most appropriate measure for addressing most research questions about environmental change and resource overexploitation because MNI is a discrete measurement that is usually represented by a number of distinct values like NRE count data. Hence, Mason and others consider MNI estimates to be more reliable than weight when assessing the taxonomic abundance of shellfish taxa in an archaeological assemblage. The use of shellfish NREs also provides analysts with a basis for estimating the number of individual shellfish taxa in an assemblage, determining the relative proportions of different taxa, and thereby understanding the relative importance of habitats from which shellfish were collected or foraged (Glassow, 2000).

According to Mason et al. (1998), some common research areas and issues that can be addressed using MNI shell data include marine habitats exploited for shellfish consumption, local environmental change due to increased sedimentation or variation in sea level, overexploitation of shellfish taxa by human foragers, and the contribution of different shellfish taxa to prehistoric human diet. They also argued that MNI based on NRE count data is the best measure of taxonomic abundance.

4.2.7 Definition of Weight

As is the case here, when “using the weight method, all fragments from a sample are identified to the most specific taxon possible and then the fragments assignable to each taxon are weighed separately” (Mason et al., 1998:308). All the NISP (including fragments) and MNI (NREs) that have been identified for each taxon by spit were weighed using an electronic balance. For the Bourewa shell assemblage, the gross weights of all shellfish species per spit for each test pit were calculated and recorded. As noted by Amesbury (1999:350-352) in her study of the shellfish taxa on Guam, “the shells were identified to the family level and, when possible, to genus or species, and counted and weighed. Whole shells and fragments were counted and weighed separately. Percentages by weight of the total weight of identified shell were calculated for the various taxa”.
4.2.8 Limitations of Weight

Despite the adoption by faunal analysts of counting measures like MNI (using NREs) and NISP to quantify archaeological faunal collections, the weight method is still popular today. But over the years it has rarely been critically examined. A major drawback of weight quantification is associated with time. Quantifying shellfish weight is often time-consuming and may limit shellfish information to very small samples (Mason et al., 1998). This is the case with the Bourewa shell midden where the quantity of shells excavated was very large and only a representative amount (sample) of the entire shell assemblage could be quantified and analysed.

Mason et al. (1998) argued that shellfish weight is not an appropriate measure for addressing certain research issues because,

- shell weight vary among different taxa,
- fragmentation and chemical dissolution may result in loss of shell mass. [Chemical dissolution or diagenesis is a process that is common in soils with low pH level (or acidic soils). The high acid concentration in the soil can dissolve/affect different shell taxon at different rates. Generally weaker shells are susceptible to shell dissolution which can cause underestimation of a site’s shell weight (mass)].
- loss of mass may occur through screening during the recovery process. The use of larger screen mesh sizes can result in shell loss and the use of NREs like umbos may cause disproportionate representation of heavier shelled species compared with lighter shelled ones (Mason et al., 1998; Claassen, 1998).
- it is a ratio scale measure with no infinite number of values.
- weight measures lack meaning and if converted to percentages cannot estimate the number of individuals and,
- it is incompatible with mathematical ecology routines and multivariate statistical techniques that require specific abundance measures.

Morrison and Cochrane (2008:5-7) noted that, “while shell weights can be useful for certain types of analysis, they may be problematic when modeling the potential impact of predation on populations of prey species. Different age and size classes in
a taxon vary by shell weights, so a gross weight of shell remains per taxon can hide a great deal of potentially valuable information”. Hence it may not provide much information about the shell assemblage (Katherine Szabó pers. comm., 2006).

4.2.9 Strengths of Weight

Although the weight method does have its limitations, shellfish weight data can be utilised to aid us in understanding many issues relating to prehistoric life ways. For instance, when comparing the reliability of count verses weight data in analysing archaeological shell assemblages, Glassow (2000:407) favoured the use of weight method because weight can provide meaningful data to address research problems of interest to shell analysts whereas NREs are difficult to define and identify.

Unlike vertebrate analysts who are constrained and have no choice but to use NISP or MNI, shellfish analysts can utilise the weight method as an additional, complementary quantifying technique or tool. Shellfish analysts should be able to estimate the quantity of shellfish meat consumed by the inhabitants of a site through the weight method. Weight data can also be employed in analyses concerned with the contribution of shellfish and other food products to human diets. Weight proportions can be utilised to trace changes in shellfish habitats or intensification of shellfish collecting effort or foraging efficiency and human predation (Morrison and Cochrane, 2008). The use of a range of mesh sizes can compensate for the apparent biases in weight data as well (Glassow, 2000).

Glassow (2000) contended that shell weight data can enable researchers to examine and understand the relative contribution of shellfish taxa to the diet of a site’s prehistoric inhabitants, the proportion of food value obtained from particular shellfish habitats, and the amount of effort expended in acquiring shellfish of a particular taxon or from a particular habitat. He stated that, where appropriate, the shell data can also be utilised by analysts to convert shell weight into meat or protein weight, or identify patterns of change in proportions of shell weight by taxon and perhaps be able to explain which shellfish were consumed at the site, and/or what habitats were exploited, and if shellfish proportions had changed over time and space.
4.2.10 Definition of Size

The type of quantifying methods used to measure shell size depends very much on the research goals and the types of shellfish (bivalves or gastropods) remains recovered from an archaeological site. As stated by Claassen (1998), size measurements can be used to define stratigraphy, estimate season of harvest, and explore modes of harvest. But what and how do archaeologists actually measure when shells come in different shapes, forms and sizes?

In their analysis of the shellfish remains from the Naitabale site, Moturiki Island Nunn et al. (2007) measured the lengths and diameters for Anadara antiquata, and basal diameters of Trochus niloticus and Tectus pyramis. Although their data did not reveal any statistically significant change in species size over time, they note that any change in species size can inform us about both human predation and/or important environmental factors. Swadling (1986) also measured hinge length for the bivalve Anadara sp. and basal diameter (or width) of Trochus in her analysis of Lapita sites in the Reef/Santa Cruz group. Claassen (1998:108) also noted that archaeologists who quantify shell size usually take measurements of “valve height and length for bivalves and valve height and aperture height for univalves”. In their study of the Natia Beach shell assemblage, Morrison and Cochrane (2008:8) quantified shell length of the two most common bivalves by measuring the “longest axis along the posterior/anterior dimension of the shell”.

For the Bourewa shell assemblage, the three most abundant shellfish taxa – Codakia punctata (MNI =7562), Fimbria fimbriata (MNI =1005) and Strombus gibberulus gibbosus (MNI=893) were measured and analysed. Both Claassen’s (1998) and Morrison and Cochrane’s (2008) size measurement techniques have been adapted for this purpose. Only whole or complete specimens of the three shell taxa were measured for size by spit and pit (especially Pits X2 and X3). Broken specimens including fragments were not considered. Each shell taxon was measured using a digital caliper and the results averaged (to determine the mean shell size) for each species.
4.2.11 Limitations of Size

Since shellfish size measurements can be applied only to whole or complete shell specimens, the size method is not appropriate for analysing shell assemblages that are highly fragmented. In such cases size measurement is limited and may not be a reliable indicator of human predation or even environmental change.

Shells that are sampled from any site can be biased in two ways. First, it is often common during the recovery or sampling stage to select large-sized shells over small-sized ones, thereby creating greater average means than the unbiased samples. Secondly, there is high chance that foragers, collectors, or gleaners may collect, gather, or glean shellfish from different populations with varying sizes but that these become mixed in the sites thus rendering the assemblage mean to become smaller compared to the mean of any one population. As observed, fragmentation is not a major issue with the Bourewa shell assemblage since most of the shell specimens measured, are relatively intact (Claassen (1998).

4.2.12 Strengths of Size

Shellfish size data can provide researchers with a range of information that is useful for understanding prehistoric human impact and non-human influences on shellfish resources. According to Morrison and Cochrane (2008), the changes in shell size may reflect the effect of human predation and/or environmental change. Any variations in shell size can also indicate human impacts on shell morphology. Shellfish size (length or diameter) is also useful for comparing different shellfish populations and for determining the kind of factors that can influence shellfish variability at a particular site (Frank Thomas pers. comm., 2007). As noted by Claassen (1998), size is often analogous to age so large-sized shell specimens may indicate a relatively older or mature specimen.
5.1 Introduction

This chapter has three parts. The first describes the geology of the Fiji Islands (section 5.2), reconstructs the palaeogeography, and describes the geography of the Rove Peninsula (subsections 5.2.1 and 5.2.2). The second part (section 5.3) outlines the discovery and excavation of Lapita-era sites between 2002 and 2007 and particularly describes the mid-2005 field season. It intends to outline the history and development of geoarchaeological work conducted over almost half a decade along the Rove Peninsula and relates its importance to the Lapita archaeology of the Fiji Islands (subsections 5.3.1 to 5.3.5). The third part (sections 5.4 and 5.5) explains the field and laboratory methods employed to collect, quantify, and analyse the shells sampled for this study.

5.2 Geotectonic development of the Fiji Islands

Various authors have described the general geology of the Fiji Islands. For example, Kroenke (1984) who reconstructed the Cenozoic tectonic history and development of the Fiji Islands, while Reddy (1995) and Nunn (1998) provided concise summaries of the geological and tectonic history of different parts of Fiji. The account provided here derived from the above works explains the Fiji Islands as a series of oceanic island arcs that were the result of at least three (or perhaps four) major stages of island arc development and numerous volcanic and tectonic events.

Almost 40-30 Ma (million years ago) volcanism linked to the interaction of the Indo-Australian and Pacific Plates along the now abandoned Norfolk – New Caledonia Ridge was responsible for generating the first stage of island arc development in Fiji. This episode created some of the oldest known rocks on Viti Levu Island, like the lower Wainimala Group. Towards the late-Miocene, the upper Wainimala Group was deposited while volcanism related to the Vitiaz Trench probably ceased around 20-10
Ma. The Wainimala rocks are widely exposed inland of the Bourewa archaeological site and most of the greenstone tools found or excavated at Bourewa for instance are dacite that were probably derived from these rock formations (Nunn et al., 2004).

The second stage is associated with the intrusion of the Colo Plutonics and the Medrausucu Range in the interior of Viti Levu Island about 10-5.5 Ma, and the uplift of limestone formations such as Volivoli, Qalimare and Tatuba groups along the upper Sigatoka Valley. The Volivoli Limestone and associated sedimentary rocks belonging to the early Quaternary Cuvu Group underlie the entire Rove Peninsula with often pebbly, infertile silt-clay soils (Nunn et al., 2004).

The third stage (5.5-3 Ma) was contemporaneous with volcanism in the northern part of Viti Levu Island, the formation of the Rakiraki and Tavua volcanoes and the intrusion of the monzonite sill in central Viti Levu. A possible Late Rifting (fourth) Stage occurred between 3-0.3 Ma. Episodes of tectonic uplift and tilting from the Pliocene to the Quaternary period are widespread on Viti Levu Island as exemplified by updoming in regions such as the Navua Plateau and elsewhere on southern Viti Levu Island. The savanna grasslands that are widespread on the leeward side of Viti Levu Island including the Rove Peninsula probably originated during the Last Glacial Maximum when climatic conditions were drier and cooler than present (Nunn, 1997).

### 5.2.1 Palaeogeography of the Rove Peninsula

While tectonic uplift and/or subsidence were insignificant due to the relative stability of the southern section of Viti Levu Island during the Holocene period, the coastal evolution of the Rove Peninsula and its suitability for human habitation were principally influenced by falling sea level and changing climatic conditions (Nunn and Peltier, 2001; Nunn, 2005).

Around 4000 cal yrs BP (2050 BC), sea level around Fiji as elsewhere in the Pacific region had been falling after it reached a maximum high stand of about 2.1 meters about a couple of centuries earlier (Nunn and Peltier, 2001). During this time Vusama, Rove, Likuri and Navo islands were located offshore at the entrance of the Tuva Estuary (Figure 5.1A). The higher sea-level stand ensured only a few narrow
discontinuous fringing reefs had formed while pockets of reefs were established along the western side of the Vusama Island, away from the freshwater influx of the Tuva River (Nunn, 2005).

As illustrated in Figure 5.1B, during the initial Lapita colonisation of Bourewa around 3100 cal yrs BP (1150 BC), sea level had fallen to about 1.5 m higher than present (Nunn and Peltier, 2001). The reefs which lagged behind during the mid-Holocene high stand had finally caught up with ocean surface causing coastal progradation and extension of the reef area. Mangroves also expanded along the sides of the Tuva River. By this time, parts of the current fringing reefs along the northwest and southwest coast of Vusama Island had already caught up with the sea surface so it is suggested that the expansion and upgrowth of the fringing coral reefs probably set the stage for attracting early colonising populations to its ecologically rich inshore marine resources (Nunn, 2005; Nunn, 2007b; Nunn and Heorake 2009).

Throughout the Lapita period, the Tuva Estuary was wider and deeper than today. At its entrance and along its southern windward side and sheltered from the freshwater influx of the Tuva River, coral reef development was enhanced by the nutrient rich long-fetch waves driven by the southeast trade winds (Nunn, 2005; Nunn, 2007b).
Towards the end of the Lapita period in Fiji (Figure 5.1C), mean sea level had fallen to around 0.9 m above present while mangroves and the reefs northwest of Vusama Island continued to expand. As the Lapita occupation of the Bourewa site was approaching its end about 2500 BP (550 BC), the Tuva Estuary became shallower and narrower causing Vusama and Rove islands to be connected to mainland Viti Levu (Nunn, 2005). Around this time also the Bourewa settlers expanded and settled in other nearby locations like Rove, Waikereira, Jugendar’s Farm (JF) and Tomato Patch (TP) (Nunn, 2007a).

Nunn (2005) explained that factors such as upward growth of most reefs, sea-level stability, and the wetter climatic conditions in Fiji during the Lapita period were responsible for enhanced shoreline progradation and expansion of the reef floor. Continuous transportation and deposition of terrigenous sediments into the estuary, coastal progradation, and sea-level fall contributed to infilling and shoaling of the Tuva Estuary. Mangrove development and other coastal processes predominantly influenced by the Southeast Trade Winds along the estuary and probably a large magnitude storm subsequently caused the attachment of Vusama Island to mainland Viti Levu.

By 2400 cal yrs BP (450 BC) (Figure 5.1D) the Lapita occupation of the Rove Peninsula as elsewhere in Fiji and the Pacific had ceased. Most of the Lapita sites were abandoned and probably the descendants of the Lapita people migrated to other parts of the Fiji Islands and established new settlements there (Nunn, 2007a). Today the Rove Peninsula hosts one of the oldest Lapita sites (Bourewa) situated close to the largest expanse of fringing reefs in the Fiji Islands, extending to a breadth about 3 km in places (Figure 5.1E) (Nunn et al., 2004; Nunn, 2005; Nunn 2007a).

According to Nunn and others, the location of Vusama Island and the environmental conditions and nutrient-rich long-fetch waves driven by the prevailing trade winds had undoubtedly encouraged healthy reef development along its windward coast and the presence of abundant marine resources. This is evidenced by the richness of the shellfish taxa present at the Bourewa shell midden. The shellfish analysis on nearby Qoqo Island also suggested that marine shellfish were abundant there during early Lapita times. The falling sea level had caused shoaling of the Tuva Estuary and encouraged the expansion of the mangrove forest along the sides and small bays of
the river thereby creating an estuarine environment that may have affected the availability and abundance of certain marine shellfish (Nunn et al., 2006).

The fall in sea level after the mid-Holocene also transformed Vusama Island by exposing the coastal plains and created attractive environments for human settlement and perhaps crop production (Nunn, 2007a, b). The recent evidence for horticultural practice at Bourewa indeed demonstrates that, not only were marine resources important for human subsistence but the coastal plain and perhaps the area behind the Bourewa settlement were utilised for food crop cultivation by the Lapita people who colonised Bourewa (Horrocks and Nunn, 2007).

According to Nunn, the Bourewa settlement was founded on a “sand spit extending 70-80 m southeastwards parallel to the present coast from a mainland promontory” (Nunn, 2007a:167). Although Nunn suggested that the earliest settlement at Bourewa was established on beach-barrier islands that were later transformed into a sand spit as sea level fell, it is also possible that the sand spit formed just prior to the first group of Lapita settlers arriving at Bourewa. A tidal embayment was formed at the back of the elongated sand spit parallel to the present coast (Nunn, 2007a:168, Figure 7).

During the mid-2005 field season, several posthole features were excavated within the central region of the Bourewa sand spit which suggests that platforms, houses or perhaps dwellings were built on stilts that stood over the sea. The sand spit was awash during high tide and the settlers discarded their food remains like hard parts of shells and other marine foods into the sea under their dwellings (Nunn, 2007a). The accumulation of the shell midden at the site is testament to the rich inshore marine environment and their exploitation of the different shellfish species and habitats.

While there were no major tectonic movements during the period of Lapita occupation of Bourewa, Nunn et al. (2005b) reported important Quaternary landforms like limestone epiphreatic (water table) or vadose caves along the Rove Peninsula that were formed by past tectonic, marine and fluvial processes prior to the Holocene. These caves may have played significant roles in the life ways of the early colonisers of Bourewa settlement. A case in point is the Qaranibourewa Cave, where the Lapita settlers of Bourewa could have used to fetch fresh water and maybe for shelter during
violent storms. It is plausible that such a cave might have formed during wetter climate conditions, like in the middle Holocene (6000-3000 BP) or alternatively, they may have formed when the relative relief of the area was much greater, as it was when sea level was 120 m lower during the Last Glacial Maximum (18,000 BP) (Nunn, 1999). Other limestone caves located along the Rove Peninsula include Qaramatatolu and the Rove Beach Caves (Nunn et al., 2005b).

Nunn had stated that understanding the nature of environmental change during Lapita times is important for it can provide valuable clues to how past tropical coastlines appeared and evolved and assist us understand their influences on human behaviour and resource availability. There is no doubt that throughout Lapita times smaller offshore island settlements were common in Fiji. Perhaps the Lapita people deliberately chose smaller-island locations because of their association with abundant marine resources (Nunn, 2005, 2007a). It appears that in a broad sense many Lapita settlements on Pacific Islands were founded on offshore islands that later became transformed due to environmental change after Lapita times.

According the Nunn the palaeogeographic reconstruction of some early Lapita sites of the western tropical Pacific has revealed that areas that are now parts of larger islands were formerly smaller offshore islands. For example, Malü (SZ-23) and Bianga-Mepala (SZ-45) sites on Tömotu Neo Island and other Lapita sites on Tömotu Noi Island, southeast Solomon Islands. Their palaeogeographic reconstruction has revealed that they were initially located on smaller offshore islands during Lapita times and later became attached to the mainland. On northern Tongatapu Island most of the Lapita sites located around the present Fanga ‘Uta Lagoon were also established on smaller offshore islands during the Lapita era (Nunn and Heorake, 2009). The Naitabale site was also located on the offshore Moturiki Island of Fiji around 1000 BC. Like the Bourewa site most of these Lapita sites were purposely established for optimal access to the adjacent reef flat for resources (Nunn et al., 2007; Nunn and Heorake, 2009) and maybe in offshore locations for protection against diseases such as malaria or dengue (Kirch, 1997).
5.2.2 Geography of the Rove Peninsula

The Rove Peninsula is a 35-m high limestone promontory, about 3 km\(^2\) in area located on southwest Viti Levu Island, Fiji (Figures 5.1E and 5.2A). Its northern boundary is at Likuri Island near the entrance of the Tuva River. The western and southern limits of the peninsula are bordered by a broad fringing reef extending up to 3 km offshore in places that terminates at Natadola Harbour (Nunn et al., 2004; Nunn, 2007a).

Figures 5.2A and 5.2B illustrate the geography and palaeogeographic reconstruction of the Rove Peninsula. As explained by Nunn (2005, 2007a), the entire Rove Peninsula comprised a number of offshore islands throughout the Lapita era when sea level was around 1.5-2 m higher than today. By the time the Lapita occupation of this area was approaching its end, sea-level had fallen to about 0.95 m. Coupled with increased sedimentation due to much wetter conditions, sea level fall has caused in the shoaling of the Tuva Estuary and the subsequent joining of the offshore islands to mainland Viti Levu.
Based on the shellfish analysis from Qoqo Island and proxy environmental data, Nunn et al. (2006) and Nunn (2005) demonstrated that the Tuva Estuary used to be an open-coast during Lapita times but was later converted to a mangrove forest and coastal lowland. Today the Rove Peninsula’s coral reef system – one of the largest in Fiji, continues to host a range of inshore marine resources that are increasingly being stressed by human activities both upland and along the coastal zone. The mangroves and reefs play an important role in the subsistence livelihoods of the present population who live along the Rove Peninsula as well as those living inland (Tai Dido pers. comm., 2005).

The principal Fijian village along the Rove Peninsula is known as Vusama. It is located a few kilometres northeast of the Bourewa site and hosts a population of about 300. The village is situated on an elevated ridge overlooking offshore Likuri and Qoqo Island, which lies in the adjacent mangrove forest north of Vusama village. Indo-Fijian farmers have been farming the Bourewa area for almost half a century with sugar cane crops although recently the farmlands, including the Bourewa site itself, has been bought for tourism development by the Shangri-La group of companies.

5.3 Lapita-era sites and field excavations along the Rove Peninsula

This section describes the Lapita-era sites discovered and excavated by researchers from the University of the South Pacific (USP) and the Fiji Museum between 2003 and 2007/2008. It provides the background on the history and development of work conducted over almost half a decade along the Rove Peninsula. The Lapita-era sites described here include Qoqo, Rove, Bourewa, Waikereira, Jugendar’s Farm (JF) and Tomato Patch (TP) (Figure 5.2B).

The Qoqo Island site is located on a bedrock island surrounded by mangroves adjacent to the mouth of the Tuva River. While Qoqo Island is 30 minutes walking distance north from Vusama village, Rove and Bourewa sites are about a kilometer away from the village. The other Lapita-era sites – Waikereira, Jugendar’s Farm and Tomato Patch, are located a few hundred meters southeast of the present Bourewa
site. Access to these sites is via gravel road that leads to the Natadola Bay and other feeder roads that traverse fallow sugar cane fields most of which have been recently abandoned.

Several papers have described and discussed the results and analysis of the geoarchaeological excavations conducted along the Rove Peninsula since 2003. Examples include Dickinson (2005), Kumar and Nunn (2003), Nunn (2005), Nunn et al., (2004, 2005a, 2005b, 2006), Nunn (2007a) and Szabó (2006). Preliminary results of the excavations conducted at Rove, Qoqo and Bourewa sites were also presented at a recent Pacific Archaeology Conference in Nuku’alofa, Tonga in August 2005 (Nunn et al., 2005a).

The discussions outlined here are based on the foregoing reports and describe the major excavation phases along the Rove Peninsula and their implications for understanding Lapita settlement patterns and resource utilisation. A summary of the three excavation phases conducted along the Rove Peninsula (from 2003 to 2005) is highlighted, while post-2005 excavation results are only briefly noted. The author participated in geoarchaeological fieldwork at Bourewa and Qoqo sites including Qaranibourewa and Qaranimatatolu Caves in the 2004, 2005 and 2007/2008 field seasons.

As cited by Nunn et al. (2004) and Nunn (2007a), the initial clues to the presence of Lapita occupation along the Rove Peninsula were first reported in the early 1960s by Bruce Palmer (Palmer, 1965). In his paper, Palmer traced a piece of Lapita pottery to a certain location near Natadola Harbour, later identified as Waikereira - a small bay southeast of the present Bourewa site. It took almost four decades after the publication of Bruce Palmer’s report for researchers from the University of the South Pacific and the Fiji Museum to discover new Lapita-era sites close to Waikereira. In 2002, during a reconnaissance survey along the Rove Peninsula, several pieces of dentate-stamped potsherds were recovered on the coastal flat at Rove Beach. Initial excavations there in 2003 confirmed Rove
Beach as a post/late Lapita-era site, but the find inspired further investigations and triggered a series of geoarchaeological excavation projects which yielded significant finds elsewhere along the Rove Peninsula. For example, the discovery of Bourewa Lapita site and the subsequent identification of other Lapita-era sites in the area like Qoqo, Waikereira, Jugendar’s Farm and Tomato Patch (Kumar and Nunn, 2003; Kumar et al., 2004).

![Figure 5.3. Bourewa excavation map of pits excavated during Phases 1 to 3 and the extent of dentate-stamped potsherds recovered during surface collection at Bourewa. Pits with prefixes TP and X were excavated during Phases 1 and 3 respectively. Pits B1, B2, B3, B4, L3, L4, RB2, RB3, and TP5 were dug during Phase 2. (Adopted from Nunn, 2007a Figure 4 p. 166).](image)

5.3.1 Phase 1 excavations at Rove Beach and Bourewa settlement

The first phase of geoarchaeological excavations along the Rove Peninsula commenced at Rove Beach in December 2003 (Kumar and Nunn, 2003). The Rove Beach site is located at the northern tip of the former Rove Island bordered to the northeast by mangroves and on the west by an extensive coral reef (Figure 5.2A).

During Lapita times, Rove was an offshore island completely separated from Vusama Island (Figure 5.2B). Toward the end of the Lapita era, Rove was attached
to Vusama as a result of sea-level fall, increased sedimentation and mangrove expansion. Today the site is heavily eroded with mostly notched-rim potsherds recovered during the 2003 excavation season. Radiocarbon dates indicate that Rove Beach was occupied around 750–550 BC (2700-2500 cal BP), which makes it a late/post Lapita site. At the time of its Lapita occupation, the Rove settlement would have been established on an offshore island that was at least 1 km$^2$ in area (Nunn, 2005).

During excavations at Rove Beach in 2003, a reconnaissance along the rest of the Rove Peninsula shoreflat led to the discovery of the Bourewa site. Four test pits were dug at Bourewa site at that time and preliminary results revealed significantly high proportions of dentate-stamped and decorated potsherds with Western Lapita motifs and dates ranging from at least 1220-970 BC (3170-2920 cal BP) (Nunn et al., 2004). Based on these finds and the general features of the site, it became clear that Bourewa was a very special Lapita-era site in Fiji, hence, the need for more extensive excavations and detail analysis of its contents.

### 5.3.2 Phase 2 excavations at Bourewa settlement, Qaranibourewa and Qaramatatolu Caves and Qoqo Island

The second phase of fieldwork conducted in November-December 2004 targeted the area’s major cave sites – Qaranibourewa and Qaramatatolu and included surveying and delimiting the Bourewa site by test excavations and surface collections (Figure 5.3). Test excavations were conducted on nearby Qoqo Island, another Lapita-era site on the Rove Peninsula (Nunn et al., 2006; Nunn, 2007a).

The Qaranibourewa Cave is located approximately 200 m inland east of the Bourewa Lapita site. Although there were no traces of human occupation there earlier than AD 1000, the cave is the largest found along the Rove Peninsula. The second largest cave - Qaramatatolu, was probably inhabited between AD 750 and AD 1250. The shellfish remains excavated at this cave site indicate it used to be an open-coast location, while the adjacent mangrove forest was probably formed only within the last few hundred years (Nunn et al., 2005b).
Nunn and others suggest that these caves would probably have been well known to the Lapita occupants of the Rove Peninsula. The Qaranibourewa Cave in particular might have been important in the life ways of the Bourewa settlers. The cave could have been a major source of freshwater for the settlers of Bourewa (Nunn et al., 2005b). While there are other smaller caves located within the area, potential uses for caves like Qaramatatolu, for example, could have been as fishing outpost and/or shellfish-processing sites although such scenarios are conjectural.

Four dentate-stamped potsherds and two notched rims (immediately post-dentate) recovered during surface collection on Qoqo Island lead to excavations there in December 2004. Nunn et al. (2006:205) described Qoqo as “a bedrock island (40,000 m²) reaching 32 m above sea level, located in the 7.3 km² mangrove swamp at the mouth of the Tuva River”. Five test pits excavated on Qoqo Island confirmed a Lapita-era occupation site established on a tombolo – a bar of sand and gravel that connected two separate hills or islands. Radiocarbon dates from both marine shellfish and charcoal from Pits F1 and R2 indicate that the earliest occupation occurred sometime between 1000-800 BC (2950-2750 cal BP). It is likely that the tombolo was sheltered from wave action during Lapita times and later became surrounded by an extensive mangrove forest.

Shellfish analysis of the Qoqo Island shell assemblage reveal a predation pattern whereby colonisers initially consumed a range of marine shells but larger shellfish taxa became less common towards the end of its Lapita occupation. This could mean that the human colonisers of Qoqo Island were heavily predating on larger shellfish taxa up to a point where fewer larger taxa were readily available so their diet broadened and incorporated smaller-sized shellfish taxa. Alternatively, as sea level was falling and the local environment was changing due to shoaling of the Tuva Estuary, the diversity and abundance of certain freshwater shellfish taxon like Batissa violacea was affected by the changing environmental conditions (Nunn et al., 2006).

Subsequent field surveys and surface collection of potsherds conducted by the research team along the shoreflat from Bourewa to Natadola beach during Phase 2 resulted in the discovery of three new Lapita-era sites. These are Waikereira (or
properly Covularo), Jugendar’s Farm and Tomato Patch (Nunn et al., 2005a; Nunn, 2007a). Nunn (2007a) reported that at Waikereira dentate-stamped potsherds were collected from the cane fields on the slope at the back of the bay about 2-4 m above present mean sea level. Dentate-stamped potsherds were also found on slopes about 2-5 m high at Jugendar’s Farm and Tomato Patch. These three smaller bays are located southeast of the present Bourewa Lapita site.

5.3.3 Phase 3 excavations at Bourewa settlement

In mid-2005, the Phase 3 of geoarchaeological fieldwork was conducted that focused largely on the Bourewa site itself (Figure 5.3). A review of the main findings of the mid-2005 excavations is given in Nunn (2007a). According to Nunn (2007a:7), “the principal aim of the Phase 3 research at Bourewa was to excavate the center of the site, where the earliest cultural deposits were assumed to exist”. A team of 32 researchers spent four weeks (June-July 2005) excavating the Bourewa site. Nunn reports that a total of 27 test-pits (each 2 m²) and trenches were excavated within the ‘hot spot’ region of the site. An area approximately 127 m² with a total volume of material of 103 m³ were sieved, sampled and prepared for analyses.

The Bourewa site is a typical “open” Lapita site located on a sand spit at the mouth of a tidal embayment. The site probably extended about 250-300 m along the coast and 40-70 m inland. During high tide, the site would be awash and most of the dwellings were probably built on stilt posts in Lapita times. It appears that the inhabitants of Bourewa discarded their “kitchen” refuse including the hard parts of shells, broken pottery, stone tools and artifacts, and shell ornaments into the sea below (Nunn, 2007a).

The discarded shell remains and other materials accumulated into a huge coastal shell midden exposed along the fringe of the Bourewa site readily observed today as protruding out of the beach sand during low tide. The shell midden actually built up the sea floor to such an extent that it eventually became dry land as sea level fell (Nunn, 2007a). Kirch (1997) noted that a situation similar to Bourewa occurred at
several Lapita-era sites in the Bismarck Archipelago of Papua New Guinea, where the Lapita people occupied stilt houses or platforms that were built over the lagoon.

The preliminary results and analysis of the mid-2005 field season finds (excluding shellfish) are described in Nunn (2007a). Some of the significant cultural materials recovered during the mid-2005 excavation include large quantities of shellfish and decorated (dentate-stamped, notched rims) and plain potsherds, stone tools and flakes, shell artifacts and ornaments, and non-human bones. Postholes, earth oven (lovo) stones, and a single piece of obsidian rock were also recovered. The excavation of sixteen human burials was also significant, although preliminary analysis of the skeletal remains suggest they are post-Lapita in age.

The three field seasons of geoarchaeological excavations along the Rove Peninsula have provided significant clues to the nature of the settlement and behaviour of the early colonisers of the Rove Peninsula almost three millennia ago. Nunn suggested that the recovery of dentate-stamped pottery at higher elevations (between 2-5 m) at Waikereira, Jugendar’s Farm and Tomato Patch might represent population “overflow” from Bourewa. The single piece of obsidian recovered during the 2005 field season was perhaps transported to Bourewa (Fiji) from the Kutau-Bao mine on the Talasea Peninsula on New Britain Island, (Papua New Guinea), possibly via the trading routes that existed during Lapita times implying a journey of at least 3250 km (Nunn, 2007a).

Nunn (2007a:10) also stated that even though analysis is continuing, “a cursory examination of the decorated sherds obtained during Phase 3 shows that the site contains a comparatively high proportion of potsherds with motifs that are normally found in the Western and Far Western Lapita provinces”. While preliminary petrologic or mineralogical analyses of the Bourewa potsherds indicate they were manufactured locally, the motifs on the decorated potsherds suggest they were probably created by people who were associated with and/or originated from the southeastern Solomons and/or the Bismarck Archipelago (Nunn pers. comm., 2005).
The identification of aroid starch and pollen of taro and lesser yam by Horrocks and Nunn (2007) also confirmed the suspicion that the Lapita people who colonised Bourewa must have practiced agriculture/horticulture at some point during their occupation of Bourewa site. They perhaps consumed starchy root crops and probably vegetables besides relying heavily on marine food resources for subsistence. Horrocks and Nunn also note that this is the first evidence of crop (aroid) cultivation or domestication east of the Vanuatu Archipelago. Similar evidence might be found in other archaeological sites within Remote Oceania. This particular find adds further evidence to over three decades of debate on the nature of prehistoric Pacific subsistence practices in the Remote Oceania region.

While the exploitation of the marine fauna (particularly shellfish resources) and horticultural practices at Bourewa may provide clues to the life ways of early settlers of the Rove Peninsula, radiocarbon dates for selected shells and charcoals from Bourewa, Rove and Qoqo also hint at the nature of the evolution of their settlement pattern. The radiocarbon dates obtained so far for the Bourewa site point to it as the “founder settlement site” from which later populations and/or new migrants expanded into other locations along the Rove Peninsula and possibly other parts of Viti Levu Island and Fiji (Nunn et al., 2004, 2005a).

According to Nunn, three major periods of settlement have been recognised. These are characterised by initial colonisation of Bourewa site (around 1200/1100 BC or 3150/3050 cal BP), subsequent “expansion” and/or influx of new migrants into Qoqo Island (about 1000-800 BC or 2950-2750 cal BP), and “overflow” into Rove Beach (sometime between 750-550 BC or 2700-2500 cal BP) and nearby bays, Waikereira, Jugendar’s Farm and Tomato Patch along the Rove Peninsula (Nunn et al., 2004, 2006; Nunn, 2007a).

It appears that the Bourewa site was never re-settled after it was abandoned at the end of the Lapita period in Fiji. But the discovery of post-Lapita human burials (subject to revision and re-dating) at the site during the mid-2005 and 2007/2008 field seasons suggest that Bourewa may have been a significant cultural (or spiritual) site even after the Lapita period. Although this proposition is conjectural, it is
possible to assume that the people who were buried at Bourewa site were perhaps familiar with the site. They could be inhabitants of other nearby sites and/or users of the limestone caves such as Qaranibourewa and Qaramatatolu.

5.3.4 Post-2005 excavations along the Rove Peninsula

According to USP News (2007), in February 2007, a 15-member team of researchers from the University of the South Pacific and the Fiji Museum “re-excavated the deepest and oldest-known part of the Bourewa site”. The team spent a week excavating at the Bourewa and Tomato Patch sites. A significant find of this field season at Bourewa site was the recovery of a pearl-shell fishhook that was excavated along with numerous potsherds and shells from the thick shell midden at Bourewa settlement. The fishhook carved from a single piece of shell was probably used as lure for beach fishing and trolling. A test excavation conducted at Tomato Patch near Natadola beach revealed early Lapita-era potsherds as well suggesting it could be older than earlier suspected and perhaps further investigations will be required to provide a much clearer picture of its content and context. Another field season was conducted in July 2007 and at least four 1 m$^2$ excavation pits were dug at Bourewa.

![Figure 5.4. Post-2005 excavations at Bourewa settlement. A: Photo of the Bourewa area excavated during the November 2007 - February 2008 field season. Area A is left and Area C is right of the white Land Cruiser. B: Student researchers - Teddy Pong sieving and collecting pottery sherds for quantification and analysis. (Photos by Tony Heorake, 2007).](image)

From 24$^{th}$ November 2007 to 4$^{th}$ February 2008, an eight-week field season was again conducted at the Bourewa settlement. The principal focus of this major archaeological work was on the areas that were not excavated during previous phases.
of fieldwork – these are Areas A and C (Figure 5.4A). Several interesting finds were also recovered during this fieldwork. These include evidence for stilt platforms, a separate dumping site for shellfish remains, and a “Lapita jewellery box” containing shell bracelets and rings. Adzes, axes, stone chisels and a range of animal bones of dogs, rats and chickens were also recovered. Another significant find was that of a finely decorated lime-filled dentate-stamped potsherd with designs that suggest close links with the Bismarck Archipelago of Papua New Guinea (USP News, 2008).

Like the mid-2005 field season, this recent excavation phase also recovered large volumes of shells. The analysis of these finds is still in progress.

5.4 Field Methods

The following outlines the field methods employed in this study and some of the factors that can influence the recovery, quantification and analysis of shellfish remains from the Bourewa site. These include sampling methods (section 5.4.1) and screen mesh size (subsection 5.4.2) (Nagaoka, 1988). In the lab, the sampled shells were cleaned, washed and quantified (subsections 5.5.1 to 5.5.4).

5.4.1 Shell sampling

As reported by Nunn (2007a), the mid-2005 excavations in the center of the Bourewa settlement covered a huge area (126.93 m²) and a considerable quantity of materials (103 m³) was excavated and recovered. All the excavated materials were dry-sieved and the artifacts, potsherds and shells, collected, sampled and bagged.

Of the 27 pits (and trench extensions) excavated during the mid-2005 field season, shellfish taxa from only 5 pits (X1, X2, X3, X5 and X6) were randomly sampled for identification, classification, quantification and analysis. These five pits were dug just behind the modern beach berm at Bourewa site where a large proportion of Lapita potsherds with Western motifs was recovered. Ideally, all the shellfish taxa excavated from the Bourewa site should be analysed and reported, but owing to their large quantity, only randomly sampled specimens were obtained for quantification and analysis.
A key to selecting the shellfish sample for this study is its representation of the entire shell assemblage so that appropriate inferences can be made. Each test pit was sampled to obtain a representative quantity of shells that can be analysed to minimise the effect of variations in sample sizes (Grayson, 1984). All the shellfish taxa within a particular spit (arbitrary 10-cm level) by pit were initially combined then divided into four equal parts. Each group was numbered I, II, III and IV and a number was randomly picked. The selected cluster of shells was then bagged and appropriately labeled while the rest of the shells were later discarded at the site. Thus 25% of the shells in each spit by pit were sampled for analyses.

The bagged shells were properly packed and transported to the USP’s Marine Studies Program postgraduate laboratory for cleaning and prepared for analysis. Four student assistants washed and cleaned the shells with soft brush (or toothbrush) in the laboratory. The cleaned shells were dried and repacked in newly labeled plastic bags. For each spit by pit, gastropods and bivalves were bagged separately and appropriately labeled to facilitate identification, classification and quantification.

### 5.4.2 Sieving

Throughout the entire field season in mid-2005, a 10-mm mesh size was used to recover the shells and other materials. This strategy is employed to ensure consistency and avoid analytical discrepancies because, as Nagaoka (1988) noted, the utilisation of different screen sizes to recover faunal remains can influence the assessment of taxonomic richness and diversity due to differential recovery rates. Nagaoka also stated that larger screen sizes tend to recover a smaller amount of faunal materials, favour larger animals, and only fewer shellfish taxa can be recovered.

In her experiment on the effects of differential recovery techniques of Pacific Island fish remains, Nagaoka (2005) noted that fish remains may be affected by individual body size, the general body size of individual families, as well as the shape of particular skeletal elements. Generally, larger individuals have greater chance of recovery, while some elements for particular taxa are more susceptible to increased
fragmentation thus affecting the element’s size, shape, and identifiability. Aspects of the archaeological taphonomic history, such as differential preservation or fragmentation are also important.

For the mid-2005 excavations at Bourewa, a 10-mm mesh sieve (1 cm²) was used all throughout the entire field excavation season. No wet sieving or switch in screen size was conducted on the faunal remains. As with the field excavations at Rove Beach and Qoqo Island, the same mesh (size) sieve was utilised to allow for comparisons between the three sites and limiting biases or other complicating factors. All the materials excavated at the Bourewa site were dry sieved and the shell remains bagged and appropriately labeled by spit and pit. Inevitably any shellfish taxa that are smaller than the mesh size used would not be recovered during the sieving process but because the shell taxa are relatively large specimens and well intact, this is not of particular concern for the analyses.

5.5 Laboratory Methods

The team of excavators including the author sampled the shells on site but no field specimen catalogue was on hand so all the shells were brought back to the University of the South Pacific Marine Studies Laboratory for identification, classification and analysis. The shellfish specimens were compared and verified with a shellfish reference collection held in the University Herbarium. A specimen collection of each shellfish species from the Bourewa shell assemblage was also made for reference purposes. The collection is kept in safe storage at the Marine Studies Program Laboratory, USP.

The shells were identified by the author with the assistance and guidance of Mr Johnson Seeto of the Institute of Marines Resources (IMR) at the University of the South Pacific (USP). General texts such as, “Marine Shells of the Pacific” (Cernohorsky, 1972), “New Zealand Shells” (Child, 1974), “Compendium of Sea Shells” (Abbott and Dance, 1982, 2000), “Shells” (Claassen, 1998), “Zooarchaeology” (Reitz and Wing, 1999), “Quantitative Units and Terminology in Zooarchaeology” (Lyman, 1994b), and other shell references from the Fiji Islands held at the PIMRIS
Estimates for MNI were based on paired elements (valves) and non-repetitive elements (NREs) for both bivalves and gastropods. Shell weight data were recorded for all shell specimens (Number of Identified Specimens - NISP) of each species by spit and pit. Shell-size measurements were conducted on the three most abundant shellfish sampled from Pits X2 and X3 – *Codakia punctata*, *Fimbria fimbriata* and *Strombus gibberulus gibbosus*.

The utility of NISP, MNI, weight and size was conducted in the lab to quantify the shellfish taxa at Bourewa. The Bourewa shell data – MNI, NISP, Weight, and size quantification are provided in Appendix 2 on the CD-Rom submitted with this thesis.

These quantification methods are appropriate and versatile for counting shellfish species from most archaeological sites (Glassow, 2000). Although Grayson (1984) suggested that these quantification methods can be problematic if used on their own, when utilised together they offer an opportunity to address many issues like the relative importance of certain taxa rather than a simple value of absence or presence (Fitzpatrick and Kataoka, 2005).

Shellfish classification was done to species level where possible, or genus or family if this was not. While all the shells were weighed, the number of identifiable specimens (NISP) and minimum number of individuals (MNI) were quantified and ranked in order of abundance. Ranking the shellfish taxa generally indicate the type of shellfish collected and the habitats exploited and targeted by shellfish collectors. Inferences were then made regarding the foraging strategies used by the shellfish collectors and testing of assumptions as derived from optimal foraging models (Bedford, 2006).

5.5.1 NISP (Number of Individual Specimens) quantification

Since NISP is a basic quantification (Lyman, 1994b), all the shellfish specimens from each identified species (including fragments) were appropriately counted and...
weighed. Where it is not practically possible to identify any shell fragment(s), these were categorised as “unidentifiable specimens”. Only NISP counts and weights were done for shell fragments.

The utilisation of the NISP method in archaeological studies in Oceania and the Fiji Islands is not uncommon. The recent Naitabale study (Moturiki Island, central Fiji) employed NISP to calculate the relative frequency of different shellfish taxa present at the site (Nunn et al., 2007). Thomas et al. (2004) also utilised the number of individual specimen counts and relative abundances to analyse the shellfish taxa from Qaranilaca Cave on Vanuabalavu Island, Fiji. In her synthesis of archaeofaunal remains from excavated Lapita sites on different Pacific Islands, Nagaoka (1988) reported five study sites in the Solomon Islands, New Caledonia and Fiji where she conducted the NISP method to quantify their shellfish remains.

In Yuen’s (2005) preliminary shell analysis of Pit F1 excavated at Qoqo Island in 2004, a count of all identifiable fragments and whole shells was conducted. Her results reveal a strong correlation between NISP and MNI proportions where those species that had high NISP counts also had similarly high MNI values. Hence, as Grayson (1984) noted, NISP estimates may provide a rough proxy for MNI counts. Thus Nagaoka (1988) stated that shellfish analysts should report NISP together with MNI counts when quantifying faunal remains.

5.5.2 MNI (Minimum Number of Individuals) quantification

The MNI count for gastropods is straightforward but for bivalves the right and left sides (valves) were initially distinguished using their characteristic features and NREs like umbos and hinges before to each valve was counted. All the quantified shellfish taxa were then recorded on an Excel spread sheet. For purposes of weight quantification, a digital scale was used to weigh the different shellfish species (NISP) including fragments by spit and pit.

Mason et al. (1998:308-309) stated that in order to calculate MNI for bivalves, “the most accurate approach is to identify right and left hinges or umbos separately and quantify the higher of the two counts, or to count the total number of hinges or umbos.
per taxon and divide the sum by two”. Bivalve shells were separated into left and right sides for each identified species (or genus) and the higher count out of the two valves taken to estimate the MNI. As an example, if there are 4 left valves and 3 right valves of the bivalve *Codakia punctata*, the MNI is 4. The sum of individual left and right valve counts is also recorded in the MNI column.

Since the Bourewa site was dug in arbitrary units (10-cm spits) rather than aggregating only natural stratigraphic layers, there are a number of bags from the same spits so the highest value for each taxon per spit is recorded. If spits 1, 2 and 3 are from the same stratigraphic layer and spit one has 4 right and 4 left valves of *Codakia punctata*, spit two has 1 right and 4 left and spit three has 3 right and 2 left valves. The MNI is not 4+4+3; it is 10 (4+4+2) as the sum of the left valves in the three spits are higher than the right valves (Katherine Szabó *pers. comm.*, 2005).

Additionally, as Katherine Szabó (*pers. comm.*, 2005) suggested and used in her analysis of the Kulu shellfish assemblage, Fiji Islands, shell fragments of known species without NREs were not counted for MNI purposes but were recorded as “p” for present in the MNI column and then assigned a value of ‘1’ (or whatever it is) in the NISP column. For asymmetrical bivalves like *Chamidae, Spondylidae* or *Ostreidae*, their MNI is quantified as “bottom” or “top” instead of “right” or “left” valves respectively, as in other symmetrical bivalves and given an appropriate value as NISP. Where either the bottom or top valve cannot be readily determined, their MNI are also recorded as present (p) and an appropriate value given for NISP.

Several archaeological studies in Fiji have utilized the MNI method to analyse shellfish remains. These include Best’s (1984) analysis of two sites on Lakeba Island, eastern Fiji (sites 101/7/196 and 101/7/197) and Thomas *et al.* (2004) who conducted MNI analysis on the shellfish remains excavated from a large sea cave - Qaranilaca Cave on the southern tip of Vanuabalavu Island. In their study of marine (shellfish) resource depression at Natia Beach, Nacula Island, western Fiji, Morrison and Cochrane (2008) also utilised MNI data to test if resource depression can be traced by a decrease over time in the ratio of large to small-bodied prey species.
5.5.3 Weight quantification

Many archaeologists and researchers still use the weight method to quantify and analyse variability in shellfish assemblages and trace resource exploitation. For example, Amesbury (1999) used shellfish weight to understand species composition of the archaeological marine shell assemblages in Guam where she noted that changes in species composition were linked to environmental changes in Tumon Bay and East Agana Bay. At Qoqo Island, Nunn and others also conducted weight analysis to demonstrate that larger marine shellfish species were abundant in the lower levels but were few in the upper levels (Nunn et al., 2006).

In this study, both MNI and NISP were weighed including shell fragments. The shell weight for each taxa is then recorded in the appropriate column of the shell quantification sheet and then recorded on an Excel spread sheet.

5.5.4 Shell size measurement

Shell-size measurements were conducted only on intact specimens of the three most abundant shellfish species of the Bourewa assemblage. These are *Codakia punctata* (MNI = 7562), *Fimbria fimbriata* (MNI = 1005) and *Strombus gibberulus gibbosus* (MNI = 893) (Figures 5.5A, B and C). Appendix 6 on the CD-Rom provides the shell-size measurement data for the three most abundant taxa at Bourewa settlement. A digital caliper was used to measure their dimensions. Fragmented shellfish specimens of these three species were not measured.

The shellfish diagrams illustrated in Claassen (1998:19, 109 and 110) provide useful guides for shell-size measurements for these shellfish taxa. For *Strombus gibberulus gibbosus*, both aperture height and shell height were measured but only the latter dimension was considered in this analysis. The right side and left sides of the bivalves *Codakia punctata* and *Fimbria fimbriata* were initially differentiated before their dimensions were recorded. The valve height and valve length of the two bivalves were measured. In this analysis, valve height was not considered. Generally the cockle-shaped bivalve families like Veneridae, Cardiidae, and Lucinidae have their hinges and umbo facing in towards each other. Left valves have their umbo,
hinges slanting in towards the right, while right valves have their umbos, hinges slanting left (Katherine Szabó pers. comm., 2005).

Swadling (1986) also employed shell size measurements to examine changes in the shellfish sizes of excavated molluscs over time at the Reef/Santa Cruz sites – SE-RF-2, SE-RF-8 and SE-RF-6. In her analysis of site SE-RF-2, Swadling demonstrated size reduction for two gastropods and one bivalve species. She noted that proportionately older, more mature and larger species of *Trochus niloticus* and *Anadara antiquata* were recovered in the lower layer (“Layer 2”) compared to the upper layer (“Layer 1”) while *Tectus pyramis* also showed progressively younger individuals throughout the site’s occupation. Archaeological studies in Fiji that have utilised shell-size measurements to understand human predation on shellfish resources include Nunn *et al.* (2007) and Morrison and Cochrane (2008).

Although it is inevitable that over time, even intact shells will develop chipping along their edges, it is important that shellfish specimens be intact in order to accurately measure them otherwise the results could become skewed. The measurement of fragmented shells will produce relatively lower size (average) values as compared to intact specimens and subsequently result in lowering of the overall shell-size mean value. Thus, as is the case here, shells that were highly chipped or broken were not measured. All measurements were done for intact shells only and recorded on an Excel spread sheet. A digital caliper proved more practical than analogue ones for these kinds of measurements due to their accuracy and appropriateness for measuring shells that are generally irregular in shape.

For purposes of this particular size analysis, only the shellfish specimens from Pits X2 and X3 were sampled for shell-size measurements since these pits were securely dated and well stratified: for example, Pit X2 at 90 cm (2817-2696 cal BP) and 20 cm (2705-2358 cal BP) depth and Pit X3 at 70 cm (2826-2605 cal BP) and 30 cm (2877-2700 cal BP) depth. Nunn (2007a) also dated charcoal and marine shells at the lower depths (> 120 cm) of Pits X2 and X3 and his dates reveal a range from about 3140-2867 cal BP to 2758-2526 cal BP. Since these dates were obtained from specific layers of each pit, any significant changes in shellfish size within these layers can be pegged to certain time periods and be compared.
The mean size of shellfish specimens for the upper and middle layers of Pits X2 and X3 were calculated and compared. It is plausible to suggest that any changes or differences in the shell size between these two layers might be attributable to human predation and/or environmental factors (Nunn et al., 2007). As Morrison and Cochrane (2008) stated, any changes in shellfish morphology are normally due to the possible impact of human predation on shellfish resources. Thus, any significant change in the mean shell size within these different layers can be verified and explained as associated with predation or environmental change.
5.5.5 Summary

According to Glassow (2000:413), MNI is considered most useful “for developing measures of collecting effort especially if NREs are well preserved” and weight is “most convenient for developing measures of relative dietary importance of shellfish taxa, especially if samples from a site are small and dispersed or if shells are highly fragmented or low in density”. Both MNI and weight have equal utility and each method can be understood by considering the nature of the shell assemblage and the particular research questions being asked. The weight approach is most reliable if assemblages consist of highly fragmented shells while MNI is more appropriate if shells are in large fragments and quantities per excavation unit are not too high.

While MNI and weight measurements both have their strengths and weaknesses for shell analysts, MNI is used for most of the analyses in this study. Mason and others recognised that MNI provides a more reliable and valid measure than weight and contend that count data is most appropriate for addressing taxonomic abundance of shellfish or fauna from an archaeological context (Mason et al., 2000:760).

Overall, the utilisation of MNI, NISP, weight or size to assess the Bourewa shell assemblage can assist in measuring relative abundance of shellfish taxa, identify and understand human subsistence practices, and indicate palaeoenvironmental conditions during Lapita times. These methods have been utilised to determine species abundance, species composition, the relative frequency of different shellfish taxa, evaluate habitat exploitation, and examine the influence of environmental factors like sea-level and climate change. These non-human factors can also influence changes in species distribution, sedimentation, coastal progradation or erosion, mangrove development and the evolution of coastlines.
6.1 Introduction

This chapter presents the results and analysis of the shells sampled and quantified for the five test pits (X1, X2, X3, X5 and X6) excavated at Bourewa settlement during the mid-2005 field season. Data for the shellfish analyses are provided in Appendices 1 to 10 on the CD-Rom supplied.

The stratigraphic profiles of the five test pits at Bourewa are shown in section 6.2 with diagrams (Figures 6.2A-E and 6.3). This chapter also describes their content and context and illustrates where radiocarbon dates were derived for each test pit (subsections 6.2.1 to 6.2.5). Section 6.3 describes the radiocarbon chronology of the Rove Peninsula and presents the radiocarbon dates obtained from shallow marine shells by the author for Pits X2 and X3. Section 6.4 presents the shellfish quantification and analysis of the Bourewa shells based on MNI, NISP, and weight quantifications and size measurements.

Section 6.5 outlines and describes the three analytical zones (A, B and C) delineated for the Bourewa shell assemblage based on near-equal shell weight distribution for each zone. The results of shellfish habitat usage and shellfish MNI analysis per zone for different shellfish habitats are presented in subsections 6.5.1 to 6.5.3.

Section 6.6 presents the shellfish species and habitat analyses based on the application of foraging theory models. The objective of this section is to assess the changes in foraging efficiency within different shellfish habitats. Section 6.7 presents the analysis of shellfish diversity and abundance by measuring diet breadth and NTAXA, evenness, and relative abundances.

6.2 Stratigraphic Profiles of Pits X1, X2, X3, X5 and X6

As illustrated in Figure 6.1C, the five test pits described here were excavated along the axis of the former Bourewa sand spit where a thick shell midden occurred. These
pits are located within the area of the earliest cultural deposits of the Bourewa settlement. Nunn described this area as lying between pits TP1, TP2, TP3 and TP4 excavated during Phase 1 (December 2003) of geoarchaeological investigation at Bourewa. It contained a high proportion of dentate-stamped pottery sherds with Western (Lapita) motifs and designs and some of the earliest radiocarbon dates for the occupation of the site (Nunn, 2007a).

The five test pits profiled here lie parallel to the present coast and are located at the back of the modern beach berm along a northwest to southeast axis (Figure 6.1C) (Nunn et al., 2004; Nunn, 2007a). During excavations in mid-2005 at the Bourewa settlement, it became clear that the top 0-30 cm of the site was highly disturbed due to ploughing for sugarcane cultivation. Beneath this layer, much of the archaeological deposits have remained relatively undisturbed although in certain places the plough had dug to about 40 cm deep. The bulk of the archaeological materials were found within 20-80 cm thick black, brown silty, sandy soil. This culturally-rich deposit was underlain by an earlier sand deposit that sits on top of the former beach and reef terrace.
The excavations at Bourewa settlement so far have revealed the character and context of the site, particularly in terms of preservation conditions and changing site use, expansion and development in association with the possible influx and out-migration of the Lapita people at the site. Some significant finds include the earliest and most extensive collection of Lapita potsherds with a high proportion of Western (Lapita) motifs, a range of stone tools and shell artifacts, other exotic materials like obsidian rock (sourced from Talasea mine in Papua New Guinea) and possibly a separate shell midden “dumping area”. Several post-hole features associated with Lapita culture and settlement patterns as observed in Near Oceania by Patrick Kirch, and human remains (though post-Lapita in age) were also excavated (Nunn, 2007a).

A total volume of about 23.4 cubic meters (m$^3$) of material was excavated from these five pits during the mid-2005 field season. The location and stratigraphy of the five test pits at Bourewa settlement, their composition, context, and the conditions of removal are presented in Figures 6.2A-E.

Each test pit was 2 m$^2$ and 4 meters apart except between Pits X3 and X5, which is separated by 15 m (Figure 6.1C). Pit X4 is not included in this particular analysis. Although the pit profiles are not drawn to scale, Figure 6.3 illustrates the generalised stratigraphic sections of the five test pits and how their layers are linked based on their character and content.
Figure 6.2A-C. Stratigraphic profiles of Pits X1, X2 and X3, Bourewa site. (Diagrams supplied by Patrick Nunn).
Figure 6.2D-E. The stratigraphic profiles of Pits X5 and X6, Bourewa site. (Continued...). (Diagrams supplied by Patrick Nunn).
Figure 6.3. The relationship between the various layers of the pits excavated at Bourewa settlement. Pits X1, X2, X3, X5 and X6. (Diagrams supplied by Patrick Nunn).
6.2.1 Stratigraphy of Pit X1

Pit X1 has at least four stratigraphic layers of varying composition and content (Figure 6.2A). Underlying the top three cultural layers is a sterile layer of beach sand, compacted in places. While the top layer (L.I) (0-18 cm) is composed of dark brown silt, some occasional shells and rootlets, it appears to be disturbed as a result of ploughing for sugarcane cultivation. The second layer (L.II) (18-32 cm) is undisturbed and consists of dark brown silt with shells accounting for about 65% by volume. The third layer (L.III) (32-58 cm) is composed of light brown silty sand, and shells account for about 75% by volume. The fourth layer (L.IV) (58-127 cm) is mostly yellow (palaeo-beach) sand with only a few shells. This layer is underlain by compacted calcareous bedrock.

A charcoal sample (Wk 17541) that was recovered from Pit X1 at a depth of 105 cm yielded a calibrated radiocarbon date range of 2710-2350 cal BP (Nunn, 2007a).

6.2.2 Stratigraphy of Pit X2

Pit X2 consists of three stratigraphic layers (Figure 6.2B). The top layer (L.I) (0-37 cm) is made up of dark brown silt with occasional shells and rootlets. Like Pit X1, the top 20 cm of this layer is disturbed by ploughing for sugarcane. The middle layer (L.II) (37-93 cm) contains the bulk of the shells accounting for 80% by volume with a matrix composed of dark brown silty material. The bottom layer (L.III) (93-130 cm) is predominantly yellow sand with occasional shells and is part of the former beach sand.

Three radiocarbon dates have been determined from three marine shell specimens at different depths for Pit X2 – one by Patrick Nunn and the other two by the author. These dates were obtained from three marine shell samples – Wk 17548 (2760-2520 cal BP), Wk 20281 (2870-2690 cal BP) and Wk 20282 (2850-2670 cal BP) (Nunn, 2007a). The OXCal plots for shell samples Wk 20281 and Wk 20282 are provided in Appendix 1 (CD-Rom supplied).
6.2.3 Stratigraphy of Pit X3

Pit X3 consists of three stratigraphic layers (Figure 6.2C). The top layer (0-49 cm) is composed of dark brown silt with occasional shells and rootlets. Again, the top 20 cm of layer I (L.I) is relatively disturbed. The middle layer (L. II) (49-96 cm) contains bulk of the shells making up 80% by volume. The bottom layer (L. III) (96-160 cm) is mostly sterile yellow sand with small number of shells.

Six radiocarbon dates were determined from five shallow marine shell specimens and a charcoal sample from Pit X3 – two by the author and four by Patrick Nunn. These are samples – Wk 17542 (3150-2860 cal BP), Wk 17546 (2780-2530 cal BP), Wk 17573 (3070-2850 cal BP), Wk 17549 (2880-2700 cal BP), Wk 20283 (2830-2600 cal BP) and Wk 20284 (2880-2700 cal BP) (Nunn, 2007a). The OxCal plots for shell samples Wk 20283 and Wk 20284 are provided in Appendix 1 (CD-Rom supplied).

6.2.4 Stratigraphy of Pit X5

Pit X5 is relatively shallow and consist of at least three stratigraphic layers or possibly four (Figure 6.2D). The top layer (L.I) (0-19 cm) consists of dark brown silt with occasional shells and rootlets. The middle layer (L.II) (19-36 cm) comprises 70% shells and is composed of dark brown silt material. A narrow band of dark brown silty material (about 2 cm thick) lies between the middle and bottom layers (L.IIa). The latter layer (L.III) is composed mostly of yellow sterile sand which is compacted in places. No radiocarbon dates were obtained from Pit X5.

6.2.5 Stratigraphy of Pit X6

Pit X6 consists of possibly four layers. The top layer (L.I) (0-20 cm) consists of mostly dark brown silt with occasional shells. The middle layer (L.II) (20-36 cm) also contains dark brown silty material and about 70% of shells by volume. As observed in Pit X5 a narrow band of dark brown silt (L.IIa) (about 2 cm thick) is embedded between the second and the bottom layers of Pit X6. Radiocarbon ages of 2940-2740 cal BP (Wk17968) and 2850-2670 cal BP (WK17547) were determined for two marine shellfish samples recovered from Pit X6 at depths of 68 cm and 94
cm respectively (Nunn, 2007a). A possible posthole feature is exposed in the south wall of Pit X6 (Figure 6.2E).

In both Pits X5 and X6 there is a relatively darker layer (L. Ila) which clearly separates both layer II and layer III. This particular layer is not present in the other pits (X1, X2, and X3). In Pit X6, there is a post-hole feature which may lend support to the idea that the settlers of Bourewa inhabited houses or platforms that were built on stilts (Nunn, 2007a). An *Atactodea striata* shell excavated from the posthole was dated to around 2940-2740 cal BP.

### 6.3 Chronology of the Rove Peninsula and Radiocarbon Dates for Pits X2 and X3

Archaeological evidence for human colonisation of the Fiji Islands prior to 3000 cal yrs BP was long regarded as equivocal although recent published dates for the Bourewa settlement suggest it may date from as early as 3170-2920 cal BP (1220-970 BC) (Nunn *et al.*, 2004; Nunn, 2005). Prior to the discovery of the Bourewa settlement, it appears that the Lapita sites on Naigani and Moturiki islands contained the earliest human settlement dates in the Fiji Islands (Nunn *et al.*, 2004). But with the publication of recent radiocarbon dates for the Bourewa site, this has seemingly pushed back the earliest known date for human occupation of the Fiji Islands by over a century more than previously known (Nunn, 2005, 2007a).

#### 6.3.1 Chronology of the Rove Peninsula

The radiocarbon dates obtained during geoarchaeological field excavations (Phases 1-3) along the Rove Peninsula has now placed Bourewa as the “probable founder” settlement site for the Fiji Islands. These dates demonstrate that they are earlier than any other dated Lapita sites in Fiji. Archaeological evidence from Bourewa settlement also reveal a significant proportion of Far Western (Lapita) ceramic decorative styles and forms and an obsidian rock traced to the Talasea mine on New Britain Island, Papua New Guinea (Nunn *et al.*, 2004, 2005a; Nunn, 2007a). The radiocarbon dates
and cultural evidence from the Bourewa site also support the suspicion that Fiji was perhaps settled only slightly later than the Reef/Santa Cruz Group and Vanuatu.

At least three major phases of occupation were associated with the human colonisation of the Bourewa settlement, referred to as Periods A, B and C (Figure 12 in Nunn, 2007a:173 and Table 6.1). Nunn also suggested that these periods were generally characterised by population increase and/or expansion of the settlement, influx of new migrants and/or movement of people from elsewhere, the settlement of other nearby sites, and the introduction of horticultural/agricultural crops and innovations, and Eastern Lapita motifs to Bourewa. The Lapita occupation period at Bourewa spanned almost 500-600 years.

More than 24 radiocarbon dates were obtained from Bourewa settlement and they generally fall within the three major periods of occupation of the Bourewa sand spit and the settlement of other nearby locations. According to Nunn (2007a), the earliest stage of settlement (Period A) was marked by the arrival of the initial settlers perhaps on the first canoes who occupied the centre of the Bourewa sand spit some time between 3139-2795 cal BP (2089-845 BC).

Around 2850 cal BP (900 BC) (Period B), the settlement expanded along its length both southeast and northwest along the axis of the Bourewa sand spit. In a broad sense this phase also marked the initial settlement of Qoqo Island by new migrants and/or Bourewa settlers sometime about 2950-2760 cal BP (1000-810 BC) (Nunn et al., 2006). It is also characterised by the introduction and perhaps intensification of taro and lesser yam cultivation and a predominance of Eastern Lapita style motifs at Bourewa settlement (Nunn, 2007a).

The Rove Beach site, which was established on an offshore island during Lapita times was settled perhaps around the late/post Lapita period about 2710-2510 cal BP (750-550 BC). Rove was occupied shortly after Qoqo Island. Further settlement expansion occurred within the Bourewa site particularly along its periphery during Period C. It was perhaps during this stage also that Bourewa settlement experienced the overflow of people into adjacent bays like Waikereira, Jugendar’s Farm and Tomato Patch. Dentate-stamped potsherds were also recovered from Waikereira, Jugendar’s Farm and
Tomato Patch – these are suspected to be mostly late/post Lapita sites (Nunn et al., 2004; Nunn, 2007a).

6.3.2 Radiocarbon Dates for Pits X2 and X3

Four additional radiocarbon dates from shallow water marine shellfish specimens of *Trochus niloticus* were derived from various depths of Pits X2 and X3 (Table 6.2). These specimens were sent by the author to the University of Waikato Radiocarbon Dating Laboratory, New Zealand in 2006 for radiocarbon age determination. The shells were physically and chemically pretreated before dating. They had their surfaces cleaned, washed in an ultrasonic bath and tested for recrystallisation (aragonite). They were then washed using 2 moles of diluted Hydrochloric acid for 180 seconds, rinsed and dried (Alan Hogg *pers. comm.*, 2007).

<table>
<thead>
<tr>
<th>Pit</th>
<th>Sample</th>
<th>Lab No.</th>
<th>Material</th>
<th>Depth (cm)</th>
<th>cal BP</th>
</tr>
</thead>
<tbody>
<tr>
<td>X2</td>
<td>Bourewa 20</td>
<td>Wk 20282</td>
<td>Marine shell (<em>Trochus niloticus</em>)</td>
<td>20</td>
<td>2705-2356</td>
</tr>
<tr>
<td>X3</td>
<td>Bourewa 30</td>
<td>Wk 20284</td>
<td>Marine shell (<em>Trochus niloticus</em>)</td>
<td>30</td>
<td>2877-2700</td>
</tr>
<tr>
<td>X3</td>
<td>Bourewa 70</td>
<td>Wk 20283</td>
<td>Marine shell (<em>Trochus niloticus</em>)</td>
<td>70</td>
<td>2826-2605</td>
</tr>
<tr>
<td>X2</td>
<td>Bourewa 90</td>
<td>Wk 20281</td>
<td>Marine shell (<em>Trochus niloticus</em>)</td>
<td>90</td>
<td>2817-2696</td>
</tr>
</tbody>
</table>
The selected shellfish specimens, two from each pit, were obtained from both the middle and upper layers since the lower layers of the shell midden for both pits were already sufficiently dated by Professor Patrick Nunn (Table 2 in Nunn, 2007a:174). Samples Wk 20282 and Wk 20281 were taken from Pit X2 at depths of 20 cm (2705-2358 cal BP) and 90 cm (2817-2696 cal BP) and samples Wk 20284 and Wk 20283 were obtained from Pit X3 at depths of 30 cm (2877-2700 cal BP) and 70 cm (2826-2605 cal BP) respectively. The results from these four shells seem to support the broad interpretation for the occupation periods of the Bourewa sand spit except Wk 20284 (2877-2700 cal BP). The earlier end of this range may fall into Period B (or middle layer).

Table 6.2 provides the radiocarbon dates for the four shell samples obtained from various levels of Pits X2 and X3. For details of calibration and other parameters used, like OXCal plots for shell samples Wk 20281, Wk 20282, Wk 20283 and Wk 20284, refer to Appendix 1 on the CD-Rom supplied. These were provided by Professor Alan Hogg of the Waikato Radiocarbon Dating Laboratory. The four radiocarbon dates for Pits X2 and X3 fall within the age range obtained for the Bourewa settlement by Nunn (2007a).

6.4 Shellfish Quantification and Analysis

The following subsections present the results and analysis of the shell count (MNI and NISP) and weight for Pits X1, X2, X3, X5 and X6 and the shell size measurements for the three most common shellfish species for Pits X2 and X3. The data for these analyses are provided in Appendices 2, 3 and 4 on the CD-Rom.

6.4.1 MNI, NISP and Weight

Tables 6.3 and 6.4 present the MNI, NISP and weight analysis and the relative frequencies of both the bivalves and gastropods present in the Bourewa shell assemblage. Data on which these analyses are based are provided in Appendices 3 and 4 on the CD-Rom.
After identifying and classifying the shells based on their non-repetitive elements (NREs) and other characteristic features, the different shellfish species were then quantified and weighed. For bivalves, the right and left valves were quantified and weighed separately, while for gastropods, quantification and weighing were straightforward.

For the sampled Bourewa shells, bivalves account for 16 families and 25 species while gastropods comprise 25 families and 83 species. The entire assemblage comprises a total of 41 families and 108 species of which five gastropod families contribute about 50% of the total number of shellfish taxa present. These are Turbinidae, Strombidae, Cypraeidae, Muricidae and Conidae. Although gastropods account for the most rich and diverse species they are significantly fewer compared to bivalves in terms of abundance (MNI, NISP) and weight.

Overall the sampled shell assemblage contains about 255 kg of identifiable shells comprising 21,505 NISP and 11,426 MNI. Unidentifiable shell specimens amount to 198 g.

Bivalves comprise the bulk of the shellfish assemblage, accounting for 81% MNI, 90% NISP, and 83% of the total weight, while gastropods make up the rest. Of all the bivalves sampled and quantified, the most abundant species is Codakia punctata comprising about 81% MNI, 79% NISP and 65% weight of the entire shell assemblage. Other important bivalves such as, Fimbria fimbriata, Anadara antiquata and the freshwater shellfish Batissa violacea, respectively account for 17% MNI, 17% NISP and 27% weight.

While the remaining bivalve taxa represent less than 2% MNI, 4% NISP and 8% weight, the following shellfish taxa were undoubtedly consumed regularly by the inhabitants of Bourewa. These include a number of Anadara and Codakia species, Periglypta puerpera, Gafrarium tumidium and a range of common rock oysters. These shellfish species are still commonly sold in markets and consumed in villages Fiji wide.
Although gastropods comprise fewer than 20% of the total shellfish assemblage, three species (*Strombus gibberulus gibbosus*, *Trochus niloticus* and *Turbo chrysostomus*) account for more than half of all gastropods quantified. Collectively they account for 63% MNI, 63% NISP and 59% weight of all gastropods present in the shell assemblage.

Despite their relatively low abundances, some large-sized gastropods were obviously targeted due to their edible meat. They include those of the families Turbidae (e.g. *Turbo crassus* and *Turbo setosus*), Strombidae (e.g. *Strombus luhuanus* and *Lambis lambis*), Trochinidae (e.g. *Trochus radiatus* and *Trochus pyramis*), Muricidae and Conidae (e.g. *Conus eburneus* and *Conus marmoreus*).

A significant find during this field season, as in subsequent excavation phases, was the recovery of two shellfish species of the Tridacnidae family – commonly referred to as giant clams due to their relatively large size. These are *Tridacna gigas* and *Hippopus hippopus*. The meat of an individual animal would be sufficient to feed a

<table>
<thead>
<tr>
<th>BIVALVA</th>
<th>MNI</th>
<th>% MNI</th>
<th>NISP</th>
<th>% NISP</th>
<th>WEIGHT (g)</th>
<th>% WT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ostrea punctata</td>
<td>7484</td>
<td>92.82</td>
<td>15258</td>
<td>79.2</td>
<td>137174.2</td>
<td>64.58</td>
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<tr>
<td>Pinctada maxima</td>
<td>975</td>
<td>10.53</td>
<td>2113</td>
<td>10.97</td>
<td>29125.92</td>
<td>13.71</td>
</tr>
<tr>
<td>Anadara antarctica</td>
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<td>3.71</td>
<td>722</td>
<td>3.74</td>
<td>14358.54</td>
<td>6.78</td>
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<tr>
<td>Balanus rusticus</td>
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<td>2.47</td>
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<tr>
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<td>115</td>
<td>0.59</td>
<td>2005.26</td>
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<tr>
<td>Ostrea sp.</td>
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<td>89</td>
<td>0.46</td>
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<td>0.47</td>
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<tr>
<td>Pecten jacobaeus</td>
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<td>141</td>
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<td>3737.21</td>
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<td>Tridacna gigas</td>
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<td>6771.57</td>
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<td>Asaphis violaceus</td>
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<td>Anadara sp.</td>
<td>6</td>
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<td>2</td>
<td>0.01</td>
<td>25.73</td>
<td>0.01</td>
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<tr>
<td>Anadara spinosa</td>
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<td>0.04</td>
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<tr>
<td><em>Hippopus hippopus</em></td>
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<td>1</td>
<td>0.01</td>
<td>41.1</td>
<td>0.02</td>
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<td>Donax sp.</td>
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<td>0.01</td>
<td>1</td>
<td>0.01</td>
<td>3.2</td>
<td>0.00</td>
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<tr>
<td>Spilopina</td>
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<td>0.01</td>
<td>59</td>
<td>0.31</td>
<td>2213.51</td>
<td>1.04</td>
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<tr>
<td>Sacculina</td>
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<td>0.01</td>
<td>1</td>
<td>0.01</td>
<td>61.15</td>
<td>0.03</td>
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<tr>
<td>Perum penguin</td>
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<td>0.01</td>
<td>1</td>
<td>0.01</td>
<td>17.92</td>
<td>0.00</td>
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<tr>
<td>Pecten sp.</td>
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<td>0.01</td>
<td>1</td>
<td>0.01</td>
<td>19.97</td>
<td>0.01</td>
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<tr>
<td>Ctenoides sp.</td>
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<td>0.01</td>
<td>1</td>
<td>0.01</td>
<td>23.8</td>
<td>0.01</td>
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<tr>
<td>Chama sp.</td>
<td>11</td>
<td>0.12</td>
<td>15258</td>
<td>79.2</td>
<td>21240.75</td>
<td>0.93</td>
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</tbody>
</table>

Table 8.3. Bourewa shellfish (Bivalves) MNI, NISP, Weight and Relative Frequencies. Note: p means the taxa are present although their NRE's (non-repetitive elements) could not be positively identified or determined. Note: * Extirpated species.
large-sized family or even a dozen or more people. Currently these bivalve species are locally extinct (extirpated) in the Fiji Islands and it was only recently that efforts were made to successfully re-introduce and breed them in Fiji (Leon Zann pers. comm., 2005). While *Tridacna gigas* and *Hippopus hippopus* are extirpated, other clam species like *Tridacna maxima* and *Tridacna squamosa* can still be found on most reefs in Fiji, including on the Rove Peninsula fringing reef.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>MNI</th>
<th>% MNI</th>
<th>NISP</th>
<th>% NISP</th>
<th>WEIGHT (g)</th>
<th>% WR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strombus gibberulus</td>
<td>928</td>
<td>38.21</td>
<td>831</td>
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<td>59</td>
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<tr>
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<td>0.66</td>
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<td>Strombus legerinobus</td>
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<td>Pseudovenerupus alloco</td>
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<td>Lunatica cincta</td>
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<td>5</td>
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<td>Conus cochlidiformis</td>
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<td>4</td>
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<td>3</td>
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<td>29.38</td>
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</tr>
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<td>Natica rotunda</td>
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<td>3</td>
<td>0.13</td>
<td>28.25</td>
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</tr>
</tbody>
</table>
6.4.2 Shell Weight Density analysis

Figure 6.4 shows the total shellfish weight density (g/m$^3$) for each of the five pits sampled at Bourewa settlement. Data for the shell weight density analysis are provided in Appendix 5 on the CD-Rom.

All these pits were excavated within the area that coincides with the three occupation phases of the Bourewa sand spit as proposed by Nunn (2007a). Of particular significance are the relatively high weight densities for Pits X1 and X2 compared to the lower weight densities for Pits X3, X5 and X6. Based on their stratigraphic profiles as illustrated in Figure 6.2D-E, Pits X5 and X6 comprise relatively shallow
cultural layers and may have been located on an elevated section of the former beach ridge during Lapita times, though Pit X3 was the deepest of all the five pits.

It also appears that Pits X5 and X6 are located within the region that was settled slightly later, perhaps during the second phase (Period B) of settlement of the Bourewa sand spit and/or possibly during the expansion stage (Period C) and subsequent settlement of the site’s peripheral regions (Nunn, 2007a). Pit X3 in general comprised relatively fewer shells by volume, hence its lower weight density.

6.4.3 Shell Size analysis

Shell length and height measurements were conducted on intact shell specimens of the three most abundant shellfish species at Bourewa settlement - *Codakia punctata* (MNI = 7484) and *Fimbria fimbriata* (MNI = 975) and *Strombus gibberulus gibbosus* (MNI = 828) for Pits X2 and X3 only. While length measurements were carried out for *Codakia punctata* and *Fimbria fimbriata*, for *Strombus gibberulus gibbosus* shell height was measured. The results of these measurements were tallied and then related to approximate length and height groups as provided in Tables 6.5, 6.6 and 6.7. Data for this analysis are provided in Appendix 6 on the CD-Rom.
As illustrated in Table 6.2, in a broad sense, Layer 1 (Upper layer) of both Pits X2 and X3 ranged from 2705-2358 cal BP and 2877-2700 cal BP, though the latter may fall well within the Layer 2. Layer 2 (Middle layer) spanned the dates 2817-2696 cal BP and 2826-2605 cal BP, and Layer 3 (Bottom layer) has been dated from between 2878-2702 cal BP and 3140-2867 cal BP. Except for the Layer 1 date range of 2877-2700 cal BP which may well be placed in Layer 2, all other date ranges seem to correspond with the occupation periods proposed by Nunn (2007a) for the Bourewa settlement.

As demonstrated by the radiocarbon dates (Table 6.2), it is clear that the Upper layer (Layer 1) is relatively younger than the Middle layer (Layer 2), while the Bottom layer (Layer 3) is older than both layers above. The shell size measurements for both pits were aggregated to provide a large enough sample for analysis.

Table 6.5 reveals that more than half (53%) of the Layer 1 deposit population of *Strombus gibberulus gibbosus* are less than 40 mm in height, whereas 47% had attained this height or more in Pits X2 and X3. A greater proportion (55%) of large-sized (≥ 40 mm) *Strombus gibberulus gibbosus* are found in the Middle layer (Layer 2) compared to 47% in the Upper layer (Layer 1) of Pits X2 and X3.

As shown in Table 6.6, there is no significant difference in the percentage of large shells of *Codakia punctata* between the two layers of the midden. In fact, it appears that large *Codakia punctata* shells (> 40 mm) were marginally common in the Upper layer (Layer 1) (67.2%) compared to the Middle layer (Layer 2) (65.2%) of both pits. This means that there is no size reduction recorded through time for *Codakia punctata*; instead there seems to be similar proportions of larger *Codakia* shells within both layers of the midden. For *Fimbria fimbriata*, large-sized shells (> 40 mm) are more common in Layer 2 (92%) than in Layer 1 (87%) of the midden (Table 6.7).
6.5 Analytical Zones for Shellfish analysis

The shells recovered from the five test pits at Bourewa settlement are unevenly distributed within the midden deposit. In general, fewer shells have been recovered from both the top (0-30 cm) and the bottom (> 80 cm) levels while larger proportions (between 65% to 80% by volume) are concentrated around the central levels (30-80 cm) of the midden.

The uneven nature of the shells within each of the test pits may influence various aspects of the analysis like correlation between sample size and the number of taxa present (NTAXA), relative abundance of different shellfish species, and evenness.
According to Grayson (1984), a large sample size usually covaries with a higher number of species compared to a smaller sample, thus any observed pattern may be driven primarily by the size of the sample.

As highlighted by Morrison and Cochrane (2008), unequal sample sizes and temporal duration of excavation levels can also cause problems when analysing species diversity and relative proportions of prey items as well. Hence the relative abundances of prey items can be strongly correlated with the sample size (Grayson 1984). Grayson and Delpech (1998) showed that differential time sampling can also create bias when assessing species diversity. Thus to avoid analytical issues and allow for greater comparability, the different spits should be aggregated to form near-equal sample sizes and temporal durations (Morrison and Cochrane, 2008).

So, to account for any bias arising from varying sample sizes, some mitigating actions were taken. The shellfish taxa from various spits within similar natural strata and context were combined for analysis. Since these test pits were excavated in arbitrary 10-cm spits they should provide the minimum comparable analytic units. The quantitative shellfish analyses were conducted on the assemblages within similar stratigraphic levels of the five test pits. Subsequently the shells from the various layers of the five pits were combined to form near equal size samples (by weight) for analysis. These aggregated units then form three main analytical zones (A, B and C) (Table 6.8) which coincides with the three layers of the Bourewa shell assemblage (Table 6.1).

Based on the radiocarbon chronology of the Rove Peninsula and the Bourewa shell midden itself, the bottom layer (Zone C) dates from at least 3140-2867 cal BP in Pit X3 (121 cm depth) to around 2705-2358 cal BP (Zone A) in Pit X2 (20 cm depth).

Table 6.8 shows the relationship between the main analytical zones and revised shellfish aggregates and radiocarbon sequence for the Bourewa shell assemblage. The combined spits for the five test pits form three analytical units (Zones A, B and C) based on their stratigraphic context, near equal shell weights and secure radiocarbon dates. Data on which this analysis is based is provided in Appendix 3 on the CD-Rom.
Since several spits within each test pit are part of the same depositional context, aggregating the spits based on their content, natural strata and radiocarbon dates should allow for optimal analysis. This approach will account for very small sample sizes and ensure that NTAXA (number of taxa) is not altered as in the case where certain small sample sizes were to be omitted (Grayson, 1984). Aggregating very small samples will also increase the number of comparable units and mitigate poor representation.

### 6.5.1 Shellfish Habitats and Usage

In a broad sense, habitats are usually classified according to the type of environment where resources are located so it is important to identify the habitats from which the prey items have been collected. In certain situations it is worth noting that particular prey items can be found in more than one environment or habitat. So the delineated environmental boundaries may overlap or integrate though generally the Rove Peninsula and the area immediately adjacent to the Bourewa settlement may have consisted of sea grass and algal beds or meadows and other communities and microenvironments.

For purposes of this analysis, two broad shellfish habitats have been delineated by the author to represent the environments (or ecosystems) targeted by the Bourewa shellfish foragers. Refer to Appendix 7 on the CD-Rom for the appropriate data supporting this analysis.
These shellfish habitats are broad-based and attempt to account for the location where the prey items were most likely to be foraged so as to minimise the overlap of prey across other environments through the different ecological habitats. This did not deter or hinder foragers gathering shellfish resources from within a range of habitats. According to Nagaoka (2000), prey distribution is often clumped and not patchy so certain prey items are more likely to be encountered in particular areas and not randomly distributed within the environment. So foragers tend to focus on specific habitats and not search for prey in all environments at one time (Morrison and Cochrane, 2008).

The habitat zones created by the author for the Bourewa shell assemblage broadly divide shellfish resources based primarily on the location of where they were most likely taken. These two analytical habitats have been delineated for the Bourewa shell assemblage - the Intertidal/Coral Reef and Shoreline Sandy/Muddy Habitats.

The Intertidal/Coral Reef Habitat consists of a range of marine micro-ecosystems and communities located along the coral reef flat. The shellfish taxa foraged in this habitat are generally filter feeders or algal grazers. They are either mobile or sedentary or are embedded in crevices in the coral substratum. Other species may be found in the sand pockets adjacent to rock boulders or scavenging on algae on the coral reef flat. A notable species within this zone is *Trochus niloticus* which can inhabit up to 20 m depth along the seaward coral reef slope (Abbott and Dance, 2000). Other shellfish species of the Trochidae, Strombidae and Conidae families can also be found in the intertidal and coral reef zones.

The Shoreline Sandy/Muddy Habitat incorporates sandy and muddy, mangroves and estuarine environments and communities. The shellfish species commonly foraged in this region are subsurface shallow dwellers that burrow in the sand and/or mud, or aggregate in high densities, and prefer mostly soft substrates. They also inhabit areas where water movement is quite subdued though not necessarily free flowing.

As indicated in Table 6.9, the most abundant shellfish taxa recovered from the Bourewa assemblage were most likely to be foraged from the Shoreline Sandy/Muddy Habitat. It appears that throughout the period of occupation at
Bourewa settlement, certain changes occurred in the shellfish collection strategies in terms of the available shellfish species and habitats being targeted.

There was a mixed foraging strategy on shellfish species and habitats targeted by the shellfish collectors. It appeared they favoured those shellfish species and habitats that were accessible, resource-rich, and closer to the settlement site. For example, meaty bivalves such as *Codakia punctata* and *Fimbria fimbriata* which inhabit soft sandy substrates located closer to the site were preferred although other species such as *Trochus niloticus* and *Strombus gibberulus gibbosus* from further away were popular as well. The latter species became targeted as the other shellfish taxa gradually declined in abundance, perhaps due to increased human predation or environmental change.
Perhaps some foragers did venture farther away from the site, targeting the freshwater bivalve *Batissa violacea* that could be collected from the banks of the Tuva River or other nearby rivers or streams. The two mangrove species, *Gafrarium tumidum* (Spennemann, 1987) and *Anadara antiquata* (Tebano and Pauley, 2001), were also present in relatively large proportions in the shell assemblage suggesting that foragers also targeted both the mangroves and the intertidal lagoons for available shellfish.

In Pit X1, Zones A, B and C all show a predominance of shellfish (MNI and weight) derived mostly from the Shoreline Sandy/Muddy Habitat. The shellfish species from the Shoreline Sandy/Muddy Habitat were once again predominant in all Zones for Pits X2 and X3. Again the shellfish species from the Shoreline Sandy/Muddy Habitat were predominant in Zones A and B of Pit X5. While Zones A and C of Pit X6 reveal the predominance of shellfish from the Shoreline Sandy/Muddy Habitat, this changed in Zone B where shellfish species from the Intertidal/Coral Reef Habitat became dominant.
It appears that the shallow water marine shellfish *Trochus niloticus* is a contributing factor to the change observed in Pit X6. For example, its total MNI and weight within Zone B is 20 and 1963.7 g respectively. That is an average weight per individual of about 98.2 g. Additionally, *Trochus niloticus* accounts for almost forty percent (39.1%) of the entire assemblage within Zone B. Hence, its weight alone is almost comparable to the combined weights of the four common bivalves (*Anadara antiquata*, *Codakia punctata*, *Fimbria fimbriata* and *Batissa violacea*) within the Shoreline Sandy/Muddy Habitat.

### 6.5.2 Shellfish MNI by Zone for Shoreline Sandy/Muddy Habitat

It is clear that the Bourewa settlers consumed more bivalves than gastropods. Except for Tridacnidae, all other bivalve species were foraged from within the Shoreline Sandy/Muddy Habitat and almost all gastropods were derived from the Intertidal/Coral Reef Habitat. Refer to Appendices 2, 3 and 7 on CD-Rom for data used in this analysis.

<table>
<thead>
<tr>
<th>Species</th>
<th>Zone A</th>
<th>Zone B</th>
<th>Zone C</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Anadara antiquata</em></td>
<td>2250</td>
<td>2597</td>
<td>2557</td>
</tr>
<tr>
<td><em>Codakia punctata</em></td>
<td>250</td>
<td>9.93</td>
<td>11.68</td>
</tr>
<tr>
<td><em>Batista violacea</em></td>
<td>19</td>
<td>2.05</td>
<td>1.57</td>
</tr>
<tr>
<td><em>Codakia sp.</em></td>
<td>37</td>
<td>0.15</td>
<td>0.10</td>
</tr>
</tbody>
</table>
As shown in Table 6.10, both *Codakia punctata* and *Fimbria fimbriata* comprise the bulk of shellfish from the Shoreline Sandy/Muddy Habitat. Both these species have also revealed decreasing trends in their relative proportions from Zone C to A, while other bivalves show increasing trends. For example, *Codakia punctata* steadily declined from 82% (MNI) in Zone C to 80% (MNI) in Zone B and subsequently decreased to 78% (MNI) during Zone A. Although there was some stability during Zone B, a general declining trend is also recorded for *Fimbria fimbriata* through time.

In contrast, other edible bivalve species like *Anadara antiquata*, *Batissa violacea*, *Periglypta puerpera*, *Codakia* spp., *Gafrarium tumidum* and *Atactodea striata* have all increased through time in spite of their relatively low proportions. Collectively they all account for 5.9 (%MNI) in Zone C, 7.5 (%MNI) in Zone B and 12.1 (%MNI) during Zone A (Table 6.10).

### 6.5.3 Shellfish MNI by Zone for Intertidal/Coral Reef Habitat

The edible shellfish species *Strombus gibberulus gibbosus* reveal an increasing trend from Zone C to A, while *Turbo* spp. declined during the same period. *Trochus* spp. consumption remained fairly steady throughout the sites occupation. The proportions of the other gastropods were significantly lower (Table 6.11).

Both *Tridacna gigas* and *Hippopus hippopus* which usually inhabit the soft substrates of coral reef areas also decreased in relative abundance from 1.3% (MNI) during Zone C to 0.8% (MNI) during Zone B and 0.4% (MNI) in Zone A. While *Tridacna gigas* has declined over time, most notably is the complete absence of *Hippopus hippopus* during Zone A, which may indicate its possible demise and/or significantly low abundance level around the end of the Lapita era. But since there are no data from other nearby sites of the presence of *Hippopus hippopus* after the Lapita era, it is still difficult to corroborate this assertion. Evidently both species of Tridacnidae shellfish have been shown to be significantly low in abundance in the Bourewa shell assemblage.
<table>
<thead>
<tr>
<th>Species</th>
<th>Zone A</th>
<th>Zone B</th>
<th>Zone C</th>
<th>Species</th>
<th>Zone A</th>
<th>Zone B</th>
<th>Zone C</th>
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<td><em>Cypraea tigris</em></td>
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<td>2</td>
</tr>
<tr>
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<td>2.32</td>
<td><em>Terebra anatolica</em></td>
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<td>2.34</td>
<td><em>Turbo rhomboides</em></td>
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<td>19</td>
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<td><em>Strasbourgia rhombus</em></td>
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</tr>
<tr>
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6.6 Assessing Shellfish Species and Habitats through Foraging Theory Models

The following subsections provide the results of the analysis conducted on the shellfish species and habitats using foraging theory models - prey and patch choice and central place to understand the roles of human and non-human factors on marine resources. As described by Morrison and Addison (2008:23) foraging models have a range of applications including to “provide a theoretical basis for examining temporal shifts in resource exploitation as a result of human resource depression, environmentally induced decreases in prey abundance, and changes in harvesting technology”.

In order to examine whether or not the temporal or spatial composition of the archaeo-shellfish assemblage varies through time, theoretically derived hypotheses aimed at explaining any variability were developed. This is to ensure that the relationships between theory, method, and research questions are clearly examined and assessed. Essentially these questions attempt to establish how humans impacted the near-shore marine environment, the type of shellfish species and habitats targeted, and whether shellfish species and habitats changed over time.

Foraging theory models are used to investigate and evaluate resource depression by assessing human foraging strategies and the types of shellfish species and habitats affected by human predation. The structure of the shell midden at Bourewa was characterised according to environmental habitats exploited, NTAXA, evenness, and relative abundances. Comparative indices were used to compare large to small shellfish species as well as for different habitats.

Shell sizes were determined by measuring shell length and height of the three most abundant shellfish species. NTAXA was calculated by comparing the number of taxa present. Shannon's Evenness Index (E) calculations were used to evaluate evenness of the shellfish taxa in each habitat. Relative abundance measures were conducted to understand important trends in the proportions of the five most abundant shellfish taxa through time.
6.6.1 Analysing Shellfish Foraging through Prey Choice

The *prey choice model* is used to measure changes in foraging efficiency – the net return rate per unit time (Morrison and Cochrane, 2008; Nagaoka, 2002). Since the goal of foraging is to maximise the rate of nutrients (or energy) obtained from the prey item, the *prey choice model* predicts that foragers usually select or prefer prey with the highest energy return rate. Thus the model holds that a predator's most efficient strategy is to capture the highest-ranked prey over low-ranked prey upon encounter (Butler, 2000). So, high-ranked prey will always be taken while less profitable ones will be bypassed by foragers. The model also predicts that low-ranked prey items will be captured and incorporated into the diet only when there is a significant decline in foraging efficiency (Nagaoka, 2002).

In most archaeological studies, prey body size and prey rank are related, so body size is often used as a proxy for energy return rate. Thus large-bodied prey are generally regarded as high-ranked resources, while small-bodied prey are usually lowly ranked (Bird and O’Connell, 2006; Butler, 2001; Morrison and Cochrane, 2008; Nagaoka, 2002). The relative abundance of high-ranked species can also influence dietary choices so the *prey choice model* can be used to trace changes in the availability of high-ranked shellfish species within an environmental habitat (Nagaoka, 2002). When there is a decline in foraging efficiency, this is usually indicated in the archaeological record by a decrease in the ratio of high-ranked prey relative to low-ranked prey, and a widening (or expansion) of the diet breadth resulting in increased species diversity (or richness). Changes in mean size and age of prey items can also be used to measure foraging efficiency (Morrison and Cochrane, 2008). According to them, a simple measure of comparative abundance of large and small prey is the Large Abundance Index (AI) calculated as;

\[
AI = \frac{\sum MNI \text{ large taxon}}{\sum (MNI \text{ large taxon} + MNI \text{ small taxon})}
\]
6.6.2 Prey Choice in the Shoreline Sandy/Muddy Habitat

As explained earlier, the *prey choice model* predicts that a decline in the ratio of large-bodied to small-bodied prey indicates declining foraging efficiency. This assumption is examined here using two common shellfish species from the Shoreline Sandy/Muddy Habitat. The ratio between *Codakia punctata* (MNI = 7484, average size of 10 cm) and *Anadara antiquata* (MNI = 344, average size of 6 cm) (Abbott and Dance, 2000) in the Shoreline Sandy/Muddy Habitat demonstrates that their proportions steadily declined earlier to later within all periods (Figure 6.5). Thus it appears that foraging efficiency steadily decreased within the Shoreline Sandy/Muddy Habitat during the time Bourewa was occupied. Weight measurements for these two shellfish taxa also support this general trend.

When the ratio of other abundant high-ranked (*Codakia punctata* and *Fimbria fimbriata*) and low-ranked shellfish species (*Batissa violacea* and *Anadara antiquata*) are measured, it is also evident that foraging efficiency steadily declined through all three zones (Figure 6.6). These shellfish species comprise about 97% (MNI) of the prey items within the Shoreline Sandy/Muddy Habitat and 78% (MNI) of the Bourewa shell assemblage. Data for this analysis are provided in Appendix 8 on the CD-Rom.

6.6.3 Prey Choice in the Intertidal/Coral Reef Habitat

The following examines the predictions proposed by the *prey choice model* for the Intertidal/Coral Reef Habitat. The *prey choice model* assumes that if the ratio of large to small-bodied prey decreases through time then foraging efficiency is declining. Data for this analysis are provided in Appendix 8 on the CD-Rom.

To investigate the impact of humans on the shellfish species derived from the Intertidal/Coral Reef Habitat, the contribution of the two most abundant shellfish species is compared. For example, *Trochus niloticus* (MNI = 253) with an average height of 120 mm is a high-ranked prey, while *Strombus gibberulus gibbosus* (MNI = 828) which has a mean size (height) of 42.5 mm is a low-ranked prey in terms of both weight and size (Abbott and Dance, 2000).
When the quantities of *Trochus niloticus* and *Strombus gibberulus gibbosus* are compared, their abundance indices decrease over time especially from Zone B to A (Figure 6.7). This trend suggests that foraging efficiency within the Intertidal/Coral Reef Habitat declined during this period. The shell weight quantities for these two shellfish species also produce/indicate similar trends though there was a slight decline in the weight of *Strombus gibberulus gibbosus* during Zone B.
A declining trend in foraging efficiency is also demonstrated when the ratio of other abundant Intertidal/Coral Reef shellfish species are compared (Figure 6.8). For instance, when the proportion of the two most abundant large-bodied taxa (*Trochus niloticus* and *Turbo chrysostomus*) were compared to the two most abundant small-bodied taxa (*Strombus gibberulus gibbosus* and *Cypraea annulus*), a marked decline in foraging efficiency particularly from Zone B to A is also demonstrated.

These four shellfish species constitute a large proportion (67% MNI) of the Intertidal/Coral Reef shellfish taxa. Thus the overall foraging efficiency within the Intertidal/Coral Reef Habitat generally decreased through time. This indicates that within the Intertidal/Coral Reef Habitat, the quantity of large, profitable prey declined relative to smaller, less profitable ones, most plausibly due to increasing human predation pressures.
6.6.4 Analysing Shellfish Habitat Utilisation through Patch Choice

The patch choice model examines how foragers decide which habitats to forage in and how long they should remain in a certain area (Nagaoka, 2002). Nagaoka stated that the patch choice model predicts that (i) high-ranked prey normally targeted by foragers tend to be susceptible to resource depression and (ii) if foraging efficiency markedly falls across certain habitats the number of habitats exploited will increase and/or the time allocated to a habitat will change. Data for this analysis are provided in Appendix 8 on the CD-Rom.

According to the patch choice model, if the overall return rate of high-ranked habitats decline, foragers will begin to target low-ranked habitats. When high-ranked prey abundance decreases, foragers tend to select younger, smaller individuals leading to a decrease in overall size of targeted prey items within the habitat (Nagaoka, 2000, 2002). Bedford (2006:237) suggested that since “patch types are ranked on the basis of the resources that are located within a patch”, habitats with high-ranked prey will be considered as productive habitats (high-ranked). Conversely less productive habitats are usually associated with low-ranked prey items.

In order to investigate human impact on the different shellfish habitats at Bourewa, a comparison is made between the three most abundant shellfish species within the Shoreline Sandy/Muddy Habitat with the three most abundant shellfish species in the Intertidal/Coral Reef Habitat. Any shift in habitat exploitation, for instance from a high-ranked habitat to a low-ranked one can be traced by the ratio of shellfish species present in a productive habitat to those in a less productive one. Also based on habitat productivity rankings, resource depression and decreases in foraging efficiency can be traced by a shift from more productive habitats to less profitable ones (Nagaoka, 2000, 2002).

A comparative Abundance Index (AI) between large and small prey items found within each shellfish habitat at Bourewa was developed using the following formula, where Shoreline Sandy/Muddy taxa are higher-ranked than the Intertidal/Coral Reef taxa.
AI = \sum \frac{(\text{Shoreline Sandy/Muddy taxa})}{\sum (\text{Shoreline Sandy/Muddy + Intertidal/Coral Reef taxa})}

The ratio of the three most abundant shellfish species of the Shoreline Sandy/Muddy Habitat (Codakia punctata, Fimbria fimbriata and Anadara antiquata) are compared to the three most abundant species from the Intertidal/Coral Reef Habitat (Strombus gibberulus gibbosus, Trochus niloticus and Turbo chrysostomus). The Shoreline Sandy/Muddy Habitat species constitute an average prey size of 83 mm, while the Intertidal/Coral Reef Habitat is slightly less profitable with an average prey size of 78 mm. The comparative indices were used to trace the relationship between the Shoreline Sandy/Muddy and the Intertidal/Coral Reef taxa and determine if there was a shift in foraging strategy through time.

The Shoreline Sandy/Muddy Habitat is regarded as the most profitable habitat based on its overall prey size, weight and abundance of its shellfish taxa, although the Intertidal/Coral Reef Habitat comprised the most diverse shellfish taxa in the entire shell assemblage. Despite the higher average sizes of the shellfish species within the Shoreline Sandy/Muddy Habitat, the Intertidal/Coral Reef Habitat also hosted
several large-sized shellfish species like *Tridacna* spp. and *Lambis lambis* but are relatively low in terms of abundance.

Out of all the shells represented at Bourewa settlement, only three shellfish species from the Shoreline Sandy/Muddy Habitat comprise the bulk (87.5%) of the entire shell assemblage. These are common shell remains found in other Fijian archaeological contexts as well (Thomas *et al*., 2004; Nunn *et al*., 2006, 2007).

The analysis indicates that there was a steady use of the Shoreline Sandy/Muddy Habitat during Zones C and B but during Zone A there was a substantial shift in focus toward the Intertidal/Coral Reef Habitat (Figure 6.9). Thus during Zone A, increasingly diverse shells were also targeted by the Bourewa settlers as is reflected by the nature and composition of shellfish species within the Intertidal/Coral Reef Habitat.

There was also a steady decrease in the abundance of *Codakia punctata*, *Fimbria fimbriata* and *Anadara antiquata* across all periods within the Shoreline Sandy/Muddy Habitat. This may signify an expansion or shift in shellfish collection strategies from the Shoreline Sandy/Muddy Habitat to increasing focus on shellfish like *Strombus gibberulus gibbosus*, *Trochus niloticus* and *Turbo chrysostomus* which were usually collected from the Intertidal/Coral Reef Habitat. There was perhaps a focus also on the collection of other shellfish species like *Batissa violacea*, *Periglypta puerpera* and *Gafrarium tumidum* which were mostly foraged from the Shoreline Sandy/Muddy Habitat though in relatively lower quantities.

### 6.7 Measuring Shellfish Diversity and Abundance

The following subsections analyse the shellfish diversity and abundance of the Bourewa shell assemblage. These include measuring diet breadth and NTAXA and evenness. The relative abundances of the five most common shell taxa are also compared to indicate changes in their proportions over time. Data for these analyses are provided in Appendices 9 and 10 on the CD-Rom.
6.7.1 Diet Breadth and NTAXA analyses

Diet breadth involves measuring the number of prey items included in the diet. It considers the taxonomic richness (or diversity of species) of the entire assemblage and the habitats from which these prey items were derived. One of the assumptions of the prey choice model is that, as the proportion of large, more profitable prey decreases over time, foraging efficiency will decline and the diet breadth will widen (or expand) to include smaller, less profitable prey items. Diet breadth can be assessed by examining the changes in taxonomic richness and the relationship between richness and sample size (Nagaoka, 2000).

Richness is measured by comparing the number of taxa (NTAXA) present in the various analytic units (or zones) within the shell assemblage. In general, a rich sample consists of a large number of species but a poor sample only has a few species (Nagaoka, 2000; Grayson and Delpech, 1998).

The entire Bourewa shell assemblage shows an increase in taxonomic richness from Zone C to B but it remains stable during A. As revealed in Figure 6.10, Zone C has 70 items while Zones B and A contains 79 and 77 items respectively, which may not be very significant, given that this assemblage was only sampled, albeit it clearly indicates a rise in NTAXA. A similar assessment was conducted for both the Intertidal/Coral Reef and Shoreline Sandy/Muddy Habitats to determine if the same trend is also evident within these two habitats.

The results of the NTAXA analysis for the Intertidal/Coral Reef Habitat show that diet breadth generally expanded from Zone C to B with an increase in NTAXA from 55 to 62 items, but from Zone B to A there was an increase by only one prey item (Figure 6.11). For the Shoreline Sandy/Muddy Habitat NTAXA also increased through time especially during Zone C to B but remained steady during Zone A (Figure 6.12).

Though NTAXA measurements are useful, they have limitations as well. For example, NTAXA does not directly measure or provide detailed information on the
relative contributions of individual taxa to the entire assemblage (Morrison and Cochrane, 2008).

According to Nagaoka (2000, 2002), another criticism of using NTAXA as a measure of diet breadth is the tendency of NTAXA to correlate with sample size. She cautions that, if the two variables covary, it is sometimes difficult to determine whether the changes in NTAXA over time are due to changing diet or simply influenced by varying sample sizes. But archaeologists can utilise the relationship between NTAXA and sample size (NISP) and/or supplement NTAXA analysis with
evenness measures. Appendix 9 on the CD-Rom provides the NTAXA data for this analysis.

6.7.2 Evenness analysis

The following examines evenness in shellfish use and tests if it varies temporally within the entire shellfish assemblage, Intertidal/Coral Reef and Shoreline Sandy/Muddy Habitats. Shannon’s Evenness data for this particular analysis are provided in Appendix 9 on the CD-Rom.

Evenness is the measure of the proportional amount of different shellfish species represented in the entire shell assemblage (Nagaoka, 2001, 2002). As explained earlier, the prey choice model predicts that as larger, high-ranked prey decrease, foraging efficiency will decline and the diet breadth will expand to include smaller, low-ranked prey. Thus evenness is expected to increase as foragers attempt to offset declining foraging efficiency (Morrison and Cochrane, 2008). This means that foragers will incorporate other shellfish taxa into their diet thereby broadening their dietary range. Although evenness measures do not track changes in specific taxa or their position in a ranked-order set (Nagaoka, 2000), they can supplement diet breadth measurements by offering researchers the ability to monitor the relative importance of specific species through time (Morrison and Addison, 2008).

Evenness is calculated using Shannon’s Evenness Index (E) (Grayson and Delpech, 1998; Grayson, 1984). The formula for Evenness is:

$$\text{Evenness} = -\sum (p_i \ln [p_i]) / \ln [\text{NTAXA}]$$

(where $p_i$ is the proportional contribution of each item)

($\ln$ is the natural log of $p_i$)

($\text{NTAXA}$ is number of taxa)

Morrison and Cochrane (2008) stated that in an even assemblage, the contribution of each taxa to the entire assemblage will be about the same so that evenness will be fairly low, while in a highly uneven assemblage where only a few taxa are dominant, evenness indices will be high. As an example, an index measure of zero (0)
demonstrates that only one species is predominant while an index value of one (1) indicates that each species is represented in equal amounts (or proportions) (Nagaoka, 2000).

The evenness analysis reveals that evenness increased throughout all zones of the entire shell assemblage (Figure 6.13). While evenness increased from Zone C to B and then declined during Zone A of the Intertidal/Coral Reef Habitat (Figure 6.14),
evenness increased across all zones of the Shoreline Sandy/Muddy Habitat (Figure 6.15).

An increase in the evenness indices suggests that large, high-ranked preys are declining while smaller, lower-ranked preys were increasingly incorporated into the assemblage (or diet), suggesting resource depression and a more diverse diet. Thus, if evenness values increase through time, it indicates that the diet breadth is expanding to include other resources, usually less profitable ones. Conversely, if the evenness values remain fairly steady through time, it means that diet breadth is stable (Morrison and Addison, 2008; Nagaoka, 2000).

Although evenness calculations have proved useful in measuring prey diversity, the method does have its shortcomings. For instance, evenness values often do not consider changes in prey ranks, they do not reflect similar resource-use patterns, and do not indicate changes in the relationships between taxa and their proportions (Nagaoka, 2001). Thus the rank and relative abundance of each taxon must be examined separately to determine if changes in evenness truly reflect a shift from high to low-ranked prey.

### 6.7.3 Relative Abundance analysis

Relative abundance measures are most helpful in two ways. Firstly, they indicate where the changes in proportions of shellfish taxa are occurring and secondly, since the samples are of near equal sizes, the absolute abundance of the taxa does not always affect the comparison of percentages between the analytical zones (Morrison and Cochrane, 2008).

Since the three analytical zones delineated for the Bourewa shell assemblage comprise roughly similar sample sizes (in terms of shell weight), any observed changes in the relative abundance of certain taxa should reflect human impact on the resources, though environmental factors cannot be completely ignored. Other factors that may also influence relative abundance measures are human preference for certain shellfish taxa, the assignment of children to collect shellfish, and the declaration of taboo on certain shellfish species. In their study of the shellfishing
strategies among Meriam children of Torres Strait Islands, Bird and Bird (2000) demonstrated that the prey choice of children differs from adults and children usually collect a wide range of shellfish resources and the resources that they collect are most likely to end up in middens because high-ranked prey are more often processed in the field. On the other hand, when a particular ban is imposed on certain shellfish resources due to some kind of customary practices these too may be unlikely to be foraged by shell collectors.

A number of notable trends have emerged from evaluating the relative abundance measures (MNI) of five most common shellfish at Bourewa. Table 6.12 demonstrates that the two top-ranked shellfish species (*Codakia punctata* and *Fimbria fimbriata*) decreased in relative abundance through all zones within the assemblage. For instance, from 78.0 %MNI (Zone C) to 77.5 %MNI (Zone B) and to 66.1 %MNI (Zone A). In contrast, *Strombus gibberulus gibbosus*, *Anadara antiquata* and *Trochus niloticus* show increases in relative abundance particularly during Zone B (9.7 %MNI) to Zone A (17.0 %MNI).

A significant increase in relative abundance is observed for *Strombus gibberulus gibbosus* during Zone A, where it changed ranks with *Fimbria fimbriata* from third (3rd) in Zone B (4.7 %MNI) to second (2nd) during Zone A (10.7 %MNI). An increase in relative abundance is also noted for *Anadara antiquata* through all three zones. The Intertidal/Coral Reef species *Trochus niloticus* also increased in its

<table>
<thead>
<tr>
<th>Rank</th>
<th>Zone C</th>
<th>Zone B</th>
<th>Zone A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Codakia punctata</em> (38.33%)</td>
<td><em>Codakia punctata</em> (67.53%)</td>
<td><em>Codakia punctata</em> (88.6%)</td>
</tr>
<tr>
<td>2</td>
<td><em>Fimbria fimbriata</em> (3.53%)</td>
<td><em>Fimbria fimbriata</em> (10.0%)</td>
<td><em>Strombus gibberulus gibbosus</em> (16.7%)</td>
</tr>
<tr>
<td>3</td>
<td><em>Strombus gibberulus gibbosus</em> (5.10%)</td>
<td><em>Strombus gibberulus gibbosus</em> (16.7%)</td>
<td><em>Fimbria fimbriata</em> (7.51%)</td>
</tr>
<tr>
<td>4</td>
<td><em>Anadara antiquata</em> (2.19%)</td>
<td><em>Anadara antiquata</em> (3.0%)</td>
<td><em>Anadara antiquata</em> (3.8%)</td>
</tr>
<tr>
<td>5</td>
<td><em>Trochus niloticus</em> (2.06%)</td>
<td><em>Trochus niloticus</em> (1.95%)</td>
<td><em>Trochus niloticus</em> (2.5%)</td>
</tr>
</tbody>
</table>

A number of notable trends have emerged from evaluating the relative abundance measures (MNI) of five most common shellfish at Bourewa. Table 6.12 demonstrates that the two top-ranked shellfish species (*Codakia punctata* and *Fimbria fimbriata*) decreased in relative abundance through all zones within the assemblage. For instance, from 78.0 %MNI (Zone C) to 77.5 %MNI (Zone B) and to 66.1 %MNI (Zone A). In contrast, *Strombus gibberulus gibbosus*, *Anadara antiquata* and *Trochus niloticus* show increases in relative abundance particularly during Zone B (9.7 %MNI) to Zone A (17.0 %MNI).
relative abundance particularly during Zone A. Despite the varying trends in relative abundances for the five shellfish species of the Bourewa shell assemblage, upon closer investigation it is clear that overall there is a general decline in relative abundance of the shellfish taxa through time.

Refer to Appendix 10 on the CD-Rom for data from which the analysis of this section is derived.
Chapter 7.  Interpretation and discussion

This chapter interprets the results and analysis of the Bourewa shell assemblage (data). A discussion of the results is also provided. There are three sections to this chapter. These are section 7.1 - shellfish species of Bourewa, section 7.2 - shellfish habitat usage, and section 7.3 - implications of archaeological shellfish data for marine resources management.

Subsection 7.1.1 interprets the stratigraphic context and radiocarbon dates for the top and middle layers of both Pits X2 and X3, while subsections 7.1.2 to 7.1.4 interpret the shellfish analysis in terms of MNI, NISP, shellfish weight density, and size, and the types of shellfish species targeted by the Lapita people along the Rove Peninsula. Subsections 7.2.1 to 7.2.3 discuss the foraging trends within the two main shellfish habitats delineated for Bourewa and shellfish diversity and abundance. Finally, section 7.3 discusses the implications of archaeological shellfish data for contemporary marine resources management strategies by providing various scenarios for resource managers.

7.1  Shellfish species of Bourewa

The Bourewa shellfish data provide useful information for understanding many aspects of human-environment relationship including, the types of shellfish species and habitats being exploited, local environmental changes (like lagoon or bay/estuary shoaling), that can be inferred from shifts in the exploitation and changing proportions of shellfish species, increased foraging pressure on particular shellfish species and habitats, and the diversity of shellfish taxa consumed by humans at the settlement site.

7.1.1  Stratigraphy and Radiocarbon Dating

At least three broad cultural strata can be identified from the five pits sampled at the Bourewa Lapita site (Figures 6.2A-C, 6.2D-E and 6.3). When the layers are correlated based on their content and context, generally the top layer (L.I) ranged
from 0-20 cm deep in most pits or even to 40 cm deep in certain pits. It consists of mostly dark silty soil with occasional shells and plant roots and other debris. The top section of this layer is the most disturbed due to ploughing for sugarcane. The middle layer (L.II) ranged from 20-30 cm in depth for Pits X1, X5 and X6 to as much as 30-90 cm in Pits X2 and X3. On average it ranges from 40-70 cm in depth for the sampled pits. It comprises the bulk of cultural materials including about 60-80% of the shells sampled. This layer contains dark silty soil and is associated with the main Lapita period at Bourewa. Below 50-70 cm depth in most pits, it is mostly sterile beach sand - part of the former sand spit, though in some places it may contain small quantities of shells and other materials. Underlying this layer is the underlying compacted sand or the former coral reef platform, which can be identified in most pits.

Based on the stratigraphic context of the radiocarbon dates obtained during Phases 1-3 for the Bourewa settlement and especially for Pits X2 and X3, the earliest period of occupation of Bourewa may have occurred sometime around 3140-2867 cal BP which corresponds to Zone C (or Layer III). Zone B (or Layer II) was deposited around 2826-2605 cal BP which correlates to the middle period, while Zone A (or Layer I) dates back to sometime about 2705-2358 cal BP, the recent period.

Over 24 radiocarbon determinations have been obtained for the Bourewa settlement thus making it one of the most securely dated Lapita sites in the Pacific (Nunn, 2007a). Based on the analysis of the cultural strata and radiocarbon dates at Bourewa, the suggested interpretation of the deposits is as follows.

- Zone C (3140-2867 cal BP): represents initial occupation phase of the Bourewa sand spit by the Lapita people with the establishment of a permanent settlement with shelters/houses that were probably built on stilts (Nunn, 2007a). Shellfish exploitation and habitat utilisation during this period focused on a range of large-sized shellfish species mostly bivalves that were obtained from the Shoreline Sandy/Muddy Habitat along the Rove Peninsula.
These shellfish species include *Codakia punctata* and *Fimbria fimbriata*, *Anadara antiquata*, *Periglypta puerpera*, and *Gafrarium tumidum* including the freshwater bivalve *Batissa violacea*. These shellfish taxa can be usually collected during low tides. Large clam shellfish species like *Tridacna gigas* and *Hippopus hippopus*, mostly foraged from the intertidal reef zone, were also consumed by the early Bourewa settlers. They also consumed large gastropods like *Trochus niloticus* and *Turbo* spp. as well as a range of strombid species including *Lambis lambis*. Shells like *Conus* spp. were also used to manufacture shell ornaments and artefacts.

There was a designated shellfish dumping area at the Bourewa sand spit where the settlers discarded their shell refuse. Over time these shells accumulated to form the thickest part of the midden. It is clear from the shell weight density analysis that this shellfish dump site is most likely to be located within the vicinity of Pits X1, X2 and perhaps Pit X3. This is somewhere adjacent to the western entrance of the Bourewa tidal inlet (Figure 6.1C) (Also refer to Nunn, 2007a).

- Zone B (2826-2605 cal BP or 2877-2700 cal BP): the Bourewa settlement experienced population expansion and/or influx of new migrants which coincided with intense (or increased) shellfish species and habitat exploitation. There was continued permanent habitation of the Bourewa site, while some settlers may have migrated to other nearby locations like Qoqo Island. The falling sea level also resulted in expansion of the coastal lowland area that may have favoured innovations like crop cultivation. As such this episode also witnessed the introduction of root crops like taro and yam. Eastern Lapita motifs appear during this time at the site as well (Nunn, 2007a).

Based on the shellfish analysis it is plausible to suggest that falling sea level may have encouraged the availability of certain reef-dwelling gastropods like *Strombus gibberulus gibbosus*, other *Strombus* spp., and *Trochus niloticus*.
perhaps due to expansion of the coral reefs and other intertidal habitats along the Rove Peninsula.

- **Zone A** (2705-2358 cal BP): significant increase in shellfish and habitat exploitation occurred during this period resulting in shifts in the utilisation of certain shellfish species and habitats. For example, the declining abundance of bivalves like *Codakia punctata* and *Fimbria fimbriata*, while gastropods like *Strombus gibberulus gibbosus* and *Trochus niloticus* including the bivalve *Anadara antiquata* increased in relative abundances. There was continued cultivation of root crops and tubers. Out-migration of settlers from Bourewa to Rove Beach, Waikereira, Jugendar’s Farm and Tomato Patch also occurred as the Lapita period was approaching its end (Nunn, 2007a).

During the later stages of occupation of the Bourewa site especially from Zone B to A, the consumption of *Codakia punctata* and *Fimbria fimbriata* gradually declined while shellfish species like *Anadara antiquata*, *Batissa violacea*, *Perigypta puerpeara* and *Gafrarium tumidum*, *Strombus gibberulus gibbosus* and *Trochus niloticus* were more abundant. Most notable during this later phase of settlement at Bourewa (Zone A) is the absence of the giant clam *Hippopus hippopus*, though it is unclear if this is directly related to human subsistence practices.

This settlement phase also witnessed the shift in shellfish habitat usage where the Bourewa settlers focused more on shellfish species from the Intertidal/Coral Reef Habitat.

### 7.1.2 MNI and NISP

The general pattern of shellfish exploitation at Bourewa reveals three major subsistence trends which were probably associated with the demographics of the site and the analytical zones delineated for the shell assemblage (Table 6.1). These are Zones A, B and C. As outlined above these zones coincide with the three periods delineated by Nunn (2007a) for the Bourewa site. Zone A which is the top layer
corresponds to Period C. Zone B is the middle layer and is linked to Period B, while Zone C the bottom layer correlates with Period A.

During the initial period of Lapita settlement of the Bourewa site (Zone C), shellfish exploitation was relatively low perhaps due to the small number of the initial colonising population. Shellfish exploitation gradually increased during the second phase of settlement (Zone B), possibly due to in situ population increase and/or as a result of an influx of people (perhaps new migrants) from elsewhere to Bourewa. The second phase also witnessed the introduction of taro and yam (Horrocks and Nunn, 2007) and the production of pottery with mostly Eastern Lapita motifs (Nunn, 2007a), implying some degree of agriculture innovation perhaps to sustain population increase and perhaps offset declining shellfish stocks. According to Nunn, this phase (or Period B) also witnessed an expansion in occupation of the Bourewa sand spit itself – along its axis where shellfish remains were indiscriminately discarded.

Towards the end of the Lapita period in Fiji and the occupation of the Bourewa settlement (Zone A), shellfish exploitation was still consistently high, possibly reflecting extension and/or expansion of the site to its peripheral areas due to increasing population, despite the outward movement (migration) and overflow of people to other nearby locations like Rove, Waikereira, Jugendar’s Farm and Tomato Patch. It is plausible to suggest that during this period the Bourewa settlers may have also increased their utilisation of other food crops like taro and yam to supplement their predominantly marine (shellfish) diet (Horrocks and Nunn, 2007). In fact the general pattern of shellfish exploitation at Bourewa seems to mirror the three major phases of human occupation of the Bourewa sand spit as posited by Nunn (2007a).

The Bourewa shellfish data contrasts markedly with that of the Naitabale site (Moturiki Island, Fiji) where gastropods comprised the bulk of the shells quantified (Nunn et al., 2007). At nearby Qoqo Island, 5 km north of the Bourewa settlement, the shellfish data indicate that comparatively fewer gastropods were represented, while more bivalves were consumed (Nunn et al., 2006). The Qoqo and Bourewa shellfish data reveal that bivalves appear to be the most dominant shellfish taxa, something that is expected given the proximity of these sites.
While it is possible that the Bourewa shellfish analysis could indicate changes in subsistence pattern, other shellfish studies from the Fiji Islands tend to suggest that shellfish exploitation by early colonisers may reflect the local availability of shellfish resources (Nagaoka, 1988) and/or both availability and preference for certain shellfish species (Clark et al., 2001). It is plausible to assume from the results and analysis that shellfish exploitation at Bourewa might reflect a combination of both local availability of shellfish taxa and the preference for certain shellfish species. It seems that bivalves were relatively abundant within the shell assemblage compared to gastropods suggesting that the Bourewa settlers preferred bivalves over gastropods. While the abundance of certain important shellfish species declined over time, the Bourewa inhabitants continued to exploit meaty bivalves that were relatively close, easy to forage, and process.

As the results and analysis reveal, the shellfish species most frequently targeted by the settlers at Bourewa include *Codakia punctata, Fimbria fimbriata, Strombus gibberulus gibbosus, Anadara antiquata, Turbo chrysostomus, Trochus niloticus,* and *Batissa violacea.* Except for *Strombus gibberulus gibbosus and Turbo chrysostomus,* all the other shellfish species are relatively big animals in terms of size and were undoubtedly targeted for their proportionally large meat content, close proximity to the site, and relative abundance.

Although their presence in the shell assemblage is significantly low, large-sized bivalves like *Tridacna gigas* and *Hippopus hippopus* were perhaps important food sources for the Bourewa settlers as well. Due to their large bulky size, it could be inferred that foragers may have foraged and processed most of these large animals, discarded their shells where they were found, and only brought back the edible parts to the site for consumption (Bird et al., 2002). This observation is confirmed by the relative abundance of other smaller Tridacnidae (eg. *Tridacna maxima* and *Tridacna squamosa*) recovered during post-2005 field seasons at the Bourewa settlement. It appears that the smaller Tridacnidae species were easier to transport across distances of more than 2 km along the reef flat than the larger and heavier taxa. So the obvious option for the foragers would be to extract the meat of *Tridacna gigas or Hippopus hippopus* and discard their shells on the reef.
Alternatively, it is plausible to assume that the low abundance of the larger Tridacna shells such as *Tridacna gigas* and *Hippopus hippopus* may in fact be a true reflection of their already low natural abundance and availability in the wild, particularly on the reefs around the then offshore island. Since the natural distribution of Tridacnidae decline eastwards from Near Oceania to Remote Oceania (Kirch, 1997), it is inevitable that the abundance of large-sized Tridacnidae taxa in the Bourewa shell assemblage would be expected to be relatively low compared to other abundant, yet smaller Tridacnidae species.

Nunn (2007a) also noted that Szabó’s (2006) analysis of the numerous shell artefacts and worked shells from Bourewa indicate a low rate of reworking of Tridacna shells (8%) which might indicate that they were perhaps not manufactured locally, though fragments of the large Tridacnidae shells in the assemblage indicate that perhaps some of the larger *Tridacna* shells were sometimes transported back to the site for various purposes and uses.

Although shellfish species of the Conidae family were relatively few in abundance, the diversity of *Conus* species in the shell assemblage may signify their importance as a source for manufacture of shell ornaments like bracelets and rings. This observation is confirmed by the recent discovery of a “Lapita jewellery box” at Bourewa settlement (USP News, 2008). As was revealed by the mid-2005 dig, most of these cone shells also had their spires broken or removed perhaps deliberately to be used for manufacture of shell ornaments since some of these species are poisonous and unsuitable for human consumption.

Apparently the Bourewa settlers collected shellfish from a range of habitats where bivalves in particular were abundant. Bivalves can be foraged from various habitats adjacent to the settlement like mudflats, mangroves, and the coral reef flats. Due to their proximity to the site, most bivalves could have been easily accessed, collected and processed. These shellfish taxa are also shallow burrowing organisms so they would not require advanced technology (or skills) to acquire. They can be easily picked or gathered up by hand or dug up with a stick from the sand or mud. Less mobile persons, like children and the elderly can gather such species easily.
It seems that during the initial stages of occupation at Bourewa, the primary focus of the settlers was on large-sized bivalves of the Shoreline Sandy/Muddy Habitat but later on they also incorporated smaller-sized gastropod species from the Intertidal/Coral Reef Habitat into their diet. This shift in subsistence strategy may indicate that, either larger shellfish resources were being stressed by increased human predation pressures, or that the settlers had adopted a strategy to allow for exploited shellfish species to repopulate and/or recover from heavy predation. The former seems more probable.

Alternatively, the observed changes in shellfish species could possibly be due to environmentally induced effects on shellfish species within both the Shoreline Sandy/Muddy and Intertidal/Coral Reefs Habitats, especially the effects of sea-level fall after the mid-Holocene on the Fiji marine environment, although this assertion is contentious.

### 7.1.3 Shell Weight Density

Based on the shell weight density analysis and the general stratigraphy of the site, it is possible to demonstrate that Pits X1, X2 and X3 were located lower than the other pits. Now, if Pits X5 and X6 were situated on a slightly elevated portion of the Bourewa sand spit during Lapita times, it is plausible to assume that the discarded shell remains in this region might have tumbled down toward the lower part of the sand spit, thus accounting for their relatively low shell densities. Alternatively the Lapita people could have carried their rubbish and discarded it along the edge of the sand spit adjacent to the entrance of the tidal inlet thereby creating the thickest part of the midden there. It is also suspected that there was a designated shell dumping site at the Bourewa settlement site somewhere in the vicinity of Pits X1 and X2. This assertion is strongly supported by recent excavations at Bourewa settlement (USP News, 2008).

The pattern of shell weight densities also confirms the suggestion for the possible extension/expansion of the Bourewa settlement itself which coincided with population increase and/or influx of new migrants into Bourewa. This trend is associated with the gradual decline of sea level during the latter part of the Lapita
era. Sea-level fall probably encouraged later migrants to settle the peripheral regions and along the northwest section of the sand spit (Nunn, 2007a). That may mean the initial settlement was established around the vicinity of Pits X1, X2 and maybe X3 (during Zone C) and, as human numbers increased and sea-level fell, the settlement expanded northwestwards to the region of Pits X5 and X6 (particularly during Zone B to A). This observation seems to lend support to the settlement pattern proposed for the Bourewa site by Nunn (2007a).

7.1.4 Shell Size

The shell size measurements for the combined shells of Layer 1s and 2s for Pits X2 and X3 have demonstrated that over time significant observable changes in shell size have been noted for both *Strombus gibberulus gibbosus* and *Fimbria fimbriata*. These two species reveal a decrease in their shell sizes from middle (Layer 2) to upper layer (Layer 1), while no significant size change is observed for *Codakia punctata*. So, although *Codakia punctata* may have declined in abundance through time, it did not experience any significant change in size, while both *Fimbria fimbriata* and *Strombus gibberulus gibbosus* exhibited some degree of size reduction from the middle to top layer of Pits X2 and X3. These trends probably reflect moderate rather than heavy levels of shellfish exploitation. Since *Codakia punctata* is the most abundant shell species and yet does not show any significant size reduction is noteworthy as it is possible that other factors besides predation may have been important. It may also signify a shift in shellfish exploitation to other intertidal/reef shellfish species over time so as to allow *Codakia punctata* to recover from human predation pressures. There is an apparent sustained predation pressure on the shellfish population which is indicated by a broadening of the resource base as the larger abundant species are preferentially exploited and adversely impacted. Alternatively, this may reflect the resilience of *Codakia punctata* despite increased human consumption due to its relatively high natural abundance.
7.2 Shellfish Habitat Usage

This section interprets and discusses the human predation patterns on shellfish species and their habitats based on the application of the different foraging models described earlier (chapter 3) in this thesis.

Shellfish analysis for the entire shell assemblage shows a predominance of bivalves mostly derived from the Shoreline Sandy/Muddy Habitat. In all the five pits analysed, a common trend is that both Shoreline Sandy/Muddy and Intertidal/Coral Reef Habitats were utilised during all periods of occupation, but the principal preference of the Lapita people was clearly for the Shoreline Sandy/Muddy Habitat which hosted a variety of large fleshy bivalves. These shellfish species include for example Codakia punctata, Fimbria fimbriata, Batissa violacea, Anadara antiquata, Gafrarium tumidum and Periglypta puerpera. They were relatively abundant, cost-effective to acquire, forage and perhaps only required simple technology and skills to process, thus making them the most attractive and energy efficient food resources for the Bourewa settlers.

The next habitat of importance was the Intertidal/Coral Reef Habitat which hosted other important shellfish resources. Foraging within this particular habitat focused primarily on shellfish species such as Strombus giberulus gibbosus, Trochus niloticus, and Turbo chrysostomus including other Trochus and Turbo species. Although these shellfish species comprise more than 60% of all gastropods consumed, they account for only approximately 12% of the entire Bourewa shell assemblage by MNI. The Intertidal/Coral Reef Habitat also hosted other shellfish species that were important in the life ways of the Bourewa settlers though they comprise only a small proportion of the entire Bourewa shell assemblage.

In her analysis of the shell-derived artifacts and pieces of worked shells from the Bourewa site, Szabó (2006) demonstrated that Tridacna shells were reworked to produce rings and double-perforated long units. These shell artifacts were perhaps used as decorations for necklaces, armbands, and/or other ceremonial purposes. While this study has demonstrated that Tridacna species were present and important during Lapita times, Tridacna gigas and Hippopus hippopus are now extirpated in
the Fiji Islands. Whether or not humans were principally responsible for the demise of these two shellfish taxa is contentious, though the natural distribution of Tridacnidae shellfish decreases from western to eastern Pacific (Kirch, 1997).

Other shellfish species that were important in the lifeways of the Lapita people include cone shells (Conidae family). As observed during the various phases of field excavations at Bourewa, certain large-sized \textit{Conus} species may have been collected purposely to manufacture shell ornaments like bracelets and rings (USP News, 2008).

From the shellfish analysis, it appears that in general shellfish from the Shoreline Sandy/Muddy Habitat were commonly preferred by the Bourewa settlers, but towards the end of the Lapita occupation of the site their subsistence practices shifted towards the Intertidal/Coral Reef Habitat which may signify some level of resource depression and declining foraging efficiency within the Shoreline Sandy/Muddy Habitat.

### 7.2.1 Foraging in the Shoreline Sandy/Muddy Habitat

As the results and analysis reveal, the three most common shellfish species of the Shoreline Sandy/Muddy Habitat in terms of MNI and NISP count are \textit{Codakia punctata}, \textit{Fimbria fimbriata} and \textit{Anadara antiquata}. These three species are common within the Indo-Pacific region. Mature specimens of \textit{Codakia punctata} can grow up to 10 cm in shell length and are found mostly in coral sand or burrowing in shallow sand and soft substrate. \textit{Fimbria fimbriata} can grow up to 9 cm in shell length and normally inhabits coral sand or shallow water. \textit{Anadara antiquata} is usually found burrowing in sandy substrates and adult animals can grow up to around 6-8 cm in length (Abbott and Dance, 2000; Lamprell and Whitehead, 1992). Another important shellfish species of the Shoreline Sandy/Muddy Habitat is the freshwater bivalve \textit{Batissa violacea}. These four bivalve taxa altogether account for almost 97\% (MNI) of Shoreline Sandy/Muddy Habitat and 79\% (MNI) of the entire shell assemblage at Bourewa.
*Codakia punctata* is a shallow marine shellfish that burrows in sand substrates along coral reefs, mostly in mudflat areas. They can be found up to 20 m depth in shallow sublittoral waters and grow to a maximum length of 10 cm, though commonly to 6 cm and, as observed at Bourewa, most species attained an average of about 5 cm in shell length. *Codakia punctata* is widespread in the Indo-Pacific region and has been utilised to manufacture lime or for shellcraft (Abbott and Dance, 2000).

A notable feature on most of the *Codakia punctata* shells examined at Bourewa is chipping along the edges of both valves which may be consistent with the use of some instrument or tool to open the shell in order to extract the meat inside the shell (see Figure 5.8). Although initially it was suspected that this could be due to the impact of equipment used to till and plough the soil for sugarcane cultivation, this assertion is no longer tenable because numerous shell samples located deeper within the shell midden also reveal chipping along their edges.

As shown by the Bourewa data for the Shoreline Sandy/Muddy Habitat (Table 6.10), *Codakia punctata* appears to have steadily declined in relative abundance through time, though not very significantly. This may imply a couple of scenarios; firstly that human predation was generally stable though increasing through all periods: secondly, that environmental change (particularly sea-level fall) throughout the Lapita occupation of Bourewa site might have reduced (or impacted) the natural availability of *Codakia punctata*. It seems clear that the first people of Bourewa may have had access to bountiful amounts of *Codakia punctata* but it was perhaps unable to withstand both increased human predation and perhaps changing environmental conditions, hence its gradual decline over time. Alternatively during the settlement of Bourewa, foragers may have intentionally shifted their foraging strategies to incorporate other shellfish species so that fewer *Codakia punctata* shells were collected. Another reason for the declining consumption of *Codakia punctata* over time is it may be that people collected smaller quantities to allow the species to recover.
*Fimbria fimbriata* is a filter-feeding reef-dwelling shell that usually burrows in shallow coralline sand. It is an important food source and its shell can be used as raw material for shellcraft and to manufacture lime. It can grow up to a maximum length of 9 cm (Abbott and Dance, 2000).

In general like *Codakia punctata*, *Fimbria fimbriata* also exhibits a decreasing trend in its relative abundance through time for the Shoreline Sandy/Muddy Habitat (Table 6.10). Although stability was recorded from Zone C to B, *Fimbria fimbriata* declined in abundance especially during Zone A. Unlike *Codakia punctata*, the decline observed for *Fimbria fimbriata* particularly toward the end of the Lapita-era at Bourewa may in fact reflect the increased human predation pressure on this already declining shellfish species. During this time as suggested by Nunn (2007a), the human population of Bourewa is likely to have been increasing as a result of in situ population increase and/or influx of new migrants which also resulted in an expanded occupation of the Bourewa site.

Tebano and Pauley (2001) noted that in Fiji, *Anadara antiquata* is associated with mangroves and muddy sands close to mangroves. It would be expected that a gradual expansion of mangroves around Qoqo Island towards the end of the Lapita era, for instance, would naturally favour an increase in abundance of *Anadara antiquata*. But instead of an increase in abundance of *Anadara antiquata* at the Qoqo site, the shell weight data indicate a decrease towards the upper layers. Hence the observed decline in abundance of *Anadara antiquata* at Qoqo Island is more likely to reflect intense human harvesting pressure (Nunn *et al.*, 2006). In her analysis of shellfish excavated from site SE-RF-2 in the Reef/Santa Cruz Group of Solomon Islands, Swadling (1986) also observed changes in the shell size of *Anadara antiquata* which she attributed to intense predation by the colonising population although she noted that these resources were far from being completely depleted.

Based on the Bourewa shell data for the Shoreline Sandy/Muddy Habitat, *Anadara antiquata* shows a general increase in relative abundance from 2.6% MNI in Zone C to 3.6% MNI in Zone B and to 5.1% MNI during Zone A (Table 6.10). At Bourewa, it appears that the increase in mangrove development along the Tuva Estuary may have contributed to an increase in the abundance of *Anadara antiquata* that came to
the attention of the Bourewa settlers as an alternative food source. It would also be possible for *Anadara* spp. to thrive on the muddy sands adjacent to the Bourewa settlement site and other nearby small bays due to increased sedimentation, reef expansion, and favourable environmental conditions along the Rove Peninsula. Today *Anadara* spp. can still be collected along the extensive sand flat near the Bourewa settlement site.

Alternatively, the increase in the consumption of *Anadara antiquata* during Zone A may also signify a shift from dependence on shellfish taxa like *Codakia punctata* and *Fimbria fimbriata*, which were gradually declining in abundance, to other large-sized edible shellfish like *Anadara antiquata*.

Several case studies from certain Pacific Islands exemplify the impact of environmental change on shellfish resources, particularly sea-level change during the mid-Holocene period and its impact on the abundance of *Anadara antiquata*. For instance, in Tonga, Spennemann (1987) recorded changes in the sizes of *Anadara antiquata* and *Gafraarium tumidum* which he attributed to local environmental change in the Fanga ‘Uta lagoon and which subsequently affected the relative abundance of these two shellfish species. The demise of the mangrove ecosystem in parts of Micronesia during the mid-Holocene period also influenced the abundance of *Anadara* species; Amesbury (2007) reports the impact of environmental change during the Prehistoric Period in the Mariana Islands and argues that sea-level change was principally responsible for eliminating mangrove habitats and mangrove-associated shellfish species like *Anadara antiquata*.

While human predation during Lapita times was an important factor in the decline of *Anadara antiquata* at Qoqo Island (Nunn *et al.*, 2006), environmental change particularly associated with changing lagoon conditions like water quality and salinity of the Tuva Estuary may have contributed to the increase in abundance of *Anadara antiquata* as revealed by the Bourewa data though this assertion needs to be further investigated.
*Batissa violacea* is a freshwater estuarine shellfish species that has a purplish shell and a thick glossy or hairy periostracum (Abbott and Dance, 2000). Its presence in the Bourewa shell assemblage may provide clues to subsistence change in general and in particular to the nature of changing environmental conditions along the Rove Peninsula like the expansion of the mangroves and shoaling of the Tuva Estuary.

The Bourewa shellfish data indicates that *Batissa violacea* increased in its relative proportions over time. For example, in Zone C - 1.6% MNI, Zone B - 2.1% MNI and Zone A - 2.8% MNI (Table 6.10). In contrast to Bourewa, the consumption of *Batissa violacea* at nearby Qoqo Island declines towards the present (Nunn *et al*., 2006).

As Nunn and others suggested, the Qoqo area was gradually transformed from an open coast to a mangrove environment during Lapita times implying its human occupants may have sought other reef-dwelling shellfish resources in order to sustain their life ways (Nunn *et al*., 2006). Possibly the changing environmental conditions at Qoqo and the shoaling of the Tuva Estuary also impacted the availability and abundance of *Batissa violacea* here as the freshwater quality declined (and became more brackish due to falling sea level).

Since Bourewa was settled sometime earlier than Qoqo Island, the settlers may have collected *Batissa violacea* from the banks (sides) of the Tuva River when they were probably common prior to the expansion of the mangroves and shoaling of the Tuva Estuary. As the local environmental conditions changed, freshwater shellfish species like *Batissa violacea* were placed at a distinct disadvantage and perhaps would be expected to decrease in abundance although this was not the case at Bourewa. While the expansion of the mangroves and increased human predation may have had an impact on the abundance of *Batissa violacea* at Qoqo Island, at Bourewa the apparent consumption of *Batissa violacea* was increasing from Zone C to A. This trend may imply that the Bourewa settlers were foraging farther inland along the banks and smaller tributaries of the Tuva River to collect *Batissa violacea*.

When the Lapita people arrived at Bourewa, they were perhaps presented with a broad spectrum of shellfish resources that were associated with the nearby mudflats.
and lagoons, small mangrove stands, rivers, and the expanding coral reef floor. The most common bivalve species (*Codakia punctata*, *Fimbria fimbriata*, *Anadara antiquata* and *Batissa violacea*) are relatively large animals with proportionally large meat yields so they probably were attractive food resources, understandably targeted by foragers for consumption. Since they inhabit shallow sandy and/or muddy environments (habitats), they tend to be readily available and easily accessible to shellfish gatherers particularly at low tide.

It appears that the strategy of the Bourewa settlers to subsistence was perhaps to weigh the costs and benefits of foraging, so they targeted prey that were cost effective and energy efficient. Although the Bourewa settlers collected other shellfish from the Intertidal/Coral Reef Habitats, initially they focused on the nearby Shoreline Sandy/Muddy Habitats which abounded with a range of edible shellfish taxa. As the most common shellfish species were becoming stressed they ventured father away from the settlement to forage and collect from other shellfish families like Corbiculidae, Veneridae, Strombidae, Turbinidae, and Trochidae.

This kind of foraging strategy (behaviour) is also reflected archaeologically elsewhere in the Pacific Islands (Amesbury, 1999; Anderson, 1981; Nagaoka, 1988, 2001; Spennemann, 1987), by ethnographic studies among the Meriam children of the Torres Strait Islands (Bird and Bird, 1997), and by mollusk gatherers in Western Kiribati (Thomas, 2002) where larger prey species were usually preferred over smaller prey.

As predicted by foraging theory, the Bourewa data indicate that when large high-ranked prey items decline in abundance due to intense human predation pressure, foragers will target smaller low-ranked prey and less profitable habitats and incorporate them into their diet. Intense human predation within a high-ranked shellfish habitat like the Shoreline Sandy/Muddy Habitat has lead to decline in high-ranked prey items and decreasing foraging efficiency which may have caused a shift in subsistence strategies to focus on less profitable preys and low-ranked habitats such as the Intertidal/Coral Reef Habitats.
7.2.2 Foraging in the Intertidal/Coral Reef Habitat

The Intertidal/Coral Reef Habitat appears to have hosted the most diverse shellfish taxa within the Bourewa shell assemblage. Of these *Strombus gibberulus gibbosus* is by far the most abundant gastropod species. Other important shell taxa include *Trochus niloticus* and *Turbo chrysostomus* (Table 6.11). At the Naitabale site, Moturiki Island, Fiji, Nunn *et al.* (2007) reported that *Strombus* spp. were also the most abundant shellfish taxa in the entire shell assemblage accounting for about 43% MNI of all gastropods present in the assemblage but at Bourewa they only account for a small proportion (19% MNI) of the entire shell assemblage.

*Strombus gibberulus gibbosus* is the largest of three subspecies and commonly inhabits the sandy areas of the coral reef flat up to 10 m in depth. Mature individuals can grow up to 5.5 cm in height (Abbott and Dance, 2000). A characteristic of the *Strombus* species is that they normally live together in aggregates (Catterall and Poiner, 1983). This particular behavioural trait elevates the cost-benefit perspective and profitability of this species despite its relatively smaller size, thus making them particularly susceptible to over harvesting by foragers. Thus, if an individual animal is encountered within a habitat, the chances of others being discovered and collected are relatively high (Nunn *et al.*, 2007).

Based on Table 6.11, *Strombus gibberulus gibbosus* generally increased through time although there was a slight decline recorded during Zone B; relevant data are Zone C (37% MNI), Zone B (30% MNI) and Zone A (44% MNI). For other Strombidae taxa there was a slight increase shown from Zone C to B (2.9% to 3.8% MNI respectively) but their relative abundance declined during Zone A (2.5% MNI).

Due to their nature, *Strombus* species can provide important information about both human predation and environmental change occurring along the Rove Peninsula during Lapita times. For example, Amesbury (2007) suggests that environmental change during the Holocene period in the Mariana Islands was principally responsible for the expansion of *Strombus* habitats and abundance and subsequently caused shellfish-collecting strategies to shift from mangroves to coral reefs. As such, Amesbury demonstrates the increase in abundance of *Strombus* species coincided
with Holocene sea-level fall, in which mangrove communities were disadvantaged leading to decline in certain mangrove shellfish species and the subsequent change in foraging to focus on coral reef species like *Strombus gibberulus gibbosus*. So, it can be suggested that any variability in the presence of *Strombus gibberulus gibbosus* at Bourewa may provide clues to the changing environmental conditions of the expanding reefs around Vusama Island during Lapita times. Thus as the results reveal, reef dwelling shellfish species such as *Strombus gibberulus gibbosus* were increasingly being consumed over time as the changing environmental conditions may have favoured their relative abundance.

*Trochus niloticus* is a large-sized gastropod found mostly associated with the Indo-Pacific region. Mature, adult specimens of *Trochus niloticus* can grow up to 13-15 cm in height. They are usually located on the shallow reef flat feeding on algae or grazing at depths of 20 m (Abbott and Dance, 2000). *Trochus* species are herbivores, carnivores or detritus feeders that live mostly on hard substrates but some crawl on sand or mud substrates and are both seasonal and continuous spawners (Gimin and Lee, 1997). Their dispersal of larvae is often spatially limited which makes replenishment in heavily exploited adult stock challenging (Nunn *et al.*, 2007).

*Trochus* species are commonly located in the intertidal and shallow sublittoral zones (Wilson, 1993) and large adults are sedentary with limited movements, so with their delicious meat they are also a particularly attractive resource usually targeted by shellfish collectors (Nunn *et al.*, 2007). *Trochus* shells too have been known to be used to manufacture a range of artifacts including fishhooks and ornaments. At Bourewa, Nunn (2007a:169) reports the discovery of “a piece of a composite fishhook made from *Trochus niloticus*” shell. Though it is uncertain whether this fishhook was manufactured locally or brought in or traded from elsewhere, this particular find demonstrates another important role of *Trochus* species in the life ways of the Bourewa settlers.

In her analysis of the effects of exploitation on the shellfish resources in the Reef/Santa Cruz Group, southeast Solomon Islands, Swadling (1986) demonstrated that at site SE-RF-2, the shells of *Trochus niloticus* in the upper layers were markedly fewer and younger than in the lower layers, where larger and older
specimens were more frequent. For the Qoqo Island shell assemblage, Nunn and others also recorded a similar pattern as observed at the SE-RF-2 site for *Trochus niloticus*. They noted that larger marine shellfish species like *Trochus niloticus* and *Tridacna* species were common in the lower layers but were less so in the upper layers (Nunn *et al.*, 2006).

Based on the Bourewa shellfish analysis, the relative proportions of *Trochus niloticus* declined over time. As shown in Table 6.11, the utilisation of *Trochus niloticus* was steady from Zone C (12.4% MNI) to B (12.4% MNI) but notably declined during Zone A (10.4% MNI). This trend in the abundance of *Trochus niloticus* is most probably due to increased human predation.

*Turbo chrysostomus* is also commonly found within the Indo-West Pacific region and is usually located within the intertidal and sublittoral zones of the coral reefs. Mature, adult specimens can be 6 cm in diameter (Abbott and Dance, 2000). The interior of their operculum may be white, gold, brown, yellow, or dark green, golden brown at the outer margin (Wilson, 1993). They also provide valuable food resources for coastal shellfish collectors including those at Bourewa settlement.

At Bourewa, *Turbo chrysostomus* is among other *Turbo* species targeted mainly for its delicious meat and can be easily accessed and foraged/collected on the intertidal reef flat. The Bourewa shellfish analysis reveals that *Turbo chrysostomus* had declined in relative abundance throughout all periods from 16% (MNI) during Zone C to 14.9% (MNI) in Zone B and to 10.2% (MNI) during Zone A (Table 6.11). Thus like in the case of *Trochus niloticus*, this declining trend is also associated with human predation.

*Hippopus hippopus* (commonly referred to as the Horse’s Hoof, Bear Paw or Strawberry Clam) (Figure 7.1) is one of the giant clam species of the Tridacnidae family which are limited to the tropical waters of the Indo-Pacific region (Abbott and Dance, 2000). Compared to other *Tridacna* species, *Hippopus hippopus* has a narrow basal orifice, closed with tight-fitting teeth. It can grow up to 40 cm in length, and has heavy valves with radial ribbings on them. *Hippopus hippopus* are sedentary
filter feeders and have a symbiotic relationship with dinoflagellete algae zooxanthellae in the mantle tissue (Copland and Lucus, 1988).

Characteristically the clam can supplement its food/nutrients by photosynthesis of the zooxanthellae. Thus its phototrophic nature dictates that most *Hippopus hippopus* species are found in relatively shallow clear water, no more than 20 m deep. As such, this behaviour makes them easy targets for foragers. Adult *Hippopus hippopus* are simultaneous hermaphrodites with gonads containing both sperm and egg tissues. Although growth rates during their juvenile development phase are generally slow, thereafter their growth is faster. So larger *Tridacna* species such as *Hippopus hippopus* may grow more rapidly compared to other smaller species (e.g. *Tridacna crocea*, *Tridacna maxima* and *Tridacna squamosa*) (Copland and Lucus, 1988).

Unlike smaller Tridacnidae clams that remain attached or embedded in hard coral substrates throughout their lives, *Hippopus hippopus* are found mostly in sandy coral rock (Pasaribu, 1988), sand or rubble areas (Taniera, 1988), and on shallow reef or sea grass flats with slightly muddy or sandy substrates (Goven et al., 1988). *Hippopus hippopus* are large shellfish species containing large amounts of edible meat. Since they are not attached to any hard substrate or embedded in the coral reef, this increases their susceptibility to collection by human foragers.

*Tridacna gigas* (Figure 7.1), another giant clam is the largest species of the Tridacnidae family. They are limited to the tropical waters of the Indo-Pacific and may weigh up to 200 kg, grow to more than a meter in length, and are located offshore and near reefs at depths up to 20 m (Abbott and Dance, 2000). Like *Hippopus hippopus*, *Tridacna gigas* is a hermaphroditic filter feeder, but can supplement its food/nutrients by photosynthesis of the symbiotic zooxanthellae attached to its mantle, and remain unattached to any hard substratum (Copland and Lucus, 1988).

A recent report on the status of giant clams from various tropical Pacific countries has highlighted that both *Tridacna gigas* and *Hippopus hippopus* are either absent and/or rare. For example, in Tonga, Langi and Aloua (1988) confirmed the absence of *Hippopus hippopus* in the Tonga Archipelago. Although there have been reported
sightings of *Hippopus hippopus* in smaller populations on some islands in Vanuatu, *Tridacna gigas* and *Tridacna derasa* are rare or absent, probably extirpated (Zann and Ayling, 1988).

Currently *Hippopus hippopus* and *Tridacna gigas* are extirpated in the Fiji Islands (Frank Thomas *pers. comm.*, 2007), but they were present in Fiji during Lapita times as demonstrated by the Bourewa shellfish data. In recent years giant clams were re-introduced in the Fiji Islands through a project conducted by the Institute of Marine Resources (IMR) of the University of the South Pacific. Giant clams were bred and reared in the 1990s at the field research station on Makogai Island, central Fiji.
At Qoqo Island, Nunn et al. (2006) reported that Tridacna species were common during the early period of settlement but became rarer later on. A similar pattern is also observed for Bourewa. Human predation could be an important factor in the reduction of both Tridacna gigas and Hippopus hippopus at Qoqo and Bourewa. Nunn (2007a) citing collaborative work done by Szabó (2006), reported that Tridacna shells comprise a small proportion (8%) of the reworked shell artifacts at the Bourewa site, possibly reflecting their relative abundance and availability during Lapita times. Perhaps due to their attractiveness as food, they were exploited beyond replenishment and consequently became extirpated, although environmental change may be important, but detailed work is required to support this assertion.

It is clear that overexploitation has led to the extirpation of giant clams like Tridacna gigas and Hippopus hippopus in most parts of the northern and southern Pacific (Copland and Lucus, 1988). So, it is plausible to suggest that perhaps increased human predation by the Bourewa settlers may be responsible for the demise of these two Tridacnidae species along the Rove Peninsula.

Although the Intertidal/Coral Reef Habitat comprised fewer shellfish species than the Shoreline Sandy/Muddy Habitat, the abundance index measures suggest that diet breadth had also been expanding through time. This conclusion is also supported by the diversity (richness) of shellfish species associated with the Intertidal/Coral Reef Habitat though it may only reflect a moderate resource depression trend within the Intertidal/Coral Reef Habitat rather than a heavy level of exploitation.

As predicted by the patch choice model, foraging efficiency within both the Shoreline Sandy/Muddy and Intertidal/Coral Reef Habitats appear to have decreased through time. Such a declining trend in foraging efficiency particularly within the Intertidal/Coral Reef Habitat during Zone B to A coincides with the time when the Bourewa area was experiencing an influx of new migrants and concomitant increase in its population. The settlement experienced expansion along its peripheral areas to accommodate the new residents (Nunn, 2007a) so perhaps this population growth placed additional pressures on the available shellfish resources.
The results of the prey and patch choice analysis suggest a decrease in the use of the Shoreline Sandy/Muddy Habitat over time particularly from Zone B to A. The increased utilisation over time of the Intertidal/Coral Reef Habitat is not necessarily reflected in the decrease in Codakia punctata but indicates that other Shoreline Sandy/Muddy Habitat shellfish species like Fimbria fimbriata had also declined in abundance. So a shift in the utilisation of shellfish resources from the Shoreline Sandy/Muddy Habitat to the Intertidal/Coral Reef Habitat during Zone A, probably signify a decline in foraging efficiency. This trend is reflected by the increasing proportion of both Strombus gibberulus gibbosus and Trochus niloticus especially during Zone A (Table 6.12) which are coral-reef dwelling shellfish species.

Alternatively, this observed trend could be due to the impact of the changing environmental conditions (sea level) along the Rove Peninsula as the Lapita occupation of Bourewa was approaching its end. It is plausible to infer from the Bourewa shellfish data that the declining sea level toward the end of the Lapita era in Fiji may have favoured certain coral-reef dwelling shellfish families like Strombidae and Trochidae over most bivalve shells. Perhaps sea-level fall would have disadvantaged certain shellfish species of the Shoreline Sandy/Muddy Habitat due to the gradual loss of their habitats, while coral reefs and mangroves were expanding thus favouring shellfish species within the Intertidal/Coral Reef Habitat. This situation is exemplified by observations also recorded by Amesbury (2007) for the Mariana Islands, Kirch and Yen (1982) on Tikopia Island, Solomon Islands, and Spennemann (1987) for Tongatapu Island, Tonga.

### 7.2.3 Shellfish Diversity and Abundance

Overall the NTAXA analysis shows an increase through all periods within the Intertidal/Coral Reef Habitat. The NTAXA assessment for the Shoreline Sandy/Muddy Habitat reveals that from Zone C to B, diet breadth increased from 15 items to 17 items but it decreased to 16 items during Zone A (Figure 6.12). Even though diet breadth appears to have increased through time within the Shoreline Sandy/Muddy Habitat, its expansion is not comparable to that of the Intertidal/Coral Reef Habitat.
The NTAXA analysis demonstrates that diet breadth expanded significantly during Zone B within both the Intertidal/Coral Reef and Shoreline Sandy/Muddy Habitats but only slightly within Zone A. Generally the NTAXA analysis of the shell assemblage represents a diversified and generalised diet breadth which indicates declining foraging efficiency over time.

Evenness analysis for the entire shellfish assemblage demonstrates that evenness remained fairly steady within Zone C to B and increased during Zone A (Figure 6.13). As such there is a general increase in the relative contribution of the different shellfish taxa to the shell assemblage over time.

Although the evenness values for the entire assemblage are notably fairly lower, this indicates widening of diet breadth to include other shellfish resources and may suggest overall decline in foraging efficiency. So for Bourewa, evenness did vary through time because evenness indices are all between 0.33 and 0.42. Thus, it can be broadly interpreted as indicating that the relative contribution of the different shellfish species at Bourewa did change over time. As such it would appear that some level of resource depression is occurring particularly toward the end of the Lapita period (Zone A).

For the Intertidal/Coral Reef Habitat (Figure 6.14), evenness remains similar through time, though there is a slight increase during Zone B. Overall this trend seems to indicate that diet breadth is relatively stable over time. In contrast, the evenness trend for the Shoreline Sandy/Muddy Habitat (Figure 6.15) is similar to that of the entire shell assemblage. Evenness within the Shoreline Sandy/Muddy Habitat indicates widening of the diet breadth to include other low-ranked shellfish resources which would signal that resource depression had been occurring.

The relative abundance measures for the five common shellfish species (Codakia punctata, Fimbria fimbriata, Strombus gibberulus gibbosus, Anadara antiquata and Trochus niloticus) lend support to the interpretations provided for both the diet breadth and NTAXA and evenness analyses of the Bourewa shellfish. Upon inspection, the total percentages of these five shellfish taxa also decreased though time for example, from 88.4% during Zone C to 87.2% during Zone B, and to 83.2%
during Zone A (Table 6.12). It is evident that while these shellfish species had declined, their proportional contributions became more evenly distributed through time.

Based on the relative abundance analysis, it appears that while *Codakia punctata* had been declining, other shellfish species (*Fimbria fimbriata, Strombus gibberulus gibbosus, Anadara antiquata* and *Trochus niloticus*) increased over time. Such analysis may signify several important trends, (i) diet breadth is expanding (ii) resource depression is occurring (iii) foraging efficiency is declining and (iv) there is a shift in subsistence strategy to incorporate other low-ranked shellfish resources into the diet perhaps to either offset the impact of declining shellfish resources, or allow exploited species to recover from increased stress due to increased human predation.

7.3 Implications of archaeological shellfish data for marine resources management

The Bourewa shellfish data have shown how human exploitation can be related to environmental change and in terms of modern resources management it can provide resource managers with numerous scenarios. These are summarised here:

- The shellfish resources of the Rove Peninsula have been continuously exploited for many centuries by the Lapita people, a period extending some 500-600 years. Thus the Bourewa shell assemblage is amongst some of the oldest known continuously exploited shellfish resources in the Eastern Lapita Province and particularly in the Fiji Islands.

- As a food source for early Lapita settlers of Bourewa, shellfish resources undoubtedly have been an important component of their diet and perhaps played a significant role in their life ways. Although certain habitats experienced declines in large-sized mollusc resources, the early settlers also utilised other shellfish resources and habitats to perhaps offset declining shellfish stocks. Increased predation may have caused early human populations of Bourewa to exploit other marine resources like fin fish, sea
turtles, echinoderms and other invertebrates and/or to develop horticultural/agricultural practices while crop cultivation was important as well during the middle stages of settlement at Bourewa (Horrocks and Nunn, 2007).

- The Bourewa shellfish data suggest that the exploitation on sessile invertebrates, such as molluscs, can be quantitatively determined by examining the shell assemblage. While it is possible that long-term subsistence exploitation can markedly reduce the average size composition of mollusc populations and the species structure of communities, the Bourewa shellfish analysis reveal moderate level of shellfish exploitation and relative stability. Although no significant reduction in shell size is being recorded for the most common shellfish species (*Codakia punctata*) at Bourewa, other shellfish like *Strombus gibberulus gibbosus* and *Fimbria fimbriata* did reveal some level of shell size reduction.

- The archaeological record for subsistence shellfish on the reefs and in lagoons along the Rove Peninsula suggests overall long-term stability and continuity. Changes in relative composition and abundance of shellfish taxa in the temporal sequence possibly resulting more from increased foraging activities, although the impact of sea level change may have been important as well but further investigation is required.

In general it can be demonstrated from the shellfish analysis that while the subsistence practices of the Bourewa settlers on shellfish resources have shown some degree of change over Fiji’s prehistory especially from about 1200/1100 to 700/600 BC, other important horticultural/agricultural innovations were also practiced at Bourewa. Although sea-level change during the mid-Holocene period may have possibly influenced the availability of certain shellfish resources and habitats along the Rove Peninsula, human predation patterns remain steady. As stated by Dalzell (1998), the patterns of fisheries exploitation in the Pacific may have significantly changed only from the period of European expansion (colonialism) and the intrusion of European, American and Asian traders during the era of commercial fisheries in
the Pacific and as a result of abrupt environmental changes like those that occurred during the “AD1300 Event” in Fiji (Field, 2004; Morrison and Cochrane, 2008; Nunn, 2003).

According to Dalzell (1998:247-249), the archaeological (evidence) record can be utilised by managers of fisheries resources to develop possible management scenarios or strategies. These include:

(i) to “reinforce the social and cultural importance of fisheries, and to help ascertain traditional property rights, even though these may have declined through European colonisation and progressive urbanisation”. An example of traditional management practice which is common in many Pacific Islands and emphasises traditional rights is Customary Marine Tenure (CMT). This practice is based on the principle of clans, chiefs and/or communities claiming exclusive rights to fishing areas while excluding outsiders from these areas which essentially contrasts markedly with the concept of the “tragedy of the commons” which is observed in areas with open access (Hickey, 2001). Hickey also recognises that CMT practices can complement contemporary management strategies to effectively manage marine resources.

(ii) to “be used comparatively with sources from colonial era and post-colonial era for developing fishery management initiatives in the Pacific Islands”. As noted by Dalzell (1998), during the colonial and post-colonial period in the Pacific region many factors have been important in influencing the perception and behaviour of Pacific islanders towards marine resource utilisation and management. A case in point is the influence of religious beliefs, doctrines like those observed by the Seventh Day Adventists (SDA) where certain marine animals (including shellfish) are not allowed for human consumption. This aspect of religion can be encouraged and combined with archaeological data to develop proper and appropriate management strategies for managing marine (shellfish) resources in different Pacific island situations.
to “provide a rich vein of information about long-term subsistence exploitation of reef and lagoon fisheries resources”. Archaeological data from most parts of the Pacific have shown that marine resource utilisation have been important to the life ways of prehistoric populations (Nunn, 2007b; Nunn and Heorake, 2009) so an understanding of the way ancient peoples interacted with resources could also provide resource managers with useful management tools and strategies. An example is the Bourewa shellfish data which spans a period of 500-600 year-long human subsistence history. Such data will be vital to develop management scenarios for marine resource managers especially when it considers the long-term interplay between both human and non-human factors.

(iv) to “develop and adopt multi-disciplinary approaches to coastal fisheries management by making use of broader range of information sources as inputs into the management process, particularly where conventional fisheries data are poor or even completely lacking”. The scarcity of fisheries data is one of the important factors contributing to inappropriate fisheries management practices and ineffective and unclear fisheries policy initiatives in most Pacific Islands. As highlighted by Aqorau, countries like the Solomon Islands have to employ the “precautionary approach” principle to fisheries management due to lack of proper fisheries data (Aqorau, 2001). But, fisheries managers could incorporate archaeological data to assist in designing and developing relevant and effective fisheries management strategies and policies because numerous archaeological (marine faunal) studies that have been conducted in most Pacific Islands in the recent past can provide very useful baseline data.

Archaeological analysis like the Bourewa shellfish study can provide marine resource managers with a robust and effective management tool for understanding modern resource management practices particularly for shellfish species and habitat exploitation.
8.1 Introduction

This chapter provides a summary of the results and analysis of the shellfish species and habitats at Bourewa in relation to the aims and objectives of this thesis.

8.2 Conclusion

According to Nunn and Heorake (2009), one of the keys to understanding early human-environment interactions is to know the types of resources that people exploited, the environments they encountered, and how environmental change influenced their subsistence strategies and behaviour over time. For most Pacific islands, human and non-human factors have been important in influencing the lifeways of the pre-historic peoples, the selection of various island environments for establishment of settlements, and the exploitation of their resources.

The geoarchaeological excavations at the Bourewa Lapita site over the past few seasons have provided new opportunities to understand the life ways of the first people who settled the Fiji Islands, lived and utilised the marine shellfish resources that were available to them at that time. In particular, by studying the shells recovered from the mid-2005 archaeological dig at Bourewa, inferences about human subsistence behaviour and their impact on the shellfish species and habitats, and the influence of environmental change on shellfish resources could be made.

As such, based on the Bourewa shellfish and habitat analyses, two possible explanations have been posited to explain the variability in the shellfish species and habitat usage at Bourewa. The first is associated with human-induced subsistence pressure on shellfish species and habitats while the second is linked to environmental impact particularly the possible influence of sea-level fall (after the mid-Holocene) on certain shellfish species and habitats along the Rove Peninsula. These two scenarios are discussed in subsections 8.2.1 and 8.2.2.
8.2.1 Human subsistence patterns as revealed by the Bourewa shellfish and habitat analyses

As Nunn (2007b) suggests, the proximity and availability of abundant marine resources on tropical Pacific Islands during Lapita times were a major drawcard for the selection and settlement of most Lapita sites. In Fiji, the Bourewa site was selected by the Lapita people principally due to the presence of and access to abundant marine resources including shellfish located on an unusually nearby broad fringing coral reef. It is evident that when the first Lapita people arrived at Bourewa some three thousand years ago, there were plenty of shellfish resources from which they could select and collect from nearby shellfish habitats for consumption. These shellfish species were energy efficient and essentially no specialised skills were required to forage and prepare these shells (Nunn and Heorake, 2009).

Through the utilisation of various faunal quantitative methods (MNI, NISP, weight, and size) and analysis, characterising the structure and composition of the shell midden at Bourewa is possible. While gastropods constitute the most diverse shellfish taxa in the shell assemblage, bivalves compose the most abundant and high-ranked shellfish species. From the shellfish analysis it appears that the Bourewa settlers consumed mostly bivalves which were generally large-sized, meaty and energy efficient. This is evident from the quantity of bivalves excavated at the Bourewa site. The common bivalve shellfish include; *Codakia punctata*, *Fimbria fimbriata*, *Anadara antiquata*, *Batissa violacea*, *Strombus gibberulus gibbosus*, *Trochus niloticus* and *Turbo chrysostomus*. Today most of these shellfish species can still be gleaned and collected on reefs in the Fiji Islands including along the Rove Peninsula, though some are becoming rarer due to over harvesting. Other large-sized bivalves like *Tridacna gigas* and *Hippopus hippopus* which were present during Lapita times are now extirpated in the Fiji Islands.

Analysis of the Bourewa shellfish assemblage using different foraging models (*prey choice, patch choice* and *central place*) has allowed for testing various assumptions and predictions concerning human foraging efficiency and the utilisation of shellfish species and habitats along the Rove Peninsula. The results and analysis indicate that
both shellfish species and habitats were subjected to human predation pressures during Fiji’s prehistory especially during the Lapita era.

The Bourewa shellfish analysis demonstrates that foraging efficiency within both the Shoreline Sandy/Muddy and Intertidal/Coral Reef Habitats generally declined through time. Although the Shoreline Sandy/Muddy Habitat remained important during Zones C and B, it decreased in status during Zone A. This trend coincided with a shift in foraging emphasis to other shellfish species and habitats that were exploited over time. Present evidence also suggests that during the middle to the end of the Lapita period (Zones B to A) at Bourewa, the Lapita people began increasingly targeting a range of diverse shellfish species from the Intertidal/Coral Reef Habitat, as those species within the Shoreline Sandy/Muddy Habitat had gradually declined both in relative abundance and status.

Shellfish diversity and NTAXA increased during all the zones of the Intertidal/Coral Reef and the Shoreline Sandy/Muddy Habitats. Evenness measures demonstrate that evenness also increased during Zone C to B but decreased during Zone A of the Intertidal/Coral Reef Habitat, while evenness increased during all periods within the Shoreline Sandy/Muddy Habitat. These results suggest that foragers were targeting more diverse shellfish species within the Shoreline Sandy/Muddy Habitat indicating declining foraging efficiency, broadening of their diet and changes in their subsistence strategies.

Based on the Bourewa shellfish analysis, it is possible that human induced resources depression within the Shoreline Sandy/Muddy Habitat has led to a shift toward the use of the Intertidal/Coral Reef Habitat especially towards the end of the Lapita period. This means that as the Shoreline Sandy/Muddy shellfish taxa were increasingly stressed, foragers began targeting shellfish species from the Intertidal/Coral Reef Habitat and over time foraging efficiency within both habitats also declined as more diverse shellfish (and low-ranked) species from both habitats were being targeted and incorporated into their diet.

Additionally, the incorporation of other shellfish species into their diet resulted in an expansion of their diet breadth and declining foraging efficiency. The decline in their
foraging efficiency also led to the consumption of small-sized, less profitable prey. Consequently they were also collecting shellfish species that were located farther away from the settlement site. This means that foragers were also spending more time in collecting shells within the different shellfish habitats.

It is important to note that this study does not suggest or imply that the early settlers of Fiji in general may have had profound negative impact on other islands, but these results can only be applied to prehistoric marine (shellfish) resources use at the Bourewa settlement. Also this study does not suggest mismanagement of marine ecosystems in Fijian prehistory, but it does demonstrate a shift in foraging to other low-ranked shellfish species and habitats from increased human predation or perhaps to allow for the exploited species and habitats to repopulate and recover. This shift in subsistence strategy also coincided with the later introduction and cultivation of root crops like taro and yam at Bourewa and the possibility of environmental impact on certain shellfish species. The present study can not demonstrate the influence of horticulture/agriculture on shellfish usage, but it is clear that horticultural/agricultural practices were important during the middle stage of Lapita occupation of Bourewa (Horrocks and Nunn, 2007).

Generally the Bourewa shellfish data suggest that the Lapita people were principally “people of the sea”. They utilised shellfish resources from a range of ecosystems like mangroves, mudflats, and coral reefs, and perhaps caught and ate turtles, sharks and other marine (pelagic) finfish and invertebrates and perhaps seaweed and marine algae (Nunn, 2007b). It is can be inferred from the available data that shellfish resources along the Rove Peninsula were generally plentiful during Lapita times and the Bourewa settlers consumed large quantities of available shellfish species. The initial Lapita settlers of Bourewa were principally consuming large quantities of shellfish from a range of shellfish habitats along the Rove Peninsula and probably their diet comprised primarily of shellfish. Perhaps later on during Lapita times, terrestrial foods like taro became incorporated into their diet, though marine food resources like shellfish still played an important role.

A notable trend is the presence of a range of edible small-sized bivalves and gastropods albeit fewer in abundance. These shellfish species were most probably
foraged by children. As observed by Bird and Bird (2000, 2002) in the foraging behaviour of the Meriam children of Torres Strait Islands, it can be assumed that small-sized shellfish species of Bourewa were collected and perhaps taken and consumed at the site by the children. Bird and Bird (2000) also noted that adult foragers do not usually collect small-sized shellfish species, but it is children who are most likely to collect low-ranked shellfish species either as part of their play and/or for consumption. That is probably how these small-sized shellfish taxa ended up in the shell midden thus contributing to the structure of the midden deposit at Bourewa. Some examples of these smaller-sized shellfish species include *Cypraea annulus*, *Cypraea moneta*, *Polinices tumidus*, *Polinices* spp., *Natica* spp., *Cerithium nodulosum*, *Cymatium* sp. and *Neverita peselephanti*.

8.2.2 Environmental impact on shellfish resources at Bourewa

Another explanation for the observed changes in shellfish species and habitat usage at Bourewa is associated with the possibility of environmentally induced effect particularly the influence of sea-level change on certain shellfish species within both the Shoreline Sandy/Muddy and Intertidal/Coral Reefs Habitats. It is clear that the occupation of the Bourewa site and other locations along the Rove Peninsula by the Lapita people occurred at a time when the environment was also experiencing significant changes both regionally and locally, so an understanding of the nature of environmental change occurring during the Lapita occupation of Bourewa and its impact on marine resources along the Rove Peninsula is important.

As posited by Nunn (2005), sea-level and climatic changes have been major factors in the subsequent changes in prehistoric settlement patterns on most Pacific Islands including Fiji. The development and upgrowth of coral reefs and expansion mangroves on Vusama Island and the subsequent shoaling of the Tuva Estuary were possibly linked to sea-level fall after the mid-Holocene which may have had an impact on the abundance and availability of certain shellfish resources. The impact of sea-level change on the availability shellfish species in the Pacific Islands is well documented (Amesbury 1999, 2007; Kirch and Yen 1982; Spennemann, 1987) and also inferred for the Qoqo Island Lapita site in Fiji (Nunn *et al.*, 2006). In fact due to
the proximity of Qoqo to Bourewa, the impact of sea-level fall on the faunal records of both sites would be somewhat similar.

Recent studies have suggested that localised sea-level fall after the mid-Holocene period had had significant impact on certain shellfish species and the subsistence behaviour of prehistoric Pacific peoples. For example, the fall in sea level on some Pacific Islands like the Marianas, Tikopia Island, and Tongatapu Island had resulted in shellfish habitat (environmental) change thus favouring certain shellfish species over others (Amesbury, 2007; Kirch and Yen, 1982; Spennemann, 1987).

It can be inferred form the present shellfish data that the fall in sea-level during Lapita times was important in influencing the abundance and availability of certain shellfish habitats and species along the Rove Peninsula. For example the decline in abundance of the freshwater bivalve *Batissa violacea* from Zone C to A can be attributed to the shoaling of the Tuva Estuary due to sea level fall and increased sedimentation. There is also an increase in the consumption of the reef-dwelling gastropods *Strombus gibberulus gibbosus* and *Trochus niloticus* which also coincided with coral reef expansion and upgrowth along the Rove Peninsula. These two cases may signify environmental influence on the availability of these shellfish taxa during Lapita times. While on the one hand sea-level fall may have been responsible for the decline of the freshwater bivalve *Batissa violacea*, on the other hand it had encouraged the availability of mostly coral-reef dwelling shells like those belonging to the Strombidae and Trochidae families.

There is also a marked decline over time in the relative abundance of *Codakia punctata* while other common shellfish taxa like *Fimbria fimbriata* and *Anadara antiquata* have increased. The present study can posit that these trends are linked with sea-level change during and after the mid-Holocene. It has been suggested that the fall in sea level after the mid-Holocene has been responsible for the declining abundance of certain shellfish species in some Pacific islands (Amesbury, 2007; Kirch and Yen, 1982; Spennemann, 1987). The Bourewa shellfish data also show that shellfish abundance and availability were linked with sea-level change during Lapita times. The impact of falling sea level on the availability of some shellfish species like *Batissa violacea*, *Strombus gibberulus gibbosus* and *Trochus niloticus*
and the subsistence strategies of the Bourewa (Lapita) people has been demonstrated. The present study also provides clues to the link between sea-level change and the availability of shellfish species and habitats along the Rove Peninsula during Lapita times.

Based on the Bourewa shellfish data and analysis, both human and non-human factors have played major roles in influencing shellfish species and habitats during the Lapita era in Fiji. While the impact of early human predation on shellfish species along the Rove Peninsula has been demonstrated, this study also highlights the possible influence of sea-level fall (change) on shellfish species and habitats and the shifts in subsistence strategies of the early Lapita people in Fiji.


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