ANALYSIS OF MARINE MOLLUSK REMAINS FROM TONGOLELEKA:
AN ARCHAEOLOGICAL SITE IN THE HA’APAI GROUP,
KINGDOM OF TONGA,
THE SOUTH PACIFIC

By

JOHN W. WOLF
DEPARTMENT OF ANTHROPOLOGICAL SCIENCES
STANFORD UNIVERSITY
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Map 1: Oceania

NORTH

Limits of Western Austronesian
Limits of Eastern Austronesian Language Family

AMLAND
MAINLAND
SOUTH
EAST
SOUTH
EAST
ASIA

AUSTRALIA
NEW
ZEALAND
CHATHAM ISLANDS

ISLAND
MALAYSIA
SUMATERA
BORNEO
SULAWESI
MARIANAS ISLANDS
PHILIPPINE
ISLANDS

MELANESIA
NEW
GUINEA
BISMARCK
ARCHIPELAGO
ISLANDS

MICRONESIA
PALAU ISLANDS
CAROLINE ISLANDS
MARSHALL ISLANDS
GILBERT ISLANDS

POLYNESIA
NORFOLK ISLAND
TONGA ISLANDS
COOK ISLANDS
AUCKLAND ISLANDS
MARQUESAS ISLANDS
TUAMOTU ARCHIPELAGO
MANGAREVA
EASTER ISLAND

AMERICAN ISLANDS
SANDWICH ISLANDS
NEW
CALEDONIA
HAWAII
COOK ISLANDS
TONGA ISLANDS
NEW
BRITISH
GUARDIAN

NZ
NEW
SIAM
AUSTRALIA
NEW
ZEALAND
TONGA ISLANDS
Map 2: Kingdom of Tonga

TONGA

NIUATOPUTAPU GROUP
-16° S

VAVA’U GROUP

HA’APAI GROUP

TONGATAPU GROUP (1-9)

STATUTE MILES
Map 3: Lapita Site Locations, Northern Ha’apai Islands

Shaded areas represent estimated island land base at the time of initial settlement.
INTRODUCTION

The Pacific Ocean is the largest body of water on this planet. Moreover, it is larger than the entire land area of the globe. On the other hand, the land area of the Pacific, excluding New Guinea and insular Asia, is less than 50,000 square miles, consisting of many scattered islands (Spate 1963). Until no later than 40,000 years ago the islands of the Pacific Ocean, Java notwithstanding, were uninhabited by humans or their ancestors. By that time people had crossed into New Guinea and Australia. Islands farther to the east would not be inhabited for another 35,000 years. Yet by the time the first European explorers reached the area in the early 16th Century AD, virtually all the inhabitable islands of the Pacific supported human populations (Irwin 1992) (Map 1). These people were engaged in subsistence practices which involved the exploitation of marine resources, as well as the intensive utilization of a wide variety of plants and terrestrial animals such as pigs, dogs and chickens (Kirch 1985; Terrell 1986).

An ongoing subject of debate among archaeologists and anthropologists of the Pacific Ocean (Oceania) is the extent and nature of what some have called the “Lapita Cultural Complex”. As applied to the Tongan archipelago (Map 2), one of the primary areas of disagreement has been over the nature of settlement in Tonga – its pattern, form and transformation. Until recently the consensus opinion has been that pre-contact and traditional Tongan settlement was not concentrated on the coast but was dispersed, as reported by the first Europeans to arrive there. In addition to a dispersed settlement pattern, it has been argued that Lapita colonizers exploited marine resources only long enough to establish their terrestrial subsistence systems (Burley 1994). It is this latter
question that I address in this paper, by examining the distribution of marine mollusk remains recovered from archaeological sites.

To address the questions of settlement and subsistence, Simon Fraser University, under the direction of David V. Burley, collected archaeological data between 1990 and 1995 from several islands of the Ha’apai group of the Tongan archipelago. I participated in the 1995 excavations on the islands of Uiha and Lifuka. A total of more than 22,000 specimens of marine mollusk remains were recovered from two sites on two islands (Vaipuna and Tongoleleka). This paper is a report on my findings regarding the distribution of species within the marine mollusk population, as represented in Tongoleleka site, located on the island of Lifuka (Map 3). The paper is divided into four parts. The first section offers an archaeological history of what has come to be called the “Lapita Cultural Complex”, with a specific focus on the archeological history of Tonga. Following this historical overview is a discussion of the 1995 excavations in Ha’apai, including the sampling and collection methodology. Part three is a presentation of the data and my statistical analyses. The final section offers my conclusions regarding the relationship between the distribution of marine mollusks and the nature of the Tongan subsistence/production systems, as well as implications relating to the nature and extent of Tongan exploitation of marine resources.

PART I
ARCHAEOLOGICAL HISTORIOGRAPHY

By 5000 BP speakers of an Austronesian language had taken up residence along the coast of New Guinea (Green 1967). Austronesian is likely to have been the most
widely spoken language family in the world by 1500 AD. Its speakers currently inhabit an area extending from Madagascar eastward across the Indian Ocean and the Pacific to Easter Island and encompassing the peoples of Taiwan, the Philippines, Malaysia, Borneo, Indonesia, Melanesia, Micronesia and Polynesia (Bellwood 1979, 1991; Shutler and Marck 1975) (See Map 1). When the Austronesians arrived in the New Guinea area, there were already humans living there. The descendents of these non-Austronesians still occupy the highland areas of New Guinea (Kelly 1990).

The early Austronesians have been identified as the “Lapita peoples” (Gosden et al. 1989; Green 1967; Shutler and Marck 1975). “Lapita” refers to the pottery recovered from the early Austronesian sites. A German Catholic missionary, Father Otto Meyer collected the first potsherds that would eventually bear the name “Lapita”, from an island (Watom) off the northeast tip of New Britain Island in the Bismarck Archipelago. He first reported his discoveries in 1909. A dozen years later additional sherds of dentate-stamped pottery were discovered along the west coast of New Caledonia by a French geologist (M. Piroutet), but his finds did not come to the immediate attention of anthropologists working in the area (Kirch 1988a).

In the 1920s the Bernice P. Bishop Museum in Honolulu sponsored several research expeditions in Oceania (Kirch 1984). One of the early expeditions, the Bayard Dominick Expedition, included two individuals who would figure prominently in Oceanic anthropology/archaeology – W.C. McKern and E.W. Gifford. During this expedition McKern surveyed in what the British called “The Friendly Isles” and is now known as The Kingdom of Tonga. During his survey of the islands of Tongatapu, Pangaimotu, Motutapu and Eua he recovered dentate-stamped pottery. As yet no
connection had been made between the sherds from Watom, New Caledonia and Tonga. (Kirch 1988a; McKern 1929). Additional dentate-stamped pottery sherds were discovered in New Caledonia and eventually were seen to be related to the earlier Watom Island types. In 1952 one of McKern’s colleagues from the Bayard Dominick expedition, E.W. Gifford, conducted archaeological excavations with Richard Shutler, Jr., along the west coast of New Caledonia on the Foue Peninsula. This is the same area in which Piroutet had recovered sherds some thirty-five years earlier. Gifford and Shutler worked at eleven sites, including some along the East Coast of the island. Site 13 was near the village of Kone and was on the property of a Mr. A. Girard. The site was also known as “Lapita.” Throughout their field season in New Caledonia the researchers collected hundreds of potsherds, the most numerous of all recovered artifacts. They recognized similarities of design motifs of the sherds that had been collected earlier from New Caledonia, Watom Island, Fiji, Tonga and other sites. This was the advent of what has come to be known as “Lapita” pottery.

The “Lapita culture” is primarily marked by an “elaborately decorated” denticulate pottery style (Shutler et al. 1994:53). The definition of “Lapita pottery” would expand over time to include incising, applied designs, and red-slipping, as well as undecorated wares. The pottery would “spread rapidly from the Bismarck Archipelago through the Reef and Santa Cruz Islands into Vanuatu” (Shutler et al. 1994:53). The Lapita culture reached Fiji and the islands of Samoa and Tonga by the mid-thirteenth century BC (3300 BP) (Kirch 1985; Green 1967; Shutler et al. 1994).

Jack Golson of the University of Auckland argued that “Lapita” was more than an intricate and varied pottery style. He argued that the widespread distribution of related
pottery throughout the southwest Pacific testified to an “ancient community of culture straddling the ethnographic boundary between Melanesia and Polynesia, earlier…than any other archaeological manifestation in the region and ancestral to the historic cultures of western Polynesia” (emphasis added) (Golson 1970:67). To Golson the Lapita material clearly represented a culture complex (Golson 1970) extending from Melanesia in the west to Samoa, and even farther east to the Marquesa Islands. In addition to the pottery, Lapita artifacts include shell (*Tridacna*) adzes (used for cutting and shaping wood), shell ornaments, other shell tools (fishhooks, octopus lures, chisels), as well as various bone tools (Golson 1970; Kirch 1988a).

One of Golson’s students, Jens Poulsen, conducted excavations on Tongatapu, the main Tongan island and site of the capital, Nuku’alofa. Poulsen defined a pottery sequence that began with the decorated Lapita ware and ended with a plain ware component (Poulsen 1964, 1968, and 1987). This entire sequence purportedly ran from the “birth of Christ up to the 15th and 16th centuries AD” (Poulsen 1968:89). Poulsen’s contention was in conflict with established opinion, because Tongan oral traditions at the time of European contact made no mention of the use of pottery.

The first reported contact between Europeans and Tongans occurred in 1616 on the island of Tahafi when the Dutch sailing ship *Eendracht* visited (Ferndon 1987). In William Mariner’s account of his years in residence in Tonga (Martin 1991) there is no mention of a pottery technology. In fact, Mariner’s discussion on “Arts and Manufactures” (Martin 1991:359-368) mentions only basket-making as a technology that produced any type of container or storage vessel. This absence of a pottery tradition in the Tongan oral traditions at the time of contact, coupled with ambiguous reports on
pottery use and post-contact Tongan technologies raised doubts regarding Poulsen’s pottery sequence chronology for Tonga.

In 1971 Groube re-evaluated Poulsen’s data and the pottery remains that had been collected by other researchers. As a result, Groube directly challenged Poulsen’s hypothesis of a continuous Tongan pottery sequence. Groube found that pottery distributions on Tongatapu were temporally discrete (not continuous) and limited (with a few minor exceptions) to the fringe areas of the lagoon. There was virtually no pottery from the interior or the southern or western areas of Tongatapu. What this suggested to Groube was that the early prehistoric settlement pattern was one of villages along the shore of the lagoon. If that was true, however, there was a need to explain why no such settlement pattern was recognized or recorded by those Europeans who made the earliest contacts with the Tongans. Instead, they had reported a dispersed settlement pattern. Groube argued that if the Lapita settlements were concentrated and located along the lagoon fringe, little pottery would find its way inland and to the other perimeters of the island. If the pottery sequence were truly continuous through time from the earliest settlers to European contact pottery should be found everywhere (Groube 1971).

Having the advantage of additional research and archaeological material to analyze, subsequent to Poulsen’s fieldwork, Groube was also able to point to the extensive distribution of Lapita ware throughout the islands of Tonga. Although in most areas the finds were sparse, an extensive distribution argued in favor of the Lapita peoples as ancestral to the modern Polynesian Tongans. Because Lapita pottery was not found beyond Tonga, Groube argued that the culture that would become known as “Polynesian” arose in Tonga.
Groube considered Poulsen’s claim of longevity for the pottery sequence to be suspect, although he admitted that the evidence was inconclusive. The few pots that had been observed by early explorers appeared to be of Fijian manufacture and not of an extant Tongan pottery industry/technology (Groube 1971). Indeed, Poulsen’s $^{14}$C dates were suspect because the excavated sites were highly disturbed and younger deposits intruded into older deposits. Therefore, Groube’s field crew excavated natural levels and point provenienced all potsherds. Disturbed areas were identified and excavated individually, in order to avoid mixing with undisturbed deposits. As a result Groube’s radiocarbon dates suggested that pottery production had ceased in Tonga somewhere between 200 and 300 AD (Groube 1971).

Groube did more than simply question the Poulsen chronology and interpretation of the Lapita presence in Tonga. He also defined a major point of the debate concerning both the settlement pattern and subsistence practices of “Lapita” peoples. To Groube these people had an economy that was restricted to the exploitation of marine and lagoon resources. They would later develop or adopt, from some other migrating group, a horticultural subsistence economy that would allow the colonization of the remainder of the Pacific by what would now be legitimately called “Polynesians.” The “Lapita” peoples represented to Groube what he called “strandloopers”, a term borrowed from J.D. Clark’s 1959 book *The Prehistory of Southern Africa*. Groube argued that the Lapita peoples were similar to the European sealers and whalers who served as an advanced guard for the agriculturalists who would be the real colonizers. Thus, Lapita peoples rapidly settled oceanic islands prior to 3000 BP. Once established along the marine shore and lagoon fringes, they would become less reliant on marine resources and become more
dependent upon terrestrial resources for subsistence. The shift to a predominately horticultural economy would enable further expansion and colonization (Groube 1971; Kirch 1988a).

THE LAPITA MODELS

Initially, there were basically two models that attempted to explain Lapita. Opinions of the various researchers have evolved and changed over the decades. Few researchers today hold a monothetic view of the nature and role of Lapita in the prehistory of Oceania. Therefore, the models presented here are not necessarily dichotomous or mutually exclusive. A third model integrates aspects of the others.

The first model is the “Fast Train to Polynesia.” Proponents claim that settlers from Southeast Asia, bearing a distinctive ceramic design motif, poured through the Bismarck Archipelago and Melanesia on their way to the eastern margins of Near Oceania – Tonga and Samoa – where they would pause and coalesce into a distinctive “Polynesian” culture. From there they would rapidly colonize Remote Oceania (Eastern Polynesia). Pre-existing inhabitants of the region were non-Austronesian, dark-skinned Papuan speakers. The Austronesians undoubtedly had some contact with the Papuans, but the extent of that contact is uncertain (Bellwood 1989, 1991, Diamond 1988, Green 1991, Kirch and Weisler 1994, Kirch 1988a, 1988b, 1997).

The second model argues that Lapita was an indigenous development in the Bismarck Archipelago. This model does not contest the appearance of Austronesian-speaking immigrants from Southeast Asia. Instead, the Austronesians arrived and became part of an already existing and developing cultural complex that included the exploitation
of marine and terrestrial plant and animal resources. The Austronesians certainly introduced their language to the region and, perhaps, their ceramic technology. However, the “Lapita Cultural Complex” was considered to be a development indigenous to the area rather than an imported lifeway to the Bismarck Archipelago (Allen 1984, 1991, Allen and White 1989, Anson 1986, Spriggs 1991).

The third approach incorporates elements of the first two models and distinguishes between developments in Near and Remote Oceania. Offered by Green (1994), it distinguishes between “Near” and “Remote” Oceania (defined below), arguing that there is a need for distinct explanations for the initial development of Lapita in Near Oceania and its subsequent spread to Remote Oceania. Green (1991, 1994) refers to the former as the “Lapita Triple I Model”, but should be viewed as a component of his larger model. The three “I’s” are: Intrusion, Innovation and Integration. This component argues for a Lapita distribution that is widespread, of long duration and culturally heterogeneous, adopting and adapting elements of subsistence production and pattern of settlement from the indigenous Papuans. The rate of dispersal in the Bismarck Archipelago is moderate, but increases as people bearing Lapita pottery move into the Solomon Islands. The component for Remote Oceania is referred to as “The Coloniser Model.” It also views the distribution of Lapita to be widespread and of long duration. It differs from the “Triple I” component by being culturally homogeneous, as the colonizers of Remote Oceania were settling previously uninhabited islands. There are no indigenous populations from which to borrow elements of production and/or settlement.
PART II

1995 TONGAN SURVEYS AND EXCAVATIONS

In 1995 archaeologists from Simon Fraser University (SFU) conducted a series of surveys and excavations in The Kingdom of Tonga, in the South Pacific. SFU had been conducting periodic archaeological research in Tonga since 1990, under the direction of David V. Burley. The project was originally designed to examine the aceramic period during which the Tongan chiefdom had developed. Through the course of the initial surveys it became apparent that there were many ceramic sites that had to be investigated, in order to gain an understanding of the mode and tempo of change in (and disappearance of) the ceramic style and technology (Burley 1993, 1994, 1996; Shutler et al. 1994).

In 1991, Richard Shutler joined the project. Burley (1996:3-4) has defined four goals for the study of the Lapita period in Ha’apai. The goals are:

1. “define the Lapita colonization strategy and underlying processes…”;

2. “define the economy and adaptation of the first colonizer groups as these were applied to pristine island eco-systems in Ha’apai”;

3. “identify the impact of initial colonization on island environments, and the implications…for later culture change”; and

4. “outline…material culture technologies, settlement characteristics, and societal features associated with the early Lapita period in Ha’apai.”
The 1995 effort was a continuation of this “Northern Ha’apai Research Project” and lasted from September to December, with actual field work occurring over an eight week period from mid-September through mid-November (Burley 1996).

The SFU field crew consisted of Burley, Rob Shortland, and myself. Both Shortland and I were graduate students at SFU. It was Shortland’s third trip to Ha’apai. Several Tongan field and laboratory workers, as well as visiting researchers from Australia, Canada, New Zealand and the United States, assisted us. Among this latter group were Professor J. Peter White, Professor Richard Shutler, Professor William Dickinson, his wife Jacquie, and Kimi Pepa. While all of us engaged in survey and/or excavation work, Shortland and I established field laboratories to process material specific to our thesis and dissertation research, respectively. Shortland’s focus is the pottery and development of methods to analyze vessel shape.

My efforts have centered on the marine mollusk remains recovered from the archaeological sites in Ha’apai, with an eye to understanding how and to what extent mollusks were used as a resource by Lapita settlers and subsequent Tongan populations. As marine mollusks are harvested over time, predation should result in a decline in the frequency of the mean shell size, as increasingly younger individuals are captured, because older (larger) specimens have been harvested. Intense predation does not allow species to recover to the age (size) distribution existing at the initial moment of colonization (Swadling 1976). Intense predation should also result in the decline in the number of larger individuals recovered and a corresponding increase in the range (variety) of species (Gosden and Robertson 1991). If predation should lessen, recovery or regeneration can occur and that will be marked by a return of large individuals to the
shell bed (and the collected assemblage). It is assumed that shellfish with greater meat weight will be preferred initially (Anderson 1981, Gosden and Robertson 1991). Therefore, changes in frequency distributions and mean sizes of mollusk genera or species may reflect the extent and intensity of the marine mollusk component of the subsistence production system (Swadling 1976, Yesner 1980).

Tonga itself is on the western edge of what is termed the “Polynesian Triangle” (Map 1), that extends in its broadest expanse from Hawaii to New Zealand to Easter Island. There are more than 160 islands comprising Tonga today, encompassing an area 750 km long by 150-175 km wide (Map 2). The islands are aligned along a southwest to northeast axis and are composed of both high volcanic islands and islands of coral limestone. The islands in the Vava’u Group to the north are high islands, while the central islands of Ha’apai, for the most part, are low coral islands. Tongatapu, to the south, is considered the third group, and includes the largest of all the islands (also called Tongatapu). All of the islands are located along parallel submarine ridges that are separated by the Tofua Trough (Burley 1996, Dickinson 1996). To the east of the island forearc is the Tongan Trench, the deepest portion of which extends to a depth of 10,942 meters (6.74 miles), making it the deepest ocean trench in the Southern Hemisphere (Wright et al., 1998). To the west of the main islands of Ha’apai is an active volcanic area that includes the island of Tofua, made famous as the site of the HMS Bounty mutiny in 1789.

In 1995 the excavations in the Ha’apai Group were on the islands of Lifuka, ‘Uiha and Ha’ano (Map 3). I was involved in the excavations and analysis of material collected from ‘Uiha (Vapiuna Site) and Lifuka (Tongoleleka Site). The Vaipuna Site was
discovered during the 1995 season, as a result of surface survey and a series of auger probes. The Tongoleleka Site was originally discovered by a Bishop Museum survey in 1978. It was excavated briefly by Thomas Dye over a one-week period in 1984. He excavated a total of nine 1 x 1 meter units, seven of which were spread out across a ridge that ran parallel to the long axis of the island (Burley 1992, 1996). As director of the SFU project, Burley decided to relocate the Tongoleleka site and to expose a broader contiguous area. The nine new excavation units were arranged within a 3 x 3 meters square block. The units were number 1-9 as follows:

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>5</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>

Because practical time limitations prevented us from collecting all of the shell from all of the units, three units were randomly selected for analysis (2, 7 & 8). The project could not afford the expense of shipping 114,022 grams of shell (251 lbs.) to Canada. Therefore, all the shell had to be cleaned, identified, measured and recorded prior to departure from Tonga. This eventually involved considerable assistance from three Tongan women who ably prepared the shell, so that I might conduct my identification and preliminary analysis. Most of the shell was in a degraded condition that had removed any surface patterning or coloring that might aid in distinguishing similarly shaped and sized species. I made species identifications only when certain, otherwise I was satisfied with genus identification. In a few cases, particularly with *Mytilidae* (mussels), the
specimens were so degraded and fragile, I felt that identification at the family level was most conservative. My measuring devices were calipers (spreading and sliding) and a triple beam balance.

Linear measurements of length and height were taken on bivalves. Measurements of length have been shown to be most reliable in ascertaining changes in bivalve size (Classen 1998, Gosden and Robertson 1991). In other words, all other shell measurements correlate highly to length.

Mass was measured in grams. For gastropods, height and mass were also measured. In the case of specimens that were in some way damaged or missing parts that prohibited a precise linear measurement, only the measurement that could be precisely made was recorded. Those specimens are noted as “fragment” in the identification record. Highly fragmented specimens were lumped by family, genus or species (as appropriate) and a count of fragments and a collective mass was recorded. (A discussion of the correlation between “count” and “mass” appears in Part III below).

At Tongoleleka 58 genera were identified, while 43 genera were identified at Vaipuna. Total specimens for the two sites totaled 22,129, with 16,628 recovered from Tongoleleka and 5,501 from Vaipuna.
PART III

THE TONGOLELEKA MOLLUSKS

This report examines the four most prevalent genera recovered from Tongoleleka, \textit{Gafrarium} (n=2058), \textit{Mactra} (n=6087), \textit{Strombus} (n=2706), and \textit{Turbo} (n=1076). The first two are bivalves and the other two are gastropods. In addition to being the most numerous \textit{Mactra} and \textit{Strombus} had a very apparent negative correlation even as I was processing them. I noticed that whenever I had a large pile of \textit{Strombus}, I had a small pile of \textit{Mactra}, and vice versa. The nature of this relationship is intriguing and demands a measure of correlation, a test for significance (albeit \textit{posthoc}) and an explanation. The habitat of most \textit{Mactra} species ranges from intertidal zones to shallow sandy environments. The \textit{Stromboidae} discussed in this paper (\textit{S. gibberulus} and \textit{S. mutabilis}) inhabit the sandy areas of the intertidal zone up to ten fathoms in depth (Abbott and Dance 1982).

\textit{Gafrarium} is a commonly used food species that has been examined by others looking at intensity of resource exploitation, as mean lengths of \textit{Gafrarium} decrease with intensity of predation (Spennemann 1987). They inhabit shallow sandy areas (Abbott and Dance 1982), generally sheltered lagoons and mangroves (Spennemann 1987). They thrive in brackish water and the more sheltered, the better for \textit{Gafrarium} growth (Spennemann 1987).

\textit{Turbo} is important because it is the most commonly identified mollusk from Lapita sites ranging across the Pacific (Kirch 1997). The various species belong to a large family (\textit{Turbinidae}) of top-shaped marine snails that usually have thick shells. The interior of the shell is iridescent and a shelly operculum seals the aperture. Most are
vegetarians that feed on marine algae. The Tongan varieties are abundant and inhabit shallow reefs or the nearby subtidal zones (Abbott and Dance 1982).

I have examined the distributions by number of specimens for each genus, mean length (Gafrarium), and mass for each arbitrary excavation level. Level 01, the “plow” or disturbed surface zone, was excluded from both collection and analysis. Therefore, levels 02 through 16 were analyzed. For each of the genera, total mass and number of specimens were highly correlated (Table 1).

**TABLE 1: CORRELATION OF TOTAL MASS AND NUMBER OF SPECIMENS**

<table>
<thead>
<tr>
<th>GENUS</th>
<th>GAFRARIUM</th>
<th>MACTRA</th>
<th>STROMBUS</th>
<th>TURBO</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPEARMAN</td>
<td>0.9669</td>
<td>0.9321</td>
<td>0.9679</td>
<td>0.8643</td>
</tr>
<tr>
<td>P VALUE</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

As a result, I believe that levels could be compared by using either total mass or number of specimens. Other researchers have found that the mean mass (or weight) of whole shells correlate highly with that of fragments, suggesting that fragment size is strongly influenced by the original size of the shells (Gosden and Robertson 1991). This is crucial in cases where the remains are highly fragmented either throughout an assemblage or within a particular excavation level or stratum. Because neither mass nor count (number of specimens) displays a normal distribution, a non-parametric test is appropriate and I used Spearman’s Rho to test the correlation (Sall and Lehman 1996).

The following table (Table 2) displays the total mass (grams) for the four genera and the entire assemblage by excavation levels:
TABLE 2: TOTAL MASS (GRAMS) BY EXCAVATION LEVEL

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>Gafrarium</th>
<th>Mactra</th>
<th>Strombus</th>
<th>Turbo</th>
<th>All Mollusks</th>
</tr>
</thead>
<tbody>
<tr>
<td>02</td>
<td>422.50</td>
<td>818.50</td>
<td>466.50</td>
<td>1136.50</td>
<td>5168.50</td>
</tr>
<tr>
<td>03</td>
<td>289.00</td>
<td>404.50</td>
<td>464.50</td>
<td>1376.00</td>
<td>5678.50</td>
</tr>
<tr>
<td>04</td>
<td>344.00</td>
<td>248.50</td>
<td>621.50</td>
<td>867.00</td>
<td>4438.00</td>
</tr>
<tr>
<td>05</td>
<td>535.50</td>
<td>187.00</td>
<td>937.50</td>
<td>852.50</td>
<td>4962.00</td>
</tr>
<tr>
<td>06</td>
<td>654.00</td>
<td>90.50</td>
<td>964.50</td>
<td>1313.50</td>
<td>5690.00</td>
</tr>
<tr>
<td>07</td>
<td>539.00</td>
<td>211.75</td>
<td>1002.90</td>
<td>2463.50</td>
<td>7618.65</td>
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<td>227.50</td>
<td>136.00</td>
<td>1161.50</td>
<td>1167.00</td>
<td>6056.50</td>
</tr>
<tr>
<td>09</td>
<td>213.50</td>
<td>291.00</td>
<td>955.75</td>
<td>2201.00</td>
<td>5785.50</td>
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<tr>
<td>10</td>
<td>95.00</td>
<td>269.50</td>
<td>447.50</td>
<td>1922.00</td>
<td>4262.50</td>
</tr>
<tr>
<td>11</td>
<td>49.25</td>
<td>464.25</td>
<td>154.50</td>
<td>4818.00</td>
<td>8511.50</td>
</tr>
<tr>
<td>12</td>
<td>33.50</td>
<td>396.50</td>
<td>169.50</td>
<td>5430.00</td>
<td>9710.00</td>
</tr>
<tr>
<td>13</td>
<td>17.50</td>
<td>725.50</td>
<td>183.50</td>
<td>2487.00</td>
<td>5578.00</td>
</tr>
<tr>
<td>14</td>
<td>28.50</td>
<td>621.50</td>
<td>146.50</td>
<td>1106.50</td>
<td>3613.50</td>
</tr>
<tr>
<td>15</td>
<td>11.50</td>
<td>295.50</td>
<td>50.50</td>
<td>1057.50</td>
<td>1967.00</td>
</tr>
<tr>
<td>16</td>
<td>7.50</td>
<td>30.00</td>
<td>123.50</td>
<td>472.50</td>
<td>921.50</td>
</tr>
</tbody>
</table>

Figures A through D contain graphical plots of the distribution of specimens by mass and numbers of specimen for each excavation level. Because the *Turbo* shells are large, heavy and dense, they clearly influence the distribution of mass for the entire assemblage (Pairwise correlation = .8194, p = 0.0002; Spearman Rho correlation = .7857,
p = 0.0005). However, the shape of the graphical plot remains similar even when *Turbo* is excluded. In other words, the rise and fall of the line (the pattern of change through time) does not change when *Turbo* is excluded (Figures A and A-1).

**FIGURE A. TONGOLELEKA: ALL SPECIMENS BY LEVEL**

![Graph showing the total mass of specimens by level with and without Turbo](image1)

**FIGURE A-1. TONGOLELEKA: ALL SPECIMENS BY LEVEL**

![Graph showing the total mass of specimens by level with and without Turbo](image2)
Mactra (left valves), Turbo, and the entire mollusk assemblage as a whole, increase steadily and steeply from level 16 to 12 (Turbo and the entire assemblage) or level 13 (Mactra). A steep and steady decline begins and extends for the assemblage as a whole until level 10, when the total mass again increases through level 07, before falling again. Turbo, however, continues to decline until level 08, recovering briefly and, then, falling to its lowest point in level 05 and 04 (Figure B).

Mactra continues its decline in both number and total mass until level 08, when the number of specimens begins to increase (Figures C and D). This trend increases steadily until level 03 and, then, takes a dramatic climb to the highest number of Mactra specimens for the site in level 02.
In the meantime, *Strombus* has increased gradually from level 15 (after a slight decline from level 16) (Figures C and D). At level 10 it surpasses *Mactra* in both total mass and number of specimens. *Strombus* reaches its peak in level 08 and eventually declines and falls below the values for *Mactra* at the margins of levels 04 and 03.
I performed several statistical tests of the negative relationship between *Mactra* and *Strombus* that I had observed in the field laboratory. The correlations ranged from -0.4638 (p = 0.0816) when comparing total mass to -0.6217 (p = 0.0134) when comparing counts of whole specimens. Using non-parametric tests (Spearman Rho), the correlations ranged from -0.4107 (p = 0.1283) (mass) to –0.4964 (p = 0.0598) (counts). If not confirming, these figures suggest that additional investigation involving analysis of material from other Tongan sites might demonstrate a statistically significant inverse relationship between *Mactra* and *Strombus*.

*Gafrarium* produced an entirely different, yet significant picture. Graphically, the volume of shell, in number and mass, increases rather slowly compared to the other genera (Figure E).

![Figure E. Tongoleleka: Gafrarium by level](image)

Beginning at level 08, however, there is a marked increase in mass and number. Total mass peaks at level 06, while level 07 is the peak for number of specimens. But what is most interesting about *Gafrarium* is the change in mean length through time. Graphically,
the change appears less remarkable after level 13 (Figure F), but that is simply due to the small number of samples in the deepest levels (n = 3 in 15 & 16) and the range of variation available to the genus.

Abbott and Dance (1982) report that the maximum length of an average adult specimen is 35mm. I chose the left valves for comparison. The following is a table that lists the number of specimens and the mean lengths:

**TABLE 3: GAFFRARIUM COUNT AND MEAN LENGTH BY LEVEL**

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>COUNT</th>
<th>MEAN L.</th>
<th>LEVEL</th>
<th>COUNT</th>
<th>MEAN L.</th>
</tr>
</thead>
<tbody>
<tr>
<td>02</td>
<td>62</td>
<td>29.1290</td>
<td>10</td>
<td>37</td>
<td>26.6216</td>
</tr>
<tr>
<td>03</td>
<td>78</td>
<td>27.7564</td>
<td>11</td>
<td>14</td>
<td>26.3571</td>
</tr>
<tr>
<td>04</td>
<td>66</td>
<td>26.8182</td>
<td>12</td>
<td>12</td>
<td>27.0000</td>
</tr>
<tr>
<td>05</td>
<td>145</td>
<td>26.2621</td>
<td>13</td>
<td>6</td>
<td>27.1667</td>
</tr>
<tr>
<td>06</td>
<td>176</td>
<td>26.2273</td>
<td>14</td>
<td>14</td>
<td>25.5714</td>
</tr>
<tr>
<td>07</td>
<td>188</td>
<td>25.4202</td>
<td>15</td>
<td>3</td>
<td>19.6667</td>
</tr>
<tr>
<td>08</td>
<td>63</td>
<td>26.0952</td>
<td>16</td>
<td>3</td>
<td>24.6667</td>
</tr>
<tr>
<td>09</td>
<td>59</td>
<td>26.4915</td>
<td></td>
<td></td>
<td><strong>TOTAL 926 26.4395</strong></td>
</tr>
</tbody>
</table>
Analysis of variance (ANOVA) tests for significance in the variation of mean lengths produced a F ratio of 4.5374 and a probability value of <.0001. Because shell length is a measure of age and, therefore, is not necessarily normally distributed, I also performed non-parametric tests of variation of the medians (1-way $\chi^2$).

**TABLE 4: GAFRARIIUM MEDIAN TEST (ALL LEVELS)**

<table>
<thead>
<tr>
<th>$\chi^2$</th>
<th>DF</th>
<th>Prob &gt; $\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>32.5999</td>
<td>14</td>
<td>0.0033</td>
</tr>
</tbody>
</table>

**TABLE 5: GAFRARIIUM MEDIAN TEST (LEVELS 02-14)**

<table>
<thead>
<tr>
<th>$\chi^2$</th>
<th>DF</th>
<th>Prob &gt; $\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>28.1295</td>
<td>12</td>
<td>0.0053</td>
</tr>
</tbody>
</table>

The resulting $\chi^2$ value was 32.5999 (DF = 14) with a probability of 0.0033 (Table 4). Both tests strongly suggest that the level (depth) has a significant affect on *Gafrarium* mean length. Because only three specimens of *Gafrarium* were recovered from each of the lower two levels (15 and 16), I also tested the size change excluding those two levels. The resulting ANOVA test produced a F Ratio of 3.4423 ($p = <.0001$). The non-parametric test of variation produced a $\chi^2$ value of 28.1295 (DF = 12) with a probability of 0.0053 (Table 5). Thus, even excluding the two lower levels, the *Gafrarium* length changes significantly through time.

It is also noteworthy that in Level 07, where the count peaks, the mean size is the lowest since Level 14. I suggest this represents the greatest intensity exploitation of *Gafrarium* relative to the available resource. Why does mean size begin to increase from
that point onward (Levels 07 – 02), while the count decreases (Levels 07 - 02) and the total mass continues to increase (Level 06), but then falls (Levels 06 – 03), recovering slightly in Level 02? One explanation is that *Gafrarium* beds had been thinned to such an extent that there was simply more room for growth. Human settlement could also have affected the *Gafrarium* habitat. Increasing horticultural and/or settlement “run-off” would also increase the expanse of muddy sand flats where *Gafrarium* are abundant. An expanding Gafrarium habitat could account for increasing size and capture. A declining capture may result from reduction in the human population exploiting the resource or a change in resource preference. A more complete comparison with other species from Tongoleleka and other Ha’apai sites will be required before the question can be resolved.

**TONGOLELEKA RADIOCARBON DATES**

Burley (Burley et al., 1998) has recently reported the radiocarbon (AMS) dates for Tongoleleka, ranging from 2760 ±60 BP from Level 15 to 2490 ±50 BP for Level 04. These are calibrated accelerator mass spectrometry (AMS) dates. AMS dating permits the use of very small samples. Thus, Burley was able to select discrete samples from particular stratigraphic contexts associated with Lapita deposits. The excavation levels and associated dates and ceramic phases are as follows:
TABLE 4: RADIOCARBON DATES

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>14C DATE</th>
<th>PHASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>04</td>
<td>2490 ±50 BP</td>
<td>Plainware</td>
</tr>
<tr>
<td>05</td>
<td>2450 ±40 BP</td>
<td>Plainware</td>
</tr>
<tr>
<td>07</td>
<td>2430 ±50 BP</td>
<td>Plainware</td>
</tr>
<tr>
<td>08</td>
<td>2600 ±60 BP</td>
<td>Plainware</td>
</tr>
<tr>
<td>10</td>
<td>2560 ±50 BP</td>
<td>Transitional</td>
</tr>
<tr>
<td>15</td>
<td>2760 ±60 BP</td>
<td>Lapita</td>
</tr>
<tr>
<td>Stratum III</td>
<td>2730 ±50 BP</td>
<td>Lapita</td>
</tr>
</tbody>
</table>

The Stratum III date was taken in 1997 and comes from an elevation below (190-230 cm below surface) level 16 of the 1995 excavations. The samples from levels 05, 08, 10, and 15 were recovered in 1995. The samples from levels 04 and 07 were recovered in 1997 from excavation units adjacent to the 1995 units (Burley 1998).

The importance of these dates is twofold. First, they demonstrate that the final eastern extent of Lapita settlement occurred later than previously postulated (Spriggs 1990). Based on other dates from the Simon Fraser University excavations in Ha’apai and an analysis of dates submitted by other researchers, Burley, Nelson and Shutler (1998:69) argue that the “eastern termination was circa 2850-2800 BP.” Rather than a “fast train” that rapidly carried Lapita peoples from the Bismarck Archipelago, beginning no later than 3300 BP (Specht and Gosden 1997) and arriving in Tonga by 3000 BP (Shutler et al., 1994; Dickinson et al., 1994; and Burley 1994), the expansion took place over a minimum period of 450 years. Second, having arrived in Tonga, the Lapita phase appears to have disappeared rather quickly, within 150 or so years. The rapid disappearance of Lapita pottery is a question that is likely related to changing social structure in the

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1 BP = calibrated radiocarbon years before present (AD 1950).
colonizer society and/or economy. That question is not addressed here, but it offers considerable opportunity for further investigation.

The display of the radiocarbon dates on the figures (A, B-F) suggests a uniform transition that can be misleading. The level designations represent arbitrary 10cm excavation levels. The radiocarbon dates are overlaid on the graphs to show a temporal trend. This visually distorts the relationship between temporal change and changes in the mollusk distributions. For instance, there is a 200 year spread between the mean dates of Levels 15 and 10, but only a 70 year spread between Levels 10 and 04. Thus, changes occurring from Level 10 to Level 04 are doing so at an accelerated pace in comparison to the earlier levels.

Figure G shows the range of radiocarbon dates with a linear regression of the means ($R^2 = 0.7864$). The regression suggests that more than 78% of the variance of the
mean dates can be explained by progression through the excavation levels. However, because we are dealing with dates that range ± 30 to 60 years from the means, the regression line best serves as a visual representation of the temporal trend through the excavation units.

PART IV

CONCLUSIONS AND CONSIDERATIONS

It is clear that in the case of the entire suite of collected specimens, as well as the four specific genera discussed here, there were significant changes in the frequency and distributions of the marine mollusks recovered from Tongoleleka. Radiocarbon dates from Tongoleleka suggest that the changes were relatively rapid. The wide variety of both bivalve and gastropod genera found at Tongoleleka reflects the site’s proximity to the harvest zone. Central place theory argues that the more distant a residential site from a harvest zone, the more likely that processing will occur in the field instead of at the residential site (Bird and Bird 1997). At the time of initial occupation the site was located just off the beach. Lowered sea levels following the mid-Holocene high stand, coupled with uplifting and tilting of the forearc block that underlies the island (Lifuka) has resulted in Tongoleleka being 250 meters inland today (Burley 1998, Dickinson et al., 1994). Other than the heavy and unwieldy giant clam \((Tridacna gigas)\) and its somewhat smaller cousins, transport of mollusks to Tongoleleka for processing would have been quick and easy.

The variety of shell deposited at Tongoleleka may also be viewed from the perspective of foraging strategies. Simply put, mean search time decreases with the
addition of each new resource. As a result a collector or harvester of mollusks ought to collect whatever is encountered (Anderson 1981). In addition, larger prey should be a first preference if yield per unit of search time is an issue. Larger mollusks are easier to locate than smaller ones. Most shell collecting occurs during ebb tide on reef flats or rocky shores (Anderson 1981, Bird and Bird 1997). Harvest time may be inelastic, but prey selection (variety and size) is not.

It seems clear that the resident collectors of Tongoleleka employed a strategy that resulted in the harvest of a wide variety of genera/species, with a prey preference for larger mollusks. However, a sustainable yield of large specimens requires recovery time for the resource. Younger, smaller individuals must have time to grow into larger individuals. In the extreme, intensive exploitation of any resource in which younger and younger individuals are captured until a viable reproductive population cannot be sustained is one pathway to extinction.

Steadman (1998) has reported on the rapid extinction of terrestrial birds in the Ha’apai island group in Tonga. No such extinction can be ascertained from the mollusk data I have examined. However, significant changes in size and species distribution did occur. Exploitation of marine mollusks commenced immediately and increased steadily and rapidly, suggesting an increasing settlement population. This is evidenced by the overall exploitation of all marine mollusk species (Figure A), as well as *Turbo* (Figure B). Dramatic declines in mass and number of specimens suggest an intensive harvesting pressure, causing marked reduction of some mollusk resources. As one resource declined due to over-harvesting (*Mactra*) another was substituted (*Strombus*) (Figures C and D). In addition, changes in the mean length of *Gafrarium* are persuasive evidence that
younger and younger individuals are being harvested through time (Figure F). This decline means that resource choice is not selective in a conservative sense. *Gafrarium* do not grow to full adult size and are not found in the cultural deposits because they are harvested before they can attain that size.

However, other explanations for changes in frequency distributions and size must be considered. A decline in mean size alone can result from environmental changes devoid of human agency. For example, changes in temperature or salinity can influence mollusk size. If all age classes of mollusks are decreasing in size, than the cause is more likely environmental change rather than human predation (Classen 1998, Swadling 1976).

Unlike the temperate climates where there are marked seasonal water temperature changes, the water temperatures in tropical regions vary little through the year. As a result seasonal growth bands that appear in the shell of temperate species do not appear among the tropical species (Swadling 1976). Although some gastropods (*Strombus luhuanus*) show morphological features that permit age determination, similar developmental changes for other species need to be identified. Without such relative assessments age classification is problematic. Spennemann (1987) did calculate size ranges for *Gafrarium* shells from Tongatapu, using annual spawning breaks observable on the shell. Microscopic analysis was not available at Tongoleleka and the degradation of the shell material was such that naked-eye assessments could not be made. Development of such assessment techniques will require study of individual mollusk species (Classen 1998, Swadling 1976). I intend to attempt such an assessment and analysis with additional collections.
On the other hand, there is data concerning temperature changes in the region that permits us to determine any regional variation that may have affected overall mollusk size. Between 750-1250 AD global mean temperatures were .5 to 1.0°C warmer than today, but the Lapita colonization of the Pacific preceded this warming period. Furthermore, the mid-latitude regions of the south-central Pacific saw little temperature fluctuation in the period of initial Lapita colonization and subsequent widespread Polynesian voyaging and expansion (Spencer 1995). Therefore, it is unlikely that water temperature changes are the cause of the changes in the Tongoleleka mollusk assemblage.

Salinity can change due to drought (increased salinity) or heavy rainfall and flooding (decreased salinity). This is more likely to be a problem in smaller, bounded bodies of waters (lagoons, lakes, seas, or gulfs), than in the expansive ocean. Sudden changes have a greater impact than long gradual changes (Classen 1998). Additional analysis of species distributions of mollusks and chemical analysis of the shells will be required to reveal salinity changes during Lapita colonization and post-Lapita settlement.

Finally, this analysis is simply a first pass at the excavated mollusk remains from one site, Tongoleleka, collected in one excavation season, 1995. The next step in my research is to broaden the Tongoleleka investigation by examining other genera from the site. In addition, the Vaipuna and shell data from the other Ha’apai excavations (1990-1997) need to be incorporated in this analysis. A complete picture of Tongan settlement and prehistory must be built upon a re-examination of earlier data collected by Poulsen, Spennemann and Dye, as well as the excavation of the Vava’u group to the north. These high islands may offer an entirely different picture of marine resource exploitation by its
earliest settlers. Only, then, will we be able to understand the “duration, intensity, and periodicity” (Crumley 1994) of human colonization and settlement of the Tongan Archipelago.
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