

## FISHERIES OF TONGA

AN ARCHAEOLOGICAL ASSESSMENT OF FISHERIES IN VAVA'U, TONGA

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**Abstract**

Archaeological explorations of South Pacific Islands tend to focus on identifying the presence of a distinct dentate stamped pottery style coined “Lapita Ceramics”. Studies concerning the subsistence strategies of Lapita settlers tend to be localized to single islands or archipelagos. An examination of archaeological fish remains can provide information concerning the kinds of fish being harvested, the diversity of the fishery, the technology used for harvest, and the relative importance of fish to the overall subsistence economy. Subsistence research in the South Pacific is predominantly centered on the marine environment and Lapita interactions with local marine resources. Identification of fish remains and analysis of the abundances of fish resources on several islands has led to a generalization of Lapita subsistence practices as dominated by reef resources. An analysis of fish remains at four Lapita sites (Falevai, ‘Otea, Ofu, and Vuna), in Vava’u Tonga indicates settlers had a complex and diverse relationship with marine environments, and demonstrates that Vava’u fisheries are characterized by the casual harvest of large bodied fish. In addition to a characterization of Vava’u fisheries, a critical comparison of the fishing practices of Tongatapu, Ha’apai and Vava’u highlights the range of subsistence practices employed by the Lapita and defies the imposition of generalized subsistence models on Lapita settlers.



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## **Dedication**

This Thesis is dedicated to my eternally supportive and loving mother Dr. Helen Lakusta. I hope she would be proud of the product.

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## Chapter 1: Introduction

The goal of this research is to present the analysis and interpretation of faunal remains from four archaeological sites in the Vava'u group of islands in the South Pacific Kingdom of Tonga (Fig. 1.1). These sites are considered within the context of settlement and subsistence strategies of Lapita settlers in the South Pacific Islands and discussions of South Pacific subsistence strategies put forth by previous researchers. The validity of applying such generalized models is questioned and an attempt is made to highlight the variety of settlement and subsistence strategies employed by the Lapita settlers.

The settlement of the South Pacific from the Melanesian and Micronesian Islands to the Remote Polynesian Islands is seen as a rapid expansion of a homogenous cultural group known as the Lapita (Kirch 1988; Terrell 2003). Much of the research conducted on the Lapita in the South Pacific is focused on the chronological sequence of their spread through the island groups (Kirch 1988; Summerhayes 2001). Many of the island groups scattered throughout the South Pacific have been studied archaeologically to determine if the Lapita settled on particular islands and, if so, when and what settlement strategies were followed (Kirch 1996). Studies incorporating a discussion of the subsistence practices are often limited to a listing of the identified fauna recovered and isolated interpretation of the subsistence strategies on each given island, which are then slotted into one of the more generalized hypotheses regarding South Pacific subsistence.

Lapita sites are frequently coined as 'typical' or characteristic of Lapita patterning. This is particularly evident when examining the distinct dentate stamped pottery from which the Lapita people received their name, regardless of the variations present between island groups (Kirch 1978, 1996). This generalization of the Lapita is also present in characterizations of subsistence strategies. Most commonly the evidence from Lapita occupation sites indicates a heavy reliance on marine resources *or* a rapid introduction of agriculture to the islands they colonized. There are, however, several studies which seem to defy easy categorization into one of these two very broad and

generalized hypotheses. Simple categorization of subsistence strategies can be misleading when the region is examined as a whole and the diversity of settlement locations and subsistence resources are compared between archipelagos and even within given island chains.

If the Lapita were reliant on the natural environment they encountered, the fish from the surrounding coastal areas should be abundant in the record and provide a good indication of shifting patterns of settlement and subsistence. This makes the fish remains from island sites a good proxy for understanding the relationship between settlers and the environments they encountered and chose to utilize. Additionally if the marine environment was as integral to Lapita subsistence strategies as is often indicated in the literature then conceivably the presence of abundant marine resources in close proximity to initial island occupation sites should be a determining factor in the settlement choices of the Lapita. Throughout this research I highlight the variety of settlement and subsistence strategies employed by Lapita settlers and question the application of generalized theories in the interpretation of their settlement and subsistence practices.

To address these issues, fish remains from four Lapita occupation sites in the Vava'u Islands of the Kingdom of Tonga were examined as a basis for understanding the settlement and subsistence choices of the Lapita settlers. The results of this analysis were compared to results of the analysis of fish remains from sites in the Ha'apai Islands (central Tonga) (Cannon and Cannon 2001) and Tongatapu (southern Tonga) (Groube 1971) to explore settlement and subsistence patterns in the Kingdom of Tonga as a whole.

Vava'u provides an interesting case study in the examination of the settlement of the Polynesian islands, as these islands are not well documented archaeologically and are situated in a natural current corridor between the southern islands of Tonga and the northern islands of Samoa (Fig. 1.1) (Burley and Connaughton 2007:131). The study of Lapita occupation sites in Vava'u is of particular interest considering the numerous Lapita occupations in the Ha'apai Islands and Tongatapu, and apparent lack of Lapita occupation in the Samoan Islands, where only one site is currently known (Burley and Connaughton 2007).

The four sites examined here, Falevai, Vuna, 'Otea and Ofu, were excavated by Dr. David Burley of Simon Fraser University in 2004-2005. They all contain marine fish resources from initial occupation through the Polynesian Plainware phase to the historic period of Tonga, making them ideal for examining the initial and continuing subsistence strategies of those occupying Vava'u. The results of the analysis illustrate that even within very limited geographical and temporal locales there is evidence that Lapita subsistence practices encompassed a variety of forms and were adapted to each island settlement context, based on available resources. It also demonstrates that the settlement choices made by the Lapita were not restricted to a 'typical' site location based on environmental parameters. Similar to arguments made by Clark and Andersen concerning the diversity of fishing strategies (including both single and mass capture techniques) for sites in Fiji (Clark and Andersen 2009).

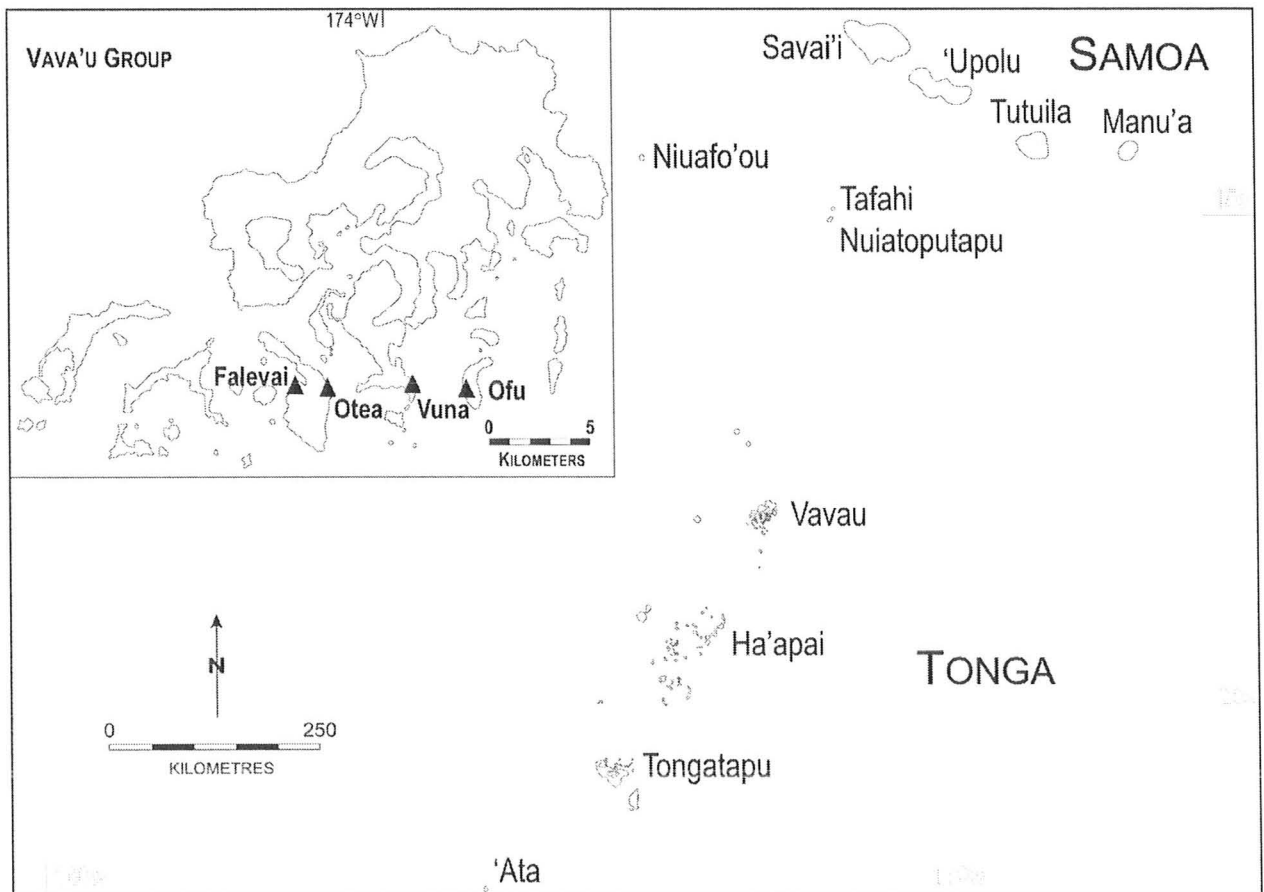


Figure 1.1: Map of Tonga and Samoa Archipelagos (Burley, 2009).

### **Archaeology of Settlement and Subsistence in the South Pacific**

Clark and Terrell (1978:300-302) point out that within South Pacific archaeology in particular, researchers tend towards being scenarists; meaning they create a generalized scenario for the settlement of the South Pacific as a whole, often glossing over the variability present in the region. They suggest there is a preconceived notion in South Pacific research that the settlement of the islands was part of migrational waves instead of an intentional settlement strategy (Clark and Terrell 1978:295).

Several interpretations have been posited to explain the settlement and subsistence economies throughout the South Pacific. Many of the trends associated with settlement and subsistence have been identified based on the correlation of settlement locations, occupation dates, and the faunal assemblages and temporal changes present within them. The importance of the marine environment to the subsistence strategies of Lapita settlers is debated by many researchers. Hypotheses that posit that the marine environment was integral to the Lapita subsistence economy range from those which argue the Lapita relied heavily on the marine environment only during initial occupation, such as Groube's (1971) strandlooper argument, to claims that the marine environment was always an essential resource. The latter can be divided into those who argue for a *potentially* sustainable economy (Fitzpatrick and Kataoka 2005; Wiesler 1994) versus those who claim the Lapita depressed the marine resources they encountered (Allen 2002; Butler 2001; Cannon and Cannon 2001). There are, however, several researchers who claim that the Lapita were first and foremost horticulturalists with a tangential interest in the marine environment as a supplement (Groube 1971; Horrocks and Bedford 2004).

### **Strandloopers**

A strandlooper subsistence economy is essentially opportunistic, with intense reliance on locally available resources associated with initial occupation of a region (Groube, 1971). The argument is that, when a group initially settles a previously uninhabited and, therefore, novel environment, they will find the most productive patch and 'skim off' favoured and efficient food resources (Groube, 1971). This subsistence



strategy is difficult to identify in the archaeological record as it can produce patterns in fish assemblages which may be interpreted quite differently. Initially intensive use of a single resource patch may lead to the mistaken assumption that reef environments -in the case of the South Pacific- were a more important component of the subsistence economy due to the abundance and density of remains recovered. It can also be mistaken for the occurrence of resource depression, as it entails intensive reef use from initial occupation which rapidly declines at the same time as a switch in the subsistence economy to agriculture, which is an intensification of an alternate resource patch. One of the ways resource depression can be recognized in the archaeological record is through a shift in the resource patch being utilized (Nagaoka, 2002b). If, as in the case of Tongatapu, the initial settlers relied heavily on the marine patch and eventually moved to a more agricultural subsistence strategy, then the decline of resources from the reef and their replacement with agricultural products may appear to indicate depression of reef resources, necessitating alternative food sources, instead of a shift initiated by preference.

Groube (1971) was one of the earliest researchers to examine the subsistence patterns of Lapita settlers in the South Pacific. Groube focused on initial Lapita occupation sites on the largest of the Tongan Islands, Tongatapu. Tongatapu is a coralline island with rich fertile soils suitable for agricultural practices (Groube 1971:290). Initial settlements are coastal settlements located in close proximity to both reefs and lagoonal environments (Groube 1971). Groube argued, based on the shell midden data associated with initial occupation (Lapita Phase) that the Lapita were heavily reliant on the marine resources of the surrounding coasts and lagoonal environments. Groube identified a shift in the ceramic composition and style, commonly characterized as a shift from Lapita ceramics to Polynesian Plainware, which coincided with a reduction of the shell middens, a decline in marine resource exploitation, and an increase in agricultural activity (Groube 1971:311).

While the patterns observed by Groube could be representative of over-harvesting or resource depression, as has been argued elsewhere in the South Pacific (Butler 2001; Cannon and Cannon 2001; Nagaoka 2002a, 2002b), Groube explicitly states that he does

not agree that the resources were depressed due to human over-exploitation but that instead the patterns he observed on Tongatapu were evidence of a 'strandlooper' economy. The pattern on Tongatapu, led Groube to argue that the initial settlers (Lapita) were 'strandloopers' characterized by a rapid expansion and initially heavy reliance on littoral environments and rapid decline of the importance of these resources when agriculture was introduced (Groube 1971). A strandlooper economy entails rapid settlement and a 'skimming off' of the most abundant and fruitful resources, prior to the introduction of an alternative subsistence practice, in this case agriculture. The lack of evidence for over-exploitation on Tongatapu, in addition to no environmental changes at the period of subsistence strategy shifts, led Groube (1971:312) to his particular conclusions.

### **Resource Depression**

Resource depression is a decline in availability of a once abundant harvested species (Charnov et al. 1976:247). Charnov et al. (1976) distinguish between three forms of resource depression: exploitation (overharvesting the prey by human populations), microhabitat (environmental changes affecting the prey) and behavioural (changes in the prey's behaviour due to predators). However, when archaeologists examine resource depression it is typically in the form of exploitation depression. Studies of resource depression often tend to focus on the aquatic environment, whether in island settings (Butler 2001; Cannon and Cannon 2001; Nagaoka 2002a, 2002b), mainland coastal settings (Butler 2000; Lyman 2003) or inland river and lake systems (Luff and Bailey, 2000).

Island environments are considered good labs for the study of human changes to the environment (Nagaoka 2002a), and there has been a proliferation of resource depression considerations in island contexts. In island settings, the native flora and fauna often share certain characteristics which make them particularly sensitive to the impacts of human subsistence needs, either in the form of resource harvesting or destruction of native flora for the introduction of domesticates. The combination of: small scale

population sizes (thus increased sensitivity to the loss of few individuals), few populations to draw upon for replenishment of the species, and lack of previous interaction with predatory species (Nagaoka, 2002b), means flora and fauna in island environments often present extreme reactions to human settlement. In addition to research on marine resources there have been a number of studies devoted to the various land birds indigenous to the South Pacific islands, which focus on the decimation of their populations upon initial settlement of the islands (Nagaoka 2002b). At the Shag River Mouth site in New Zealand, Nagaoka (2002b) determined that the indigenous Moa (a now extinct land bird) was harvested from the local environment to the point of depressing the species' abundance. Resources from the Shag River Mouth were classified as having come from one of three possible patches (offshore –requiring a canoe, coastal, and inland) (Nagaoka 2002b:424). Each patch was considered independently in relation to the abundances of high ranking species (since the ranking is based on body size and the Moa is one of the largest taxa present they are considered very highly ranked in this analysis) in relation to lower ranking species, and in relation to the frequency of patch exploitation. Nagaoka (2002b:437) determined that high ranking prey from both the inland (Moa) and coastal (Seal) patches were depressed due to overharvesting and that it was only after decline of these two species that the offshore patch began to play an important role in the subsistence economy of the site.

The most common obstacle to arguing for the presence of resource depression is the possibility of alternative explanations for the observed patterns. Resource depression is a change in the faunal assemblage indicating that at one time there was a targeted species which was harvested intensively and, due to its decline in the environment, was replaced with one or more alternative species. This change in the assemblage can manifest in several ways. Changes in the relative abundances of represented species, an average decline in the size of the harvested species, reduction in the average age of harvested species, and alteration of utilized resource patches are all variables that may imply resource depression. Although all of these variables may indeed indicate that the human population depressed the favoured food species, they may also imply an

environmental alteration affecting the local biota, a shift in the subsistence technology spurred by choice rather than necessity, or a change in cultural attitudes restricting the harvest of particular species.

In the Kingdom of Tonga, the depression of food fish has been observed in the central islands of Ha'apai. The Ha'apai Islands are predominantly coral atolls with drainage not suitable for productive agriculture. The site of Faleloa, for example, is located on a beach on Foa Island, and is estimated at over 750 m<sup>2</sup> (Burley 1998). There is an abundance of fish remains recovered beginning at initial settlement, and continuing through later occupation. Continued occupational presence from initial settlement and a consistently large fish assemblage suggests that the surrounding reef environment was an important resource. In the earlier levels the assemblage is characterized predominantly by species in the Lethrinidae family, a common food fish throughout the South Pacific. Over time there was a decline in the Lethrinidae, coinciding with an increase in the presence of Acanthuridae (Cannon and Cannon 2001).

Similar results were found at Mele Havea on Ha'afeva and Vaipuna on 'Uiha. While Faleloa indicated an inverse relation between Lethrinidae and Acanthuridae, Mele Havea and Vaipuna show slightly different results. In the earlier levels of both sites there is a more even distribution of Acanthuridae and Lethrinidae (Cannon and Cannon 2001). In the later occupation levels however both Mele Havea and Vaipuna have more than three times as many Acanthuridae as they do Lethrinidae, indicating an extreme shift in the abundances of the fish families (Cannon and Cannon 2001). Tongoleleka on Lifuka and Pukotala on Ha'ano present different patterns than Faleloa, Mele Havea and Vaipuna. At both of these sites Acanthuridae are more abundant than Lethrinidae consistently from initial occupation (Cannon and Cannon 2001). There is no shift in family abundances at these two sites, which would indicate no shift in the harvesting strategies. While no argument is made for resource depression at these sites, the presence of the smaller bodied Acanthuridae suggests that from initial settlement the reef surrounding Tongoleleka, and possibly Pukotala as well, was harvested intensively resulting in the

greater abundance of less desirable fish from initial settlement (Cannon and Cannon 2001).

Unlike Groube's (1971) interpretation of changing fish use on Tongatapu, the correlation between the decline of Lethrinidae with the increase of Acanthuridae, without significant alterations in the subsistence economy suggests that settlers did not shift their harvesting due to a shift in the economy, but due to the depression of Lethrinidae at Faleloa, Mele Havea and Vaipuna (Cannon and Cannon 2001). In addition to the increase of Acanthuridae through time there is also the presence of families such as Diodontidae and Balistidae which are considered less desirable as food fish due to their smaller size (Allen, 2002) and the possible presence of toxins (Randall et al. 1996) at all five of the examined sites (Cannon and Cannon 2001). This presence of less desirable taxa, in addition to the increase of the smaller bodied Acanthuridae, and decline or absence of the Lethrinidae family, supports the argument that the surrounding reef environments in the Ha'apai Islands were intensively pressured due to human harvesting (Cannon and Cannon 2001).

The Cook Islands provide another example of islands where human induced resource depression of marine resources has been argued. Sites in the Cook Islands have been the subject of investigations by Kirch et al. (1995) who conducted excavations during the early nineties, while the fish remains from Tangatatu, Mangaia, were analyzed by Butler (2001). The marine environment of Mangaia, in the Southern Cook Islands, is mainly fringing reefs though there are offshore resources available as well (Butler 2001:89). Overhanging cliff-faces offer limited access to these marine resources, and the agricultural possibilities on the island are limited to small alluvial basins and valley bottoms abutting the relatively unproductive limestone ring around the island. Tangatatu is a rockshelter, near a limestone reef environment, located on the south facing shore of Mangaia (Butler 2001:90). The radiocarbon dating from the site suggests human occupation between 1000 and 1700 cal AD (Butler 2001:90).

The 3.2 mm screening of material from Tangatatu recovered a large quantity of bone and teeth, 90% of which is identified as fish (Butler 2001). The fish assemblage was composed of not only marine fish but also freshwater fish. Analysis of the fish was conducted primarily on seven paired elements: dentary, premaxilla, maxilla, hyomandibular, cleithrum, quadrate, and articular (angular) (Butler 2001:90). The fish assemblage was 80% composed of the following six families: Eleotris sp., *Anguilla* sp., Serranidae, Cirbitus sp., Labridae, and Acanthuridae. Due to the presence of fish remains from both the surrounding reef environments and freshwater systems on the island, the analysis of shifts in the assemblage was conducted separately for those from the marine patch versus the freshwater patch. To test for temporal shifts in resource procurement, particularly attempting to identify if there was an intensification of the fisheries, Butler (2001) conducted an osteometric analysis of average body size of the dominant species for each patch to determine if the sizes of the favoured fish declined over time. The osteometric analysis was conducted on the dentaries of Serranidae (marine patch) and *Anguilla* sp. (fresh water patch) (Butler 2001). While the osteometric results indicate that there is a general decline in average fish body size, which could be explained by an intensification of the fisheries, this pattern could equally be explained by an environmental alteration, or an independently chosen technological change targeting smaller bodied fish (Butler 2001:93). In order to rule out both of these alternative explanations for the present pattern, Butler (2001) examined the presence of fish hooks at the rockshelter, and pollen and sediments from the island. While there is a change in the abundances of the fish hooks at the site, Butler (2001:94) argues this is not due to shifting subsistence economies but is instead related to patterns of discard. While the environmental data indicate that silt run-off would have altered the freshwater systems of the island, it is difficult to determine if this change would have affected the average body size of freshwater fishes (Butler 2001:95-96). Although the freshwater species may have been affected by environmental changes on the island they would not have had a significant impact on the marine patch or available fish therein (Butler 2001:96).

Based on Serranidae dentary measurements, which indicate a decrease in average size over time, coupled with the assumption that the environmental degradation due to silt run-off did not significantly affect the local marine environment, Butler (2001) argues Serranidae were depressed due to human harvesting practices. The over-exploitation of Serranidae forced fishers to rely on smaller fish from the same family, as well as a wider variety of smaller taxa (Butler 2001:93). This over-exploitation is only evident in the marine patch; the fresh water *Anguilla* dentaries indicate no significant change in size over time (Butler 2001).

### **Importance of Marine Resources**

It is evident that in some locations Lapita settlers exerted pressure on the reef systems. However, other studies contradict assumptions that this pattern characterizes the South Pacific subsistence economy for the entire region. Studies in the Pitcairn Islands in Marginal Polynesia and the Palau Islands in Micronesia both demonstrate that the marine environment was indeed an integral aspect of initial subsistence but make no claim that the resources were depressed due to over-harvesting.

Henderson is a limestone island, 36 km<sup>2</sup> in size with a maximum elevation of 33m in the Pitcairn Island chain, in Marginal Polynesia (Weisler 1994:85). The north-eastern and north-western coastal areas are dominated by fringing reefs while the southern coasts are cliff faces (Weisler 1994:85). While the geology of Henderson is not generally conducive to agricultural success, there are isolated areas which have soil suitable for the maintenance of gardens (Weisler 1994:85). Several explorations have led to the discovery of more than 20 sites on Henderson, many of them rockshelters or caves; but also several burials and other site forms, including garden locations (Weisler 1994). Between all of the site types and locations, approximately 5.5m<sup>2</sup> were excavated using 6mm mesh with bulk samples sieved through both 3 and 1.5mm mesh as well (Weisler 1994:87). The radiocarbon dates from the excavated sites indicate a range of occupation dates between the sites, spanning a range from approximately 1200 cal BP to 100 cal BP (1 sigma) (Weisler 1994:91). The faunal record from Henderson implies a strong reliance



on both bird and fish resources (Weisler 1994:95). The fish assemblage, composed of over 8000 specimens, is comprised most commonly of Elasmobranchii (*Shark or Ray*), Holocentridae, Serranidae (*variola louti*), Carangidae, Labridae, Acanthuridae, Scaridae (*scarus* and *calotomus*), and Diodontidae (Weisler 1994:95). Although it is clear that fish were part of the subsistence economy at these sites, analysis of the fish remains is still in progress so there are no data on potential changes occurring within the fish assemblage. The fish assemblage from Henderson is significant as it provides the largest assemblage collected from any of the Eastern Polynesian Islands thus far (Weisler 1994:95). While it is not necessarily a large assemblage in comparison to other areas of the South Pacific, such as those recovered from Ha'apai (Cannon and Cannon 2001), that it represents one of the largest assemblages in the more remote Polynesian Islands may be indicative of shifting resource use between the settlement of the Western and Eastern Polynesian Islands. While the marine environment is argued to be an important part of the subsistence economy on Henderson, the abundance of bird remains implies that here the local avifaunas were also an integral component of the subsistence economy (Weisler 1994:97).

In the Micronesian archipelago of Palau it is argued that the diversity of fish and their relative abundances are due to the geological diversity of the islands making up Palau (Fitzpatrick and Kataoka 2005:1-2). The Palau islands are referred to as the Rock Islands due to their geomorphology, which consists of volcanic and limestone with poor drainage. The archipelago in general has a very diverse environment, ranging from the reef islands in the south to the volcanic and limestone islands in the north. The site of Chelechol ra Orrak located in the northern part of the archipelago is situated on the coast with numerous rock shelters and overhangs adjacent for shelter (Fitzpatrick and Kataoka 2005:3). The earliest occupation of Chelechol ra Orrak is dated to between 3300-3000BP (Fitzpatrick and Kataoka 2005:3). While most material recovered at the site (and making up the analysis) is from the upper layers, circa 1700 BP, the presence of fish bones in the



earliest cultural deposits and all subsequent occupation layers indicates that fishing in Palau is likely to have occurred since initial occupation (Fitzpatrick and Kataoka 2005:5).

The fish material was wet screened through 1/8<sup>th</sup> inch mesh, the preservation of material was excellent and the excavations produced over 8000 specimens. The fish were identified primarily with the five typical mouth elements: maxilla, premaxilla, dentary, articular and quadrate, however, several morphologically specific elements were chosen for additional identification including pharyngeal plates (Scaridae), dorsal spines (Balistidae) and dermal spines (Acanthuridae) (Fitzpatrick and Kataoka 2005:6). The majority of specimens were in the Scaridae family. The top six Osteichthyes families represented were: Scaridae, Serranidae, Acanthuridae, Labridae, Lethrinidae and Diodontidae.

The marine environment surrounding the island is predominantly sand flats bordered by shallow coral reefs, which are the major habitation environments for Scaridae, explaining their predominance at the site (Fitzpatrick and Kataoka 2005:7). The diversity of families represented at the site indicates that a range of marine patches were likely utilized, including the sand flats, lagoonal environments, coral reefs, as well as sea walls and surge channels (Fitzpatrick and Kataoka 2005:7).

The results from the Northern Rock Islands were compared to the southern islands because of the high degree of biodiversity in the marine environment of Palau. This was done to examine different harvesting strategies through time in the archipelago (Fitzpatrick and Kataoka 2005). While this study was focused on a different point in the occupation history of the Palau Islands, the results were compared to the analysis conducted by Masse (1989) of changes in the fishing strategies during the period AD 650 -1900's, on the smaller Southern Rock Islands.

While the comparative analysis indicates that harvesting patterns on the Northern Rock Islands fit relatively well with the Southern Rock Islands, where fish on the lagoonal sand flats (parrotfish) and sea walls and surge channels (sea bass and parrotfish) are prevalent (Fitzpatrick and Kataoka 2005:7), there are some obstacles to the validity of this comparison. To ensure the full range of fish families and sizes were represented,

Fitzpatrick and Kataoka (2005) wet screened the fish material through 1/8 inch mesh, while the excavation material analysed by Masse (1989) was only screened through 1/4 inch mesh, leading to potential loss of smaller fish material. While initially it appears as if subsistence activities throughout the north and south islands of Palau are similar in their location and chosen fish family for harvest, the subsistence strategies in the south may actually be more diverse than initially thought, depending on the diversity of smaller fish.

Temporal analysis of the site, indicates that reliance on fishing declined from initial occupation (as was argued by Masse for the southern islands) but did not reveal any significant indication that resource depression was the cause for decline (Fitzpatrick and Kataoka 2005:11). This pattern of decreasing reliance on the marine patch has been observed in several other areas of the South Pacific with different interpretations as to what this implies about the subsistence economy of the islands, including a strandlooper economy on Tongatapu (Groube 1971), and such reliance on the reefs that it leads to resource depression on Mangaia in the Cook Islands (Butler 2001). However, based on the analysis at this time, it is impossible to rule out any of these potential causes for change in the faunal record.

### **Horticultural Predominance**

While researchers arguing that the marine environment was an integral aspect of the subsistence economy are often working with assemblages rich in fish remains, many of those arguing for a horticultural focus are working at sites with few or no fish remains. This lack of abundant remains from the marine environment is used to validate the claim that horticulture was brought with the Lapita to each of the islands during initial settlement. Other proponents of a predominantly horticultural economy base their interpretations not on the faunal assemblage but on the macrobotanical or pollen remains.

In Vanuatu, Horrocks and Bedford (2004) conducted a microfossil and pollen analysis to determine if horticulture was a component of the initial occupation of sites in the Remote Oceanic Islands. The island of Uripiv is a small island (under 2km<sup>2</sup>) off the northeast coast of Malekula, one of the largest islands in Vanuatu (Horrocks and Bedford

2004:68). The site examined contains evidence of Lapita occupation and is located on the Western coast of the island surrounded by beach flats, with fringing reefs along the eastern coasts (Horrocks and Bedford 2004:68). Pollen and microfossils from early levels of excavation were examined against the native flora of Vanuatu to identify whether the domesticates were locally derived. The remains recovered from the initial occupation phase did not have any connections to the pre-existing flora on Vanuatu. The Bismarck Archipelago in Melanesia is the only other area that has had microfossil evidence of food plants associated with the Lapita occupation phase (Horrocks and Bedford 2004:71). The evidence of introduced food plants in conjunction with similar patterns in the Bismarck Islands and macrobotanical evidence of horticulture in Massau (Kirch 1989), led to the conclusion that horticulture must have been an essential component of the Lapita subsistence economy, since the evidence suggests that cultivates were transported and introduced during the Lapita occupation phase, and were not a later (during the Polynesian Plainware) introduction (Horrocks and Bedford 2004:72).

In contexts where remains from the marine environment are abundant, resource depression as a result of over-harvesting is often observed, such as on Ha'apai (Cannon and Cannon 2001) and Mangaia (Butler 2001). This concentration on resource depression has likely emerged from a combination of Groube's (1971) 'strandlooper' theory, the notion that island environments provide a natural laboratory in which human induced environmental changes can be easily studied (Nagaoka 2002a), and the recurring pattern of settlement and depression of multiple resource bases on small Pacific islands (Butler 2001; Cannon and Cannon 2001; Nagaoka 2002b). However, these examples of intensive marine-based subsistence economies are equally matched by examples where the marine environment plays a relatively diminished role in the overall subsistence economy of the island or archipelago. In Tongatapu we see the reliance on surrounding reefs only until the establishment of stable agricultural practices (Groube, 1971). Similarly the importance of agriculture overshadows that of the marine environment in Vanuatu (Horrocks and Bedford 2004) and, as this study will show, potentially the Vava'u Islands of Tonga as well.

Similar to the present study, the Southern Cook Islands also indicate declining importance of marine resources throughout the occupation history. Unlike the present study, changing fish abundances on the island of Aitutaki are associated with both the depression of favoured fish - at mainland sites - and a shift in fishing technology - at special purpose sites - (Allen 2002). Aitutaki is an 'almost atoll' of approximately 16km<sup>2</sup> in size comprised of a volcanic mainland, a lagoon with two volcanic islets, and several coastal coral islets, in the Southern Cook Islands (Allen 2002:196). Allen (2002) explored the fish assemblage of 15,000 identified specimens from four sites; mainland sites of Ureia, Hosea, and Aretai, and MR-1 on Moturakau (one of the volcanic islets). MR-1 is a special purpose; fishing and basalt production rockshelter site (Allen 2002:198). These four sites span an occupation history of 1000 years beginning approximately 1000 BP (Allen 2002:196).

The mainland sites of Ureia, Hosea and Aretai, indicate a general decline in fish bone densities from the initial occupation through to the historic period (Allen 2002). However this decline is seen most dramatically at the MR-1 where the density dramatically declines from 6046 NISP/ m<sup>3</sup> in the earliest layers to 563 NISP/m<sup>3</sup> (Allen 2002: 201).

Temporal analysis at Ureia indicates that larger-bodied nearshore (highly ranked prey) fish decline in abundance throughout the occupation history (Allen 2002:203). There is an associated increase in off-shore resources indicating the *potential* depression of favoured inshore fish necessitating a shift to the offshore patch (Allen 2002:203-204). MR-1 on Moturakau indicates a different pattern of use, here there is the decline of off-shore fishing and an increase in the large-bodied nearshore fish abundances. As a special purpose site MR-1 is not believed to have been permanently inhabited which may explain the lack of identified harvesting pressure on the surrounding marine resources, additionally examination of the fishing gear indicates that the decline of off-shore fish coincides with the loss of pearl fish hooks, indicating the pattern on Moturakau may be

due to a change in fishing technology – specifically a move away from single capture techniques (Allen 2002).

It is clear from the relatively few studies here that there is diversity in the subsistence economies of South Pacific Islands, and that settlement strategies may not be dependent on the local environment but instead that the subsistence strategy employed depends on the island encountered. The geological differences between the lagoonal Tongatapu, coral limestone atolls of Ha'apai and the volcanic and fertile Vava'u, in addition to the diverse nature of their fish assemblages allow for an examination of how the Lapita adapted their subsistence economy for each environment they encountered. Vava'u presents a key set of data in establishing the essential diversity of subsistence strategies of Lapita settlers and highlights the fact that settlement strategies are not necessarily regulated by a standardized subsistence economy.

## Chapter 2: Context and Methods

### Tonga

Tonga is a double island chain in Remote Oceania on the Austral-Indian Plate divide, consisting of both active volcanic islands and coral limestone islands (Burley 1998; Fall 2005:452; Irwin 2008). The Pacific tradewinds create a mild tropical climate for the Tongan Islands (Fall 2005:452) and facilitate vertical movement between the groups along a natural current corridor running south to north (Burley 1998). Active volcanic islands form the western island chain including; Late, Fonualei, Kao, Tofua, Metis Shoal and Falcon (Cunningham and Anscombe 1985:228-229; Ewart et al. 1973:431). These islands have limited reef access, which may contribute to their lack of human occupation, but do provide a natural source of basalt for the material culture recovered from Tongan sites (Burley 1998:339). The limestone islands (where settlements are located) can be divided into three major groups; the southernmost Tongatapu, the central Ha'apai Islands and the northernmost Vava'u Islands (Burley 1997; Cunningham and Anscombe 1985; Ewart et al. 1973).

The native fauna of Tonga are quite limited. There are native landbirds which could have contributed to initial subsistence strategies (Burley 1998:340), though Steadman (1997) argues that Lapita settlement caused resource depression and subsequent extinction of a number of landbirds throughout much of the Kingdom of Tonga. There are no native mammalian species besides the fruit bat (Burley 1998:340). There is little native flora that could be harvested for subsistence (Burley 1998:340), and the act of burning the local flora may have led to the extinction of several plant species on the islands (Fall 2005:457). There are three major classes of vegetation on the Tongan islands: coastal forests, which were widespread on the low coral islands, lowland rainforests on the islands with moderate elevation (a few meters above sea level (masl)), and diverse tropical hardwood forests on those islands which have high elevations, up to 300 masl, including 'Eua and 'Uta Vava'u in Tongatapu and Vava'u respectively (Fall 2005:452). Fall (2005) argues the extinction of land birds could lead to significant

changes in the vegetation of the islands, since birds were often central to the seed dispersal of many of the pre-existing plants. Despite the lack of native flora which could be utilized for subsistence, the soil at many of the occupation sites is fertile and well suited to agricultural practices, particularly in Tongatapu, where major sites are in lagoonal environments, and in the Vava'u Islands.

On the basis of radiocarbon dating, Tongan history is argued to have begun between 2800 and 3000 cal BP (one sigma calibration), on the southernmost island of Tongatapu (Burley 1992; Burley et al. 1999). The occupation of Tonga is thought to have been continuous since this time, undergoing several distinct 'phases' and becoming a chiefdom before European explorers arrived (Burley 1992). The three phases of occupation during the prehistory of Tonga and other Polynesian island groups within the eastern Lapita horizon are determined by ceramics (Burley 1994; Kirch 1978). The Lapita period, which is the initial settlement and occupation phase, is characterized by distinctive dentate stamp pottery from which the Lapita received their name. This is followed by the Polynesian plainware phase and finally the aceramic phase.

Extensive research has been conducted on the islands of Ha'apai (Burley 1992, 1998; Burley et al. 1999; Shutler et al. 1994) and Tongatapu (Burley and Dickinson 2001; Groube 1971; Poulsen 1987; Steadman 1997), but until recently, relatively little exploration of the Vava'u Islands had been carried out. The first settlement in Tonga is on Tongatapu ca. 2800 - 3000BP; from there Lapita settlers expanded north to the central Ha'apai Islands and northern Vava'u Islands (Burley 1998; Burley and Dickinson 2001).

### **Vava'u**

The Vava'u Island group consists of 71 islands, most of which are coral limestone (Crane 1992). The most productive reefs surround the south and east islands (Burley 2009). In comparison to Tongatapu and Ha'apai, relatively little archaeological exploration has been conducted in Vava'u (Burley 2009:3). Archaeological study in Vava'u can be divided into three phases. In the 1920's William McKern (1929), identified 15 archaeological sites in the Vava'u Islands, though this identification of sites



was the extent of McKern's research. Janet Davidson (1971) revisited the Vava'u Islands to conduct an extensive survey. Her conclusions were that there was a ceramic presence in the islands and that a number of excavations should be conducted on a variety of them, to determine the scope of occupation. From the 1990's to the present Dr. David Burley has been surveying and excavating the Tongan islands, including the Vava'u group, with the intention of understanding Tongan transitions from the Lapita ceramic period to the Polynesian Plainware ceramic period (Burley 1992, 1997, 2009).

When the initial survey was conducted in the Vava'u Islands, to maximize the number of Lapita occupation sites discovered, the survey was focused on locations which met the following criteria: proximity to a reef, access for canoe travel from the beach and a large and protected area for the settlement of villages. Sites were identified on present day back beaches (beach area above the maximum tidal range, inland of the current shore (pers. comm. Burley 2010)), indicating that the shoreline during the initial Lapita occupation was equivalent to today's shoreline (Burley 2009:4). The survey identified five Lapita sites, 12 Polynesian Plainware middens and 20 Polynesian Plainware scatters, and is believed to be representative of the distribution and proportion of sites in the Vava'u Islands (Burley 2009). The Polynesian Plainware phase in Vava'u is distinct from that in the southern Tongatapu and Ha'apai islands (Burley 2009:8). In the southern Tongan Islands the Polynesian Plainware phase is not only characterized by the shift in ceramics but also by an intensification of agriculture and an increase in inland settlements (Burley 1998). All of the Lapita phase sites in Vava'u are in locations that indicate horticulture may have been a consideration in the initial occupation (Burley 2009:8). It has been established that the Lapita colonizers of Tonga brought a range of domesticate food floras and faunas with them during initial occupation (Burley 1992:127). Furthermore, all the Lapita settlements in Vava'u are located in an area where cultivation of *Colocasia* and/or *Cyrtosperma* taro (a common domesticate in Tonga) could be successful (Kirch 1997:211). Settlement patterns of the Polynesian Plainware phase in Vava'u generally follow the existing Lapita settlement strategy, with the addition of new



sites on larger islands (Burley 2009). The sites examined here are four of the five sites that contain material from the Lapita period; Falevai, 'Otea, Ofu, and Vuna.

The subsistence economy of Lapita settlers in Tonga has been the source of study in both the southern Tongatapu (Groube 1971) and central Ha'apai Islands (Cannon and Cannon 2001). These studies have led to different interpretations concerning the nature of the subsistence strategies of the settlers and the impact they had on the local reef environments. In Ha'apai, as elsewhere in the South Pacific, it is argued that reef environments were an important aspect of the subsistence economy and that the fishing strategies pressured the reefs to the point of diminishing select resources (Cannon and Cannon 2001). In contrast to Ha'apai, on Tongatapu marine resources are argued to have been a secondary resource used mostly during initial settlement to provide an alternate food source before intensive agricultural practices were implemented (Groube 1971). The disparity in the importance of marine resources on different island settings in Tonga makes the unstudied Vava'u group an intriguing case, which very clearly indicates that the practices of settlers in the South Pacific were much more diverse than argued in generalized subsistence economy models. Vava'u also provides a unique opportunity to view changes in subsistence economies between the Tongan and Samoan archipelagos as it sits in a natural current corridor between the southern Tongan Islands and the northern Samoan archipelago (Burley and Connaughton 2007:131), and is the last portion of the Kingdom of Tonga to be settled before the Lapita moved north to Samoa.

### Characteristics of the Faunal Sample



Figure 2.1: Locations of Lapita occupation sites in Vava'u Islands, Kingdom of Tonga. (modified from Burley 2009)

All four sites are located in the southern portion of the Vava'u Islands, and excavations were conducted in 1m x 1m units. The preservation between sites seems to be comparable; each site's faunal assemblage is well preserved and in most cases the morphological features of individual elements are well defined. While the assemblages are generally well preserved, they are also highly fragmented. None of the four assemblages are particularly dense, when compared to the size of fish assemblages recovered from sites on the islands of Ha'apai. All of the Vava'u radiocarbon dates presented, are to one sigma calibration.

*Falevai*

Falevai is on the west coast of Kapa island located in the southern region of the Vava'u group (Fig 2.1). The site is 600m<sup>2</sup> in size, of which 13m<sup>2</sup> were excavated to a maximum depth of 1.8m during the 2004 season (Burley 2009:6). Eleven of the excavated units contained fish remains, and all were analysed in the present study. Falevai is different from the other three sites in that initial occupation occurs later here than at 'Otea, Ofu or Vuna, at the end of the Lapita phase into the Polynesian Plainware phase (Burley 2009). There were three radiocarbon dates taken from Falevai, the earliest (2779-2733 cal BP) is within the Lapita occupation, while the other two (2760-2620 cal BP and 2685-2362 cal BP) are both part of the Polynesian Plainware phase (Burley 2009:8).

*'Otea*

'Otea is on the east coast of Kapa Island located in the southern region of the Vava'u group (Fig. 2.1). The site is 800m<sup>2</sup> in size, 16m<sup>2</sup> of which were excavated to a maximum depth of 2.0m in the 2004 season (Burley 2009:6). Excavated units 1-15 contained fish remains, 14 of which were analysed in the present study. There were three radiocarbon dates collected from 'Otea. The two early dates (2790-2740 cal BP and 2693-2363 cal BP) are within the Lapita occupation and the later date (1516-1407 cal BP) is part of the Polynesian Plainware phase (Burley 2009:8).

*Ofu*

Ofu is located on the southwestern coast of Ofu Island in the southern region of the Vava'u group (Fig. 2.1). The site is 1500m<sup>2</sup> in size, 22m<sup>2</sup> of which were excavated in 2005 to a maximum depth of 0.9m (Burley 2009:6). Excavated units 2-22 contained fish remains, and 13 were analysed in the present study. There were two radiocarbon dates collected at Ofu (2854-2769 cal BP and 2755-2545 cal BP) both of which fall within the Lapita occupation (Burley 2009:8).

*Vuna*

Vuna is located on the Pangaimotu island in the south-central region of the Vava'u group (Fig. 2.1). The site is 1500m<sup>2</sup> in size, 26m<sup>2</sup> of which were excavated to a

maximum depth of 1.3m during the 2004 season (Burley 2009:6). Thirty-two of the excavated units contained fish remains, 14 of which were sorted for isolation of the fish material and three of those were analysed in the present study. There were three radiocarbon dates collected for Vuna (2837-2744 cal BP, 2762-2621 cal BP, and 2668-2358 cal BP) all of which are within the Lapita occupation.

### *Sampling*

All of the material examined was screened in the field through 3.2mm mesh screen. The use of 3.2mm mesh allows for in depth comparison of material analysed by Cannon and Cannon (2001) from Ha'apai to Vava'u, as the sites in Ha'apai were also screened through 3.2mm screen. The screen size used by excavators can significantly impact the comparability of different faunal assemblages, as well as interpretations during a single site analysis. The smaller screen sizes allow for the recovery of smaller taxa, which can be lost if larger mesh sizes are used. Screen size is a particularly pertinent methodological obstacle in the analysis of fish remains. Fish remains are often much smaller than mammalian remains, and when taphonomic processes lead to fragmentation and deterioration, they can become unrecoverable even within the 3.2mm mesh.

There is extensive debate within zooarchaeology over whether the inclusion of smaller mesh sizes during excavation yields a more complete and useful dataset (Densmore 2009) or simply adds to the fragmented and unidentified portion and is outweighed by the costs (Vale and Gargett 2002). The extreme range of body size – and thus bone size – of reef fish means a large number of elements are too small to be recovered using the larger mesh sizes, and in some cases entire families may be lost due to their small body size. Fish morphology and preservation issues coupled with the restriction to 3.2mm mesh and not smaller sizes means these assemblages may be biased towards the recovery of larger bodied fish. This has interpretive implications, as changes in the sizes of fish being harvested can be indicative of harvesting pressure, or a shift in the fishing practices.

A pilot examination of unit 16, from the Faleloa excavations conducted in 1997, revealed that within the smallest mesh size (1/16 inch) additional identifiable vertebrae

were recovered (Densmore 2009), indicating the importance of a fine mesh recovery, particularly where changes in the fish assemblages are being examined. In Ha'apai the examination of the fish assemblages conducted by Cannon and Cannon (2001) indicated that as the Lethrinidae declined it was the smaller bodied fish which were harvested as alternatives. If smaller bodied fish are frequently relied upon, in the case of resource depression, as has been shown by both Butler (2001) and Cannon and Cannon (2001), then the use of smaller mesh sizes in the recovery of fish material is also essential for accurate osteometric analysis as well as for documenting changes in the abundance and diversity of small-bodied fish within an assemblage. The neglect of smaller mesh sizes can significantly colour interpretations concerning fishing strategies at a given site. A lack of recovery of small bodied fish may imply that the size variation present at the site is more homogenous than it actually is, which could lead to mistaken assumptions about harvesting techniques (i.e., nets that are larger than the missing small-bodied remains) or the use of selective harvesting, targeting larger-bodied fish. It can also lead to assumptions about temporal characteristics of the assemblages. If smaller-sized screening is not conducted, then smaller-bodied fish used as supplements for depressed fish may be absent from any analysis. This could lead to the mistaken conclusion that when Lethrinidae began to decline there was a shift away from the reefs, since the remains of small-bodied fish used as replacement would be absent.

Screen size is an unavoidable concern for zooarchaeological study and in Vava'u, where there is an abundance of large bodied fish and an absence of smaller remains, it is recognized that there are potentially small-bodied fish missing from these assemblages as a function of the screen size used during excavation. However, while the loss of material cannot be controlled for, the comparative restrictions presented by screen size can be considered negligible in the present study. The sites in Ha'apai and Vava'u were excavated and screened in the same fashion. Therefore, while we may be losing families of fish too small to be caught by the utilized screen, we can expect them to have been lost in both Ha'apai and Vava'u, maintaining comparability among the families recovered.

A defining characteristic of the fish assemblages from Vava'u is their size. All four assemblages examined in this study are significantly smaller than those recovered from excavations in the Ha'apai islands. While the small size of the assemblages can be viewed as limiting the interpretive possibilities of the sites to coarse-grained analysis, it does provide an interesting comparison to the general interpretations of Lapita subsistence strategies and the relative importance of marine resources during initial and continuing occupation phases among different archipelagos.

### **Identification**

The identification of fish remains was done using the tropical marine comparative collection housed in the Fisheries Archaeology Research Centre at McMaster University. In addition to this collection the comparative collection from Simon Fraser University (currently held at McMaster) was also used.

The morphology within South Pacific fish families makes identification difficult when attempting to identify specimens to the species level. Additionally, certain families of South Pacific fish are morphologically quite similar, making it complicated even to distinguish between certain families. Analysts studying fish remains in the South Pacific often practice selective identification, choosing particular elements to identify. The five mouth elements (premaxilla, maxilla, dentary, articular, and quadrate), or elements of the vertebral column are frequently selected for identification, with the addition of other elements if needed (Butler 1994; Fitzpatrick and Kataoka 2005; Nagaoka 2002).

When analysing these four sites I did not selectively identify elements for three main reasons: 1) the diversity of morphologies between South Pacific fish, 2) the fragmentation, preservation and general size of the assemblages, and 3) my previous unfamiliarity with South Pacific fish families and their distinguishing features.

### *Morphology*

As stated, families of fish in the South Pacific exhibit diverse morphologies. This does not only lead to difficulties with identification, but also leads to differential preservation of elements within a particular fish and the same element between families

of fish. For example, Scaridae (Parrotfish), which are abundant in these assemblages, subsist on algae which grow on coral. This requires them to bite and break off portions of coral which are then ground in the throat and released back into the water (Randall et. al 1996:342). This requires robust mouth elements, which in the parrotfish are very distinct, while their vertebrae, especially in younger, smaller specimens, can be comparatively delicate, making them more susceptible both to fragmentation and preservation concerns. Other families such as Acanthuridae (unicornfish, doctorfish), which are herbivores that eat floating debris (Randall et. al 1996:419), have very delicate mouth elements which are not often recovered in the archaeological record since they typically do not preserve well. However, Acanthuridae are well represented by their vertebrae, which typically are morphologically unique. This inconsistency in preservation demonstrates the danger of selective identifications, potentially resulting in the under- or over-representation of certain families.

#### *Researcher Obstacles*

In addition to morphological obstacles during identification, there are analyst biases which can affect the degree of identification (Beck and Jones 1989; Gobalet 2001). Prior to this project I did not have experience identifying South Pacific fish, which meant I was unfamiliar with the unique and identifying features of specific fish families. As Beck and Jones (1989) note; even among practiced analysts there is bound to be at least some variation in the confidence of fish identification. They argue that there will also be minute changes within the confidence level of one analyst's identifications over time. When reexamining Falevai (the first of the four sites analysed) it became clear that even within this project the author's confidence in identification of families (particularly Acanthuridae) increased, as there were several additional bones included in the final analysis presented in Chapter 3.

While the comparative collections used in this project adequately represent the most common fish families represented in South Pacific archaeological contexts, they do not cover the entire range of diversity of available families. Therefore, if a bone did not match one of the available comparative specimens it was classified as 'unidentified'.

Many of the unidentified bones were fragmented or their features were obscured, either because there was coral sand fused to the bone or the features were eroded due to taphonomic processes; however, those pieces which were identifiable but not represented in the comparative collection were marked as being potentially identifiable with a different comparative collection.

### *Assemblage Characteristics*

The assemblages from the four sites in Vava'u are relatively small and the density of material that is identifiable is so low per unit and level that if certain elements had been chosen for selective identification the proportion of identified material would be so small that it would have been difficult to make any meaningful interpretations. Additionally, while the preservation of material was generally good, the fragmentation of elements is high. This led to the proportion of the assemblage that was deemed identifiable as comprising less than 25% of the material examined.

Due to the morphological diversity, and the relatively small size of the assemblages, the identification of bones was made as conservatively as possible for all elements from all taxa. To minimize the possibility of misidentification of morphologically similar taxa, unless an element matched one of the comparative specimens, it was considered unidentified. The conservative nature of the identifications coupled with the fragmentary nature of the elements left a large portion of assemblages unidentified.

### **Additional Procedures**

While most of the material could be identified without alteration there were some units from 'Otea that had coral sand fused to the bone; this was particularly present in the older layers. These specimens could not be identified until the sand was removed, as it obscured the identifying features on the bone. These specimens were soaked in a 10:1 water:vinegar solution to dissolve some of the bonds and remove the sand grains; this was successful in most cases. Certain pieces required additional cleaning and were treated in a sonicator, using a 10:1 water:solvent cleanser for up to 2 hours, this was effective in



removing the remaining sand. These procedures were effective in clearing away enough of the fused material to make the features on the bones visible for comparative purposes.

When identification was complete to the extent possible with the two available comparative collections at McMaster, there were several potentially identifiable specimens still unidentified. These had enough discriminating features present to warrant further investigation. These samples were taken to the Royal Ontario Museum (ROM) and compared to their comparative paleovertebrate collection. The collection at the Royal Ontario Museum yielded several additional identifications. However, even with the addition of the Royal Ontario Museum collection, there are still identifiable remains with distinct morphological features not represented by any of the three utilized comparative collection.

### **Osteometric Analysis**

Osteometric analysis is useful when considering potential changes in subsistence strategies. Size is a variable marking a change in the fish assemblage which is associated with a shift in the subsistence economy. Osteometric analysis can also indicate whether selective harvesting is occurring at a site. If the fish analysed indicate little diversity in size it can imply that selective capture may have been occurring, while if there is vast diversity in average fish sizes it could indicate that mass capture techniques (such as poisons or nets), which do not discriminate based on size, may have been employed.

Osteometric analysis conducted on the most abundant species, showing a decline in the average fish size through time, could indicate that pressure from fishing practices negatively affected the marine biota. On Mangaia in the Cook Islands, Butler (2001) measured the dentaries of the two most prominent fish families in the early levels, Serranidae from the marine patch and *Anguilla* from the fresh-water patch. From her analysis she concluded that, due to the combination of declining size and count of Serranidae remains and the increase in smaller, less productive food fishes like Acanthuridae, the marine patch was over-harvested, resulting in a shift to less desirable fish (small Serranidae and Acanthuridae) (Butler 2001:95). While the evidence from the

marine patch confirmed resource depression, the fresh water *Anguilla dentaries* showed no significant change in size through the occupation layers, leading Butler (2001) to argue that while the marine environment was negatively affected by the subsistence strategy of the settlers, the fresh water biota of the island were not significantly affected. In New Zealand, the historic marine patch was studied for changes in the sizes of fish harvested. In this case, although resource depression of the marine patch had been argued to be present, the size data did not reveal any significant changes (Nagaoka 2002b). The osteometric data were collected to explore both the potential for changes in fish size through time, indicating pressure on the preferred species, and differences in the capture techniques between sites.

As the density of fish remains in the Vava'u study was low, osteometric analysis was initially only conducted on vertebrae, as they were the most abundant element recovered in each assemblage. Only vertebrae that had their entire centrum intact were measured, to ensure standardization of the data. The measurement was taken laterally across the face of the centrum. The vertebra size data were analysed for the Serranidae family, which is the most abundant family at Falevai, 'Otea, Ofu, and among the three most abundant families at Vuna.

Morphological differences between recovered families (particularly Scaridae, and Diodontidae) led to differential recovery rates for identifiable elements. While the Serranidae and Lethrinidae families were well represented by their vertebrae, the Scaridae family is represented more commonly by the more robust mouth elements. The lack of Scaridae vertebrae coupled with the observation that there was a high degree of variability in Scaridae size between the sites, prompted additional osteometric analysis of Scaridae mouth elements. Scaridae osteometric data were collected from dental elements including the dentary, premaxillary, and upper and lower dental plates (used for grinding coral in the back of the throat). Figure 2.2 indicates where measurements were collected.

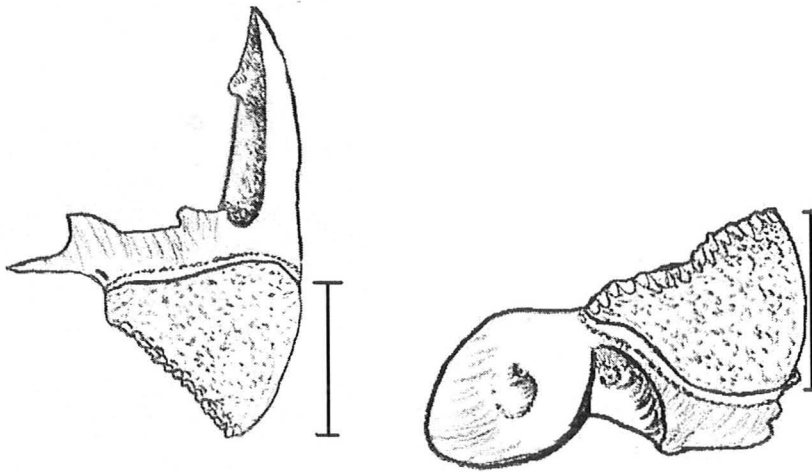


Figure 2.2: Scaridae mouth element measurements

*The Scaridae dentary and premaxilla measurements were taken along the grain of the teeth.*

### Quantification Methods

The most common quantification methods used by zooarchaeologists are Number of Identified Specimens (NISP), Minimum Number of Individuals (MNI), and Meat Weight measures. There has been extensive debate over the viability of both NISP and MNI as representative quantification methods.

Number of Identified Specimens (NISP) is calculated by counting the total number of skeletal elements and fragments of elements from particular taxa. Fragmentation becomes a concern when using NISP as it does not consider that the fragments being counted in each taxon's NISP may be from the same bone. This fragmentation can over-represent certain taxa, which are more susceptible to extensive fragmentation. While these assemblages are characterized by extensive fragmentation, the majority of highly fragmented remains are unidentifiable which will not affect the family abundances.

In addition to issues of fragmentation, the skeletal morphology of certain taxa can also skew abundance counts (Gilbert and Singer 1982:30). When analysing the relative counts of species which make up a faunal assemblage, the NISP of certain taxa may require modification to account for the advantage offered by their skeleton (Gilbert and

Singer 1982:30). This is particularly essential for fish with an abundance of the same element leading to over-representation of the fish in the sample (Grayson 1984). The morphology of Diodontidae (Porcupinefish), which can contain up to 350 dermal spines per fish (Randall et al. 1996), and are commonly represented by their spines in these assemblages, risks distorting its relative importance in the assemblages.

One way around the potential distorting effect of repeated elements is the calculation of Minimum Number of Individuals (MNI). MNI identifies the lowest possible number of live individuals required to create the archaeological assemblage. MNI is calculated from the most common paired element, assuming that all repeated specimens (e.g.: left hyomandibular from Serranidae) are from individual fish. There are several additional variables that need to be considered when calculating MNI including size, age and sex. With a range of species within families as wide as it is within many of the South Pacific fish families, it would be necessary to consider the size of each specimen when calculating MNI. The Serranidae family contains over 450 species ranging in full adult sizes from approximately 45cm to over 2m in length (Randall et. al 1996:89). If paired elements, such as the hyomandibular, were from different sides of the fish, they might be counted as one individual, but if they were of different sizes, they would need to be considered separate fish. To account for this factor, the size of fish would need to be determined before MNI could be calculated. Age and sex potentially present similar obstacles as size, though these variables are also closely correlated to size in most cases. The determination of fish age, sex and size is not warranted in this study. The small size of the assemblages means that there would be relatively little variation among families based on MNI calculations. The use of MNI in small samples, where certain taxa may only be represented by singular elements, can also over-emphasize the importance of the rarer taxa in an assemblage (Grayson 1984:54; Payne 1972). This issue is diminished in larger samples. The small size of the Vava'u assemblages increases the risk of inflating the importance of rarer taxa.

One way to reduce this inflation is to consider the abundances at an ordinal scale, limiting interpretations to discussions of taxa rank order abundance (e.g. Serranidae are

more abundant than Acanthuridae). The nature of the questions being asked concerning the relative importance of the marine environment and potential impacts of fishing practices only necessitates analysis on the ordinal scale. Using the same measure in the Vava'u analysis ensures comparability to the Ha'apai results.

### **Density**

The density of fish bones within the archaeological deposits can be used as an indicator of the relative importance placed on marine resources between locations and over time. On Tongatapu, Groube (1971:109) noted that the number and general density of fish remains decreased with the shift from the Lapita Phase to the Polynesian Plainware phase. Sites in the Ha'apai Islands show high densities of fish bones at all five sites examined and do not indicate any decline in density between the upper and lower deposits (Cannon pers. comm. 2010), suggesting marine resources remained important to the subsistence practices of the settlers. The consistently low density of remains at sites in Vava'u implies that marine resources were not as important to the subsistence practices as they were in Ha'apai or were initially on Tongatapu. The relative density of fish remains at the Vava'u sites and indications of decreasing density over time are consistent with other lines of evidence presented in chapter 3 that strongly suggest that the Vava'u sites were not dependent on fisheries for their subsistence needs. There are two depositional forces which can affect the validity of employing density calculations as a means of understanding relative importance of a resource: cultural deposition and natural deposition. Cultural deposition becomes of particular import when dealing with shell midden sites as an increase of waste deposits from other resources (i.e. shells) can decrease the density of fish bones, making it appear as if the fish resources had declined in importance, when in fact they had not. However, the sites being examined here are not shell middens and so we can assume that the density of fish bone remains is a valid proxy for relative importance of the marine resources. Natural deposition, or rather *differential rates* of natural deposition can limit the comparative analysis of fishbone density between sites. In the case of Ha'apai and Vava'u the comparison is between sites with similar

initial and terminal occupation dates – so similar time frames – which also have similar excavation depths, so, while not exact, the volume of matrix in both contexts covers roughly equivalent periods of occupation. Again, we can assume that any difference in the rate of natural deposition will have a negligible effect on the density interpretations.

### **Summary**

The density of fish remains and the relative abundances of the identified fish families indicate the focus, relative richness and diversity of fisheries at each site. These data indicate the importance of fishing and any similarity in harvesting practices between sites. The conservative nature of the identifications in conjunction with the size of the assemblages means that the identified portions of the assemblages are small, which creates some limitations for comparison. Several identified families are represented by a single bone. While it is important to acknowledge that these families are present at the site and that they add to the diversity of families, they do not necessarily indicate an increase in the richness of the assemblages, or represent regularly harvested families. The osteometric analysis is even more limited because of the small number of suitable elements available for comparison, but it provides another basis for comparison of fisheries between sites and over time. The overall results of the analysis of the fish assemblages from Vava'u provide a good comparison for understanding the diverse nature and importance of marine resources in Tonga and the South Pacific more broadly.

## Chapter 3: Analysis and Results

The following chapter outlines the results of the analysis. The density of fish bone remains is presented for both Vava'u and Ha'apai, and indicates the difference in intensity of fish use. To understand fishing practices at each site, family abundances are presented in chart and graph format. From basic family identifications it is clear that the preferred food fish in Vava'u was Serranidae as it is the most abundant family. Following the family identifications is a site to site comparison of the most prominent taxa to understand any preferential differences between sites. Vuna presents patterns distinct from the general preference for Serranidae in Vava'u and may indicate some connections to Ha'apai fishing strategies. Results from osteometric analysis of Serranidae vertebrae and Scaridae mouth elements are examined to address fish body size differences between sites. As outlined above, Tongan occupation history is divided into distinct cultural phases distinguished by the form and style of ceramic remains. This cultural shift has been identified to coincide to a shift in subsistence strategies from marine resources to an intensification of agriculture. Temporal analysis of the Vava'u assemblages was conducted to identify any changes in local marine resource use coinciding with the shift to the Polynesian Plainware phase.

### **Density of Fish Remains**

The density of fish bone recovered from occupation sites in Ha'apai is much higher than all sites examined from Vava'u. While Vuna can be characterized by a casual reliance on reef resources – as with the other three sites examined here – the higher density of bones, smaller body size of fish, and predominance of Lethrinidae, differentiate Vuna (Table 3.1, Fig. 3.1d) from other Lapita occupation sites in Vava'u while connecting it to Ha'apai. The Ha'apai settlements indicate that initially Lethrinidae were the preferred fish, which only declined when Acanthuridae became more abundant (Cannon and Cannon 2001). This is distinct from Falevai, Ofu and 'Otea in Vava'u where Serranidae were clearly the preferred fish. The fish assemblage at Vuna presents a

family distribution similar to Ha'apai in that the most abundant fish initially at Vuna was Lethrinidae. The early radiocarbon dates for Vuna, coupled with its relatively high density for a Vava'u settlement, and the distribution of Lethrinidae and Serranidae distinguish Vuna from both Ha'apai and Vava'u.

Table 3.1 Fish bone densities for Ha'apai and Vava'u (Ha'apai figures from Cannon and Cannon (2001) and Cannon pers. comm. 2010).

To ensure comparability only identified bones were utilized as available data from Ha'apai are presented in identified numbers. Since the same comparative collections were used in both studies we can assume similar representation of identified specimens.

Site	Excavated Matrix (L)	Fishbone Count	Density (bones/100L)
Mele Havea, Ha'apai	1700	830	48.8
Tongololeka, Ha'apai	1400	1204	86.0
Pukotala, Ha'apai	900	482	53.6
Falevai, Vava'u	9700	117	1.2
Ofu, Vava'u	23,600	284	1.2
'Otea, Vava'u	13,100	247	1.9
Vuna, Vava'u	3000	157	5.2

### Family Representation

The family identifications are presented first individually by site; the remains are broken down into the analysed units from which they were recovered. This was done to determine if the abundance of any recovered family is over-represented by an unusually high distribution in one analysed unit. The relatively even distribution of families throughout the analysed units indicates that no unit is disproportionately contributing to the abundances of families.



Table 3.2(a): Family Representation per Unit at Falevai, Tonga

Family	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9	Unit 10	Unit 12	Unit 13	Total
Acanthuridae	0	1	2	2	0	0	1	1	0	0	0	7
Balistidae	0	2	0	0	0	2	0	0	0	0	0	4
Carangidae	0	0	0	0	0	0	0	0	0	0	0	0
Diodontidae	3	2	10	1	1	2	2	1	3	1	5	31
Holocentridae	0	0	0	0	0	0	0	0	0	0	0	0
Labridae	0	0	0	0	0	0	0	0	0	0	3	3
Lethrinidae	0	3	0	3	1	1	0	0	0	0	2	10
Lutjanidae	0	0	1	0	0	0	0	0	0	0	0	1
Mullidae	0	0	0	0	0	0	0	0	0	0	0	0
Scaridae	1	3	4	2	2	0	1	1	2	1	4	21
Scombridae	0	0	0	0	0	0	1	0	0	0	0	1
Serranidae	3	4	7	5	1	3	3	0	2	4	6	38
Shark	0	0	1	0	0	0	0	0	0	0	0	1
Siganidae	0	0	0	0	0	0	0	0	0	0	0	0
Sphyraenidae	0	0	0	0	0	0	0	0	0	0	0	0
<b>Total identified</b>	<b>7</b>	<b>15</b>	<b>25</b>	<b>13</b>	<b>5</b>	<b>8</b>	<b>8</b>	<b>3</b>	<b>7</b>	<b>6</b>	<b>20</b>	<b>117</b>
Unidentified	41	25	99	33	31	37	29	30	63	8	38	434
<b>Total</b>	<b>48</b>	<b>40</b>	<b>124</b>	<b>46</b>	<b>36</b>	<b>45</b>	<b>37</b>	<b>33</b>	<b>70</b>	<b>14</b>	<b>58</b>	<b>551</b>

Table 3.2(b): Family Representation per Unit at 'Otea, Tonga

Family	Unit 1	Unit 2	Unit 4	Unit 5	Unit 6	Unit 7	Unit 9	Unit 10	Unit 11	Unit 12	Unit 13	Unit 14	Unit 15	Unit 16	Total
Acanthuridae	17	20	6	0	1	12	0	1	0	2	2	0	0	1	62
Balistidae	0	1	1	0	1	0	1	0	0	0	0	0	1	0	5
Carangidae	1	0	2	0	1	0	0	0	0	0	0	0	0	0	4
Diodontidae	1	4	4	6	2	2	25	0	0	1	0	0	1	1	47
Holocentridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Labridae	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2
Lethrinidae	3	1	6	0	0	4	0	1	0	1	0	0	1	0	17
Lutjanidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mullidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scaridae	5	1	9	0	0	0	0	0	0	1	0	0	0	0	16
Scombridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Serranidae	21	8	39	1	1	4	6	0	1	8	1	0	1	3	94
Shark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Siganidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphyracnidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<b>Total identified</b>	<b>49</b>	<b>35</b>	<b>68</b>	<b>7</b>	<b>6</b>	<b>22</b>	<b>32</b>	<b>2</b>	<b>1</b>	<b>13</b>	<b>3</b>	<b>0</b>	<b>4</b>	<b>5</b>	<b>247</b>
Unidentified	139	99	236	23	13	35	39	8	8	25	16	5	6	15	667
<b>Total</b>	<b>188</b>	<b>134</b>	<b>304</b>	<b>30</b>	<b>19</b>	<b>57</b>	<b>71</b>	<b>10</b>	<b>9</b>	<b>38</b>	<b>19</b>	<b>5</b>	<b>10</b>	<b>20</b>	<b>888</b>

Table 3.2(c): Family Representation per Unit at Ofu, Tonga

Family	Unit 2	Unit 3	Unit 4	Unit 5	Unit 7	Unit 8	Unit 10	Unit 13	Unit 15	Unit 16	Unit 19	Unit 20	Unit 21	Total
Acanthuridae	2	7	2	3	1	8	5	1	6	0	1	0	0	36
Balistidae	0	1	1	0	0	1	0	0	2	2	0	0	0	7
Carangidae	0	0	0	1	0	3	0	0	0	4	0	0	0	8
Diodontidae	5	16	52	3	2	3	11	1	6	3	1	1	2	106
Holocentridae	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Labridae	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Lethrinidae	0	0	0	3	2	7	0	1	1	1	3	0	0	18
Lutjanidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mullidae	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Scaridae	1	2	2	2	0	6	1	2	6	7	3	0	1	33
Scombridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Serranidae	4	13	2	9	5	11	5	2	6	8	0	1	1	67
Shark	0	0	1	0	0	0	0	0	0	2	0	0	0	3
Siganidae	1	1	0	0	0	0	0	0	0	0	0	0	0	2
Sphyraenidae	0	0	0	0	0	0	0	0	1	0	0	0	0	1
<b>Total identified</b>	<b>13</b>	<b>40</b>	<b>60</b>	<b>21</b>	<b>10</b>	<b>39</b>	<b>22</b>	<b>7</b>	<b>29</b>	<b>27</b>	<b>9</b>	<b>2</b>	<b>5</b>	<b>284</b>
Unidentified	122	159	188	149	92	165	116	78	164	171	62	43	42	1551
<b>Total</b>	<b>135</b>	<b>199</b>	<b>248</b>	<b>170</b>	<b>102</b>	<b>204</b>	<b>138</b>	<b>85</b>	<b>183</b>	<b>198</b>	<b>71</b>	<b>45</b>	<b>47</b>	<b>1835</b>

Table 3.2(d): Family Representation per Unit at Vuna, Tonga

Family	Unit 4	Unit 11	Unit 14	Total
Acanthuridae	1	8	8	17
Balistidae	0	5	6	11
Carangidae	0	1	0	1
Diodontidae	0	6	3	9
Holocentridae	0	0	1	1
Labridae	0	0	0	0
Lethrinidae	3	22	15	40
Lutjanidae	0	0	0	0
Mullidae	0	0	0	0
Scaridae	2	15	21	38
Scombridae	0	0	0	0
Serranidae	2	12	19	33
Shark	0	1	0	1
Siganidae	0	3	3	6
Sphyrinae	0	0	0	0
<b>Total identified</b>	<b>8</b>	<b>73</b>	<b>76</b>	<b>157</b>
Unidentified	133	662	850	1645
<b>Total</b>	<b>141</b>	<b>735</b>	<b>926</b>	<b>1802</b>

While Falevai was not sampled, 'Otea, Ofu and Vuna only had a selection of units analysed. Tables 3.2b-d, indicate that the represented taxa present negligible variation in their abundances between units. The even distribution of families in the units selected for analysis implies that the patterns present in these units are representative and that no singular unit disproportionately contributes to the identified abundances.

Table 3.3a: Identified fish family representation by site.

Family	Falevai		Otea		Ofu		Vuna	
	No.	%	No.	%	No.	%	No.	%
Acanthuridae	7	6.0	62	25.1	36	12.7	17	10.8
Balistidae	4	3.4	5	2.0	7	2.5	11	7.0
Carangidae	0	0.0	4	1.6	8	2.8	1	0.6
Diodontidae	31	26.5	47	19.0	106	37.3	9	5.7
Holocentridae	0	0.0	0	0.0	1	0.4	1	0.6
Labridae	3	2.7	2	0.8	1	0.4	0	0.0
Lethrinidae	10	8.6	17	6.9	18	6.3	40	25.5
Lutjanidae	1	0.9	0	0.0	0	0.0	0	0.0
Mullidae	0	0.0	0	0.0	1	0.4	0	0.0
Scaridae	21	18.0	16	6.5	33	11.6	38	24.2
Scombridae	1	0.9	0	0.0	0	0.0	0	0.0
Serranidae	38	32.5	94	38.1	67	23.6	33	21.0
Shark	1	0.9	0	0.0	3	1.0	1	0.6
Siganidae	0	0.0	0	0.0	2	0.7	6	3.8
Sphyraenidae	0	0.0	0	0.0	1	0.4	0	0.0
Total Identified	117	100.0	247	100.0	284	100.0	157	100.0
Unidentified	434	78.8	667	73.0	1551	84.5	1645	91.3
<b>Total Sample</b>	<b>551</b>		<b>914</b>		<b>1835</b>		<b>1802</b>	

While the order of the five most common families varies between sites, it is clear they comprise the majority of the identified portion of the assemblages. As discussed in Chapter 2 the skeletal morphology of Diodontidae means that it is most often represented by its spines. This repetition of a single element can lead to an inflation of the relative importance of this family. To deal with the potential exaggeration of Diodontidae it has been excluded from the discussions of inter-island variation examining differences in rank order of the most abundant families. The temporal analysis was conducted in order to examine changes within each fish family independently, and so, has been included as its abundances will not affect the representation of other families.

Table 3.3b: Hypothetical abundances of fish families by site had selective identification\* been used.

Family	Falevai		Otea		Ofu		Vuna	
	No.	%	No.	%	No.	%	No.	%
Acanthuridae	0	0.0	0	0.0	1	0.6	0	0.0
Balistidae	3	4.1	3	3.5	7	4.0	7	10.3
Carangidae	0	0.0	3	3.5	5	2.9	0	0.0
Diodontidae	31	41.9	42	48.8	105	60.0	9	5.1
Holocentridae	0	0.0	0	0.0	0	0.0	1	1.5
Labridae	0	0.0	1	1.2	0	0.0	0	0.0
Lethrinidae	7	9.5	4	4.7	10	5.7	15	22.1
Lutjanidae	0	0.0	0	0.0	0	0.0	0	0.0
Mullidae	0	0.0	0	0.0	0	0.0	0	0.0
Scaridae	16	21.6	11	12.8	24	13.7	26	38.2
Scombridae	0	0.0	0	0.0	0	0.0	0	0.0
Serranidae	17	23.0	22	25.6	23	13.1	10	14.7
Shark	0	0.0	0	0.0	0	0.0	0	0.0
Siganidae	0	0.0	0	0.0	0	0.0	0	0.0
Sphyraenidae	0	0.0	0	0.0	0	0.0	0	0.0
Total Identified	74	100.0	86	100.0	175	100.0	68	100.0
Unidentified	475	87.6	802	90.3	1586	90.1	1732	96.2
<b>Total Sample</b>	<b>542</b>		<b>888</b>		<b>1761</b>		<b>1800</b>	

\*Elements included: dentary, premaxilla, maxilla, angular, quadrate, acanthuridae dermal spine, Balistidae dorsal spine, Diodontidae dorsal spines, and Scaridae dental plates.

Table 3.3b presents fish family abundances had selective identification been employed.

This reconstruction demonstrates that had selective identification been used the interpretations of fish family importance at each of these sites would be quite different particularly with respect to Diodontidae and Acanthuridae (Table. 3.3a, 3.3b).

Table 3.4a indicates that the identified portion of the assemblages at all four sites is a small percentage of the total number of recovered fish bones. In part this is due to the abundance of small bone fragments which are unrecognizable as elements. However, the majority of unidentified specimens are small eroded vertebrae, which, due to the lack of visible features, are unidentifiable and as such will be disregarded for the remainder of the analysis. However, there is a small sample of 110 elements and 6 vertebrae which present clearly distinct features and are deemed identifiable but could not be assigned to a family. This is a result of unfamiliarity with the full range of South Pacific fish morphology and the limits of the comparative collections used. Table 3.4b is a hypothetical reconstruction of the portion of the assemblages for the four sites which would have been identifiable had selective identifications been conducted. The decline in proportion of the assemblages which could have been identified demonstrates the limitations of selectively identifying (particularly small) fish assemblages. Additionally, one of the family specific elements added for selective identification is the dorsal spine of the Diodontidae family. This addition of dorsal spines from Diodontidae could lead to further exaggeration of Diodontidae's presence when examining the relative abundance of fish families.

Table 3.4a: Identifiable component of assemblages for Falevai, 'Otea, Ofu and Vuna, Tonga.

Component	Falevai		Otea		Ofu		Vuna	
	No.	%	No.	%	No.	%	No.	%
Identifiable	157	28.5	287	31.4	366	20.0	227	12.6
Unidentifiable	394	71.5	627	68.6	1469	80.0	1575	87.4
Total	551		914		1835		1802	

Table 3.4b: Hypothetical Identifiable component of assemblage for Falevai, 'Otea, Ofu and Vuna, Tonga using selective identification\*.

Component	Falevai		Otea		Ofu		Vuna	
	No.	%	No.	%	No.	%	No.	%
Identifiable	87	15.8	101	11.1	207	11.3	81	4.5
Unidentifiable	464	84.2	813	88.9	1628	88.7	1721	95.5
Total	551		914		1835		1802	

\*Elements included: dentary, premaxilla, maxilla, angular, quadrate, acanthuridae dermal spine, Balistidae dorsal spine, Diodontidae dorsal spines, and Scaridae dental plates.

Tables 3.5a-d illustrate the breakdown of the identifiable portion of the assemblages indicating the recovered elements per family. Those in the unknown column are deemed to have enough distinguishing features to be possibly identifiable given a more diverse collection.



Table 3.5a: Element recovery rates per family for units 2-10, 12, 13 Falevai, Tonga.

	Acan.	Bali.	Cara.	Diod.	Holo.	Lab.	Leth.	Lutj.	Mull	Scar.	Scom.	Serr.	Shark	Siga.	Sphy.	Unknown	Total
Angular							1					3					4
Atlas																	0
Basioccipital																	0
Ceratohyal												1				4	5
Cleithrum																1	1
Cranial Element																	0
Dental Fragment													1				1
Dental Plate A						3											3
Dental Plate B										2							2
Dentary							2			2		5				2	11
Epihyal																2	2
Hyomandibular							1					4				5	10
Interopercular																	0
Lower Dental Plate										5							5
Maxilla							2			1		4				3	10
Opercular																	0
Palatine												1					1
Parasphenoid												1				4	5
Pharyngeal																1	1
Post-Temporal																1	1
Premaxilla							2			4		4				5	15
Quadrate												1				3	4
Scapula																	0
Spine		3		31													34
Supracleithrum																	0
Upper Dental Plate										2							2
Vomer																	0
Caudal Vertebra	4						2	1		2	1	7				3	20
Precaudal Vertebra										1		2				3	6
Thoracic Vertebra												4				4	8
Ultimate Vertebra		1								4							5
Identifiable Element																	157

Table 3.5b: Element recovery rates per family for units 1-2, 4-7, 9-16 'Otea, Tonga.

	Acan.	Bali.	Cara.	Diod.	Holo.	Lab.	Leth.	Lutj.	Mull.	Scar.	Scom.	Serr.	Shark	Sig.	Sphy.	Unknown	Total
Angular							2									1	3
Atlas							1					2					3
Basioccipital												3					3
Ceratohyal												2				2	4
Cleithrum																	0
Cranial Element																	0
Dental Fragment																4	4
Dental Plate A				4		1										1	6
Dental Plate B				1													1
Dentary							1					5				2	8
Epihyal																	0
Hyomandibular												1				2	3
Interopercular																	0
Lower Dental Plate										5							5
Maxilla			1				1					4				3	9
Opercular																	0
Palatine												1					1
Parasphenoid	1		1									2				8	12
Pharyngeal																	0
Post-Temporal																1	1
Premaxilla			2			1				4		6				2	15
Quadrate												7				7	14
Scapula																	0
Spine		3		42													45
Supracleithrum																	0
Upper Dental Plate										2							2
Vomer												2					2
Caudal Vertebra	52						2			1		36				4	95
Precaudal Vertebra	7	1					6			3		9				3	29
Thoracic Vertebra		1					4					14				2	21
Ultimate Vertebra										1							1
Identifiable Elements																	287

Table 3.5c: Element recovery rates per family for units 2-5, 7-8, 10, 13, 15-16, 19-21 Ofu, Tonga.

	Acan.	Bali.	Cara.	Diod.	Holo.	Lab.	Leth.	Lutj.	Mull.	Scar.	Scom.	Serr.	Shark	Sig.	Sphy.	Unknown	Total
Angular																6	6
Atlas					1		1										2
Basioccipital																2	2
Ceratohyal												4				6	10
Cleithrum																	0
Cranial Element																1	1
Dental Fragment																8	8
Dental Plate A						1											1
Dental Plate B				1													1
Dentary							2			3		5	1			3	14
Epihyal												1				1	2
Hyomandibular												2				11	13
Interopercular																1	1
Lower Dental Plate										13							13
Maxilla			1				4									4	9
Opercular			1													1	2
Palatine																2	2
Parasphenoid																3	3
Pharyngeal																	0
Post-Temporal																1	1
Premaxilla			4				4			4		9				7	28
Quadrate												9				10	19
Scapula												1					1
Spine	1	7		105													113
Supracleithrum							1										1
Upper Dental Plate										4							4
Vomer												4					4
Caudal Vertebra	30		2				1			2		20	2	1		6	64
Precaudal Vertebra	1						3			2		4		1	1	3	15
Thoracic Vertebra							2			1		8				8	19
Ultimate Vertebra									1	4						2	7
Identifiable Elements																	366

Table 3.5d: Element recovery rates per family for units 4, 11, 14 Vuna, Tonga.

	Acan	Bali	Cara	Diod	Holo	Lab	Leth	Lutj	Mull	Scar	Scom	Serr	Shark	Sig.	Sphy.	Unknown	Total
Angular																	0
Atlas																2	2
Basioccipital																	0
Ceratothyal							4					5				7	16
Cleithrum																	0
Cranial Element																	0
Dental Fragment										2						9	11
Dental Plate A																	0
Dental Plate B																	0
Dentary		3					4			6		5				1	19
Epihyal																1	1
Hyomandibular		3										1				7	11
Interopercular												1				3	4
Lower Dental Plate										7							7
Maxilla							4			1		2				3	10
Opercular																1	1
Palatine							3										3
Parasphenoid																5	5
Pharyngeal																	0
Post-Temporal												2				3	5
Prefrontal							1										1
Premaxilla					1		6			5		1				2	15
Quadrate							1					2				9	12
Scapula												1				2	3
Spine		4		9													13
Supracleithrum																	0
Upper Dental Plate										5							5
Vomer							1									2	3
Caudal Vertebra	12		1				11			7		6	1	3		5	46
Precaudal Vertebra	5						1			3				2		2	13
Thoracic Vertebra							4					7		1		7	19
Ultimate Vertebra										2							2
Identifiable Elements																	227

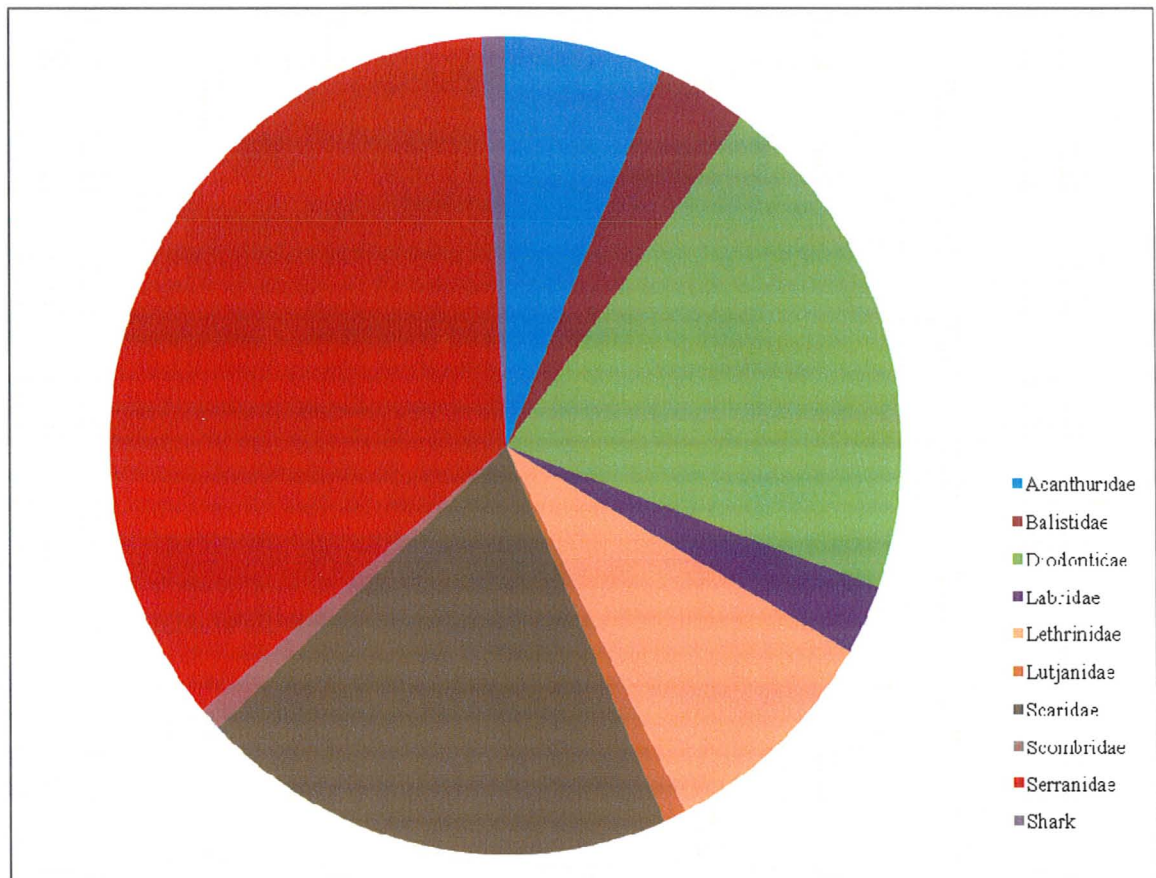


Figure 3.1a: Family Representation at Falevai, Tonga.

Falevai is characterized by a small fish assemblage dominated by large bodied taxa including Serranidae, Scaridae, and Diodontidae families. There appears to be a focus on larger fish families at Falevai. This is the only site which contains a Scombridae vertebra -which includes tuna- possibly from one of the larger species in the family. In addition to Scombridae there is also the presence of an undetermined species of shark at this site.

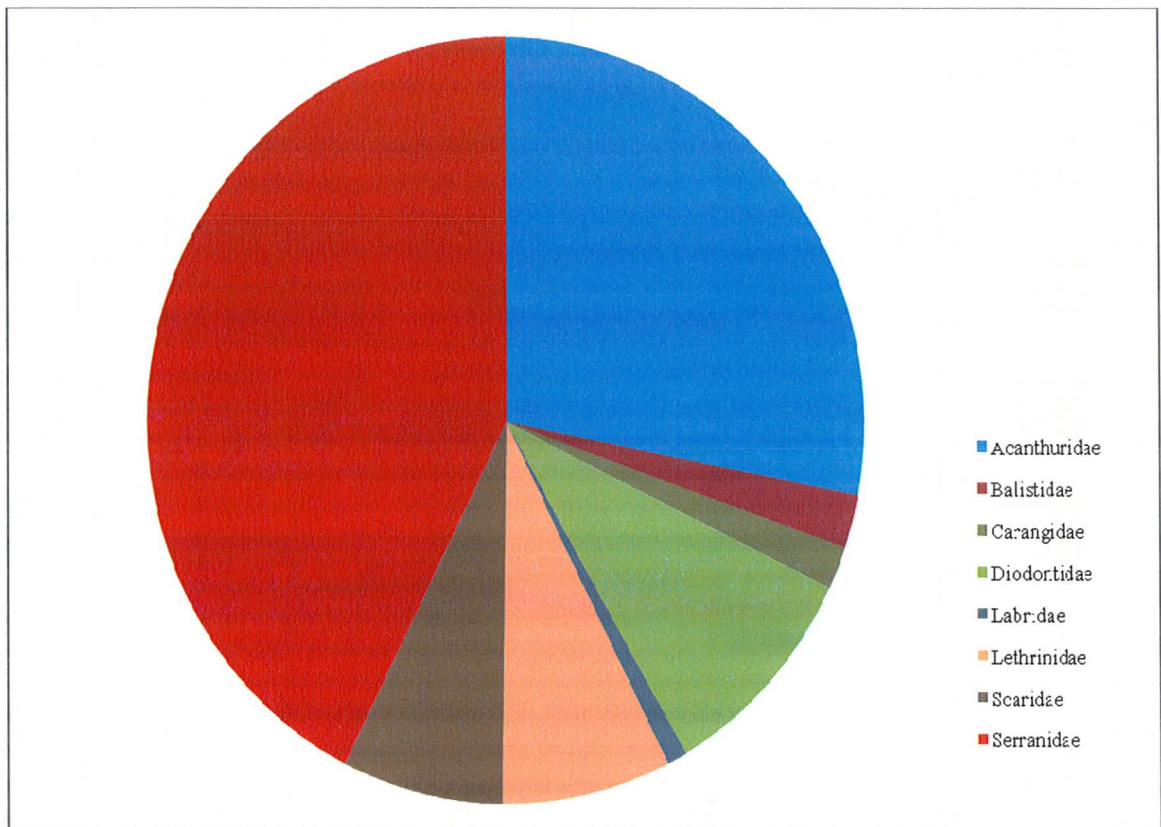


Figure 3.1b: Family Representation at 'Otea, Tonga.

At 'Otea the assemblage is dominated by Serranidae and Acanthuridae which together comprise over half of the assemblage (Fig. 3.1b). While Acanthuridae made up a small portion of the assemblage at Falevai (Fig. 3.1a), here they are ranked second in abundance. The remaining portion of the assemblage is distributed mostly between Lethrinidae, Scaridae and Diodontidae, restricting the diversity of families represented.



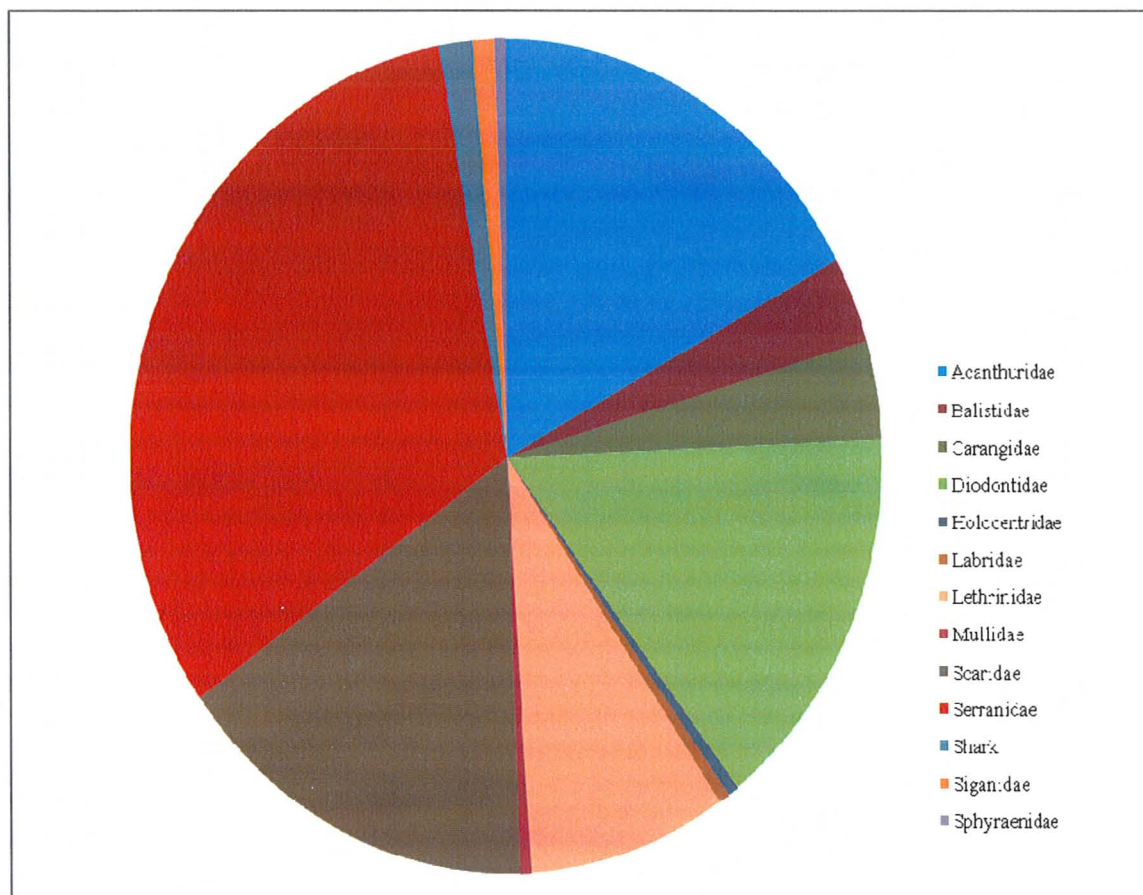


Figure 3.1c: Family Representations at Ofu, Tonga.

As at 'Otea, Acanthuridae represent a significantly larger portion of the Ofu (Fig. 3.1c) assemblage than seen at Falevai (Fig. 3.1a). However, unlike either 'Otea or Falevai, Ofu presents a more diverse assemblage. While several of the families contributing to the diversity at Ofu are represented by a single specimen (Holocentridae, Labridae, Mullidae, and Sphyrnidae) the dominant families are also more evenly distributed than at either Falevai (Fig. 3.1a) or 'Otea (Fig. 3.1b) where the assemblages are mostly comprised of two or three families.

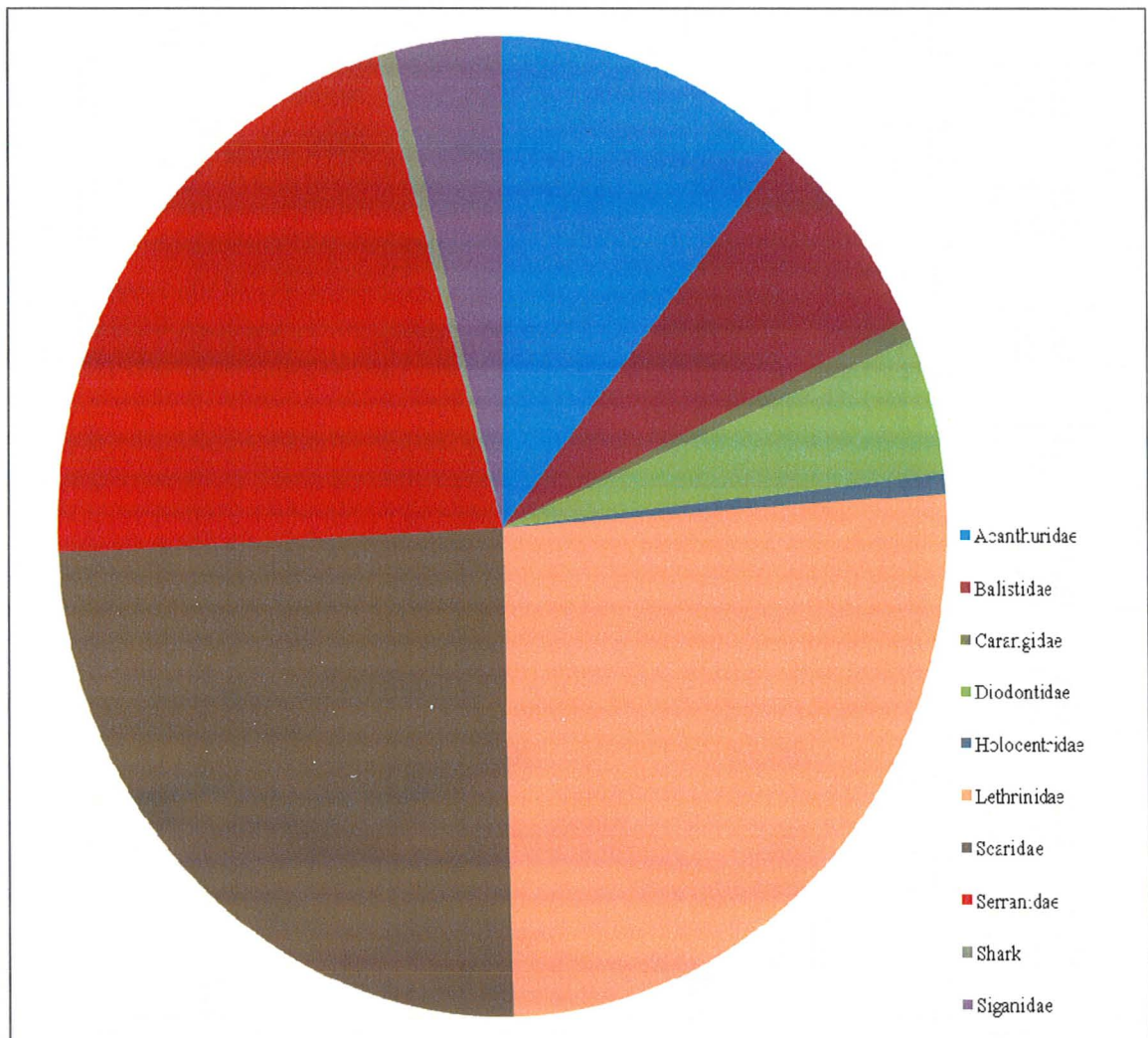


Figure 3.1d: Family Representations at Vuna, Tonga.

At Vuna (Fig. 3.1d) the composition of the assemblage is again different from the other three sites. Here Lethrinidae represents a distinctly larger proportion of the assemblage than at any of the other three sites. Interestingly Vuna is not only the largest of the Vava'u Lapita sites but its fish assemblage also contains the highest density of fish bones. Of the four sites examined, Vuna is most like those examined in Ha'apai where Lethrinidae is the preferred fish. While it does present similarities to Ha'apai in the density and dominance of Lethrinidae, the assemblage composition does not imply any



pressure on the reef fishery as there is a relatively small representation of smaller bodied fish.

### Inter-Island Variation

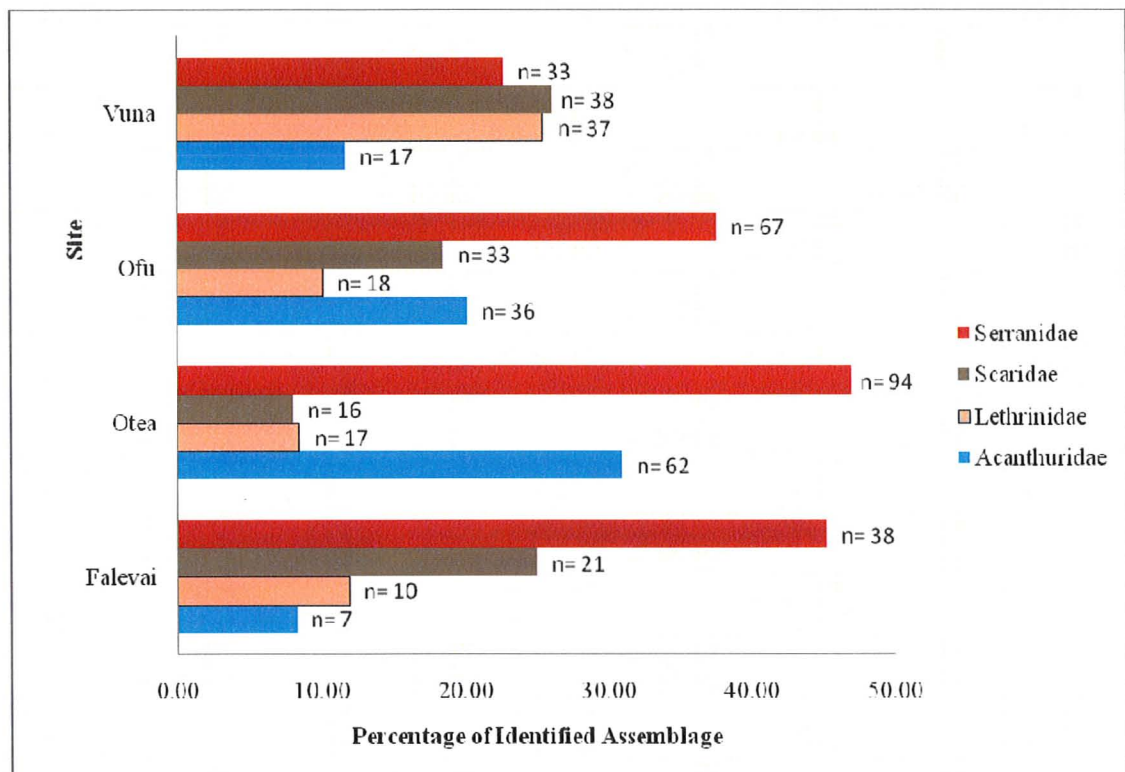


Figure 3.2: Representation of four most abundant identified families.

The five most abundant families (Fig. 3.2) Serranidae, Scaridae, Lethrinidae, and Acanthuridae are all within the top six most common families represented at archaeological sites in the South Pacific (Butler 1989). Between the four sites in Vava'u there are three general patterns which emerge with regards to family abundances. At Vuna, which has the highest density of bones, there is a fairly even distribution between Scaridae, Serranidae and Lethrinidae. The most prominent distinction between Vuna and the other three sites is the relative abundance of Lethrinidae. Vuna also presents decreased abundances of Acanthuridae and Diodontidae (Fig. 3.1d). Serranidae is predominant at Falevai, Ofu and 'Otea but is comparable to the abundance of Scaridae

and Lethrinidae at Vuna (Fig. 3.1d). Acanthuridae is less abundant at both Vuna and Falevai, and more common at Ofu and ‘Otea, with the highest concentration occurring at ‘Otea.

While there is variation between the four sites they do present quite a different pattern of reef use from sites in Ha’apai. None of these sites indicate intensive harvesting or pressure being put on the reefs, all four sites are predominantly characterized by large bodied food fish like Serranidae, Scaridae, and Lethrinidae, though the rank order varies between sites. Some of this variation may be exaggerated because of the relatively small size of the assemblages, but it is not great in any case.

### Osteometric Analysis

Osteometric data were collected for Serranidae vertebrae – with complete centra – and Scaridae dentary and premaxilla elements –with complete tooth development – to determine if there are significant differences in fish sizes or more or less diversity of fish sizes between Vava’u settlements.

Table 3.6: Statistical Analysis of Serranidae Vertebra sizes for Falevai, Ofu, ‘Otea, and Vuna, Tonga.

	N	Minimum	Maximum	Mean	Std. Deviation
Falevai	7	6.12	13.62	9.11	2.95
Ofu	20	4.78	15.44	8.60	2.89
‘Otea	36	4.56	22.23	11.44	3.97
Vuna	6	4.29	15.76	10.67	3.97
Valid N	6				

The Serranidae osteometrics indicate there is very little variation in the size of fish being harvested across the sites. The range of variation in fish size is particularly small at Falevai and Ofu. The osteometric data were not examined through time as the variation

in size was so slight and when coupled with the small size of the assemblages, any change in relative sizes would be deemed negligible. The two vertebrae at 'Otea which are outside the second quartile are interpreted here as outliers – unusually large Serranidae – as they fall so far from the mean (Fig. 3.3). However, the sample size of analysed vertebrae is so small that the quantitative analysis is not significant, and with a larger sample it may alter the mean such that those Serranidae are within the typical size range of fish captured at this and other locations in Vava'u.

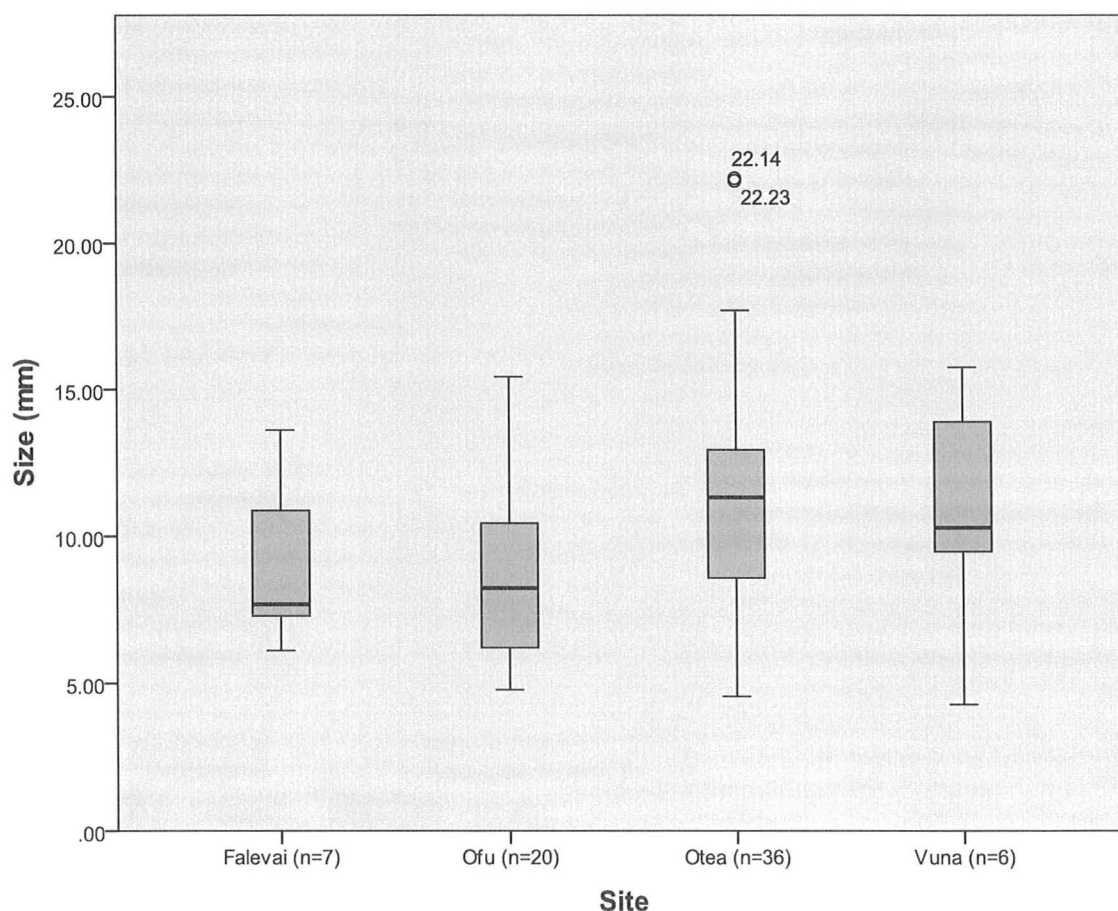


Figure 3.3: Osteometric Analysis of Serranidae Caudal Vertebra for Falevai, Ofu, 'Otea, and Vuna, Tonga.

Table 3.7a: Statistical Analysis of Scaridae Dentary sizes for Falevai, Ofu, and Vuna, Tonga.

	N	Minimum	Maximum	Mean	Std. Deviation
Falevai	1	27.46	27.46	27.46	.
Ofu	1	14.83	14.83	14.83	.
Vuna	6	8.20	18.93	12.47	4.10

There were no Scaridae dentaries recovered from ‘Otea allowing for an osteometric examination.

Table 3.7b: Statistical Analysis of Scaridae Premaxilla sizes for Falevai, Ofu, ‘Otea, and Vuna, Tonga.

	N	Minimum	Maximum	Mean	Std. Deviation
Falevai	3	10.48	11.68	10.88	0.69
Ofu	3	11.34	12.35	11.71	0.56
‘Otea	3	14.72	18.81	16.98	2.08
Vuna	4	7.92	16.48	11.91	3.55

Scaridae osteometric analysis was conducted to illustrate any size variations among Scaridae harvested in Vava’u. Measurements were taken from dentaries and premaxillae as they demonstrated the highest degree of visual size variation and, due to their robustness, presented less fragmentation than vertebrae. Though measurements were taken from all whole dentary and premaxilla specimens recovered, the sample size is too low for any significant quantitative analysis. It is clear, however, that at Vuna Scaridae sizes are more variable than at Falevai, Ofu or ‘Otea (Table 3.7b).

## Temporal Analysis

The four sites analysed in this study were chosen because they not only present evidence of Lapita occupation, but continuous occupation through the Polynesian Plainware phase and into the Aceramic period. This continuous occupation allows for an examination of potential shifting importance of marine resources or the possibility of resource depression over time. As discussed previously, one way to identify resource depression in a fish assemblage is to identify a corresponding decline of preferred fish families with increase in the abundance of less desirable fish. The following figures indicate the frequencies of fish families represented in the different cultural deposits. Excavation was conducted in 10cm levels for all units at all four sites. Thus, the density of bones /100L of soil was used for analysis, as opposed to NISP to ensure comparability between cultural phases, and sites.

Table 3.8a: Density (bones/100L) of fish remains through cultural phase at Falevai, Tonga.

	Lapita	Polynesian Plainware	Mixed/Aceramic
Acanthuridae	0.03	0.10	0.10
Diodontidae	0.33	0.40	0.23
Lethrinidae	0.17	0.07	0.06
Scaridae	0.06	0.40	0.19
Serranidae	0.50	0.23	0.39
Other*	0.06	0.25	0.06
Unidentified	3.92	4.87	3.42
Total	5.07	6.32	4.45

\*Other includes: Balistidae, Carangidae, Labridae, Lutjanidae, Scombridae, and Shark.

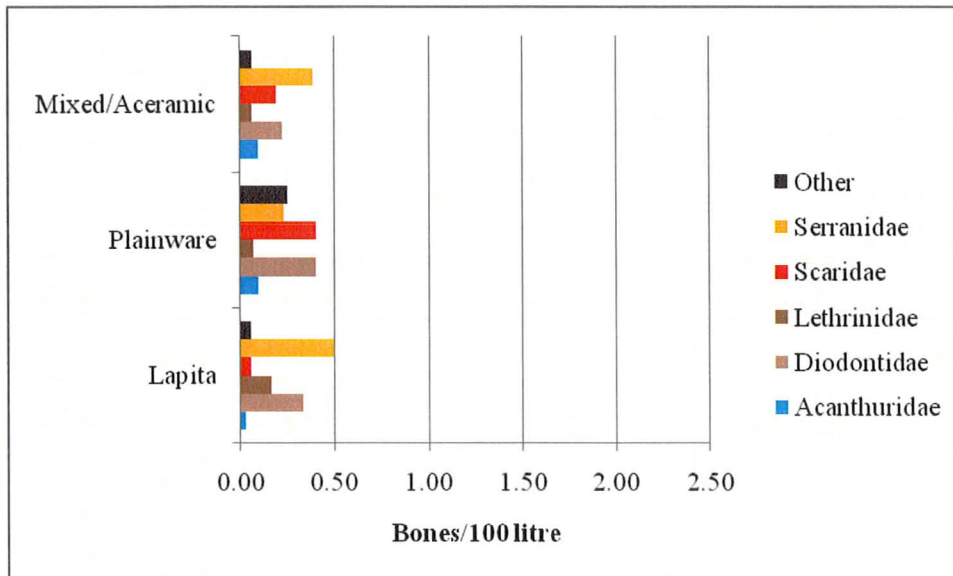


Figure 3.4a: Family distribution through cultural phases at Falevai, Tonga.

Analysis of temporal changes within Falevai indicates that Serranidae remain the preferred food fish throughout the occupation history, with a period of Scaridae and Diodontidae as the most abundant in the Polynesian Plainware (Fig. 3.4b). During Lapita occupation at Falevai there is little diversity in harvested fish and Serranidae represent more than half of the assemblage. With the shift to the Polynesian Plainware there is an increase in the diversity of fish families recovered with a notable rise in the abundance of Scaridae. Falevai presents a noticeably lower density of fish remains throughout all of its occupation history than 'Otea, Ofu and Vuna.

Table 3.8b: Density (bones/100L) of fish remains through cultural phase at Ofu, Tonga.

	Lapita	Polynesian Plainware	Mixed/Aceramic
Acanthuridae	0.48	0.31	0.02
Diodontidae	1.26	1.63	0.04
Lethrinidae	0.26	0.00	0.04
Scaridae	0.50	0.06	0.02
Serranidae	0.77	0.88	0.09
Other*	0.29	0.19	0.06
Unidentified	20.21	14.50	1.25
Total	23.77	17.57	1.52

\*Other includes: Balistidae, Carangidae, Holocentridae, Labridae, Mullidae, Shark, Siganidae and Sphyraenidae.

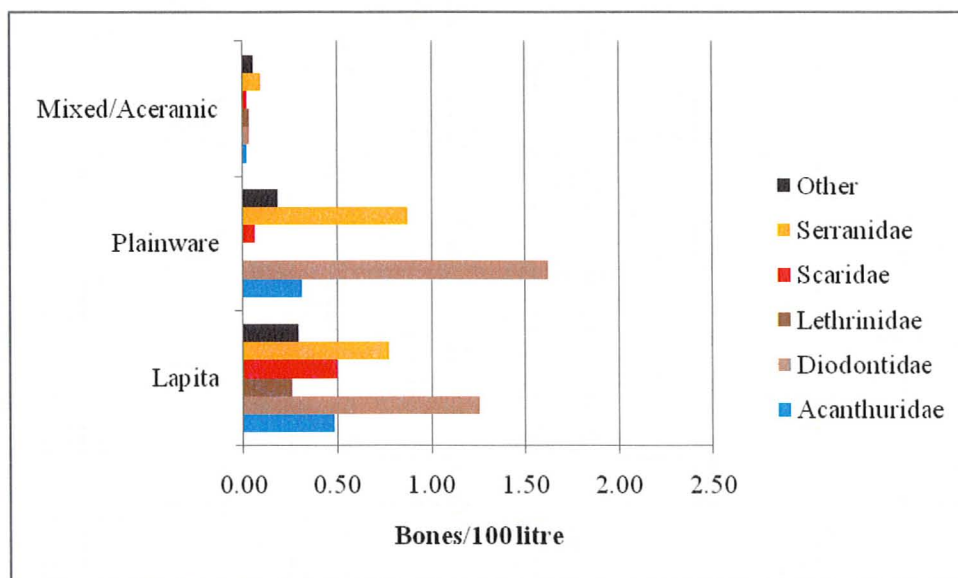


Figure 3.4b: Family distribution through cultural phases at Ofu, Tonga.

At Ofu there is a general decline in the abundance of fish from the initial Lapita occupation through to the Aceramic period (Fig. 3.4b). From the Lapita to Polynesian Plainware phase there is a significant decline in both Lethrinidae and Scaridae, while Serranidae, Acanthuridae and Diodontidae continue to be prominent in the assemblage, until the Aceramic/Mixed phase.



Table 3.8c: Density (bones/100L) of fish remains through cultural phase at 'Otea, Tonga.

	Lapita	Polynesian Plainware	Mixed/Aceramic
Acanthuridae	0.75	0.45	0.02
Diodontidae	0.64	0.28	0.00
Lethrinidae	0.25	0.03	0.01
Scaridae	0.25	0.03	0.00
Serranidae	1.25	0.59	0.01
Other*	0.13	0.10	0.00
Unidentified	8.74	4.07	0.11
Total	12.01	5.55	0.15

\*Other includes: Balistidae, Carangidae, and Labridae.

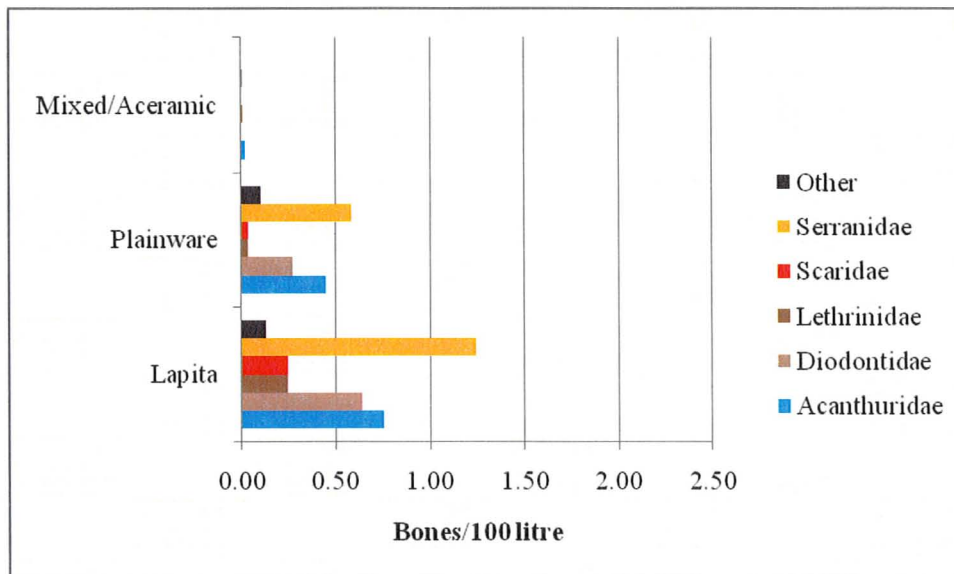


Figure 3.4c: Family distribution through cultural phases at 'Otea, Tonga.

The pattern of fish procurement at 'Otea (Fig. 3.4c) is similar to that present at Ofu (Fig. 3.4b). There is a general decline in fish abundance from the Lapita occupation through to the Aceramic period; however Serranidae, Acanthuridae and Diodontidae continue to dominate the assemblage into the Polynesian Plainware phase, with a notable decline in Lethrinidae and Scaridae from the Lapita occupation to the Polynesian Plainware phase.



Table 3.8d: Density (bones/100L) of fish remains through cultural phase at Vuna, Tonga.

	Lapita/Polynesian Plainware	Aceramic	Mixed
Acanthuridae	0.94	0.00	0.00
Diodontidae	0.33	0.20	0.00
Lethrinidae	2.11	0.40	0.00
Scaridae	2.00	0.40	0.00
Serranidae	1.50	1.20	0.00
Other*	0.94	0.40	0.14
Unidentified	88.67	9.00	0.57
Total	96.49	11.60	0.71

\*Other includes: Balistidae, Carangidae, Holocentridae, Shark and Siganidae.

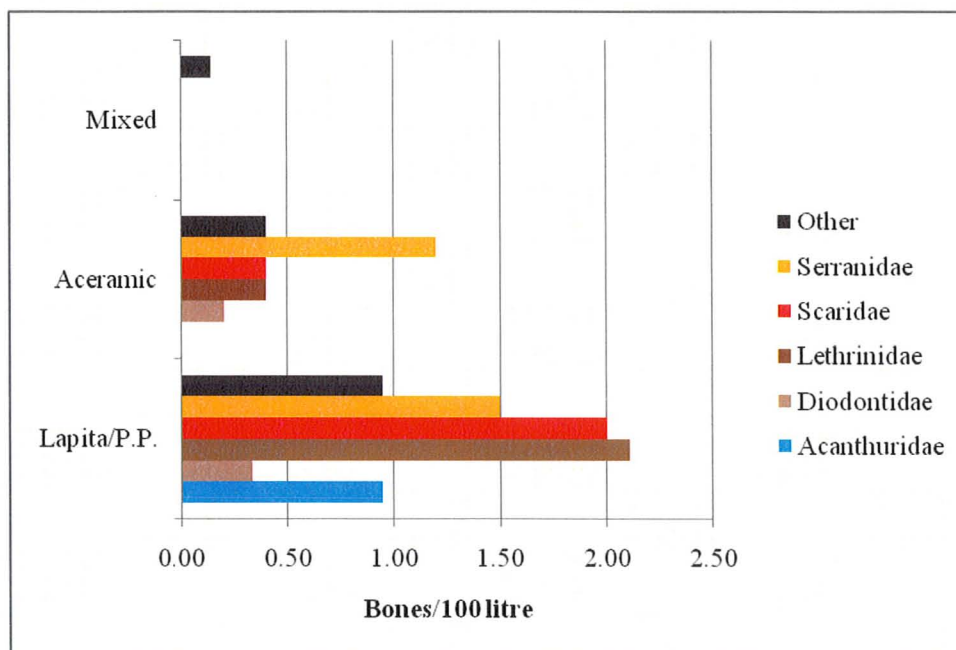


Figure 3.4d: Family distribution through cultural phases at Vuna, Tonga.

Lapita and Polynesian Plainware cultural deposits at Vuna cannot be divided into distinct cultural phases due to the mixed stratigraphy of the site. However, there is still a general decline in fish abundances from the Lapita/Polynesian Plainware phases to the Aceramic and Mixed phases (Fig. 3.4d). The shift from Lapita/Polynesian Plainware mirrors the shifts observed at Ofu (Fig. 3.4b) and 'Otea (Fig. 3.4c) from the Lapita to the

Polynesian Plainware occupation, where there is a rapid decline in Scaridae and Lethrinidae. While Serranidae persist into the Aceramic phase, in contrast to the pattern at Ofu and 'Otea, Acanthuridae declines with Scaridae and Lethrinidae.

At Vuna, Ofu and 'Otea, there is a general decline in fish abundance. The majority of fish at these three sites were recovered from the Lapita occupation phase, and with the shift to the Polynesian Plainware phase, represented primarily in the ceramic styles and associated elsewhere with the intensification of agricultural practices, we see a general decline in the reliance on marine resources. There is also a consistent pattern in the differential decline of the four most abundant families (Scaridae, Lethrinidae, Serranidae and Acanthuridae). While Scaridae and Lethrinidae decline dramatically through time, Serranidae continues to be most abundant until the almost complete abandonment of marine resource use in the Aceramic/Mixed period.

### **Overview of Vava'u Fishing**

The Vava'u fisheries can be generally characterized as casual. Serranidae and Lethrinidae can be argued to be the preferred food fish recovered at these sites, though their abundances are not high enough to indicate pressure on the reefs. The osteometric analyses indicate there is a preference for large bodied fish and not a significant range of fish sizes represented at these four sites. Although the fish assemblages in Vava'u do not indicate an intensive fishery, the temporal analysis indicates that the procurement of fish from local marine environments became less important through time. Broadly, Falevai, Ofu, 'Otea and Vuna all show that utilization of the reefs in Vava'u was opportunistic and selective of large bodied fish, and that by the Aceramic/Mixed cultural phases fishing was almost entirely absent. However, examining the sites individually does reveal subtle differences in fishing practices, most notably at Falevai and Vuna.

#### *Falevai*

The most striking difference at Falevai is the persistence of fish use through all analysed cultural phases. The extended use of fish at Falevai may be explained by the occupation and settlement history of Vava'u. The radiocarbon dates for Falevai indicate

that this was the last of the four sites settled, and initial occupation occurs at the end of the Lapita phase (Burley 2009). The very late Lapita component at Falevai might reasonably be expected to be similar to the Polynesian Plainware pattern that immediately follows. This can be seen in the density calculations as well where the Lapita phase at Falevai has the lowest density (Fig. 3.4a) of fish from the four sites examined.

### *Vuna*

Vuna appears to exhibit a pattern comparable in some way to patterns evident at both Ha'apai and Vava'u. The density of bones at Vuna is distinct from the other sites in Vava'u, which have very low overall densities (Table 3.1). In Ha'apai the density of fish bones at all five sites examined by Cannon and Cannon (2001) is very high (Table 3.1). Vuna also presents a unique pattern from the other three Vava'u sites in its family representations. While at Falevai, Ofu and 'Otea, Serranidae clearly dominate the assemblages Vuna is equally dominated by Serranidae, Scaridae, and Lethrinidae (Table 3.3a-b). The abundance of Lethrinidae –absent at the other sites – is also reminiscent of the Ha'apai fisheries where Lethrinidae are the preferred family (Cannon and Cannon 2001). There is no obvious explanation for this pattern at Vuna.

Though each is somewhat unique, Falevai, Ofu, 'Otea and Vuna all indicate a general pattern of non-intensive harvest when compared to the southern islands of Tonga. While we can see a shift in reliance away from the reefs at these sites this analysis suggests that at no point in the occupation history of Vava'u was the marine environment the foundation of the subsistence economy. The low density of remains from initial occupation suggests that the patterns observed in Vava'u represent non-intensive harvest.

## Chapter 4: Discussion and Conclusions

### **Abundances and identification of fish remains**

The overall small sizes of the analysed assemblages from Vava'u limit some of their interpretive potential, especially when examining changes through time. The grossly low density (Table 3.1) of remains from Vava'u is quite distinct from other fish assemblages elsewhere in the Kingdom of Tonga, however they do allow for a broad comparison of fishing patterns in Tonga, as they indicate a stark difference in harvesting intensity between Ha'apai and Vava'u.

### **Vava'u marine resource use**

#### *Family Representation*

The results of the Vava'u study reported here indicate a non-intensive reliance on surrounding marine environments at initial Lapita occupation sites. The four assemblages are characterized by a predominance of Serranidae, Lethrinidae, Scaridae, Diodontidae and Acanthuridae, which can be harvested from the local reefs and surrounding coastal flats. Although all four sites share the same five preferred species, the abundance of each varies somewhat between sites. The diversity of secondary families is also variable between sites. The most notable variation is at Vuna, where the relative frequency of Lethrinidae (Fig. 3.1d) suggests it was the preferred family, whereas at Falevai (Fig. 3.1a), 'Otea (Fig. 3.1c) and Ofu (Fig. 3.1b) Serranidae is most abundant and Lethrinidae is ranked third or fourth, falling consistently after Serranidae, and Scaridae.

The diversity of fish represented at the four sites is also roughly similar, though Ofu (Table 3.3a-b) has the widest range of fish families. The remaining recovered families include several reef fish (Holocentridae, Mullidae, Labridae, and Siganidae), those which reside at reef drop-offs (Sphyraenidae), those that are pelagic (Scombridae), and, those that inhabit multiple environments (reefs and pelagic waters) (Lutjanidae, Balistidae, Carangidae, and sharks). The diverse habitats represented indicate that settlers were harvesting fish from multiple contexts and not just the reef systems.

*Temporal Change*

The temporal patterning in Vava'u (as in southern Tonga) indicates a decline in marine resources through occupation phases (Fig. 3.4a-d). As in Tongatapu, there is a general decrease in fish abundance corresponding to the shift to the Polynesian Plainware Phase. Although the general pattern in Vava'u is a decreased reliance on the reefs, it is not considered a result of harvesting pressure put on the reefs. Additionally, there is no inverse relationship observed between species abundances at 'Otea, Ofu, or Vuna, which could indicate a shift in selected fish due to a decline in availability of the preferred Serranidae, or Lethrinidae. Falevai presents a different pattern of use through time. While there is still a general decline in the overall abundance of remains, there is evidence for an inverse relationship between Serranidae and Scaridae (Fig. 3.4a). While Serranidae is the preferred fish during the Lapita occupation, a decline in Serranidae and increase in Scaridae coincides with the shift to Polynesian Plainware Phase. Again, this cannot be interpreted as an indication of resource depression at Falevai, as the density of remains examined temporally is too low to form a significant correlation. The osteometric data, though based on a modest number of elements, indicate no significant variation in the size of Serranidae and Scaridae (Table 3.6 and 3.7a-b) at Lapita sites in Vava'u, and indicate no significant change to fish size through time.

The fishing strategy in Vava'u appears to be non-intensive, such that immediately surrounding marine environments were utilized, but did not provide the foundation of the subsistence economy. Because the initial survey conducted to find Lapita occupation sites was targeted to areas with immediate access to a reef, it is not surprising that the marine environment would be utilized to some degree. However, the conclusion made by Burley (2009:8) that horticulture may have played an active role in the initial occupation locations in Vava'u is supported by the fish assemblages which indicate that reliance on the reefs (from initial occupation through all subsequent occupation phases) was distinctly casual.

### **Tongan Subsistence Strategies**

Tongatapu, Ha'apai and Vava'u all present different patterns of interactions between Lapita settlers and the marine resources. On the agriculturally productive Tongatapu, there are adjacent reefs, which were an integral component of the early subsistence strategies. However, with the shift to the Polynesian Plainware phase there is a shift away from the marine patch and an intensification of agricultural practices (Groube 1971). This pattern was interpreted by Groube (1971) to be indicative of a shift in the subsistence economy, from fishing to horticulture.

Lapita interactions with the reefs of Ha'apai, unlike Tongatapu and Vava'u, indicate the reefs were initially and continually the foundation of the subsistence economy. Unlike Vava'u and Tongatapu where fertile agricultural soils can be found scattered across most of the islands, the Ha'apai islands are coral atolls, with poor drainage, which are not optimal for agricultural success. There appears to be heavy reliance on local reefs immediately upon occupation at all five sites examined by Cannon and Cannon (2001). At Mele Havea, Vaipuna and Faleloa the pressure of Lapita reliance on the reefs depleted Lethrinidae, and necessitated the inclusion of less productive fish families such as Acanthuridae (Cannon and Cannon 2001). At Pukotala and Tongoleleka, while there is no evidence of resource depression, Acanthuridae are already abundant in early occupation levels, which may indicate immediately intensive harvesting practices (Cannon and Cannon 2001).

Vava'u presents yet a third and equally distinct pattern of resource use in Tonga. Due to their volcanic nature, the Vava'u islands are scattered with areas of rich fertile soil suitable for agriculture. Identified Lapita occupation sites in Vava'u are all in close proximity to a fringing reef and in areas suitable for agriculture. If we were to contend that the Lapita settlement strategy was determined by the importance of close proximity to a productive reef environment, because of the importance of the marine resources to their subsistence economy, then what could explain the contradictory evidence in the Vava'u Islands? The low density of fish remains, the preference for larger-bodied fish, and the presence of fertile soil in the vicinity of sites suggests that while reefs provided

for casual harvest of fish during the settlement of the Vava'u Islands the resource which may have played a more active role in determining settlement locations was the soil.

The different patterns presented on each of the island groups within Tonga do not allow for the imposition of a generalized subsistence economy on the settlers of Tonga. While it can be argued that on both fertile, agriculturally productive Tongatapu and Vava'u Islands the marine environment played a secondary role to agriculture, its importance to the subsistence economy still varied between the two island contexts. On Tongatapu there was a brief period during initial occupation when marine resources were an important component of the subsistence economy, however, the complete absence of any period of intense harvesting in Vava'u indicates the reefs were never integral at these settlements. The continued occupation of the Ha'apai islands – despite the lack of agriculturally productive land – indicates that on islands where agriculture was not as viable, the subsistence economy was adapted to utilize the local resources.

It is clear that within the geographic confines of Tonga the subsistence economy of Lapita settlers was determined at least in part by the local environment of the islands chosen for occupation. Where there was the possibility for agricultural success, as in Vava'u and, Tongatapu, marine resources were used, but not relied upon as the basis of the subsistence economy. However, on Ha'apai, where potential agricultural productivity is much lower, it is evident from fish assemblages that the marine environment was an integral aspect of the subsistence economy throughout the occupation history. This is demonstrated by the fact that even when the productivity of the reef was depressed - due to the intensity of harvesting practices – the reefs were still relied upon and less desirable taxa were used to supplement the loss of Lethrinidae.

### **South Pacific Subsistence Economies**

One of the goals of this research was to test the validity of generalized subsistence theories in South Pacific archaeology. This analysis indicates that even within a single island chain it is not possible to argue for a general subsistence economy. While there do appear to be repeated patterns concerning the subsistence economies of the South Pacific,



they do not imply a standardized or consistent subsistence strategy, but instead an economy that was capable of adapting to multiple environmental contexts.

The distribution of dominant families in Vava'u is not surprising given that similar environmental niches were chosen for exploration during the discovery of Lapita sites. In addition, the five most common families recovered in Vava'u fall within those Butler (1988) has identified as the eight families most commonly recovered at sites throughout the South Pacific (Scaridae, Diodontidae, Lethrinidae, Serranidae, Labridae, Lutjanidae, Balistidae, and Acanthuridae). Continued recovery of these eight families across diverse island settings may contribute to a generalization of a 'standard' strategy of reliance on inshore reef environments (Butler 1988). While the recovery of these same taxa may give the impression that Lapita fishing strategies concentrated on the same eight taxa, Butler (1988:112,115) highlights three key points: 1) the rankings of these taxa are not the same for each location, 2) the less prominent species are diverse across different sites, and 3) the material remains of fishing technology are variable between island groups. These details are integral for understanding the potential diversity of fishing choices made at different locales. Butler's (1988) critique of fish analysis in the South Pacific describes several alternative explanations beyond a 'standardized' fishing strategy that may account for the similarity of dominant taxa including researcher bias (uneven identification of families based on distinct morphological features of the dominant eight taxa) and biological factors (dominant presence of these eight taxa throughout South Pacific reef systems). While the uniform pattern of dominant fish may indeed be due to preferred fishing environments and technologies, it is possible that in areas where the marine patch is argued to be an integral component of the subsistence economy, the similarity of local reef environments creates a similar distribution of available resources.

### *Adaptable Subsistence Strategy*

The different researchers that have examined South Pacific subsistence strategies have adequately demonstrated the validity of their interpretations for the island or island group in their individual studies. Their diverse results obviate the application of a



‘typical’ Lapita subsistence economy. Studies on several islands in the South Pacific (Ha’apai, Mangaia, New Zealand) clearly show depression of the reef environments surrounding chosen habitation locales due to the intensity of fishing. It has been shown equally on other islands that reefs may have played only a secondary role to agriculture in local subsistence (Tongatapu, Vava’u, Vanuatu).

South Pacific subsistence economies appear to be constrained by a small number of environmental parameters. Islands with rich fertile soil and therefore greater potential for agricultural success consistently exhibit a lack of evidence for fish resource depression or for the sustained importance of reef resources throughout their occupation histories. Islands presenting little to no agricultural potential exhibit archaeological evidence that settlers utilized local reefs and sand flats so intensively that preferred fish were over harvested necessitating a shift to less desirable fish, or alternate resources.

Although both Tongatapu and Vava’u are islands rich in agriculturally productive soils, they also show different patterns of reef use. The evidence from Tongatapu indicates that while the reefs were used initially, the dominant subsistence strategy was horticulture, as there is a severe decline in reliance on the reefs when agriculture is intensified on the island. Vava’u is characterized by consistently casual harvest from surrounding marine environments. At present there is no information on the horticultural practices in Vava’u, but the presence of arable land within the vicinity of discovered Lapita settlement sites may indicate that horticulture was the dominant subsistence strategy. Evidence from Vanuatu also suggests a predominantly horticultural subsistence economy for Lapita settlers. Here there is evidence that domesticates were derived from the Bismarck Archipelago in near Oceania and then transported through the islands to Vanuatu (Horrocks and Bedford 2004). Vanuatu, similar to Tongatapu and Vava’u, is composed of arable land suitable for cultivation. The evidence from these islands indicates that local reefs were utilized during the Lapita occupation, but it is clear that the foundation of the subsistence economy on these islands was not marine based.

Ha’apai is composed mainly of limestone atolls with very poor soil drainage, not suited to agricultural success. Mangaia in the Cook Islands has scattered areas of arable

land, but the distribution is restricted and dispersed, with most of the island covered in sterile soils. In both of these locations, there is little potential for extensive agricultural success, necessitating reliance on local reefs and sand flats, and leading to the depression of preferred food fish.

## **Conclusions**

The examination of fish remains from Vava'u and comparison to those of Ha'apai and Tongatapu allows for a clear illustration of the varying importance of the marine environment to South Pacific subsistence economies. This analysis indicates that settlement locations in the South Pacific were arguably *not* bound by the presence of particular environments. Instead, the environmental parameters of chosen settlement locations determined what subsistence choices would be made for each island (e.g. presence of reef without fertile soil leads to a reef fishing economy).

In the case of Vava'u, while the initial occupation locations are placed such that utilization of the reefs is possible, it is clear from the composition of fish assemblages that the presence of fertile arable land may have had a more important role in the choice of settlement location. The density and abundance of fish remains from Falevai, 'Otea, Ofu and Vuna indicate that in Vava'u, reef environments were not intensively harvested by settlers, and while there is general decline in the abundance of fish remains through time it is not argued to be due to over-harvesting or human induced pressure on the reefs, but rather is more likely the result of the declining importance of a non-intensive fishery.

## **Future Directions**

The survey exploration in Vava'u was targeted at areas with reefs in the immediate vicinity. While this was useful in identifying five sites in Vava'u that include a Lapita component, the results of this study suggest that the presence of a reef may not have been a determining factor in the choice of site location. The implication of this is that targeting surveys of initial occupation based on specific environmental parameters may be biasing interpretations of settler subsistence strategies. It would be interesting to know if a more generalized survey would reveal additional Lapita occupation sites that are not located near reefs, but do lay on agriculturally productive soil. If this were the

case, it would strengthen the argument put forth by Burley (2009), supported by this study, that horticulture was an important part of the initial subsistence economy of Vava'u.

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