Ethnobotany and Construction of a Tongan Voyaging Canoe: The Kalia Mileniume

Mark Nickum

Research

Abstract

Construction of the world's largest existing double hulled voyaging canoe, the 108 foot Tongan Kalia Mileniume, was completed in August 2000. The **kalia** was documented on three research trips. Tuione Pulotu, master chainsaw artist and canoe builder designed the canoe and proposed the project to the Tongan government as a celebration for the New Millennium. This ethnobotanical study documented canoe architecture and plant species used for the Kalia Mileniume, as well as for voyaging canoes of the past. Construction procedures were recorded through series photography, digital video, and interviews with the builders. Detailed measurements were taken of the final product. As near as one can judge authenticity of a reproduced cultural artifact, the Kalia Mileniume was a successful recreation.

Preface

Here I am writing a preface with more personal depth and story to it than is normal for a professional document. First, I believe it is important for the issue of "scientific reproducibility" for the reader to gain an understanding of my background, the kind of living situations I found myself in, in Tonga, and how the wonderful Tongan people I worked with helped me. Second, I believe it may be important for future researchers (and perhaps future graduate students) to see how this project came into being and how it developed. My story may offer encouragement or food for thought for future students. Lastly, and perhaps more importantly, I intend this preface to be a tribute and acknowledgment to the people of Tonga who took me into their homes, into their work places, and into their lives. To these people I owe a great debt of gratitude because I would never have been able to write this thesis or witness the amazing creation of the Kalia Mileniume without their help and care. I would like to thank my Tongan friends from the bottom of my heart. **Malo'aupito**.

The Kalia Mileniume is simply the most amazing thing I have ever seen in my entire life. It is grand in size, beauty, historical significance, and depth of emotional spirit. I have been privileged to witness the creation of this canoe through various stages in its development, from the first cut of the log to the last finishing touches.

My favorite moment throughout the year and a half of my involvement was on June 10, 2000. I arrived in Tonga early that Saturday afternoon after nearly a year since my previous visit. Manatu and Ana, two ladies from the Tonga National Centre, picked me up from Fua'amotu International Airport, driving the "traditional" TNC van. It was a pleasant ride. Tonga had never looked so green or clean to me before. I wasn't sure why this was the case, but the best I could figure out was that some cleaning up had taken place for the New Millennium celebrations earlier in the year. Maybe the sun was exceptionally bright and I was in good spirits. From the airport they took me immediately to the **kalia** construction site on Vuna Road between Queen Salote Wharf and the Saturday flea market area. All I can say is the canoe was amazing. My jaw really dropped. I was in no way prepared for the "ship"

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which stood before me. What caught my eye the most wasn't the massive hulls, but the hut which seemed to stand so high up on top of the deck. It towered far higher above the earth than I ever imagined it would. We pulled up to the canoe and I could hardly get out of the van I was so excited. When I did manage to get the door open and crawl out of the back, I immediately saw Tuione Pulotu, the canoe wright. All I could do was walk up to him with my eyes wide open and a gaping smile on my face, expressing my surprise and admiration for what he and his men had completed in the time I had been away.

As I walked up to him, he shouted, "Toki Ukamea," which had become a nickname of mine. This was the nickname of William Mariner, who nearly 200 years ago, on December 1, 1806, was taken captive in Lifuka, Ha'apai, Tonga. He was fortunate to be looked upon favorably by one of the chiefs, and his life was spared during the hostile takeover of the Port au Prince (Martin 1991:57). **Toki** means adze, and **ukamea** means iron, so the translation is Iron Adze. I was happy to be in Tonga, and Tuione was happy to have me back. Thus began in a very positive way the best of my three trips to Tonga.

"Formal Ceremony Launches Construction of Millennial Double-Hulled Canoe"
The Tonga Chronicle. 36(8):3. Nuku'alofa, Tonga. Thursday, February 25, 1999.

"Logs for a traditional **kalia** (double-hulled canoe) were cut at Tu'imatamoana Wharf on Tuesday (February 23, 1999) by the Hon. Sione Ikamafana Tuita (King Topou IV's grandson) during a ceremony to mark the start of construction. The vessel is being crafted by Mr. Tuione Pulotu, formerly of Pangai, Ha'apai, now residing in Laie, Hawai'i, to help recall the 17th century Hifofua, which was constructed in Fiji and presented to Mataeletu'apiko, the third Tu'i Tonga. In delivering the ceremony's opening speech, the Hon. Giulio Masasso Paunga, Minister of Labour, Commerce, and Industries and chairman of the National Kalia Committee, said that the vessel would help to welcome the year 2000 and the beginning of the third Christian millennium as part of a national programme to attract tourists. He pointed out that while no committee member had ever seen a **kalia** in operation, the one under construction would provide the public with the means to learn how people lived and navigated the oceans in earlier times. In those days, the Minister said, each **ha'a** (clan) had one. The Minister pointed out that even though it is known that **kalia** existed as far back as the 17th century, the diary entries, paintings, and drawings of Dutch explorers in Tonga that century did not include a depiction of a **kalia** but only of a smaller canoe called a **tongiaki**. When Captain James Cook arrived in the Pacific during the next century they sighted and drew a **kalia**, but it was almost like an improved **tongiaki**. The Minister urged Ministry of Education and Tonga National Centre researchers to work together with the committee to gather more information about **kalia** construction."

Researcher Background

I grew up in the mid-west where the only sea around was the "Sea of Corn." Bloomington, Illinois was a very comfortable place to live and dream. As a high school sophomore I wrote a history paper about Captain James Cook. His exploits fascinated me, and a deep desire to sail the South Pacific took solid root.

For my undergraduate degree, I went to a small liberal arts college in Galesburg, Illinois named Knox College. Knox was famous as a site for one of the Lincoln-Douglas debates. I earned my degree in Biology in March of 1997. Along the way I managed to keep my dream of sailing in the South Pacific alive.

Early on in my college career, I decided to apply for a travel fellowship called the Thomas J. Watson Fellowship. Graduating seniors of fifty small liberal arts schools were eligible to apply. This eccentric grant awarded its winners $20,000 to travel around the world for one year on a project of their own devising. I decided my project would be to travel the South Seas and document canoe construction. I spent a full year preparing my grant application with encouragement and praise from my dean. When I found out I did not win the fellowship, my heart was broken. (The winning student from our school went to New Guinea to study trash dumps. Now I'm sure this was a noble cause, but you be the judge of which project sounds more interesting!)

After graduating from college, I put my dream on hold for a while in order to enter the working world at Missouri Botanical Garden. There, as an herbarium assistant, I was able to cultivate my new interests in botany and ethnobotany. The Garden was a terrific place to work. Up until that time I had little to no botanical training, and I was able to catch up and prepare for what became my next career move, graduate school.

My dreams of studying canoe building were resurfacing, and by December of 1997 I contacted Dr. Will McClatchey at the University of Hawai'i, Manoa. I was looking for a school where I was certain I would be able to study canoe building, because for me, the research was the most important aspect of the graduate student experience. Dr. McClatchey's almost immediate suggestion that we write a Sea Grant proposal to study canoe building in the Marshall Islands got my attention, and gave me the confidence that the University of Hawai'i was the school for me.

Arrival at the University of Hawai'i, Manoa

Upon arriving at UH, I spent a great deal of time networking within the University and the East-West Center. Among others, I spoke with Dr. Ben Finney (Professor of Anthropology, UH) and Dr. Geoffrey White (East-West Center). As luck would have it, a Pacific specialist by the name of Dr. Bob Kiste was looking for possible graduate students to document a canoe being constructed in Tonga. This request had come via Dr. Eric Shumway, who is an expert in Tongan language and custom, and currently president of Brigham Young University, Hawai'i. (I heard it said both in and out of Tonga, by Tongans and **palangi** that Dr. Shumway speaks the Tongan language better than many Tongans themselves.) To my benefit, Dr. Kiste asked both Drs. Finney and White if they knew of anyone who would be interested in the project, and my name came up both times. With that, introductions were made, and I met separately with both Dr. Shumway and the canoe builder, Tuione Pulotu.

In our meeting, Dr. Shumway explained the Kalia Project and the need for someone to document this important historic event. He was looking for an ambitious graduate student with a sense of adventure who was willing to go to Tonga on short notice. With that, I said "when do I leave." Dr. Shumway made contact for me with a Tongan noble, the Honorable Luani. This man was one of the 33 titled nobles of Tonga. He had land holdings on the island of Tongatapu, in the village of Malapo. Hon. Luani was also director of the Tongan Visitors Bureau (TVB). Dr. Shumway later told me I had been invited to stay with Luani.

My first meeting with Tuione Pulotu proved to be amusing. I had prearranged a time to meet with him at his home in Laie, O'ahu, and when I arrived, it turned out he had gone fishing for the day. Consequently, I spent a great deal of time exploring his workshop, which contained a Maori war canoe that was under construction. It was a beautiful canoe with amazing artistry, including a sculpted face on the bow which was quite captivating. I shot two rolls of pictures as I rummaged around the workshop, and I began to feel real good about what was to come.

I came and went a couple of times that day, and at one point Tuione's wife and another lady were home for lunch. They both worked just down the street at the Polynesian Cultural Center. In typical Tongan style, I was offered a meal. This particular day it consisted of a McDonald's cheeseburger, fries, and a soft drink! They were very cordial.

When Tuione did arrive home, he had quite a catch with him. Laid out on a tarp must have been over two dozen fish. As we introduced ourselves to one another, he was busily cleaning out the deep freeze and loading it up with the day's catch. We were both pretty quiet and just chit chatted back and forth during the pauses in his work. We spoke a little of the **kalia** and the architectural plans for the canoe. After what I felt was a sufficient introduction, I took my leave.

I went to check out the beaches around Laie, and before I left that side of the island to return home to Manoa, I went to visit Tuione once more. I was once again fed. This time there was both raw and cooked fish from the day's catch. This second meeting between Tuione and I was more cordial. We spoke about what life in Tonga would be like for me. In parting he said, "See you in Tonga."

A few days later I called Dr. Shumway again. He said that he had spoken with Tuione, and that Tuione and I were now "friends." I could expect Tuione and the Honorable Luani to take good care of me in Tonga. I was advised to leave for Tonga as soon as possible because Tuione was a fast worker and would be starting canoe construction in short order.

I still had obligations as a graduate teaching assistant, but with a little negotiation I was able to find two people to fill in for me for the month I would be away. In the back of my mind though, was to return to Tonga in the summer and stay there for the duration of the canoe construction.

Travel to Tonga

About three weeks after my initial meeting with Tuione I found myself on a plane bound for Tonga. As I traveled nervously on this red eye flight to my first stop in Fiji, I was studying. Normally a person might be boning up on the local language of their destination. But instead, I had two Olympus cameras in front of me. All the lights in the plane were out except mine.

One thing I realized just shortly before I left Hawai'i was that I knew absolutely nothing about photography. Luckily Dr. David Webb had a reprint handy of a short and sweet article he had written about the basics of SLR photography. This was a primer I sorely needed. With a little fast reading, I started to get the basics down. (As an aside, I had a rather large "wide angle" lens with me. I used it a few times, but it was so big and heavy for just that simple purpose, I felt it was more of a bother than it was worth. When I returned to Hawai'i I later realized through a discussion with Will McClatchey that it was a "zoom lens" and that you had to pull out on the lens in order to get it to zoom. Live and learn!)

I spent two days and one night in Fiji. The flight arrived in Nadi, and I took a four hour express bus to Suva. With a roach crawling across the seat in front of me and a not so insignificant stream of rainwater running in through the window onto my foot, I was welcomed to Fiji. While in Suva, I visited the Fiji National Museum in order to begin examining canoes.

This was my first look at two very important Fijian canoes, the **camakau** (Figure 1), and the **drua** (Figure 2). The **camakau** was a Fijian sailing outrigger canoe. It sailed using the shunting rigging system (Hornell 1936). The **drua** was

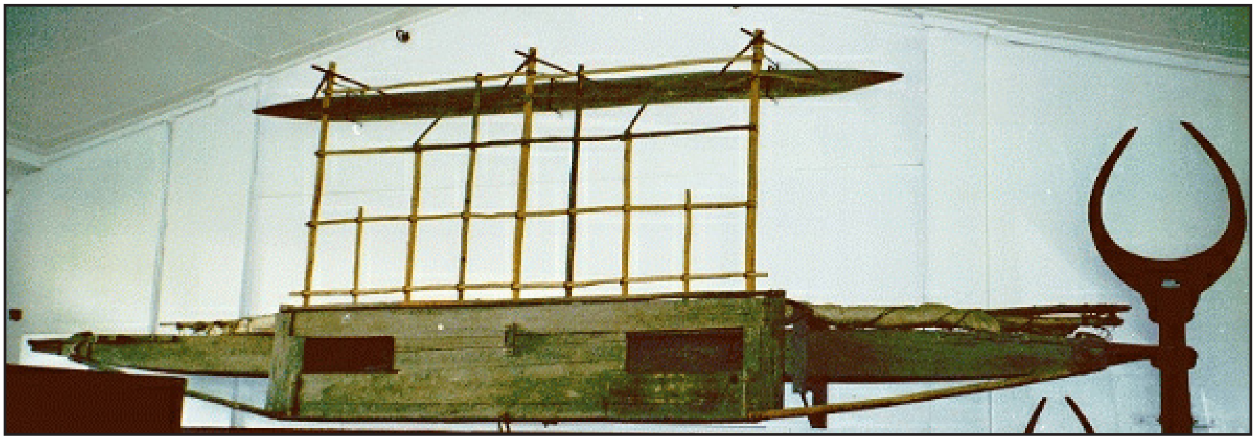

Figure 1. Hanging on the wall of the Fiji National Museum is the Fijian **camakau**.

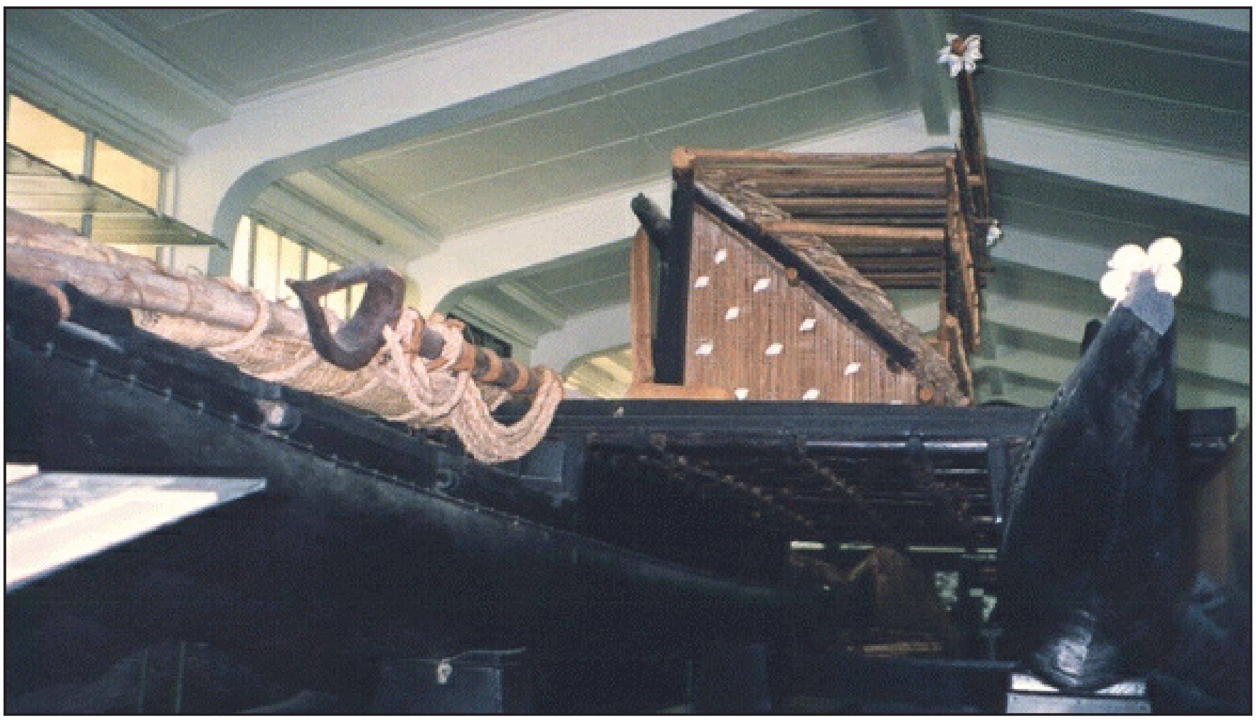

Figure 2. Small Fijian **drua** at the Fijian National Museum.

a two hulled sailing canoe with one hull slightly larger than the other. It also sailed using the shunting sailing system, and being an analogue to the **kalia**, was of particular interest to me. While I did not make any measurements of the canoe, I later found detailed measurements in a Fiji Museum Catalogue (Clunie 1986). This was a smaller **drua**, with each hull built from a single log of **vesi** (*Intsia bijuga* (Colebr.) Kuntze). The main hull (**kata**) was 13.43 m and the outrigger hull (**cama**) was 12.18 m (Clunie 1986).

Until this point I had been unable to get in touch with the Honorable Luani to let him know my exact arrival date. When I finally did contact him, it was to say that I was in Fiji and would be arriving in Tonga that night.

Life in Tonga

Upon my arrival in Tonga, the Honorable Luani put me up temporarily in Winnie's Guesthouse. A couple of days later it was arranged for me to stay with a family (relations of Luani's) by the name of ʻaholelei. The ʻaholelei's turned out to be terrific people, as well as moderate English speakers! The fact that the ʻaholelei's spoke English was good and bad. It meant that life was comfortable for me, but it also meant that I wasn't as persistent at learning the Tongan language as I should have been.

There were four members of the ʻaholelei family living together at the time. Kato, the mother; Masiu, the father;

Hainite, the youngest of three sons; and Hinemoa, Kato and Masiu's granddaughter. Kato was in her late fifties. She bore three children, all boys, all full grown. While I was there, the middle boy (age mid to late thirties I think) lived with his wife's family. However, when I was not there, he and his wife usually lived in Masiu and Kato's home. The fourth member of the "in house" family, Hinemoa, was the young daughter of the oldest son. The oldest son and his wife lived in Australia and it seemed Kato, not having had a daughter to raise herself, wanted the opportunity to raise Hinemoa in the "Tongan way" (Figures 3 & 4).

Masiu was working as a warden at the nearby prison, and Hainite worked at the wharf. Masiu was about one year away from retirement, having worked for the prison system for nearly 30 years. When retired, he would earn a pension of about US$3000 a year. Fortunately, while I was there Masiu was on vacation, which for Tongans can be a several month period.

The ʻaholelei's were of very modest means by American standards, but moderately well off by Tongan standards. They had two small homes. One residence was in the small village of Malapo. This home used to belong to Masiu's father, from whom he inherited it. Masiu was not the oldest, but the oldest brother moved to Australia, and thus their father willed the home and property to Masiu. Masiu kept pigs in a pen and hens in a chicken coop. The pigs were brought from ʻeua during a time when Masiu lived and worked at a prison on that island. The chicken coop provided fresh eggs for the family. Other chickens lived around the house and roosted in nearby trees at night. These free running chickens provided the occasional Sunday meal when they could be shot out of their nightly roosts with a slingshot. (They had to be killed before 12:00 am Sunday morning because no work was allowed on Sunday. Therefore, we hunted chickens at around 11:45 P.M. on Saturday night.)

The Malapo home was where the family usually went on weekends, particularly to attend their local church. On Friday evenings, after school and work, the four ʻaholeleis usually went to Malapo, and then they returned to Nukuʻalofa on Sunday evening. Periodically during the week Masiu chose to spend the night at Malapo both to keep up on the pig and chicken feeding responsibilities and because their Malapo residence was located closer to the prison.

Their home in Nukuʻalofa was very pleasant, with two bedrooms, two full size beds, a good size kitchen and a bathroom with shower (no hot water of course!). The outside was painted a nice light purple color, and the front had a raised concrete porch which was covered by an overhang with a small white picket fence built directly around it. Masiu built the home himself with the aid of prison labor. The land was Masiu's family's land. His mother was about 90 years old and continued to live in the next-door house.

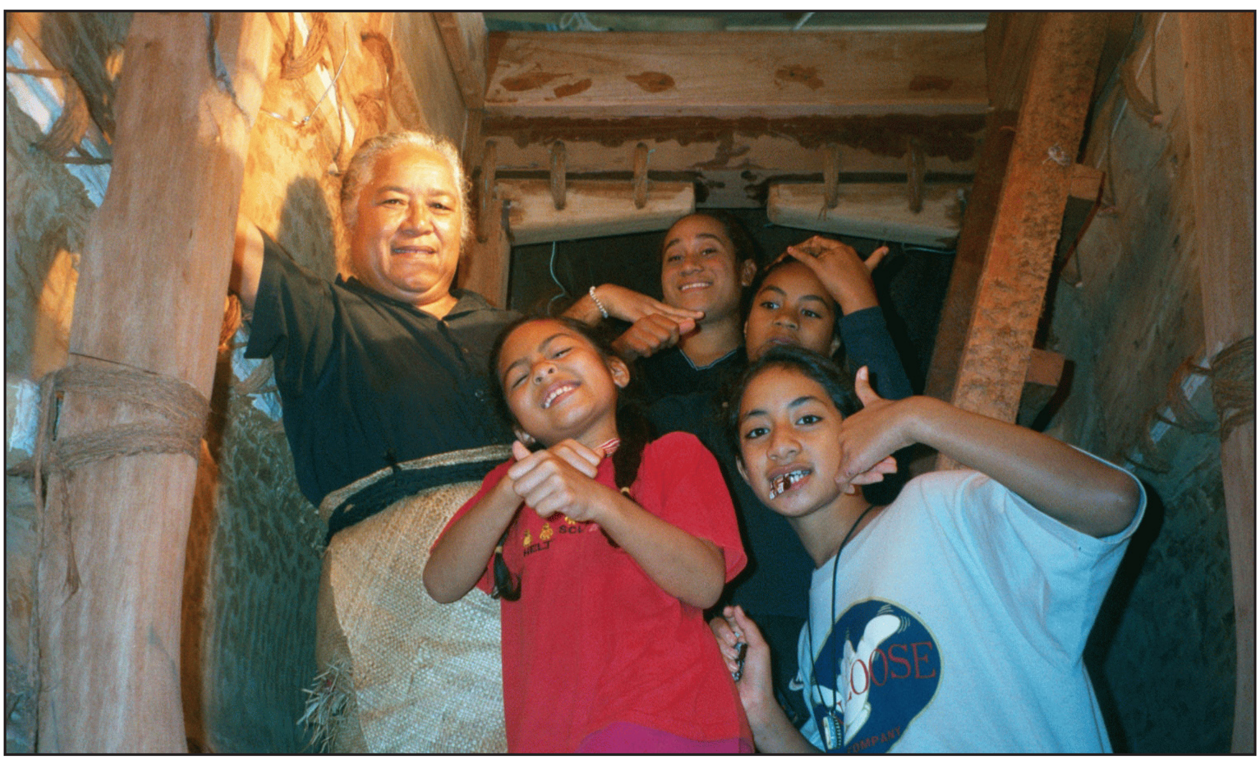

Figure 3. Kato ʻaholelei, my "Tongan Mother" pictured on the left with her granddaughter Hinemoa in the front middle.

Figure 4. Masiu ʻaholelei, my "Tongan Father," pictured in upper left, with his brother on the upper right.

Two of Masiu's sisters also were neighbors and several of their children lived there, the oldest of which, William, was a college student at the University of the South Pacific. (One night William and I were hanging out and he mentioned he had a guitar. I said I had a guitar also and asked if he played. He said he could play the G chord and maybe the C chord. I perked up and said, "oh, well then I can show you a few chords and write out the tablature for them." He said OK, and asked if I could play him a song. So, I meekly played a song I knew, then offered him the guitar, about to show him a few "new chords." To my amazement he began ripping out the first of about thirty songs, both American pop and some he had written himself for a past girlfriend! I'd been had! The joke was on me! I got out my tape recorder and taped many of his songs for him to keep.)

Masiu had a seven acre plot of land in the country. The ʻaholelei family was given rights to the use of this land in the past by their noble of Malapo, a predecessor of the Hon. Luani title. This plot size of seven acres was the norm, and many families in Tonga have a plot out in the country, or **uta**, where they are able to carry on subsistence activities. Masiu planted taro, sweet potatoes, yams, and bananas on his land. There was also scrub land where he kept a cow. While I was there in February 1999 the cow bore a calf, and thus when weaned, the cow provided a source of milk for the family.

The daily diet was typical of Polynesia with a "touch" of foreign influence. Breakfast consisted of hot tea, bread and butter, and sometimes eggs. Lunch and dinner always consisted of the tuberous **ufi** (yam), **kumala** (sweet potato), and sometimes **maneoka** (tapioca). Large non-salted saltine crackers or biscuits were often served. Meat consisted of chicken, pork, canned beef, fish, and sheep. Usually food was very plain to the palate. Curry, if used, was usually cooked with **sipi** (lamb) and **maneoka** was the starch of choice with this meal. About the only other flavoring used was small chili peppers. Often on the work site, Fanta orange soda was poured into a half loaf of unsliced bread to produce a unique snack. Chinese lo mein noodles and ramen noodles sufficed for pasta dishes. My favorite meal was a thick chicken soup or corned beef soup simply made with a few vegetables such as onions and carrots. Maybe that is why I enjoyed soup the most, because vegetables were included.

Sundays included more traditional meals such as **luu** which was composed of taro leaves wrapped around meat such as marlin or chicken with perhaps onions and some scant vegetable, or else simply corned beef by itself within the leaf wrap.

The ‘aholelei’s attended a Methodist church in Malapo. The organization of the church was such that congregation members took turns leading the services. On my first Sunday in Malapo it so happened that Kato and Masiu were leading the service. Kato was dressed in splendor and stood behind the pulpit which was probably raised about ten feet off the ground. There, she delivered what appeared to me to be a dramatic and heart felt sermon. I was completely surprised by the fact that not only did the families share the responsibilities of the ministry, but also that a woman delivered the sermon. Being in a culture that I would consider to be closer to older Christian views and traditions, I would have assumed there would be a **tapu** on women delivering the sermon. In all of the other church services I have attended in Tonga, maybe ten or twelve in all, I haven’t seen any other women give the sermon. This made me very proud to be living as part of the ‘aholelei family.

So, with a little informal kava drinking before church, a little kava afterwards, a nice meal, an afternoon nap, and the pouncings of little neighborhood children, Sundays went by. Once a month the ‘aholelei’s would go to the neighboring village of Vaini for communion. This we did on my third Sunday in Tonga. At Vaini was a great big church, painted a light blue on the inside with a large white cross on the front wall. One of the main church leaders was a short and very thin man with a very high pitched voice, quite a rarity for a Tongan. After we went up and took communion, there was a period in the service where anyone who wanted to, could stand up and state their prayers out loud. Everyone prayed at the same time, and when the last person finished, the short, thin man with the high voice walked down our row and pointed to me, saying “You sir, you there, you come here.” Startled, I looked at a lady next to me and she nodded. So I stood up and walked to the man. He grabbed me by the wrist and walked me to the front of the congregation. There he said aloud, “You look like a good man!” “Yes?” “You look like a man who knows God very well!” “Yes?” “Then tell us here, today sir, how God loves you.”

“Well, God loves me very much. He has brought me here to Tonga, to meet the people of Nuku‘alofa, of Malapo, of Vaini. I have been blessed by God. But I have a problem. I do not speak the Tongan language very well. So I ask God, today, to please help me learn the Tongan language, so that I may speak with, and understand you all, better than I do now.” My speech was very slow and considered with emphasis on each phrase in the hope of overcoming the language barrier. Afterwards, Kato told me how very proud she was of me. She also told me that the teenage girl who was sitting next to her said, “Kato, I will help Ma‘ake learn Tongan.” Kato grinned and laughed saying that the implication was that maybe then I would marry the girl.

So this was the family atmosphere within which I lived and participated (Figure 5).

Research in Tonga

The Tonga National Centre (TNC) served as my base of operations. It was a tourist center which provided activ-

Figure 5. Mark Nickum pictured on the island of ‘eua, Tonga, dressed for Sunday church. Also pictured is Montana, the son of my hosts.

ities such as island tours, dinner shows with traditional Tongan dance (of which I was a regular guest), a small museum, a souvenir shop, and a site for meetings and conferences. Most of the buildings on the site were built to represent the large traditional Tongan **fale** or house (St. Cartmail1997:48), with pillars, lashings, high ceilings to provide space for heat to rise, and a great deal of open space to the outside to allow the free movement of air.

The TNC was able to provide me with much needed transportation. They took me to the wharf, which was the site for **kalia** construction, provided me with my own office space, fed me free lunch when it was available, and helped me in countless other ways. The TNC employees worked long hours from early morning to late at night to provide these activities and services. To the TNC, I owe a great debt of gratitude.

Through the TNC, I made many of my contacts and identified people I wanted to interview. In particular I was interested in interviewing the Ha'a Havea Lahi clan. There are seven members of this clan, each of whose noble titles are named after a part of the **kalia** (Tu'ivakano, Lavaka, Lasike, Vaea, Ma'afu, Fohe, and Fi'elakepa). My aim was to record stories told by the different families of their past voyages and canoe related responsibilities. Unfortunately due to time constraints I was unable to complete this project, but it is something I would like to see done in the future.

Everyone with whom I worked was very cordial and helped me to the utmost of their ability. Thank you to everyone in Tonga who helped make this research possible.

Introduction to the Kalia

The Kingdom of Tonga is a nation in the South Pacific, with Fiji to the northwest and Samoa to the northeast (Figures 6 & 7). Tonga is made up of three island groups, Tongatapu, Ha'apai, and Vava'u (Figure 8). The Kingdom of Tonga has managed to keep its political independence from colonizers since the time of the first king, the Tu'i Tonga, in 950 A.D. This fact makes Tonga unique among all other Pacific island nations which have succumbed to foreign rule in various ways.

Part of Tonga's strength and identity comes from their past political control over vast expanses of the Pacific. Besides the three main island groups of Tonga, the Tongan Maritime Chiefdom has encompassed 'upolu and Savai'i in Samoa (Wood 1932), the Lau group of Fiji and various

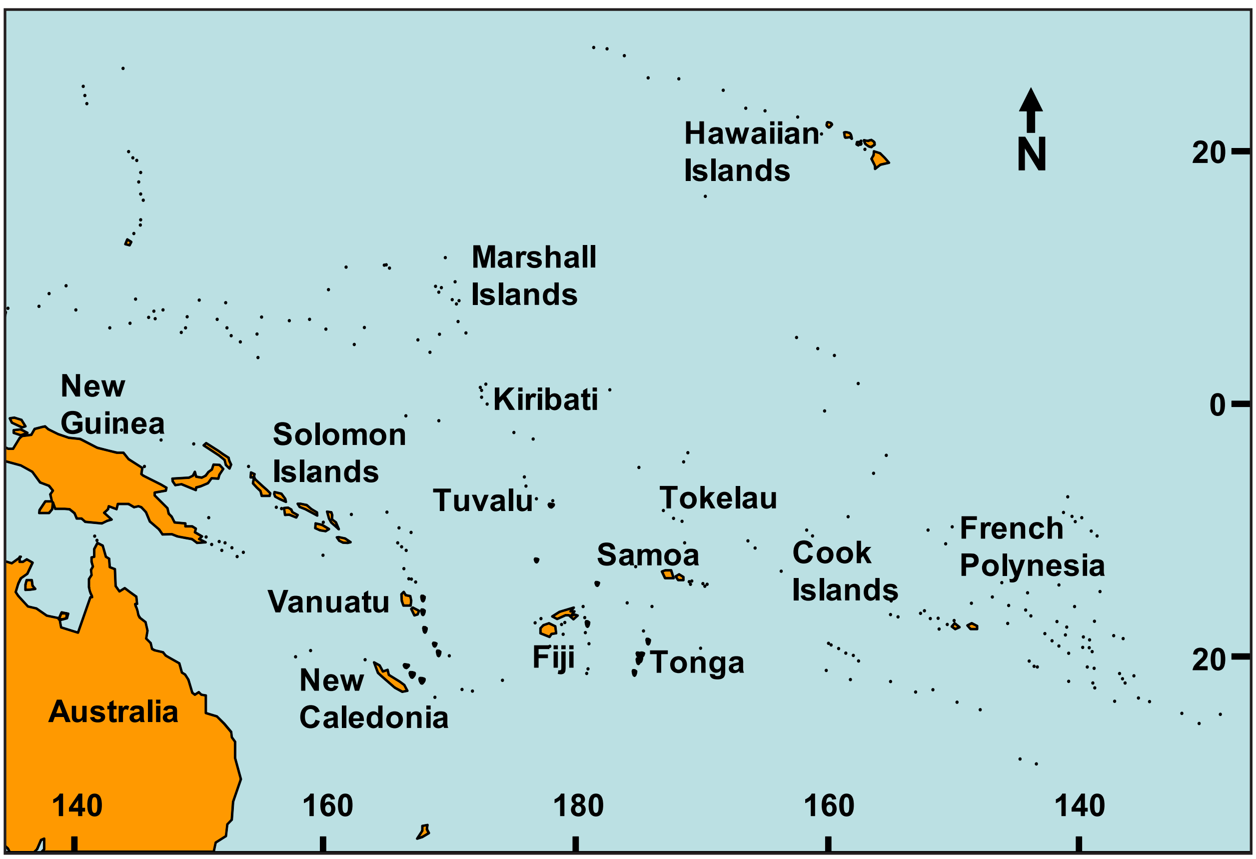

Figure 6. Pacific Island locations from 140°E to 160°W / 20°N to 20°S.

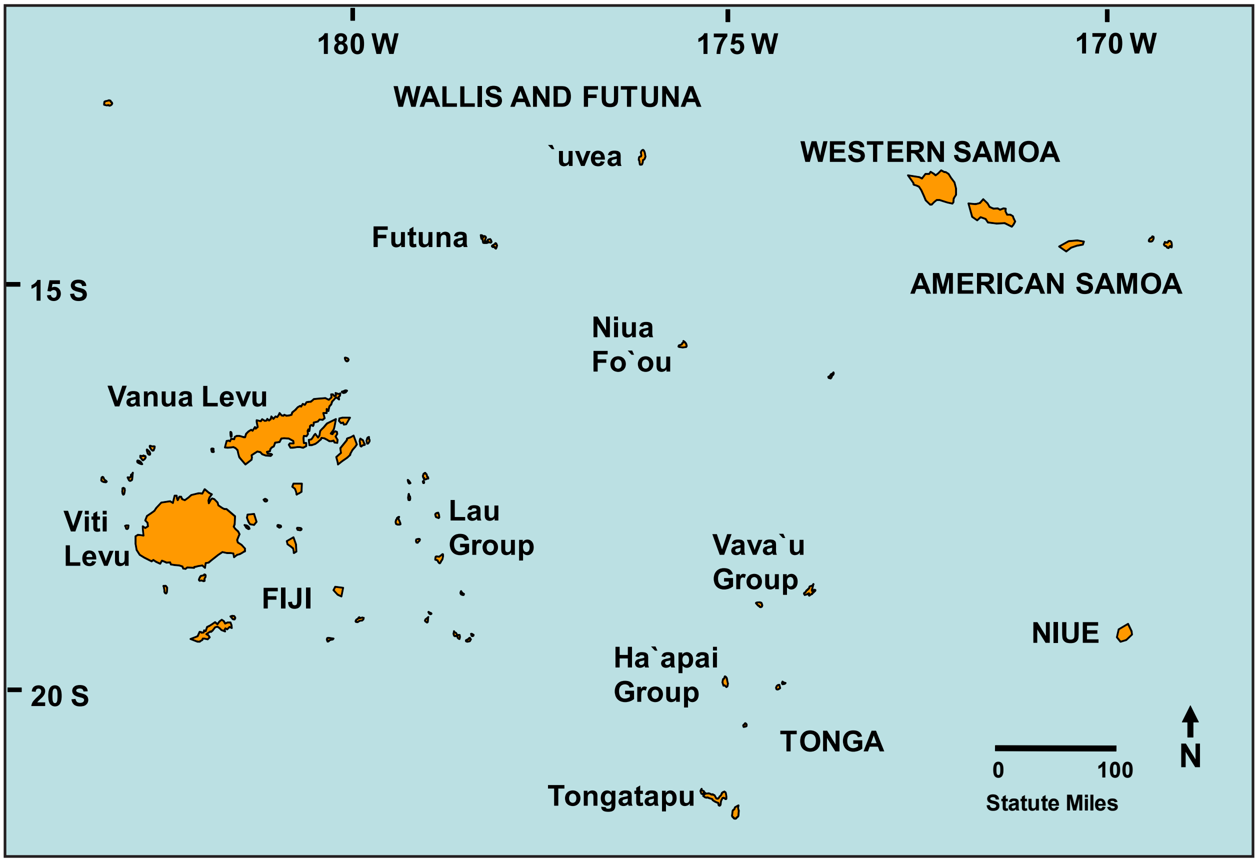

Figure 7. Map of Western Polynesia.

relations with ‘uvea, Futuna, and Rotuma (Derrick 1946). In order to maintain trade relations and conduct warfare, large voyaging canoes were required by the ruling chiefs. These canoes were among the most important pieces of equipment in the Tongan Maritime Chiefdom.

The first part of the introduction serves as a primer for a basic understanding of canoes and how they function. It also explains the historic significance and cultural context of the Tongan **kalia** voyaging canoe. The second part focuses on the **kalia** canoe itself, reviewing the literature on **kalia** architecture, construction techniques, and plant material choices. This information is referred to in the discussion to compare between the recently built **kalia** and those canoes constructed in the past. The third part of the introduction discusses the recent revival in Polynesian canoe construction and voyaging. The introduction is concluded with the hypotheses for this thesis project.

General Context and History of the Kalia

While smaller outrigger canoes were used for fishing and other every day uses, the **kalia** was clearly the ship of an empire, a political tool, and an instrument of power, war, and trade. The majestic Tongan **kalia** was a chiefly canoe, belonging to the most powerful nobility in Tonga. In Fiji, the comparable **drua** was called **wangga tambu** or sacred canoe to indicate its chiefly status (Hornell 1936:319). Tonga acquired **kalia** through trade, reciprocity, spoils of war, or else by contract from builders. Most **kalia** were built in the Lau group of Fiji because that was where the raw material of **vesi** trees (*I. bijuga*) was available (Figure 7). “In Tonga, there was little timber of a size and quality suitable for the construction of these large vessels, and it became the practice for parties of Tongans to sail up on the wind to Lakeba, arrange with the chiefs there for logs and food in exchange for Tongan bark cloth, weapons, or services in war, and then to establish themselves on islands such as Vulaga and Kabara and build, or help to build, the canoes,” (Derrick 1946:121).

Kalia Sailing Practices

The traditional **kalia** was a two-hulled canoe with one hull slightly larger than the other. It was built symmetrically so that the front and back of the canoe were the same and the canoe had the ability to sail with either end forward

(Figures 9 & 10). The smaller hull always faced to windward.

The **kalia** had a lateen sail. This was a triangular sail tied or "bent" on to two spars. The upper edge of the sail (head) was bent on to a spar called the yard. The lower edge of the sail (foot) was bent on to a spar called the boom. The yard was thus hoisted up the mast, raising the sail (Figures 9 & 11). The forward point of the sail, where the yard and boom connected, was positioned on the leading prow of the main hull when under sail.

The heel of the yard slid into a cavity or hole in the bow designed to hold it (Figure 12). When it was time for the canoe to change directions, the yard heel was raised from its cavity, dropped onto the rail, and walked to the other end of the canoe, where it was lifted and placed into the "new bow's" cavity (Figures 13 to 15). The canoe then took off in the opposite direction (Pulotu 1999, Lewis 1994:59). This kind of tacking maneuver is termed shunting (Doran 1974:130).

Other sailing outrigger canoes of Polynesia often sailed using the tacking maneuver, meaning that the bow and stern (front and back), starboard and port (right and left) remained constant. As noted earlier, a shunting canoe always kept its outrigger to windward. This was not the case for tacking canoe, where the outrigger may be to windward on one tack, acting as a counterbalance, and to leeward on the next tack, acting as a float. Regardless of which sailing style was utilized, the concept of the outrigger was to allow for a narrower canoe hull, which sailed more quickly with less resistance, but was still stable in the open ocean. Most of the sailing canoes documented in Tonga, Samoa, Fiji, and Lau, were all shunting canoes (Burrows 1936, 1937, Derrick 1946, Hiroa 1930, Hocart 1929, Hornell 1936, Krämer 1994, Thompson 1940, Tippett 1968, Wilkes 1845, Williams 1858). If the tacking canoe was a larger canoe, both hulls would be the same size. Figure 1.11 compares the tacking and shunting maneuvers.

> "A well-built Lauan sailing canoe is a seaworthy and swift craft. In a stiff breeze she easily attains a speed of 10 knots an hour. She sails best with the wind just off the stern but cannot sail directly before the wind, because the outrigger must be kept to windward. In stormy weather the man who holds the sheet watches the outrigger and the sail constantly. If he does not slacken the sail at a gust, the float rises out of the water and the canoe is in danger of capsizing. If the outrigger swings to leeward, the float is forced under water and the canoe swamps. Care is taken to balance the load on a canoe by favoring the outrigger side. If the load is unbalanced the canoe capsizes; if it is too heavy, the canoe sinks. Loads are often thrown overboard. A capsized canoe is righted by the crew and bailed out, and the journey is resumed.
>
> If the wind is very strong, the sail is lowered while a reef is taken in the foot of it. In dangerous gales the sail is lowered, rolled, tied, and adjust-

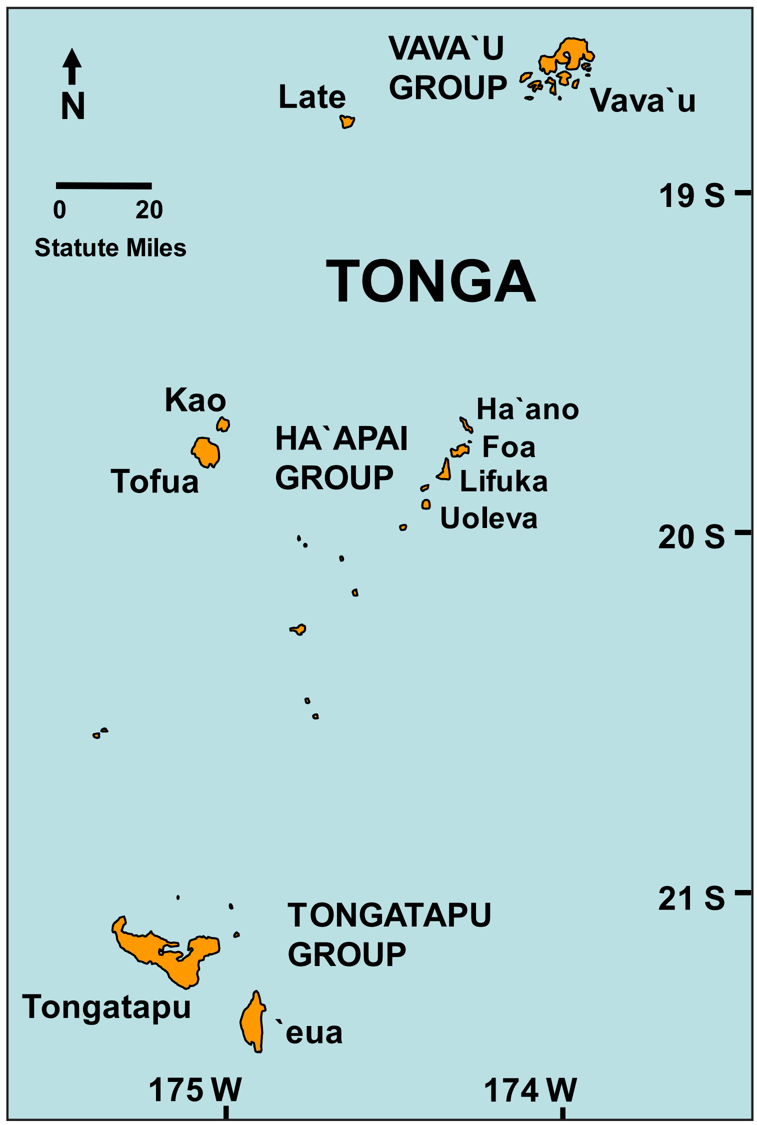

Figure 8. Kingdom of Tonga.

Figure 9. Kalia model by Tuione Pulotu. The smaller hull pictured in the foreground is always kept to windward. The masts and sails are positioned over the main hull.

> ed to the mast in order to catch the wind. A canoe with lowered sail so adjusted makes 4 knots an hour in a gale" (Thompson 1940:176).

Kalia,* ʻalia*, Drua Complex

The literature available on the Tongan **kalia** is limited, and it has been necessary to expand the literature search to include other similar canoes within the region of Western Polynesia. Hornell (1936:272) made the observation that "like the **ʻalia** of Samoa, the Tongan **kalia** is in no essential particular different from the Fijian **ndrua**." Therefore I have grouped the Tongan **kalia**, Samoan **ʻalia**, and Fijian **drua** into what I will refer to as the **kalia**, **ʻalia**, **drua** complex, or more simply the **kalia** complex. This class of canoes will be considered as essentially the same.

The documentation of the **kalia** complex is restricted to a limited number of canoes examined by explorers of the Pacific in the late 1700's and 1800's (Dodd 1972, Dumont d'Urville 1830-34, Hornell 1936, Wilkes 1945, Williams 1858), and a few ethnographies of the region in the late 1800's, early 1900's (Burrows 1936, 1937, Derrick 1946, Hiroa 1930, Hocart 1929, Hornell 1936, Krämer 1994, Thompson 1940, Tippett 1968).

In terms of the traditional architecture of the **kalia**, I have developed a fairly comprehensive description of its design and likely construction techniques utilized by the canoe wrights, from descriptions of the Tongan **kalia** and **tongiaki** (Dodd 1972, Dumont d'Urville 1830-34, Hornell 1936), the ʻuvean **kalia** (Burrows 1937), the Fijian **drua** and **camakau** (Hornell 1936, Clunie 1984, 1986, Gillett *et al.* 1993, Hocart 1929, Thompson 1940, Tippett 1968, Williams 1858), the Samoan **ʻalia** (Hiroa 1930, Hornell 1936, Krämer 1994), and the Cook Islands' **vaka katea** (Hiroa 1944, Hornell 1936). It was necessary to cover this breadth of literature in order to find various descriptions of hull construction. Key details of construction included how multiple dugout logs were joined end to end to form a hull, how internal ribs were affixed, and how masts were constructed. No single description of an individual canoe or canoe type covered all aspects of canoe design and material choice, so descriptions have been combined of the above mentioned Western and Central Polynesian canoes in order to fill in gaps in knowledge. It has been possible to determine, with relative accuracy, what the preferred timber and non-timber plant choices were for the canoe wrights of the past. This literature review is covered in the section Architecture and Botany.

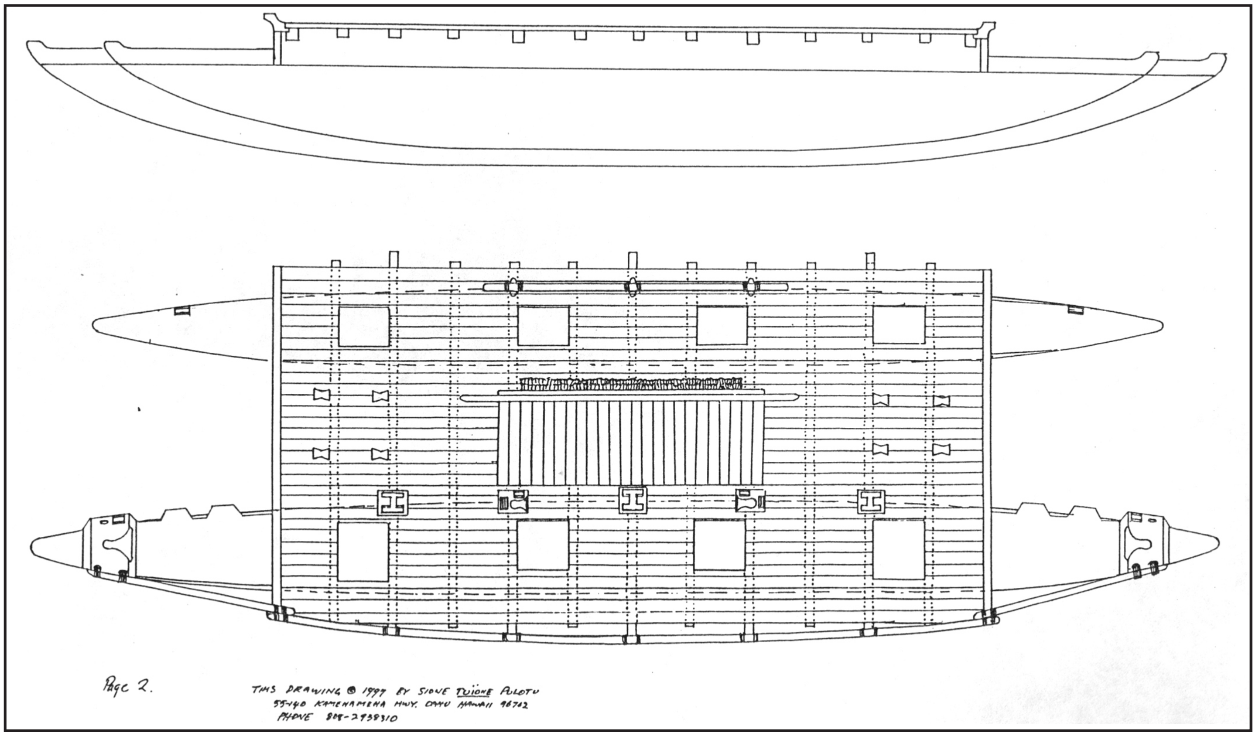

Figure 10. Blue-print plans for the **kalia** drawn by Tuione Pulotu before construction began. Again notice the relative lengths of the larger and smaller hulls. Note the hulls are bilaterally symmetrical from prow to prow.

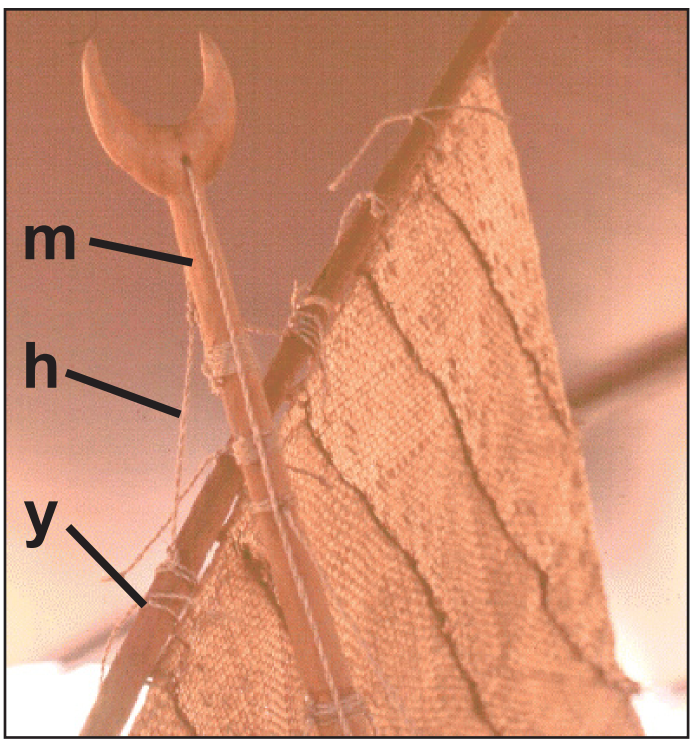

Figure 11. The upper spar of the sail is called the yard (y) and the lower spar is called the boom. The yard is hauled up by the halyard (h), and the sail is thus supported by the mast (m).

Last Known Kalia

Construction of the **kalia** complex of canoes probably spanned the mid 1700's to late 1800's, with its prevalent usage somewhere in the middle. Geographically they were built in the Lau group of Fiji. The following set of accounts details a few canoes in existence or being built throughout this time. According to Hornell (1936:272):

> "In Cook's time, 1773-74, the Tongans had begun to acquire some of these magnificent craft from the Fijians in substitution for their smaller and more primitive form of double canoe, the **tongiaki**. A few years later the process was accelerated and Thomson (1908:295) states that 'from 1790 to 1810 it had become the custom of Tongan chiefs to voyage to Fiji in their clumsy **tongiaki**, join in the native wars, and take as their portion of the loot Fijian **ndrua**, in which they beat back to Tonga; and in a very few years the **tongiaki** was extinct.'"

Fulaga (then Vulaga) and Kabara were two islands in the Lau group of Fiji where a predominance of canoe building took place. In 1840, Wilkes (1845:167) found the following on Fulaga:

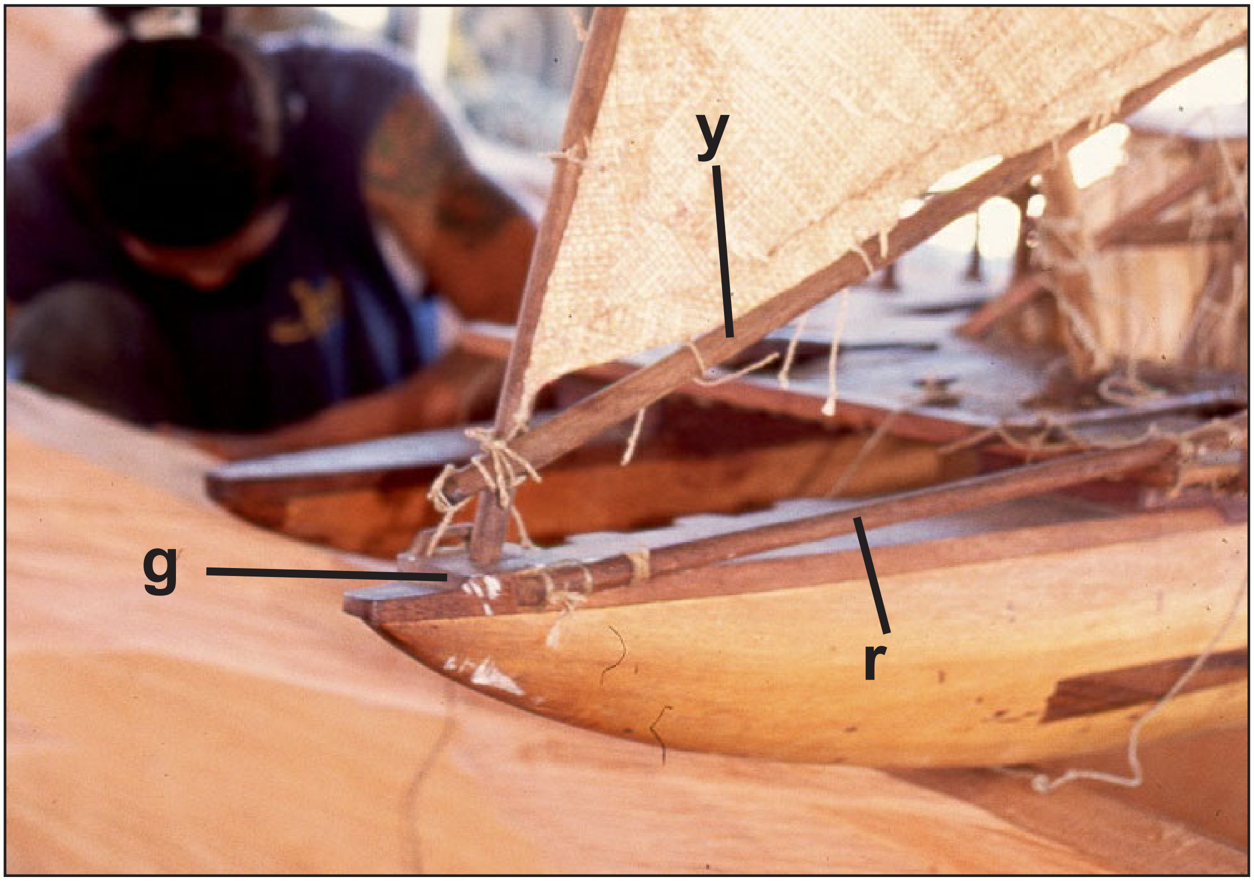

Figure 12. The foot of the yard (y) is tucked into yard groove (g) of the "bow." When it is time to shunt, the yard foot is removed from the groove and run along the rail (r).

> "This island is one of those on which Fiji timber grows, and is, therefore, resorted to by the Vavao and Friendly Islanders for building canoes. Three of these were seen in the process of construction, under a long shed, one of which, on measurement, was found to be one hundred and two feet long, seven feet wide, and five feet deep, of a beautiful model; the other two were somewhat smaller. The builders said that they were constructing them for a Vavao chief, called Salomon, for the Tonga war. The work was performed under a contract, and the price agreed on was to be paid in Whales' teeth, axes, guns, &c."

Thompson also heard of a double canoe being built on Fulaga (1940:186):

> "An old informant, Semitchi of Mbutonikoro, Mothe, told me of a **tambetembete** double canoe called **Tangimautchia**. It was built on Fulanga just before the measle epidemic in 1875 by Setareki, **matai** (carpenter) **Yalona**, from Tonga, for Tupou, a Tongan chief. Tupou remained in Tonga and sent his herald, Hala Hafihafi, to Fulanga. Hala Hafihafi and his wife and children remained on the island during the two years required to construct the canoe. The **tambetembete** was of greenheart with a mat sail. Semitchi, who was about 16 years old at the time, was a member of the crew which sailed her to Tonga. Ten of the crew were Tongans. There were about 25 men and women aboard. The canoe carried a load of mats from Fulanga."

The majority of voyaging canoes of the **kalia** complex slipped from existence in the late 1800's, early 1900's. According to Thompson (1940:176), on the island of Kabara in the Lau group of Fiji, her informants reported that the last double hulled canoe to be there was about 30 years ago, placing the date at about 1910. On 'uvea, Burrows (1937:114) says that **kalia** were formerly much used, but Father Marquet saw the last of them in Hihifo during the early years of the twentieth century. In Samoa, Hiroa (1930:371) states that with the introduction of foreign transport the **'alia** began its decline. Even as early as 1849, a new innovation in their own outrigger canoes based on an adaptation of whale boat lines began displacing their more traditional **'alia**. According to Hiroa

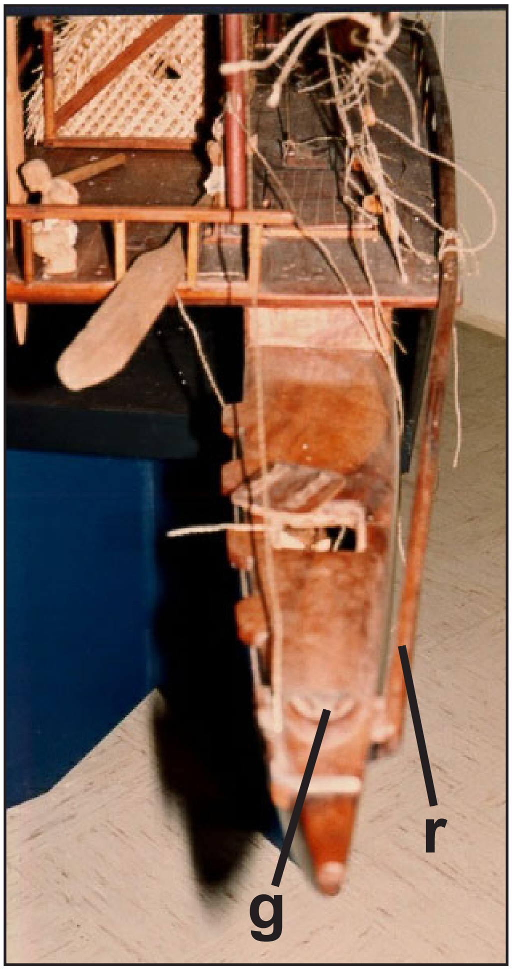

Figure 13. When the yard foot is popped out of the groove (g), it is then slid along the yard rail (r) which can be seen on the right side of this model.

Figure 14. The sail is slid from its previous bow, over the railing, to the “new” bow.

Figure 15. The yard foot is tucked into the groove of the new bow and lashed down.

(1930:407), the last full sized **‘alia** rotted away in Mulinu‘u near Apia to the “deplorable lack of interest of those who might have preserved it for study by sending it to a museum.”

Controversial Origins for Kalia Design

The origin of the **kalia** complex is debated in the literature. The most important questions include: Where did the **kalia** complex originate? What were the cultural, ethnic, and geographical influences for designing this shunting canoe? Hornell (1936) pointed to the Fijian **drua** as the prototype. However, Fergus Clunie (1986:15) offers the following complex origins: “Given long cherished myths claiming ‘Fijian’ origins for **camakau** outriggers and **drua**, it must be stressed that while made of Vitian timber, their design and handling skills came from Tonga and Uvea, their rig courtesy of Micronesia (very likely Kiribati), and their builders from Tonga and Samoa.” The origin of these canoes and their rigging being from Micronesia, and even pinpointing Kiribati may be a plausible hypothesis, however I have found no direct evidence to support this. There may be elements of truth in each of these explanations.

As Tonga expanded its influence, it truly became the hub of a trade network between Tonga, Fiji, and Samoa. Tongans were the voyagers and the navigators. They maintained a monopoly over all exchange between these three archipelagos (Kaeppler 1978). The maintenance of this exchange system required a seaworthy craft that could beat back into the wind when returning from Fiji. This craft was the **kalia**. Derrick (1946) and Thompson (1940) both cite Kabara and Fulaga as centers of **kalia** construction.

> “In Tonga, there was little timber of a size and quality suitable for the construction of these

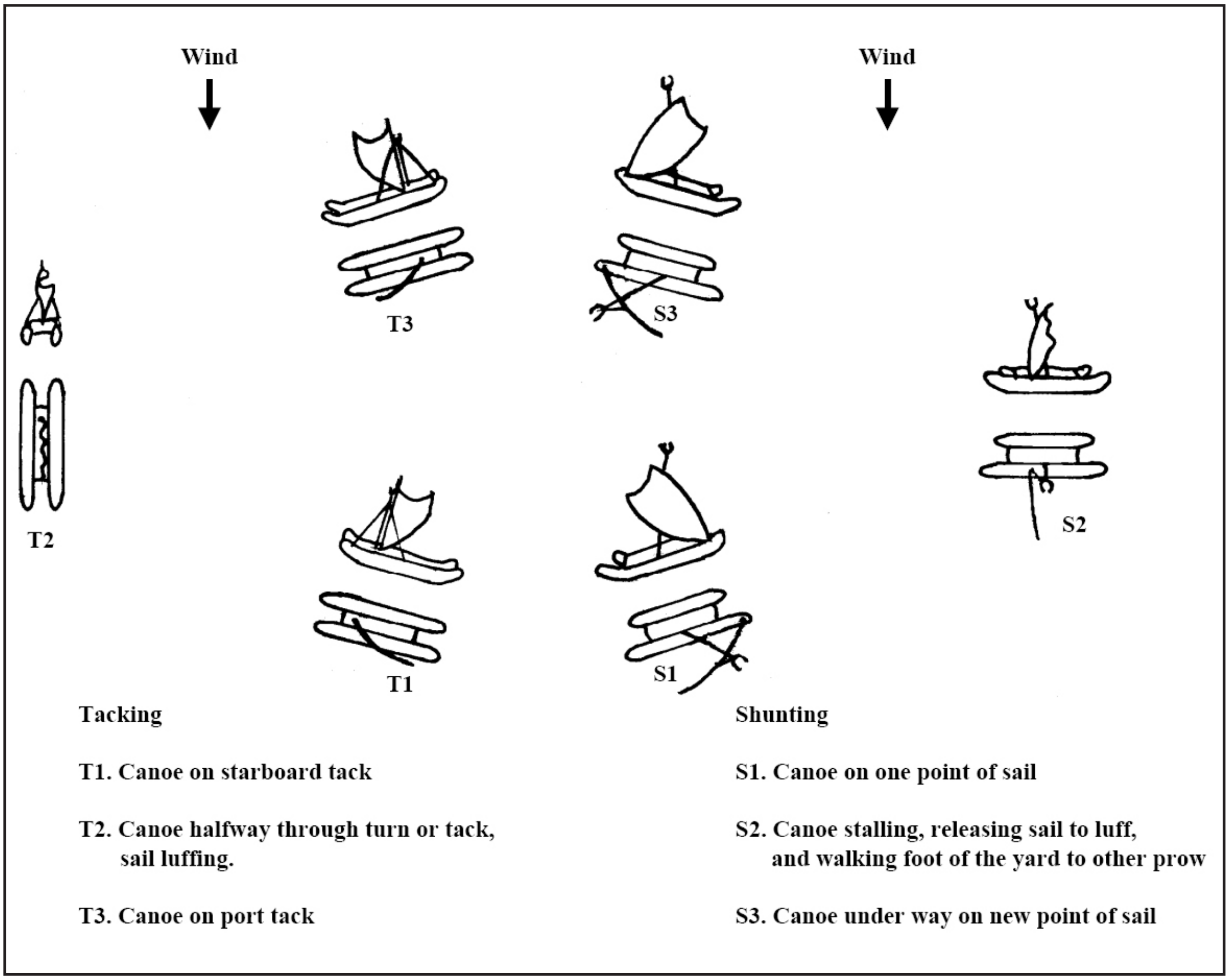

Figure 16. Comparisons of the tacking and shunting maneuvers.

large vessels, and it became the practice for parties of Tongans to sail up on the wind to Lakeba, arrange with the chiefs there for logs and food in exchange for Tongan bark cloth, weapons, or services in war, and then to establish themselves on islands such as Vulaga and Kabara and build, or help to build, the canoes," (Derrick 1946:121).

"Canoes from southern Lau were used by chiefs throughout the Fiji islands and in Tonga where there is no hardwood. Tongan chiefs sent their own carpenters and workmen to Kambara and Fulanga where they lived for two years or more building large double canoes to be used in Tonga," (Thompson 1940:175-176).

Canoes were built in the Lau islands, by expert Samoan craftsmen (the Lemaki and Leha), under the direction and control of the Tongans (Clunie 1991, Thompson 1940:34). So yes, the **kalia** was built in the Lau group, but was it of Fijian design (the **drua**)? Or was it more likely that the Tongans, being the sailors and navigators of the time, were the developers of the **kalia**? William Mariner was shipwrecked on Tonga in 1806, and described the relations between Fiji and Tonga at that time (Martin 1991:358-359).

"The Tonga people have obtained a considerable share of information in the art of building and rigging canoes, from the natives of the Fiji Islands. It has already been observed, that, in all probability, the communication between these two nations, at the distance of one hundred and twenty leagues, began on the part of the Tonga people, who being situated to windward, it is very likely that one or more of their canoes were formerly drifted to the Fiji Islands by stress of weather, although they have no tradition of such circumstance. It is highly probable that neither

> of them went out on a voyage of discovery, or if such an opinion be admitted, there is little doubt but that the people of Tonga first made the attempt, although the construction and rigging of their canoes were at that time far inferior. The grounds for this opinion are, first, their situation to windward; and, secondly, their superior enterprising spirit, in affairs of navigation, which may be said to constitute a feature of their national character. Their superiority in this respect is so great, that no native of Fiji, as far as is known, ever ventured to Tonga but in a canoe manned with Tonga people, nor ever ventured back to his own islands, but under the same guidance and protection.
>
> The Fiji islanders make their canoes principally of a hard firm wood, called **fehi** (*I. bijuga*), which is not liable to become worm-eaten; and as the Tonga Islands do not produce this wood, the natives are not able to build canoes so large or so strong as those of their instructors. All their large canoes, therefore, are either purchased or taken by force from the natives of Fiji."

Trade with Fiji

Lacking appropriate timber resources (Derrick 1946:121, Thompson 1940:175-176, Martin 1991:358-359), Tonga had to find other means of obtaining canoes. Tongans were the reigning traders, and carried to Fiji such prestige items as whale's teeth (which was a most sacred item for use in contracting the construction of canoes), fine Samoan mats, ornaments, and bark cloth. Tonga traded these items to the Fijians for canoes (the **kalia**), sandalwood for oil, and red parakeet feathers (Kirch 1984:239, Thompson 1940).

Tonga also engaged in spouse trade with Fiji. It was tradition for the princess (**Tu'i Tonga Fefine**) to marry a Fijian chief. The purpose of this spouse trade was to remove the **Tu'i Tonga Fefine** from the Tongan royal power structure[1]. As gifts, the Fijian family would often offer wooden goods such as bowls, neck rests, slit gongs, sandalwood, and the highly valued canoes. These were important gifts due to Tonga's lack of wood resources (Kaeppler 1978:248).

The 'inasi

Trade within the Kingdom of Tonga took the form of the **'inasi**, or annual first fruits ceremony. Canoes such as the **kalia** were thus desired by the Tongan Dual Paramountship in order to maintain their influence with Ha'apai, Vava'u, 'uvea, Niuatoputapu, and Niuafo'ou. The Dual Paramountship was housed or located on the island of Tongatapu, on the eastern shore of the central lagoon, in Lapaha, Mu'a. This location was chosen for its safety as a canoe port. A mound, Mounu, was built out into the lagoon and served as a great dock (Kirch 1984:227).

During the **'inasi**, local and outlying island districts of Tonga brought their tribute to the Tu'i Tonga. Yams (*Dioscorea* spp.) were the primary and mandatory good. Other tribute included taros (*Alocasia macrorrhiza* (L.) Schott, *Colocasia esculenta* (L.) Schott), bananas (*Musa* spp.), breadfruit (*Artocarpus altilis* (Parkinson) Fosberg), and Tahitian chestnuts (*Inocarpus fagifer* (Parkinson) Fosberg) (Kirch 1984:221). Thus through a system of tribute, the dual paramountship[2] maintained its authority and the people maintained their association. A circular flow of goods was maintained, with tribute flowing inward towards the paramounts, and prestige goods flowing outwards to the local chiefs. "Monopolization of the sources of prestige goods by the paramounts helped to secure their power over the system as a whole" (Kirch 1984:241).

Architecture and Botany

Having established a definition for the **kalia**, **'alia**, **drua** complex, explained their unique method of sailing called shunting, and placed their utility for the Tongan Maritime Chiefdom, historic canoe architecture and material choices will now be explored. First the generalized construction procedures for a "fictitious" outrigger canoe are described to introduce the reader to the parts of a canoe and the overall construction procedures. This is not the description of how to build a specific canoe type and not the description of a particular culture's methods. This is an introduction to general canoe building techniques and canoe anatomy terminology. Specific examples from canoe traditions of several Polynesian cultures are then discussed in detail in subsequent sections.

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[1] In Tongan society, women rank above men. Thus, in the same family, sisters rank above brothers. This is a problem for a monarchy which has a prince and a princess. Which child should inherit the thrown? The solution was to marry the princess - who when of age was called the **Tu'i Tonga Fefine** - to a Fijian chief. Thus being married off, she and her children would belong to the foreign Fijian line, and politically they would be taken out of account in terms of the political power structure and succession to the thrown. Fiji, thus being the male spouse giver to Tonga, would give accompanying gifts with their husbands including such wood products as canoes, wooden bowls, wooden neck rests, slit gongs, and sandalwood (Kaeppler 1978:248).

[2] The Tongan Dual Paramountship consisted of a sacred paramount (**Tu'i Tonga**) and a secular paramount (**Tu'i Kanokupolu**). The Dual Paramountship was formed in the 15th century and concluded in 1865.

Building a "Typical" Outrigger Canoe

Construction of smaller canoes (perhaps 15 to 30 feet long) began with cutting the tree or trees to be used for the hull. The log was hollowed out on the site where it was cut, (Holmes 1981). If the log was harvested from the forest, 80 to 100 people worked together to haul the log 5 to 15 miles from the forest to the coast (Vaka Taumako Project 1998). Once in the village, the hull was finished off.

Washstrakes were boards used to build up the sides of the dugout hull. They were fitted on to the upper ridge surface of the hull in order to add greater freeboard (distance from top of the canoe to the water surface). The strakes were either carvel-built, meaning they were laid edge to edge to produce a flush and smooth surface between the strake and hull, or clinker-built, to produce an overlapping of the strake over the hull (Haddon & Hornell 1938). Paired holes were drilled or chiseled into the edges, one row along the main hull and a corresponding row on the strakes. Lashings were then made to secure the strakes. Caulking was applied to the outer surface of the canoe to protect the lashings and prevent water from leaking into the hull. End covers were used to cover the bow and stern topsides, thus capping off the ends of the hull and keeping out rough seas. They were cut, fitted, and attached by lashings in much the same way as the strakes.

Often on the front of the bow cover there was a wave breaking mechanism, which received the Polynesian term **manu**, literally meaning bird. On the aft side of the bow cover there was a coaming, which was a raised lip of five or so inches high to keep splashed up water from coming inside the hull. The outer surface of the hull was then sanded to smoothness with tools made of coral or basalt called rubbers. Completion of the above was very labor and time intensive. For instance in Anuta, three to four months, working six day weeks during daylight hours was required to build a small outrigger of about 30 feet in length (Feinberg 1988). In Fiji, to build a large voyaging canoe of up to 100 feet, such as the **kalia**, took three to five years, or even longer (Derrick 1946:121).

Following completion of the hull, the next step was to build and attach the outrigger. Outrigger floats can be attached directly to the outrigger booms, or indirectly by stanchions (smallish rods) running between the outrigger and booms. The number of outrigger booms varies regionally, from two directly attached, to three or several attached with stanchions (Haddon & Hornell 1938). Very light wood was used for making a buoyant float. The type of platform built also varied, from completely covering the area from hull to outrigger, to covering half the area, to having no platform at all.

Last, the mast and sails were constructed. Usually the mast was stepped and unstepped each time the canoe was sailed. If a shunting canoe, the foot of the mast was concave so it could be angled toward the bow when under way. Sometimes it was necessary to bind two pieces of wood together to form the necessary mast length. Some masts had a U shaped claw on top for the sail yard to rest upon, or else as part of the traditional design. A pandanus sail was made from mats which were usually woven by the women. The outline of the sail was pegged out on the ground and coconut sennit cord was rapped around the pegs. Men sewed the pandanus mats together and also sewed them to the sennit cord edges in order to make the sail. The sail was a lateen sail (triangular in shape) with two spars (poles), one on each of two sides. The upper spar is called the yard; the lower spar is called the boom. Where the two spars intersect is called the tack, and is the leading point of the sail. The yard was the upper spar that was hoisted up the mast in order to raise the sail. The tack was tucked into the front of the canoe.

Architecture of Extant **Drua** *and* **Camakau**

There were two extant **drua** as of my July 2000 visit to Viti Levu. One resided in the Fiji National Museum in Suva, Fiji, which I witnessed and photographed in February 1999 (Figure 17). The other **drua** was sitting on the side of the road across from Orchid Island just a few miles west of Suva. I was not aware of this canoe until July 2000, and at the time I was unable to get close enough to see it due to political unrest in Suva. A third **drua** which I heard about was at one point housed at the Fiji Cultural Centre in Pacific Harbour. It was sailed in a popular "cannibal" show in which a few of the men would dress up as traditional warriors, and hold a mock battle for their audience. I met briefly with Sefo Kaliova who was part of this production and still worked at the Fiji Cultural Centre. He said the **drua** was built in the Lau group on Fulaga, and it fell into disrepair about five years earlier. It was burned as firewood.

Other extant canoes on the island of Viti Levu, included three **camakau** outrigger canoes. One **camakau** resided hung against a wall in the Fiji National Museum in the same room as the **drua** (Figure 18). I found one **camakau** displayed at the Nadi International Airport, and one afloat at the Warwick Resort, located along the Coral Coast of Viti Levu. The airport and Warwick canoes both had a spar that extended from one of the middle outrigger crossbooms to the mast as a kind of support. I hypothesize that the spar's purpose was to keep the tension in the shroud which ran from the outrigger float to the mast. Otherwise, when under sail, the outrigger might rise up and the shroud would become slack. Also it might act as a support to keep the outrigger crossbooms from snapping if a wave suddenly forced them up (Figures 19 & 21).

A difference between the two canoes was the top of the mast, where one had an open claw and the other had a closed design (Figures 20 & 21).

The hull of a canoe at the Nadi Airport had pronounced tumblehome. Note how the side of the hull on the outrigger side (right) was more upright (less tumble-home), while the side on the left was rounder (more tumble-home). This contributed to the hydrodynamics of the canoe when under sail (Figure 22). Tumblehome refers to the curve from the widest point on the hull to the top, narrowing at the upper part of the hull (Schult 1992:301).

The **camakau** on display at the airport afforded a quick study of canoe anatomy. The endcover covers the top of the prow. The breakwater is essentially a washstrake covering the gap between the endcover and the deck. The yard rail supports the sail when it runs from one prow to the other during the shunting maneuver (Figure 23). Parts of the outrigger such as the crossboom, stanchions, and outrigger float were visible (Figures 24 & 25). The sail was a pandanus mat sail with a fine (narrow) weave pattern (Figures 26 & 27). Other important parts of the canoe included the dugout hull, the batten, the washstrake, and the yard rail (Figure 27).

In 1984, Sandra Banack traveled to the island of Kabara in the Lau group of Fiji, where she contracted to have a **camakau** built (Banack & Cox 1987). As of 2001, the canoe was maintained at the Polynesian Cultural Center in La‘ie, Hawai‘i. Canoe builder Tuione Pulotu had the canoe at his work site in La‘ie and was preparing to restore it (Figures 28 & 29).

Voyaging Canoe Hulls

The largest **drua** on record was described by Williams (1858:75) to be 118 feet long, with a deck length of 50 feet and a deck width of 24 feet. The mast was 68 feet long and the yards were 90 feet long. The canoe was named the Rusa i vanua “Perished inland,” signifying that it would be impossible to launch it. Williams also cites a 99 foot **drua** with a set of measurements proportionate to above. Such canoes seldom exceeded 100 feet in length.

Figure 17. Paddle, sail, and hut of the Fijian **drua** at the Fiji National Museum, Suva.

During the J. Dumont d’Urville voyage of 1826-1829, Admiral F.E.Paris drew many Polynesian canoes. From Tonga, Paris depicted a 51 foot **kalia** which showed the main hull as being made from three lengths of timber joined end to end. The cross-section views of the main hull showed that each of the three hull segments were constructed of essentially two strakes, which met at the keel line (midline at the bottom of the hull). So these **kalia** hulls were not made from one long dugout log (Dumont d’Urville 1830-34).

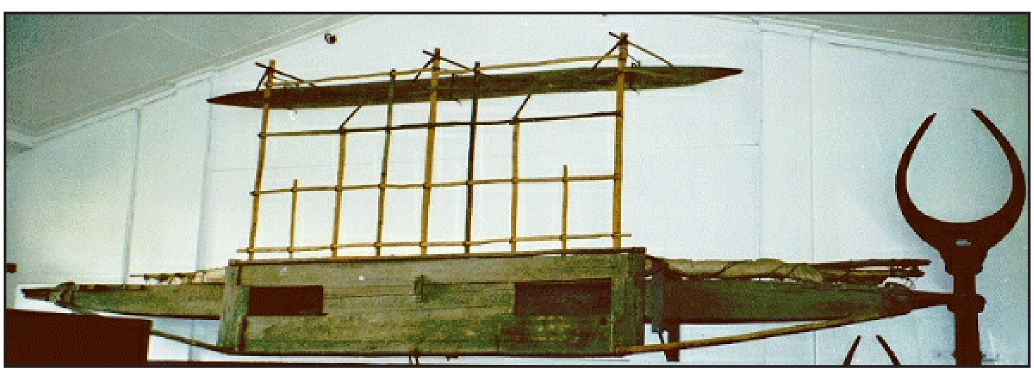

Figure 18. Fijian **camakau** on hanging on the wall on display at the Fijian National Museum.

In the Cook Islands, multi-segmented canoe hulls were made of two and sometimes three dugout logs to achieve the desired hull length (Hiroa 1944:178). Butt joints were used between these hull segments. Of interest is that there were no flanges to increase the thickness at the butt joint, and the paired lashing holes nearest the midline of the hull

Figure 19. Camakau on display at the Nadi Airport in Fiji.

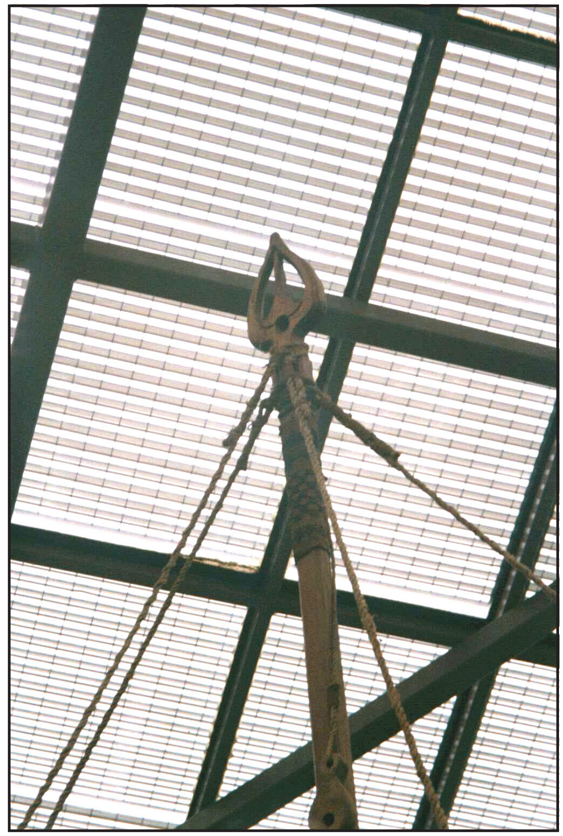

Figure 20. Top of mast with four shrouds (Nadi Airport).

(i.e. that part which drags lowest in the water and would come into contact with the coral, sand, or beach) were drilled to recess the lashings, keeping them from contact with the exterior elements (Hiroa 1944:179).

Of the Fijian **drua** recorded by Williams (1858:73), were canoes of thirty or forty feet in length built from single trees, but building a larger canoe was much more complicated:

> “A keel is laid in two or three pieces carefully scarfed together. From this the sides are built up, without ribs, in a number of pieces varying in length from three to twenty feet. The edge of each piece has on the inside a flange; as the large pieces are worked in, openings of very irregular form are left to be filled in, as suitable pieces may be found. When it is recollected that the edges of the planks are by no means straight, it will be seen that considerable skill is required in securing neat joints; yet the native carpenters effect this with surprising success.”

According to Burrows (1937) the two hulls of the ‘uvean **kalia** differed in size, with the larger one called the **katea** and the smaller one called the **hamani**. The hulls were used to store food and firewood. ‘uvean double canoes were described as being:

> “built of two hollow logs, 50 to 60 feet long, of the diameter of a huge cask, thinner and raised in the form of a prow at their extremities. Over these two logs, place parallel 6 or 7 feet apart, is placed a platform which extends for about a third of their length; in the center of the craft rises a little house to shelter the navigators; then with the aid of a tiller, a mast, and a sail made of mats, they go seeking adventure on the seas. There are double canoes which can hold more than 100 persons, and with which they travel from one archipelago to another,” [description by Bataillon (1895) as quoted from Hornell (1936:285)].

The hulls of the Samoan **‘alia** did not utilize dugout logs joined end to end. Instead they built a keel piece, to which strakes were added to build up the sides. This is more of a true plank construction and was described in detail by both Krämer (1994:292) and Hiroa (1930:388-389).

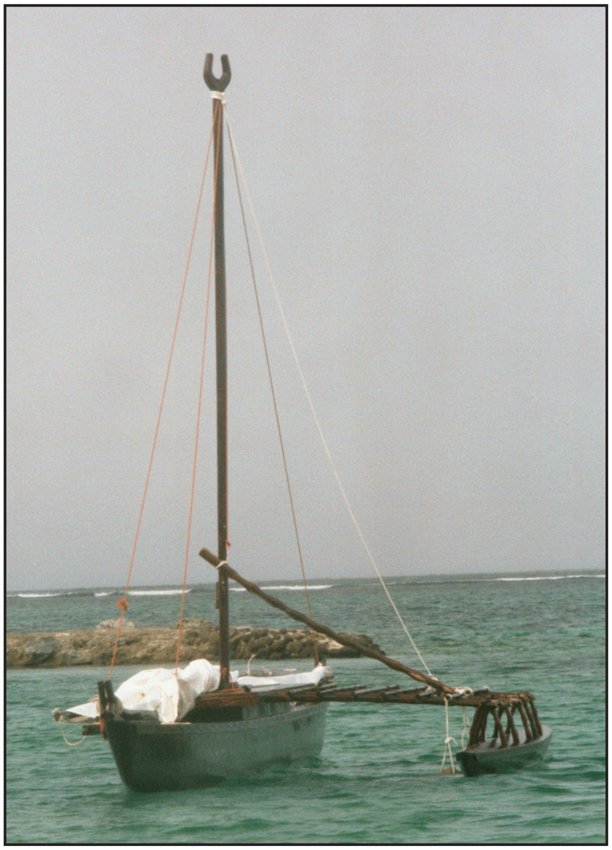

Figure 21. **Camakau** showing the mast, all four shrouds, the outrigger, and the mast spar (canoe located at Warwick Resort).

Figure 22. Tumble-home on a **camakau**. (Nadi Airport).

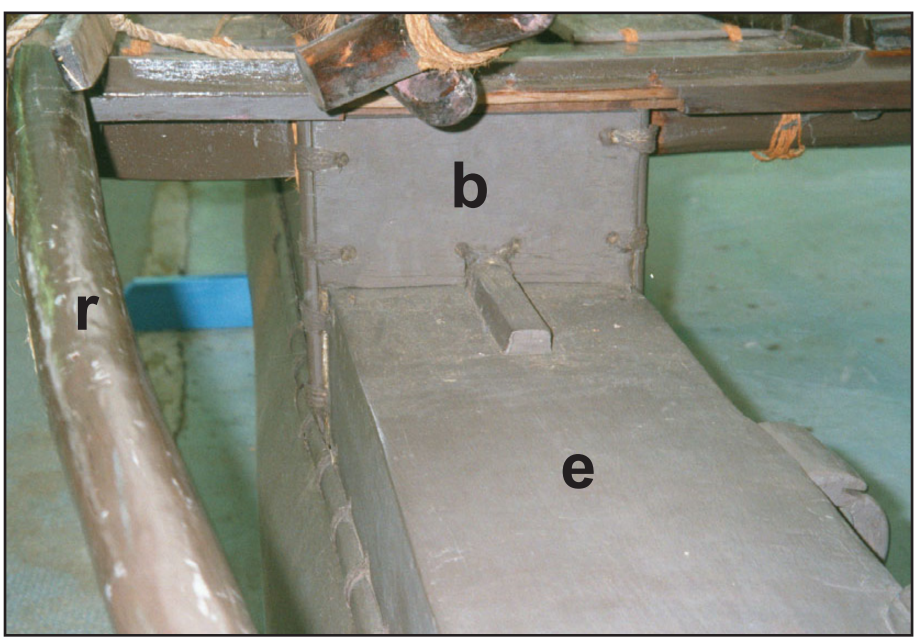

Figure 23. Endcover (e), breakwater (b), and yard rail (r).

It stands to reason that it would be necessary to gain workable access to the underside of such a large canoe hull during the course of construction, particularly when repairing rotten or damaged sections with patches, or joining hull segments end to end. On the island of Kabara in Southern Lau this was achieved by using a ditch across which the hull of a double canoe was laid while under construction. Thompson (1940:23) indicated that one such ditch could still be seen. In Samoa when building an **'alia**, launching blocks were dug into the ground and the keel was lifted up and laid on the blocks in order to expose the underside of the hull (Krämer 1994:291).

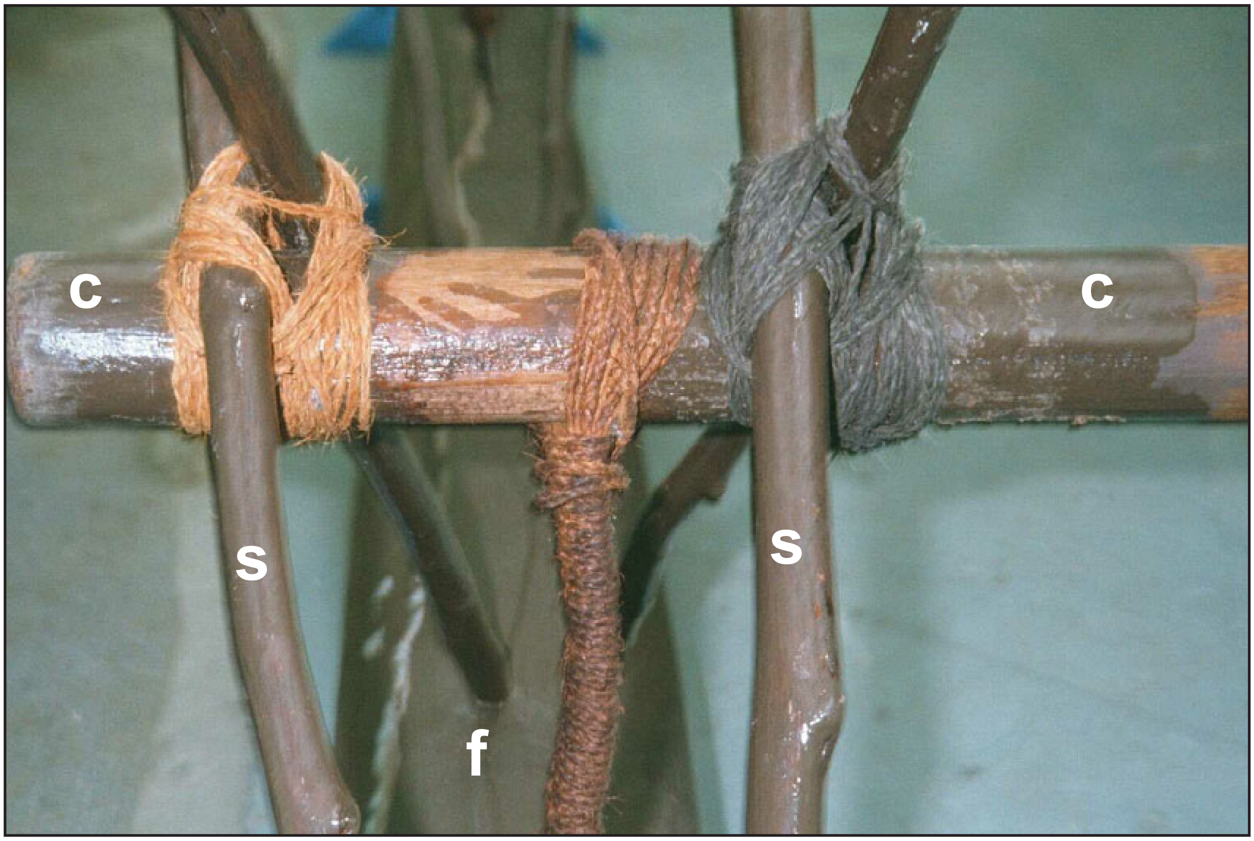

Figure 24. Lashings of outrigger crossboom (c) to stanchions (s) and outrigger float (f).

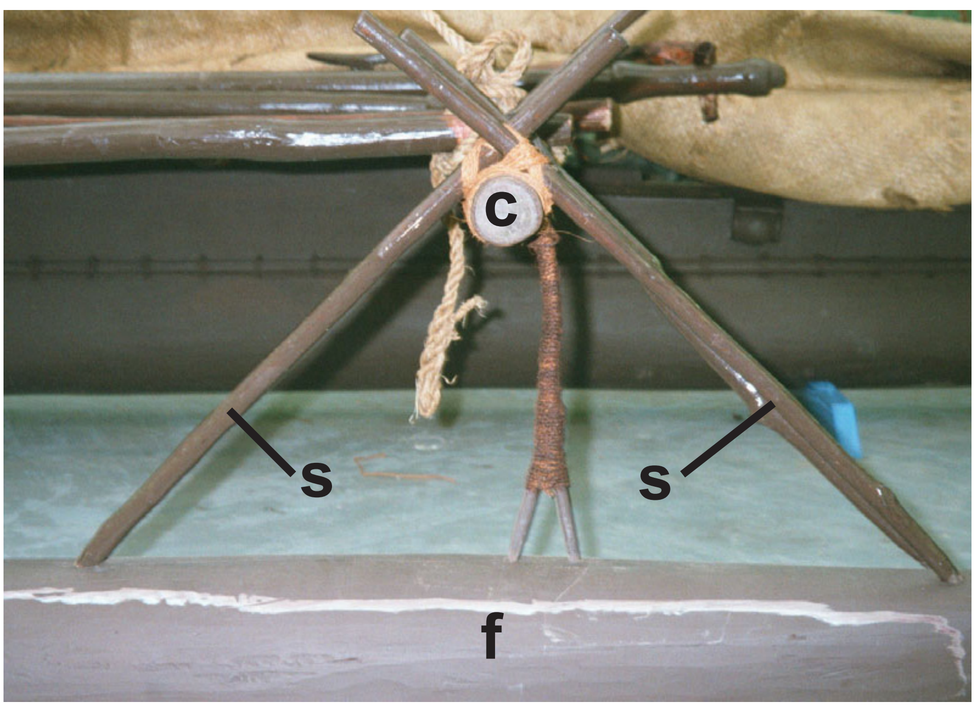

Figure 25. Side view of outrigger crossboom (c), stanchions (s), and float (f).

An important aspect of the hull to consider is its thickness. While investigating the issue of proper hull thickness, I visited Tuione Pulotu on July 20, 2001 at his work site in La'ie, Hawai'i, and among other things we looked over a **camakau** that had been built in Kabara in association with Sandra Banack's research (Banack & Cox 1987). He pointed out two holes developed from deterioration in the bottom of the hull and told me he was surprised at how thin they made the hull. He said the hull was only about a quarter inch thick where the holes were.

Figure 26. Pandanus mat sail of a fine weave.

In comparison to the thin hull of the **camakau**, in Hawai‘i, the hull of the Hawai‘i loa, the second canoe built by the Polynesian Voyaging Society, was built of sitka spruce from Alaska. Initially, the builders kept the hulls of the Hawai‘i loa thick until after the first sea trials, because spruce has a tendency to crack. Wright Bowman Jr. was the original contractor and Wallace Froiseth, with whom I conducted a telephone interview (April 11, 2001), was an assistant. This canoe was originally built with hulls 8” thick on the bottom and 6-7” thick on the sides. Mr. Froiseth said that at the time he believed this was too thick and was trying to convince the others to make the hulls thinner. During World War II he was a skipper on wooden hulled tug boats. He said that on those boats, three inches was the thickest the hulls would be. The Hawai‘i loa was launched for a sea trial, and it rode very low in the water. There was not much freeboard (distance from deck to waterline), and even in light seas there was great risk that the hulls would take on water. Therefore the canoe was hauled out and the hulls were thinned to 3”. They also thinned down the **manu** (endcovers), spreaders (u-shaped spreaders or ribs in the hull), and other parts. In all, about 6,000 pounds was removed by the thinning down process!

Hull Timber Species

The hulls of the Fijian sailing outrigger canoe (**camakau**) were made of “Fijian kauri or greenheart” (Hocart 1929:128). Fijian kauri was *Agathis vitiensis* (Seem.) Bentham & Hooker f. (Araucariaceae). *A. vitiensis* was light, easy to work with, and can grow to a magnificent size. According to Gillett *et al.* (1993:15) greenheart was **vesi** (*I. bijuga*).

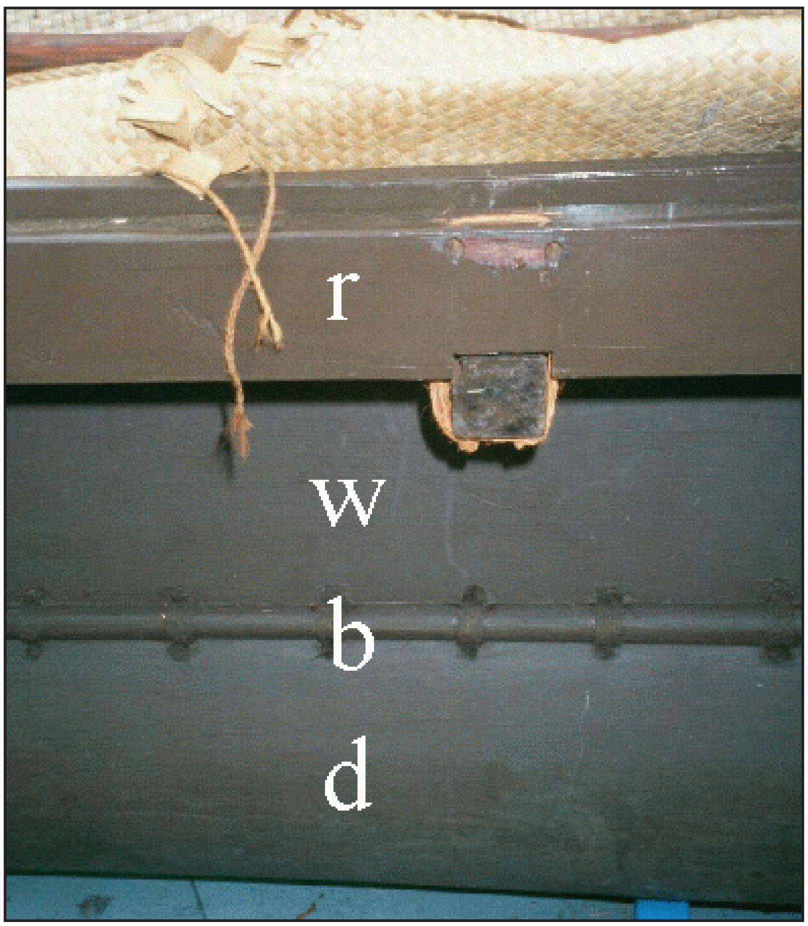

Figure 27. Side of the hull which shows yard rail (r), washstrake (w), batten (b), and dugout hull (d).

Wood choice for the **kalia** complex of canoes were similar, with **vesi** used for the **drua** housed at the Fijian Museum in Suva (Clunie 1986). Krämer (1994:291) indicated that keels on the Samoan **‘alia** were made of *Afzelia* (now called *Intsia*) and *Terminalia* wood.

Based on the literature, canoe timber species used for each component of a canoe have been compiled for the Cook Islands, Samoa, Fiji, Southern Lau, ‘uvea, and Futuna in Appendix C.

> In the Cook Islands, “**tamanu** [*Calophyllum inophyllum* L.] timber was preferred for the canoe hull because it had a tall straight trunk and was durable (**pakari**), lasting from eight to ten years. The **puk**a was also used, but it had a short trunk that necessitated joining and lasted but one to two years. The introduced mango (**vi**) [*Mangifera indica* L.] has been used in late years as it has a straight trunk and lasts two to four years. The gunwale

strake, or rail, was made of breadfruit wood, the bow and stern covers of **'utu**, and the stern piece of **tamanu**, **miro** [*Thespesia populnea* (L.) Sol. ex Corrêa], or **tou** [*Cordia subcordata* Lam.]," (Hiroa 1944:178).

In 'uvea, "woods considered suitable for canoe underbodies include **tongovao** (*Elaeocarpus*), **maota** (*Dysoxylum*), **ngatae** (*Erythrina indica* Lam.), **tavai** (*Rhus taitensis* Guill.), and **fetau** (*Calophyllum inophyllum*). They differ considerably in quality; thus, **ngatae** is light but soft, **fetau** tough but heavy," (Burrows 1937:112).

In Futuna, "**tamanu** (*Calophyllum* species) ranks with **tsilo** (*Calophyllum inophyllum*) as the timber most prized for canoe underbodies. Other woods used for this purpose are **toi** (*Alphitonia zizyphoides* A.Gray), **afa** (*Guettarda speciosa* L.), **angai** (*Eugenia*), **tava** (*Pometia pinnata* J.R. Forst. & G. Forst.), **kolivai** (*Eugenia*?), **pipi** (*Hernandia*), **ngatae** (*Erythrina indica* Lam.), **puka** (*Hernandia peltata* Meisn.), and **ma'ota** (*Dysoxylum*). **Tamanu** and **tsilo** are among the heavier of these woods but are considered the most durable; their trees grow large enough to provide good logs," (Burrows 1936:154).

Figure 28. Hull of **camakau** built in Kabara, Fiji, as it was sitting in Laie, Hawai'i, waiting for repairs.

Figure 29. Outrigger and deck of **camakau**. The * (asterisk) shaped piece is the breakwater. The left side was the yard rail, and leading to the right were the crossbooms which attached to float.

It is clear that *Calophyllum inophyllum* was used very frequently as a canoe hull plant in the Cook Islands (Hiroa 1944), 'uvea (Burrows 1937) , and Futuna (Burrows 1936). Other *Calophyllum* species were also utilized in Futuna (Burrows 1936). *Calophyllum neo-ebudicum* Guillaumin was utilized in Samoa (Hiroa 1930), and Dysoxylum seemed to be popular in both 'uvea and Futuna. Burrows (1936:154, 1937:112) also indicates the breadth of different timber species utilized by canoe builders in 'uvea and Futuna in the above quotes.

Strakes, Endcovers, and Lashings

In Tonga, Paris depicted a **kalia** which had flanges on the interior side of the strakes and hull segments through which paired holes were drilled and lashings made to hold the pieces together (Dumont d'Urville 1830-34).

Thickened flanges were also made around the edges of the strakes in Samoa. This was depicted by Hiroa (1930:387). Dubbing out the strakes for a small bonito canoe was described as follows:

> "The dubbing-out process (**fufu'e**) is to complete the flanges at all edges and reduce the remainder of the section to the permanent thickness which ranges from 0.25 inches to 0.5 inches. The flanges at the edges are kept at the original plank thickness of 1.5 inches or slightly less. The sections are carefully sloped in from the edges to get the inclination of the flange and the remaining material dubbed out. On the lower edges, the flange portions in the temporary slots are made

> continuous. In addition to the flanges, intermediate raised ribs (**fa‘aau** or **iviivi**) are left at intervals to strengthen the plant. A hook projection (**fa‘alave**) is also provided for," (Hiroa 1930:388-389).

When fitting strakes and other components to the keel or dugout hull, it was important to get a tight fit. When a strake was first into position, there were usually large gaps between the keel and the strake, or between strakes themselves. It was necessary to shave down the high points in order to fit the piece in properly. This had to be done by hand, and was often done using the aid of a paint. For example, the keel's adjoining survace would be painted and then the appropriate strake would be placed on top of the painted surface. The painted marks left on the strake were then planed down in order to make a snug fit between strake and keel. In Samoa:

> "Exact fittings are made by using the mixture of red volcanic earth (**eleele**) which must not be confounded with the special red earth (**‘ele**) used in dyeing bark cloth. The mixture with water is termed **sama**, the husk brush becomes **au sama**, and the process of marking the boards is termed **ango**. The mixture is applied to the narrow side surfaces of the keel and the stern piece fitted over it to take the impression of the wet **sama**. The parts marked on the stern piece are carefully chipped off and by repeated trials the fit is made perfect. The same procedure applies to the bow piece and all plank sections," (Hiroa 1930:385).

Krämer (1994:291) also cites this technique for the construction of the Samoan **‘alia**.

> "Then the carpenter shouts: Pick up the plank. And so they bring it and place it on the keel. Then the carpenter reaches for his axe, and mixes the paint. They take it and spread it on the keel. Then they lift the plank up and press it down at the place where the paint is spread. Then the plank is cut to fit the beam."

A similar technique was used in Anuta to join the strakes to the hull (Feinberg 1988:40).

> "The fit between the plank and main hull must be perfectly flush in order to prevent leakage, and much time and effort is put into this phase of construction. The top surface (**te ngutu** ‘mouth’) of the main hull is carefully smoothed with an adze and finished with a metal plane, of which there are several on the island. The plank is then cut to the general shape of the **ngutu**. It is held atop the main hull so that one of the carpenters may estimate the contours and mark the line to be cut. For the latter purpose, pencils are used if available; otherwise a lump of charcoal serves the purpose. The plank is removed from the hull, cut to the line, and replaced for further measurement and refinement. After this procedure has been repeated several times and the fit is almost perfect, mud is painted on the **ngutu**. When the plank is set on top, the mud adheres to those points on the plank which set in direct contact with the main hull, while those parts that are not flush remain clean. These markings indicate the sections that require further shaving. The offending sections are carefully shaved with an adze and then retested. The process is often repeated several times before the carpenters are satisfied."

In Southern Lau, the endcovers on the **camakau** were built and attached to the hull in similar fashion to the washstrakes. (Interestingly, for a shunting canoe, each endcover receives a unique name. I suppose in terms of construction or repairs it makes sense to specify between the two, though perhaps it was Western thinking that translated these two names into English inappropriately as "head and stern boards.")

> "Head- and stern-boards (**mua levu** and **mua lailai**) are hewn from solid **mbau vuntchi**. They are fitted over the entire fore and aft parts of the hull and are lashed to it in the same way as the washstrakes," (Thompson 1940:180).

Sennit cord made out of coconut husk fiber was used almost ubiquitously around the Pacific. This was the main binding material available for canoe builders at the time. Much about lashings, starting lashings, and different binding patterns, particularly for Samoa, were well documented and diagramed (Hiroa 1930:386-401, Krämer 1994:292). A common Polynesian term for sennit represented at least in Tonga and Futuna was **kafa**, and the related term **‘afa** was used in Hawai‘i. In Futuna, "traveled Futunans, who had seen European carpentry and learned a little English, were fond of calling sennit ‘Futuna nails’, " (Burrows 1936:152).

Outrigger Booms, Ribs, and Decks

Some canoes were designed with platforms which covered the full span from one hull to the other, while other canoes had platforms which covered only part of the span. Platforms were built resting on outrigger booms, which connected the two hulls. Sometimes the platforms would cover the upper surface of the canoe hull and sometimes the hull would remain open. The crossbooms could be short or long, depending on how far out it was desired for the outrigger to be from the hull. Most crossbooms were laid singly at a given juncture, but some were doubled up to offer extra reinforcement at locations where a mast or other force bearing component was to connect.

Hornell (1936:320) discussed a small **drua** found in Suva which he took measurements of in 1925. The larger dugout hull was 44' long, the smaller one was 40', and there were 17 cross beams. He reported "three stout stringers were lashed underneath to add rigidity." On this same **drua**, 11 ribs were inserted into the hull in between the outrigger booms. Thus ribs and crossbooms were alternately spaced and not connected to one another.

Patches and Repairs

Logs and tree trunks were clearly not flawless building materials. Thus a craftsman needed to use ingenuity to overcome the limitations of his medium. Even during the course of construction, wood sometimes rotted and required replacement. The checking or splitting of wood as it dried may have required repair and reinforcement. In Samoa:

> "A flaw in an otherwise good piece of timber was met by cutting out the flaw and putting in a patch rather than to waste material. Such patches (**fa'asosolo**) are often seen in perfectly good canoes and <u>their presence does not depreciate the value of the canoe</u> [my emphasis]. Canoe builders were masters of shaping, fitting, and lashing, and though they had a general rule as to the number of sections to be used in each tier, they had no hesitation in altering details to make the available material suit their purpose," (Hiroa 1930:381).

Also during the course of sailing, damage to the hull would occur, which made it necessary to make repairs.

> "In Samoa, when damage occurred to a plank resulting in loss of material, the whole plank had to be removed and a new one of the same size made, with flanges at all edges for joining. Patches could be put in before the sections were thinned down, as the thick material allowed flanges to be made at any shaped edge. Similarly, cracks could be repaired by the flange method, if the cracks occurred before the timber was thinned. Cracks in finished canoes could not be repaired by the flange method so alternative methods were adopted," (Hiroa 1930:404).

> "In Southern Lau, holes or cracks in the hull are repaired by inserting a wooden patch inside the hull and calking the seams with **yangai** pitch made soft with a glowing brand. Ongea men are said to be skilled in canoe repair work. Nearly every Ongea canoe shows a crack at one or both ends due to the inferior timber found on the island," (Thompson 1940:184).

Caulking

The purpose of caulking was clearly to control the leaking of water into the boat. It was necessary to caulk in between the strakes, endcovers, crossbooms, and anywhere water might leak into the hulls. Generally, some sort of fibrous material was pounded in between the seam. This could have been old tapa, coconut husk, inner bark, or other materials. This was then followed by a gummy or sticky substance, which would bind to the caulking and improve the seal.

> In 'uvea, "joints are calked (**mono**) with small sticks of **ifi-ifi** (*Parinarium glaberrimum* Hassk.) crushed and driven in. Bast of *Hibiscus tiliaceus* L. is also used for calking, especially in the holes about the lashing when they come through to the outside. The joints are further tightened by smearing, outside and inside, with a gum made of the crushed fruit of **ifi** (*Inocarpus edulis* J.R.Forster & G.Forster)," (Burrows 1937:113).

> In Samoa, "before the pieces and sections are permanently fixed, heated breadfruit gum is smeared over the joining surface of the keel and acts as caulking. The best gum is obtained from the varieties of breadfruit known as **puou** and **'ulu uvea**," (Hiroa 1930:389).

> In Anuta, "once a proper fit has been achieved, the junction is caulked. As of 1973 traditional materials were used for this purpose. These consisted of a strip of bark cloth from the **mami** tree (*Antiaris toxicaria* Lesch.), impregnated with breadfruit pitch. Since that date, Anutans have experimented with other materials, such as cotton cloth. In 1983 the preferred material was adhesive tape and industrial strength plastic cement, which had been left over from a crew of workers who had installed a piped water system on the island. Several canoes were caulked with tar from a drum that washed ashore some years ago," (Feinberg 1988:40).

Masts, Rigging, and Sails

Sails in the **kalia** complex were of the Oceanic lateen type. This type of sail and its rigging were defined by Haddon & Hornell (1938:11) as having:

> "a sail [in] the form of an isosceles triangle, set apex downward. The apex is typically stepped in a socket on the fore decking or on a thwart near one end. The two long sides are tied or laced to two spars, the yard and the boom. When the

> shorter margin, which forms the base of the triangle, has a deeply concave form, the sail is sometimes termed a 'crab-claw' sail. It is normally slung from a mast which is stepped amidships and capable of being raked toward either end by means of running stays."

All documented shunting canoes of the **kalia** complex used only one mast and one sail. There were some reports of canoes with two or three masts in 'uvea, but these multi-masted canoes did not use the Oceanic lateen sail (Burrows 1937:115).

> "The king's canoe has two masts, the mission's three. But in the old days even the huge double canoe, **Lomipeau**, had but one mast, according to Henquel. Sails are nowadays of canvas instead of mats. The rig of the sails on the king's canoe is shown in figure 13. Uveans say that this type of sail is modern, and I could not get a clear description of the old sails," (Burrows 1937:115).

The figure Burrows (1937:115) cites is of a four sided sail, with a yard which props up the upper corner.

It does seem that in parts of Polynesia, for instance in the Cook Islands, a European rig was adapted, but a modified shunting maneuver was still used. Two mast steps were cited as being placed on a canoe which utilized only one sail. While sailing the entire mast was moved during the shunting maneuver.

> "The use of sails has long been abandoned, except in Aitutaki, where practically every canoe has a sail made of canvas, with a European rig. The masts are poles of **'au** which pass down through a median hole in the thwart and are stepped in a wooden ring on the bottom of the hull. There is a perforated thwart fore and aft, for the canoes always sail with the outrigger on the windward side because they have no balance board on the other side," (Hiroa 1944:201).

Pacific island sails were often made of pandanus mats. Besides using pandanus for making sails, a sedge called **kuta**, *Eleocharis dulcis* (Burm. F.) Trin. ex Henschel (Cyperaceae) was used in Southern Lau.

> "Informants on Kambara say that besides pandanus, **kuta**, *Elaeocharis* (sic) *articulata* sensu Seem., was formerly used for making sails. **Kuta** does not grow on Kambara. It was brought in long rolls of about 65 cm. wide from Viti Levu and cut and sewn into sails on Kambara," (Thompson 1940:182).

Many adaptations to canoes occurred over the years, particularly the adoption of modern materials. In many areas of Polynesia canvas sails were adopted in preference to the pandanus sails. But "Lauan sailors say that a mat sail is better than a canvas one for the mat allows the wind to pass through and therefore the mast is not easily strained or broken," (Thompson 1940:176).

This was an important idea, because a mast made of wood could easily be snapped in two under heavy winds if not made properly and from the right timber materials. Also it is important to note that masts were sometimes made of two parts. Hornell (1936:314) described a 27'6" mast from a medium sized 46' **camakau** from Fiji.

> "The mast is made up of two sections, a short upper one, the topmast (**ndomondomo**), about 6 feet long, fastened to the longer and stouter lower section, 22 feet long, by means of a simple scarf joint served with sennit. In large canoes the **ndomondomo** terminates in a large crescent, horns upward, having a transverse perforation in the thickened base, through which one halyard (**ndarandara ni vaka-rewa**) is rove, a second (**virimbali**) passing between the horns. In smaller canoes this "truck" takes a flattened ovate shape perforated by one wide hole or two smaller ones. The crescentic form of **ndomondomo** is termed **tanganga**, the other, **vakaseniyambia**; they are always made of the hard **vesi**, whereas the main section is of the tough, springy wood of the **ndamanu**. The **ndamanu** (*Callophyllum burmannii* Wight, and other species) is not the same tree as the Polynesian **tamanu** (*C. inophyllum*), which according to Im Thurn (1925:133), is called **ndilo** in Fiji."

The Fijian masts Tippett (1968:96) describes are essentially the same as Hornell's (1936:314) description above. However, Tippett goes a step further and describes the Fijian yards and sails (1968:96-97):

> "The yards were complex artifacts, not a single piece. They comprised two pieces of **makita** (*Parinarium laurinum* A.Gray) known as **noi roiroi**, which fastened together the main part of the yard (**loco**, made of **damanu** [*Calophyllum* sp.] one of Fiji's best timber trees), and the foot (**vu**), a 3-foot piece of hardwood especially designed to wear. At the outer end of the yard was another piece of timber 6 to 12 feet in length according to the size of the vessel, selected for its natural curve and set as required by the sail."

> "The sail was woven by the women from **voivoi**, prepared by a process of boiling and drying the leaves of a species of pandanus (*Pandanus caricosus* Spreng.). From this they made strips

of matting about two feet wide, and from these the sail itself. It was the business of the chief to give instructions about the sewing of the sail and to supply the necessary sinnet thread and the needle, which was made from the shin-bone of a man."

Canoe Hearths

In ‘uvea, on the deck of the **kalia** was placed a box partly filled with earth and supplied with stones for heating. The box was used as an earth oven which was called **talafu** (Burrows 1937). Fergus Clunie (1984:104) stated that **drua**'s canoe hearths (**miqa**) were very similar to the **kalia**'s hearths (**talafu**). The **miqa** was described as being carved from a hardwood slab, and it was possible on a large **miqa** to cook up to "100 big yams or several whole pigs simultaneously."

Revival of Polynesian Canoe Construction and Voyaging

Hokule‘a

In 1975, an experiment was begun to test the purposeful long distance voyaging abilities of Polynesians without using modern instruments for navigation. The Hokule‘a, was a canoe designed by Herb Kane, Ben Finney, and Tommy Holmes to test their hypotheses. While it was not built of traditional materials, it was constructed true to the design, size, sailing characteristics, and carrying capacity of Hawaiian voyaging canoes. This, more or less, offered a true test of seamanship and handling ability comparable to that experienced by ancient Hawaiians.

After the Hokule‘a's first successful long distance voyage from Hawai‘i to Tahiti, navigated without modern navigational instruments by Micronesian Mau Piailug, enthusiasm around Polynesia grew. Two canoes in the Cook Islands, two in Aotearoa, and one in Tahiti, were all built and sailed to the 6th Pacific Arts Festival in Rarotonga, Cook Islands in 1992 (Finney 1999:1, Low 2000:44).

The most recent addition to this revival of Polynesian voyaging canoes has taken place in Tonga, where a 108 foot **kalia** was launched in August of 2000. This Kalia Mileniume was the creation of head canoewright, Tuione Pulotu. In celebration of the new millennium, Pulotu wanted to create a true replica of a traditional long distance Tongan voyaging canoe for the people of Tonga.

Origin of the Kalia Project

The Kingdom of Tonga is located on the international dateline and was the first nation to greet the New Millenium. This fact inspired master canoe builder Tuione Pulotu and the Kingdom of Tonga to build a traditional, double-hulled, **kalia** canoe. "On the **kalia**, King Taufa‘ahau Tupou IV and all of Tonga will ride the sunrise into the New Millennium," (Pulotu 1999).

Tuione Pulotu (1999) expressed that "building the **kalia** will serve to bring back one of the major traditional canoes of Tonga. The art of building and sailing a **kalia** has been lost for almost a century and knowledge has faded. We know of no one in Tonga who remembers a **kalia** existing in their life time or how to sail it."

Three **kalia** were actually built. Two 40 foot **kalia** were built in order to train the crew in proper handling of the sailing system. The main Kalia Mileniume was 108 feet long. Fifteen logs were harvested from Viti Levu, Fiji, shipped to Tonga, and were on site for the opening ceremony of the **kalia** project on February 23, 1999.

It was planned that the King of Tonga would cruise on board the **kalia**, sailing into the sunrise of the New Millennium, which would inspire many years of voyaging and a cultural revival for the Tongan people. Both young and old would paddle out with their community in a flotilla to escort the **kalia** on its historic maiden voyage. On this sacred day, the first day of the New Millennium, the King of Tonga was to sail the **kalia**.

The original concept for the project was to complete the Kalia Mileniume by November 1999, in time for the worldwide New Millennium celebrations. Two smaller 40 foot **kalia** were completed in time for the celebration, however the 108 foot Kalia Mileniume was not finished and launched until August 2000. One Tongan woman from the Tonga National Centre (Manatu) described the Kalia Mileniume as "mammoth to our eyes."

Mission Statement for the Kalia Project

According to Tuione Pulotu, the Kalia Project was begun in order to achieve the following goals and missions:

1. Build a 100 foot **kalia** for the New Millennium. Completion of such a large canoe is a monumental feat and will probably not be duplicated again.
2. Educate Tongan youth about their strong cultural heritage. Building this fantastic symbol of Tongan history is inspiring and helps show people how they became Tongan.
3. Develop the **kalia** project into a community effort. By getting the community involved in the daily work of canoe construction, an important part of canoe culture was relived.
4. Increase Tongan national pride.
5. Draw international attention to the Kingdom of Tonga. Issues of tourism and economic development are always present, and the Kalia Mileniume was seen by Kalia Project Committee members as a vehicle to promote Tonga to the world.

Tuione Pulotu

Because of his efforts, Tuione Pulotu was considered a hero by many involved in the **kalia** project in Tonga. This was particularly true for the men who worked with Tuione to become canoe builders, as well as for the men who made up the sailing crew. Tuione Pulotu was born and raised in the Ha‘apai Group, Tonga, in the village of Pangai. Son of Mormon parents, he moved to the main island of Tongatapu with his family, when they relocated there for missionary work. Later Pulotu left Tonga for La‘ie, Hawai‘i, as part of a Tongan group who came to build the Polynesian Cultural Center. He now calls La‘ie his home.

The Hypotheses

In science there are two kinds of studies, or problem solving approaches. The first kind is a descriptive study, and the second kind is an experimental study. Experimental studies begin with an hypothesis, and then set out to support or refute the null hypothesis using a set of predefined methodologies. A question that has been posed to me many times has been “do you have a hypothesis?” The answer is yes, I have several hypotheses, but for the most part this is a descriptive study.

The Hokule‘a offers us an example of an experimental study. The Polynesian Voyaging Society set out to test whether it was indeed possible for the Polynesians to conduct voyages to known islands by purposeful navigation without instruments. In order to test their hypothesis, they constructed a double-hulled sailing canoe of comparable design, size, and sail handling abilities to those believed to have been used by the ancient Hawaiians. The rest is history, as the Micronesian navigator Mau Piailug navigated the Hokule‘a to Tahiti and back without navigational instruments in 1976.

Construction of the **kalia** was for the purpose of a cultural revival in Tonga. In this case it was desirable to build a canoe to be as traditional and authentic in both structure and function as could be done. According to the Kalia Project Committee, my purpose in this project was to document the construction and compare its authenticity to the traditionally built Western Polynesian **kalia**, **‘alia**, and **drua** sailing canoes for which we have records. For the purposes of my academic research for the thesis in partial completion of the M.S. Degree in Botany, I have developed the following three hypotheses.

1. The architectural design of the Kalia Mileniume is true to the structures and canoe anatomy found recorded in literature and extant canoes.
2. The canoe timber species used for the Kalia Mileniume were consistent with the timber choices documented for canoes in Fiji between the years of 1773 to 1874. [These dates were chosen to begin at Cook’s first visit to Tonga in 1773. The time span includes Thomson’s (1908:295) recorded dates of 1790-1810 as being a time when Tongan chiefs voyaged to Fiji to take part in wars and trade their **tongiaki** for the Fijian **drua**. These dates also include Ma‘afu’s reign in the Lau Group in Fiji. Ma‘afu first went to Fiji from Tonga in 1848, acquiring sovereignty over the islands of Northern Lau by 1855. He held control over this region until the cession of Fiji to Great Britain in 1874, which is the ending year for this hypothesis (Derrick 1946)].
3. There will be the use of modern materials for fastenings, caulking, preservatives, and other purposes.

These being the hypotheses, it must be said that it was known at the beginning of the project, that this would not be an entirely traditional canoe. The canoe was being built in the midst of a relatively westernized society. Forklifts, chainsaws, drills, and band saws were just a few of the modern tools to be used in the canoe’s construction. Furthermore, building this giant canoe in Tonga, versus Fiji, was a new concept. In the past, **kalia** had to be built in Fiji, particularly in the Lau group, because that was where the timber resources were located. Indeed, Fiji is still where the major timber resources are, but with the advent of cargo ships, it was possible to ship the timber to Tonga for construction at home.

Research Methods

The purpose of this ethnobotanical research was to analyze the architectural and botanical authenticity of the Millennium Kalia. In order to examine authenticity, traditional construction of the **kalia** sailing canoe was determined from the literature, and this information was compared and contrasted with the current construction of the Millennium Kalia. Literature research focused on determining 1) the traditional architecture of the **kalia**, and 2) the timber species traditionally used to construct its hulls. Field research documented 1) construction and architecture of the Kalia Mileniume, 2) timber species used, and 3) performance under sail.

Background Research

Background research focused on determining 1) the traditional architecture of the **kalia**, and 2) what timber species were traditionally used to construct its hulls. This documentation was presented in the section “Introduction to the **Kalia**”, and served as the comparison point for examining authenticity of the Kalia Mileniume. Using a term such as authentic could be controversial, particularly with the canoe builders themselves, who have labored so hard to bring the majestic **kalia** to life. In this document the term authentic is not meant as a value-based judgement or a judgement of culture. It is, however, meant to reflect as near as can be determined scientifically, if the Kalia Mileniume itself is a fair replica. How close is the Kalia Mileniume, both architecturally and botanically, to what the **kalia** was in ancient days when it plied the seas during the Tongan Maritime Chiefdom? A brief description of each of these points explains the overall methodology, which is followed by detailed methods used to acquire the necessary information.

The **kalia**'s traditional architecture was determined by literature review. Timber species utilized in traditional canoe hull construction were found listed in ethnographies of Fiji, Samoa, 'uvea, Futuna, and the Cook Islands.

Traditional Kalia: Architecture and Timber Species

Materials examined in order to determine traditional **kalia**, **'alia**, and **drua** architecture included personal accounts of explorers and missionaries (Wilkes 1845:167, Williams 1858:70-76, Martin 1991:358-359), and historical photographs, drawings, **kalia** diagrams, and ethnographies (Burrows 1936, 1937, Clunie 1984, 1986, Dumont d'Urville 1830-34, Hiroa 1930, 1944, Hocart 1929, Hornell 1936, Krämer 1994, Thompson 1940, Tippett 1968, Williams 1858). Thus, a comprehensive picture of traditional **kalia** architecture was developed.

Literature Review

The literature review was conducted at the University of Hawai'i, Manoa, utilizing the Pacific Collection and other references of Hamilton Library. The three volume, Canoes of Oceania, is considered by many to be the bible of oceanic canoes. In Volume I. The Canoes of Polynesia, Fiji, and Micronesia, (Hornell 1936), a review and summary of known literature on **kalia** architecture is presented. By tracing back to the literature cited by Hornell, published records of traditional **kalia**, **'alia**, and **drua** architecture were compiled and consulted.

Ethnographic and other literature was reviewed from regions where the **kalia** were constructed or recorded as plying the seas. Architectural, nomenclatural, and technological information was noted from each text for outrigger canoes, double-hulled canoes, and the **kalia**, **'alia**, **drua** complex of canoes. Canoes other than the **kalia** were reviewed because of the high quality descriptions of canoe construction techniques. This information thus either corroborated with recorded **kalia** construction techniques, or filled in gaps in knowledge about construction procedures not recorded for the **kalia**. Regions reviewed included Tonga (Dumont d'Urville 1830-34, Hornell 1936), Fiji (Banack & Cox 1987, Gillett *et al.* 1993, Hocart 1929, Thomson 1908, Thompson 1940, Tippett 1968), Samoa (Hiroa 1930, Krämer 1994), 'uvea (Burrows 1937), Futuna (Burrows 1936), Cook Islands (Hiroa 1944), and the Polynesian Outliers of Anuta (Feinberg 1988) and Kapingamarangi (Hiroa 1950).

Timber species discussed in the above literature sources were recorded. Common or local plant names were often mentioned in the literature with no scientific names, in which case floras from the following areas were referenced to determine possible species identification: Fiji (Smith 1979, 1981, 1985, 1991), Samoa (Whistler 1984), Tonga (Yuncker 1959), Niue (Yuncker 1943).

Archival Review

The Bishop Museum archives were utilized as a source of historical photographs, drawings, sketches, and diagrams of the **kalia**. These included loose photographs and sketches under transportation files. Photographs from the Boone and Crocker Expedition of 1931 to 1933 proved to be especially useful. Also photographs of an **'alia** model were helpful. The archives were a great aid to my early research, though none of this material was included as results in this document.

Field Research

Field research documented **kalia** architecture and timber species used. Current **kalia** architecture was recorded through detailed measurements taken of the finished **kalia**, series photographs taken during the construction process. Botanical data was collected in the form of wood voucher specimens from **kalia** construction. It was attempted to collect herbarium voucher specimens from the site of the timber harvest, but due to the rainy season, it was not possible to visit these sites.

Documentation of Kalia Construction

In Tonga, two 40 foot **kalia** and one 108 foot **kalia** were constructed. Fieldwork was conducted in Tonga and Fiji for the purposes of observing and documenting **kalia** canoe construction. Construction phases were documented through participant observation, series photography, and interviews with canoe builders. The completed **kalia** were documented through photography, interviews, and measurements.

Construction Phases

Visits to the construction site were limited to 5 weeks in February-March 1999, 4 weeks in July 1999, and 4 weeks in July 2000. Through these field visits the majority of construction phases were witnessed and documented. Splitting and hollowing the logs, making comb cleats, lining up hull segments end to end, making strakes, placement of strakes on the hull, making the mast, and making paddles were all observed and photographed in the first two field visits. Harvesting of logs for smaller paddling canoes was also photographed. The last stages and finishing touches took place during the third field visit, when the nearly completed canoe was measured and photographed.

Series Photography

Most of the activities of canoe construction, daily life at the work site, and ceremonies related to canoe construction were documented using series photography. Through series photography, a number of consecutive still photos were taken to depict a particular process of construction. Sometimes series photos depicted very fast paced procedures which yielded an immediate and marked change in a particular phase of canoe construction (perhaps five or more photographs taken in a two minute period). At other times pictures were taken over a period of several days and collated to show overall construction procedures and results. Procedures such as splitting the logs, roughing in the hulls, connecting hull segments, form fitting the strakes, and building the deck and lookout deck were documented in this way. The resulting series of photos if on slides or prints were scanned and digitized onto the computer.

Architectural Photography

Photos were taken both of the actual three **kalia** and of the models built by the canoe builder, Tuione Pulotu. Specifically, photos were taken of architectural points of importance: prows, strakes, ribs, lashings, end covers, yard grooves, yard rails, deck platform, the lookout deck, hut, masts, and sail rigging. Pictures were taken from different distances (Johnson &Taylor 1993:350). This resulted in a group of pictures which helped me to develop a three dimensional understanding of the canoe design and how parts fit together.

Digital Video Documentation

Digital video was recorded with a Sony PC100 Digital Video Camera and was useful for many purposes. Video was a natural for documenting construction procedures. It was easier to catch the action on video than with still photography, and later still shots were extracted from the video, which were included in the thesis results.

Interviews

This project is atypical in that the informants selected the researcher. Thus, the canoe construction documentation was initiated from inside the culture and from those who were part of building the canoe, not by an outside researcher, combing the Pacific, looking for people with canoe construction knowledge.

Questions were designed to elicit technical information about tools, materials used, wood, and construction techniques. Details were discussed such as: How did the planned design compare with reality? What stage of construction were they at? What difficulties were encountered along the way? Semi-structured interviews were conducted (Martin 1995:110). Usually an observation was made about the construction procedures or the completed canoe architecture, then Mr. Pulotu was asked to elaborate or explain about what was observed. Sometimes questions were asked comparing what was written in the ethnographic literature to what choices were made for the Kalia Mileniume. Some questions were predetermined based on observations made around the work site, but as other questions occurred to during the interview, they were asked as well. Questions were phrased in English. Most often Tuione Pulotu was the one interviewed, and he was fluent in English.

Our interviews occurred around the canoe construction site, permitting easy discussion of what timber species were used for different parts of the canoe, what construction methods were used, and what was working and what was not (Banack 1991). The interviews were videotaped (Alexiades 1996:68-69) with a Sony PC100 Digital Video Camera. The small size of the camera allowed the video taping to be unintrusive, and made it easy to move smoothly around the work site. The canoe parts in question were videotaped as questions were asked and as Tuione Pulotu explained construction procedures.

The interviews were transcribed from these video recordings into Appendix A. Sometimes questions were asked, and other times observations of the canoe were made with a pregnant pause left afterwards for Tuione Pulotu to elaborate upon. I chose this approach because I felt I had spent so much time around the site watching his work, that to only ask questions would have been insulting, as though I hadn't paid any attention to the hard work he was doing. The following is a list of these questions and observations as posed to Mr. Pulotu.

1. Tuione, in your proposal you asked to have a year for the timber to season.
2. What is going on here where they are chiseling away such a large area of the hull?
3. What can you tell me about the crossbeams? What are they called in Tongan?
4. How were the battens made?
5. Can you tell me about the lamination of the masts?
6. How many pieces were put together for the mast?
7. So what happened to this mast here? What is this mast made of? (Indicated broken mast of small **kalia**)
8. Can you tell me about the sail?
9. How are you making the sails for the big **kalia**?
10. The runners on the prows here are all solid?
11. In Tongan what are the runners called where the rope goes through?
12. What [timber species] are you using for the yard rails?
13. I noticed on the hulls of the small **kalia** that the ribs are only on the leeward side of the hulls. Can you explain that a little?

14. Can you show the metal dowel and glue system to me?
15. What is the metal dowel with the hole in the end for?
16. What is the metal dowel with the hole in the middle for?
17. How often do you put the metal dowels in along the washstrake? What about where [the strakes] butt together?
18. I saw you did some different things here than you had on your original plans. What do you call these big cleats in Tongan? [two big cleats, one on either side of the **fale** on the windward side over the outrigger hull].
19. Do you tie the ropes on to the cleat, or do you tie them on to the **kiato** and have them go over the cleat?
20. I also noticed when I was looking over some of the plans of the **tongiaki**, that there were some fore and aft beams underneath the crossbeams, under the deck.
21. On your original plans you had eight hatches going in. Now you just have four.
22. When they are out on the seas and something happens with the masts or they need to make other repairs, are they going to be taking spare wood and spare materials for that?
23. Are there going to be sculling oars?
24. Are all the beams made out of **tamanu** or are some made of **dakua** wood? Because some look like they are whiter [in color], like this one.
25. Did you guys laminate the masts yourself? How did you get the copper dowels in?
26. The middle laminates go cross-grained here where it is important to have extra strength? [at the cleats and claw of the mast]
27. I noticed on the small canoe's mast there were two holes at the claw of the mast, and there were two ropes that looked like they were used to haul the sail up. Do you only use one of the ropes or both?
28. So then you can get a couple of guys on either one, and
29. Are all the mast laminates made out of **dakua** wood?
30. What kind of glue did you use to laminate the big mast?
31. On some of the small hull patches - but not too many - there is no wood. What did you use as filler?
32. I also noticed the other day before they went sailing on the small **kalia** that you made a little adjustment on where the **fohe** [stearing paddle] goes in.
33. Did you make any other adjustments on the small **kalia**?
34. Here, on the smaller **kalia**, you have a board running along nailed into all the ends to bind all the **kiato** together. Are you going to do that here on the big **kalia**?
35. Where will you be placing the two yard grooves that have to be amidships on the deck?
36. Where does the block and tackle you were talking about go for the mast shrouds that lead from the deck?
37. In the **fale** you've got a nice birth here. What kind of plywood did you use for the floor?
38. Are you going to put some sealing or any kind of a coating on the deck?
39. Down here beyond where the **kiato** are, there are how many sets of ribs?

Interviews with timber suppliers on Viti Levu and Tongatapu were made with Amenatave Tuisawau of the Southern Forest Products (Fiji) and Samuela "Manu" M. Pomelile of Tonga Timber Limited. The interviews took place in each gentleman's office. Questions regarding the timber they supplied were addressed. In Fiji, the timber was harvested from natural stands of trees.

There was a large map of Viti Levu on Mr. Tuisawau's wall which facilitated the following interview on June 7 1999. Results from these questions are in Appendix B.

1. From which land tenure area did you harvest the timber?
2. How was your company contracted to harvest the timber for the **kalia** project?
3. How frequently do you find logs of the size and quality required for the **kalia** project?
4. Where do you find **dakua**?
5. You said you log all the different species. About how much of that would you say is *Agathis*?
6. What was the common name for *Dacrydium*?
7. How long has logging been going on in this area?
8. Who are the landowners? Are they usually the villages?
9. Do you work with the **turanga ayavusa**?
10. Who makes up the Native Land Trust Board?
11. So do they get a little bit of money then for each license?
12. When were these land tracks surveyed?
13. Are there forestry reports that are made each year on quantity of resources remaining?
14. In terms of particular timber species, comparing *Agathis vitiensis* to *Intsia bijuga*, how do you think *A. vitiensis* compares in terms of how heavy, how dense, rot resistant to being in the ocean or on land, or pest resistance to insects and things? Do things come to mind about preferences you would have if you were building a canoe or building something similar to this?

In Tonga, Mr. Pomelile was asked the following.

1. What tree species did you provide?
2. What other tree species were available and could have been used for this canoe construction?

The interview followed a semi-structured interview style (Martin 1995:110). Mr. Tuisawau's interview was videotaped and I transcribed a portion of his interview in the results section. The remainder of the interview was transcribed in Appendix B. I showed him the video afterward.

After the Kalia Mileniume was completed, I wanted to find out more information about hull thicknesses of other canoes. The Kalia Mileniume's hull thickness seemed surprisingly thin to me and I wanted data of other wooden canoe hull thicknesses for comparison. I decided to analyze the construction methodology used to build the wooden two hulled canoe, the Hawaiʻi loa, for comparison sake. Ben Finney's involvement with the Polynesian Voyaging Society made him a logical contact. During my interview with Dr. Finney (April 11, 2001) I asked him about the thickness dimensions of the Hawaiʻi loa's hulls and why those thicknesses were chosen. Then, via Ben Finney's recommendation, I contacted Wallace Froiseth who assisted the contractor Wright Bowman Jr. in the construction of Hawaiʻi loa, and I asked him the same questions on the same day.

Further hull thickness comparisons were made, when on July 20, 2001, I examined the **camakau** built in Kabara, Fiji, which was earlier documented by Banack & Cox (1987). This **camakau** was under the care of the Polynesian Cultural Center in Laie, Hawaiʻi in July 2001. It was at Tuione Pulotu's worksite in Laie, and he was preparing to restore it. We examined the canoe together, identified a hole in the hull, and estimated the thickness of the hull in the region where the hole occurred.

One day in the fall of 2001, I was again visiting Tuione Pulotu's work site in Laie, Hawaiʻi. While observing the builders at work, a Tongan man by the name of Emil Wolfgramm and I were discussing the Kalia Mileniume. He had looked at part of the rough draft of this thesis and was already familiar with the project. I said I had found no mention in the literature of a shunting canoe having two masts, and I wondered where Tuione Pulotu came up with this design. Mr. Wolfgramm then told me how he had played a role in the Kalia Mileniume project which partially answered this question (Wolfgramm 2001).

About a year after the Kalia Mileniume was completed I found out Kate Thompson, a Nurse Practitioner from the University of Hawaiʻi, Manoa, School of Nursing, had gone on a yachting vacation to Tonga from July 25 - August 2, 2000, about three weeks after my final visit. She was kind enough to permit me to include five of her pictures of the finished **kalia** in the results section of this thesis.

Voyaging Canoe Measurement Techniques

The canoes observed in Tonga during fieldwork were measured in order to allow future comparisons between canoe designs. Hull dimensions and symmetry were examined. The length of platforms and crossbeams joining hulls to one another were measured. Measurements of rigging included sail pattern, sail area, and mast length. No measurements were made for mast-shoe placement on the platform, since this part of construction was not completed by the end of the final field visit.

The hulls of the Kalia Mileniume were measured and recorded at 20 stations on the outrigger hull and 6 stations on the main hull (Figure 30). A station in this case is a two dimensional cross section of the hull (Figure 31). Originally stations were planned to be spaced continuously 4 feet apart, but after doing this for a few stations from midship on the outrigger hull, it was found that there was not much variance in the beam measurement (canoe hull width) or rise in the bottomline. Thus between 20 to 8 foot spacing was used from midship, until a significant change of more than an inch in hull rise was noticed. On one outrigger prow, stations were set up at 2 foot intervals, because the rise of the hull bottom and the narrowing of the hull were more pronounced.

Dillion's Method 3 - Vertical Staff - Level Measurements (1993:126,143) was followed with modification as follows. First, for most boat measurements, it is normal to "take off" or measure only one side of the hull. The hull is assumed to be bilaterally symmetrical between the port and starboard sides. Thus only one side of the hull is measured. Since the canoe hull was made out of tree trunks, this assumption was not followed and both sides of each hull were measured (Dillion 1993:117).

For Vertical Staff - Level Measurements, a plumb vertical staff is placed next to the sheer of the hull. The lowest part of the hull bottom (baseline) is marked directly on the staff with a zero mark by leveling across to the staff from the baseline (Figure 31). Masking tape is then placed on the full length of the staff so that at each station, fresh markings can be made on the tape. At each station, the bottom of the hull is marked by leveling off from the station's hull bottom to the staff. The distance from the "0" baseline mark to the station's hull bottomline mark is the rise of the hull. Dillion's method includes particulars for dealing with a keel and also measuring from each plank seam to the shear, which was modified for the canoe hull.

Instead of a vertical staff, a plumb line was used to measure the **kalia**. At each station, a plumb bob consisting of some flexible line and a fishing weight was dropped on both sides of the hull beginning from deck height. Tape was used to hold the line to the side of the hull. The line was allowed to grace the sides of the canoe so that the plumb bob ultimately hung freely from the widest portion of the hull. A tape measure was then run underneath the canoe, between the points where both fishing weights touched the ground. The distance between the lines themselves (not the weights) was considered the beam, or greatest width of the canoe hull at that station.

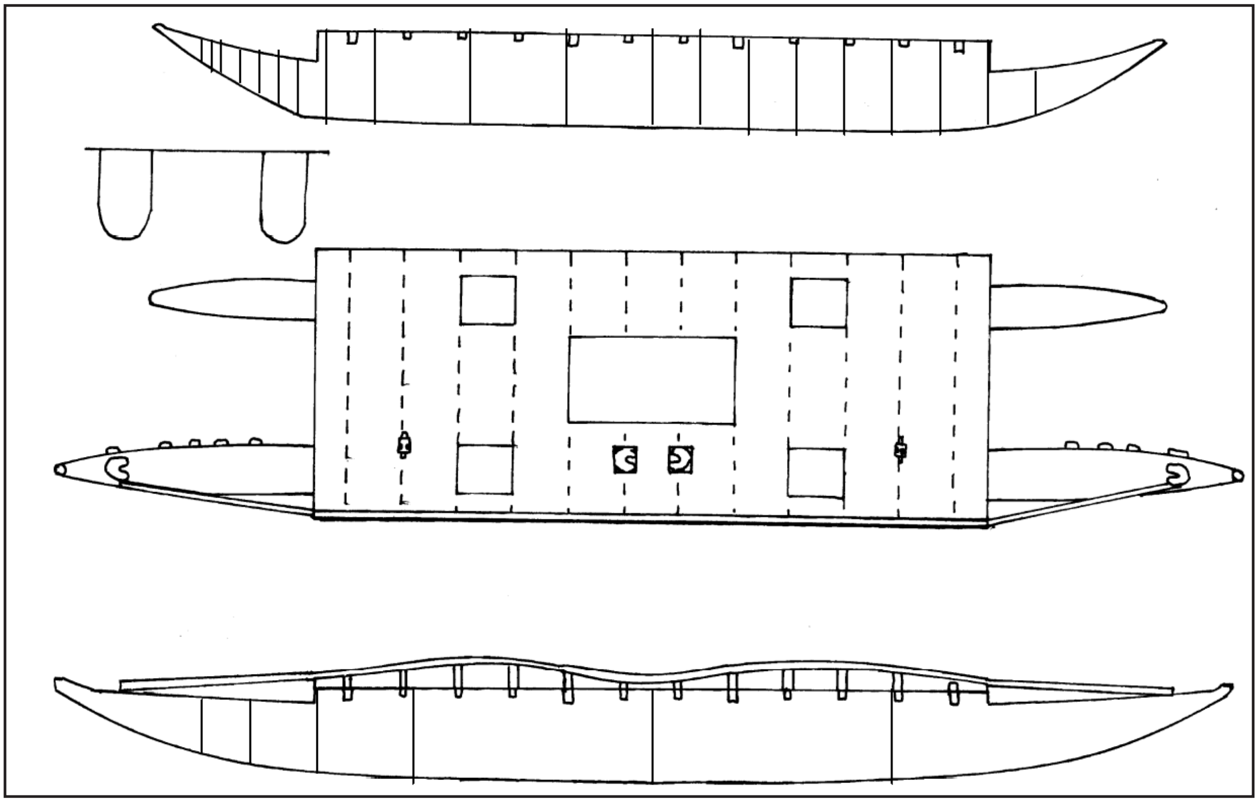

Figure 30. Vertical lines across the hull profiles at top and bottom (leeward sides pictured) plot where the stations were measured (not to scale).

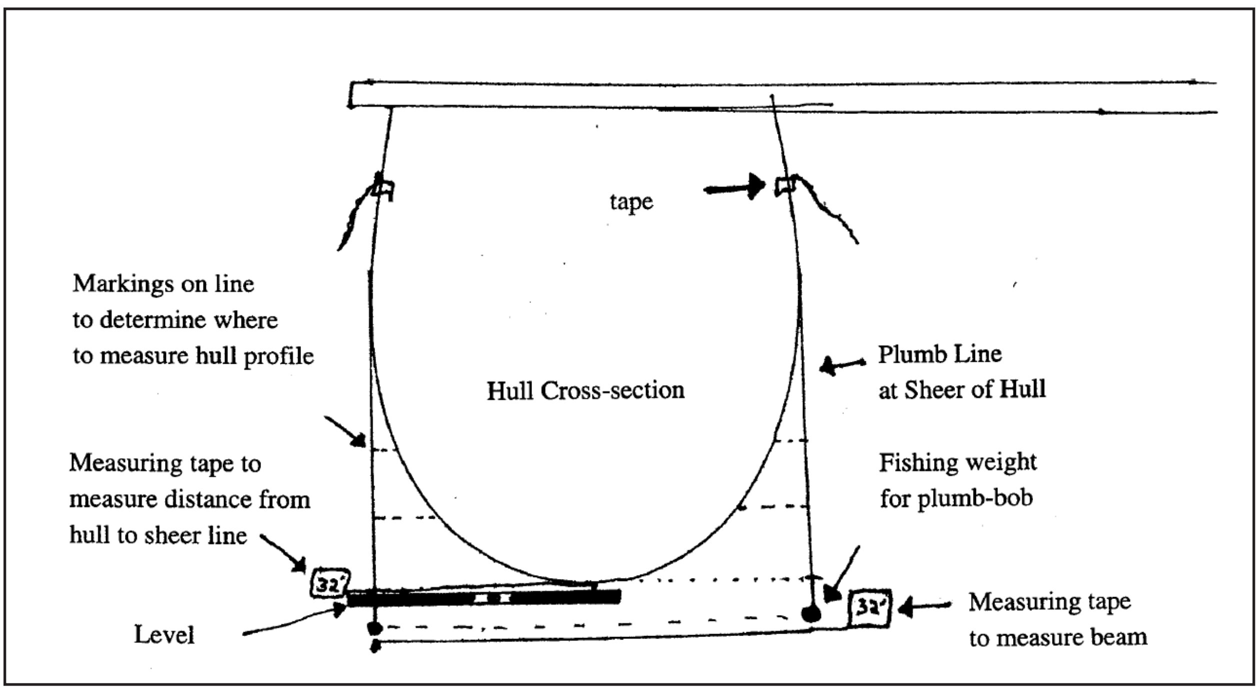

Figure 31. Illustration of techniques used to measure the station.

For the **kalia** measurements, the plumb line was marked every three inches for the first foot (from the hull bottom) and every foot for the rest. Markings on the line were made at 0” (bottom of the canoe), 3”, 6”, 9”, 1’, 2’, 3’, and 4’. A slip knot was tied just below the zero marking so that the fishing weight could be adjusted, and the line could therefore always be adjusted with the zero marking at the bottom level of the hull. The baseline of the canoe from amidships rested at eleven inches above ground level. Ground level was a level concrete slab, essentially a sidewalk laid under each hull. Eleven inches above ground level was used as the zero mark (baseline) that Dillion put on his vertical staff. At each station, measurements could be taken from the station’s hull bottomline to the concrete platform bottom, and the rise of the canoe hull from the baseline could be determined. A four foot level was rested up against the canoe bottom in order to measure the canoe bottom rise on the plumb line.

Then, from each of the markings on the plumb line, a measurement was taken from the line to the edge of the hull. At zero, the contact point was assumed to be half of the beam measurement. Then at each subsequent marking the four foot balance was used with the tape measure for accuracy in measurement. Beyond one foot, the hull had usually come very near to matching its ultimate beam width, so it was appropriate to spread out the measurements to a foot apart after that. This was a very time consuming process and complete measurements were not obtained, however the most important measurements were recorded and it could be possible to determine displacement and make other calculations from this data. The full data set was recorded in the results section.

Timber Species Used

Herbarium Voucher Collections

Collection trips were made to the sites of timber production on ‘eua and Viti Levu in order to document the harvested species with herbarium vouchers from their site of origin.

One collecting trip was made to ‘eua (July 1999) for the purpose of collecting timber species grown and harvested in an agroforestry project by the Ministry of Agriculture and Forestry (MAF). Due to cultural obligations with the researcher’s Tongan hosts, it was not possible to collect the targeted timber species (it was socially required for me to be present with family activities).

Two trips were made to Viti Levu (February 1999 and July 2000) to collect voucher specimens. Site visits and interviews were made with the logging manager of the source for **kalia** timber, Mr. Amenatave Tuisawau of Southern Forest Products (Fiji) Ltd, Pacific Harbour. It was not possible to enter the tenured lands where the timber was harvested because of heavy rains. Thus in order to document availability of *A. vitiensis* in the natural stands of that region (Nabukavesi, just northwest of Suva), all Bishop Museum collections of *A. vitiensis* were examined, making note of location and collection date. This data was recorded in Appendix D.

Wood Voucher Collections

Wood specimens are collected for taxonomic study of wood anatomy, and also for identification purposes related to an artifact of material culture (Martin 1995:55). When collecting in the field from a live specimen, a fertile voucher specimen is taken along with the wood specimen. A wedge is taken out of the trunk making sure to take bark, which can increase the value of the specimen, and also to take mature wood which is at least several years old (Martin 1995:55). Preferred size ranges for wood specimens vary in the literature, from 12cm x 8cm x 4cm (Ter Welle 1989) to 30cm x 10cm x 8cm (Womersley 1976:64). Wood samples can simply be stored in a dry, shady place without any other specific treatment (Ter Welle 1989, Womersley 1976:65).

Wood voucher specimens were collected by picking up blocks of wood from the construction site. Size range for wood vouchers was more than adequate from about 5” x 5” x 5” (13cm x 13cm x 13cm) to roughly 6” x 6” x 15” (15cm x 15cm x 38cm). These vouchers were extracted predominantly from the inner portions of the logs as they were being hollowed out, to be sure that mature wood was sampled. For *A. vitiensis*, heartwood, sapwood, and deteriorated wood were collected for purposes of anatomical comparisons. However, the anatomical work was not completed. As the wood vouchers were collected, the common name of the wood type was written on the block so they would not be confused later on. The wood vouchers were deposited in the Bishop Museum.

Loose bark was collected from the *A. vitiensis* logs. The bark was not physically connected to the above mentioned heartwood wood voucher, but was bark that was stripped off the logs during the canoe construction process. Inner bark was present on the sample of *Tectona grandis* L. No bark was available for *Calophyllum vitiense* Turrill or *Toona australis* (F. Muell.) Harms.

It was not possible to make herbarium voucher collections of *A. vitiensis* from the individuals harvested. When I went to Viti Levu in June 2000 and interviewed Mr. Tuisawau, it was too rainy and wet to get back to the site of log harvest. Therefore the species identifications of *A. vitiensis* and *C. vitiense* are based upon Mr. Tuisawau’s identification of the logs sent to Tonga for the **kalia** project. Mr. Tuisawau’s expertise was derived in part from earning a Forestry degree from Papua New Guinea and working for three years as a botanist in the herbarium at the University of the South Pacific, Suva, Fiji.

Results

Timber Materials Used to Build Kalia Mileniume

Figure 32. Amenatave Tuisawau pointed out recently harvested *Agathis vitiensis* logs.

The primary timber species utilized to construct the hulls of the **kalia** was **dakua** or *A. vitiensis*. Fifteen logs were selected from trees on the island of Viti Levu in Fiji. They were harvested by Southern Forest Products (Fiji) LTD located in Nabukavesi. The logs' dimensions ranged from 6 to 7 feet in diameter and 20 to 30 feet in length. These logs were used to form the bottoms for the two hulls, the **katea** (main hull), and the **hama** (outrigger hull).

Southern Forest Products LTD. also milled *A. vitiensis* planks to 6" x 24" x 20' and 8" x 24" x 20' to be used as strakes to build up the hulls' sides. This species was recommended by the president of Fiji, Sir Rata Sitione Mara, to be an appropriate main timber source for building the **kalia**.

My primary informant from Southern Forest Products (Fiji) LTD was Logging Manager Amenatave Tuisawau. Southern Forest Products was the only one out of four or five logging companies in Fiji which was able to find large enough *A. vitiensis* logs in their licensed areas of harvest.

Amenatave Tuisawau (Figure 32) described the circumstances under which Southern Forest Products was contracted to harvest the 15 logs of *A. vitiensis*.

> "A special order was made from the King of Tonga directly to the President of Fiji [Sir Rata Sitione Mara]. The President first approached Fiji Forest Industries, Fenings, and some other saw mills in the west of Viti Levu. They made their request in September, wanting the timber delivered by January. This was quite a last minute request. We had quite hard work searching for timber to fill the order. They wanted five logs 160 cm in diameter and 6.9 m in length. That is about one in one hundred **dakua**, so we had a hard time searching through our area. Their order also included 80 blocks of milled timber sized 2' x1' (by about 20' long) of *Agathis*. It was a very tough order, in fact we almost gave up [laugh] but it was a pride thing for our company. We cut close to 20 logs and brought them to the mill and the gentleman from Tonga [Tuione Pulotu] came and chose the logs he wanted. Then we had to look for more logs to fill the order for the blocks. Even though log export was prohibited in Fiji[3], since it was an order direct from the President, we broke the rules. [laugh] We managed to get the logs out by the deadline of January or February."

The *A. vitiensis* was harvested from Veisari, one of Southern Forest Products' tenured lands, just south of Mt. Korobaba and north of Suva Harbour (Figure 33).

Wood voucher specimens of *A. vitiensis* were collected in February 1999 from the canoe construction site in Nuku'alofa, Tonga (MN# 283 BISH).

All *A. vitiensis* herbarium specimens located at the Bishop Museum, Honolulu, were recorded in Appendix D to aid in determining availability of the timber for traditional Tongan canoe builders between 1773 and 1874.

Tamanu or *C. vitiense*, (Clusiaceae) (MN# 284 BISH) is a species which produces a "very durable timber" (Smith 1981:337). Wood voucher specimens were collected in February 1999 from the canoe construction site in Nuku'alofa, Tonga. *C. vitiense* was used for structural components of the canoe such as the larger four crossbooms (**kiato**) joining the two hulls. The four major cross-

[3] Fijian law bans the exportation of raw logs. They will only export milled timber in order add economic value to their resource.

booms of *C. vitiense* were 12” x 8” x 22’+. All crossboom timbers were milled at Southern Forest Products.

Calophyllum vitiense was also used to construct the yard rail. The rail behaves as a track on which the sail is moved to change the point of sail during the shunting manuever. The corner of the sail, where the yard and boom intersect, rests on the rail and is moved across the length of the deck.

Australian Red Cedar or *T. australis* (Meliaceae) (MN# 285 BISH) was used to construct deck planking. Wood voucher specimens were collected in July 1999 from the canoe construction site in Nuku‘alofa, Tonga. This non-traditional timber source was also used to make the batten on the hulls which overlaps the joint between the washstrake (uppermost strake between hull and deck) and the hull strakes. *Toona australis* timber was harvested from an agroforestry project on the island of ‘eua, Tonga. Samuela “Manu” M. Pomelile of the Tonga Timber Limited identified the species name for me. He took part in the *T. australis* plantings of the original agroforestry project.

A teak tree, *T. grandis* (Verbenaceae) (MN# 286 BISH) was found by Tuione Pulotu in July 2000 on Tongatapu. This wood was used to make one-eye pulleys for the shrouds and to construct the mast step. Two mast steps were made, one for each mast.

Eight smaller crossbooms of dimensions 6” x 8” x 22’+ [half the thickness of the four main crossbooms (12” x 8” x 22’ +)] were also suppose to be made of *C. vitiense*, but Southern Forest Products was unable to fulfill the order due to insufficient stock in the lumber yard. Rain prevent-

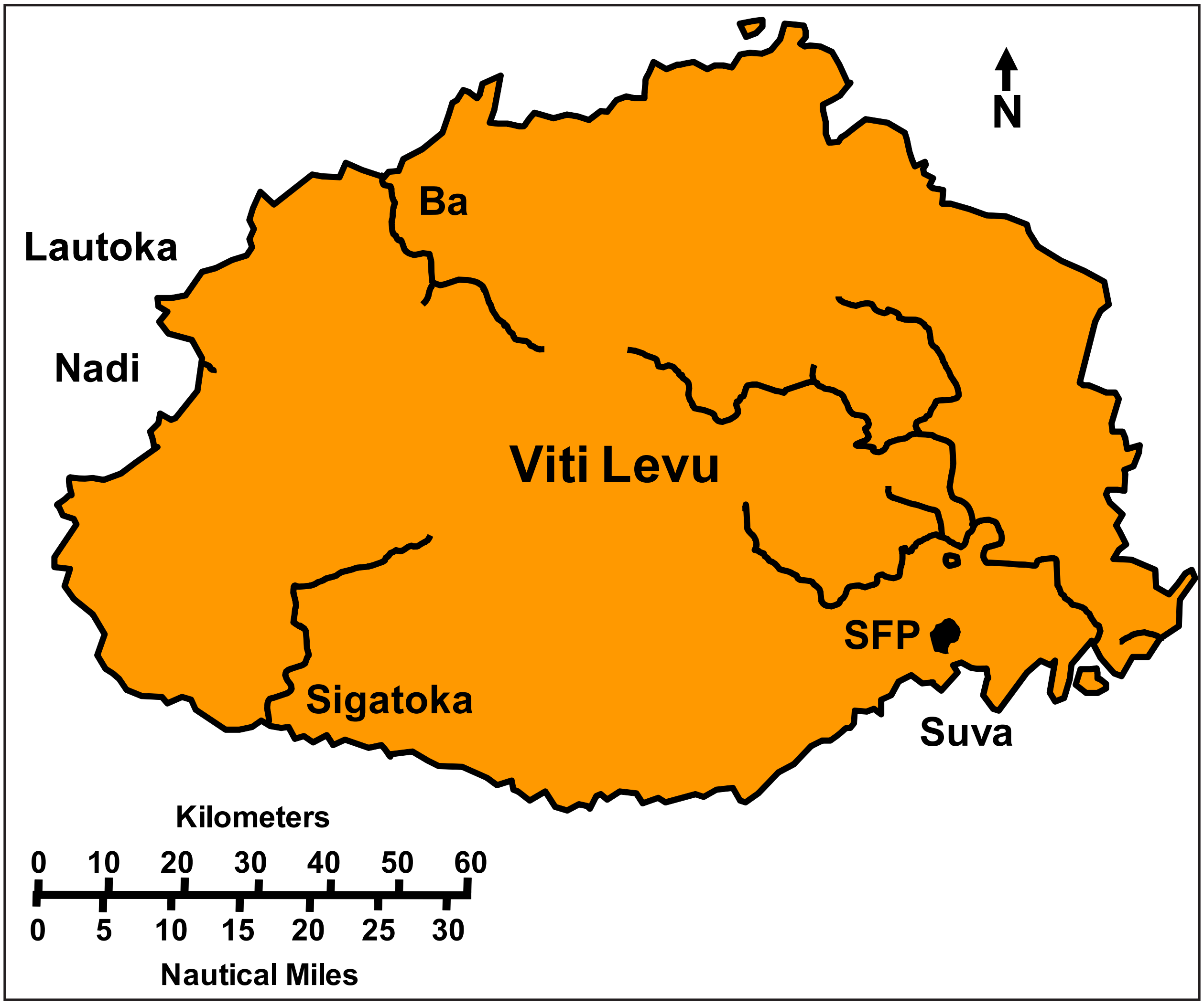

Figure 33. Map of Viti Levu, Fiji. The blackened area labeled SFP is the location of the tenured land where Southern Forest Products (Fiji) LTD. harvested the large *Agathis vitiensis* logs for construction of the Kalia Mileniume.

ed logging fresh stock. Another timber species was used to fill this order but has not been identified. It was not possible to make wood vouchers because the crossbooms were already fitted in place.

Other Possible Timbers

Mr. Pomelile suggested other possible timbers for canoe construction including sandalwood (he said was not Hawaiian sandalwood), **mo'ota** [he identified as *Dysoxylum forsteri* (Juss.) C.DC.], **puataukanave**, which he said is used for wood carvings (he identified as *Cordia subcordata* Lam.), **feitai** [if **feifai** is the same name, then *Schleinitzia insularum* (Guillemin) Burkart, (Whistler 1992:41)] and **lekileki** [*Xylocarpus moluccensis* (Lam.) M. Roem. (Whistler 1984)]. He also indicated two other good boat timber species as being **fehi** (*I. bijuga*) and **milo** (*Thespesia populnea*), both of which he gave the scientific names.

A literature review of ethnographies and botanical literature from 'uvea (Burrows 1937), Futuna (Burrows 1936), Lau (Banack 1987, Gillett *et al.* 1993, Thompson 1940), Samoa (Hiroa 1930), and the Cook Islands (Hiroa 1944) was used to compile lists of all the plant species mentioned in canoe construction (Appendix B).

Splitting Logs

The *Agathis* logs were cut and shipped to Tongatapu between January and February of 1999. There they sat in Queen Salote Wharf until the shipping fees could be paid. However, it was agreed that five of the logs could be released for the opening ceremony of the Kalia Project before payment was received. The logs were 20 to 30 feet long and 5 to 7 feet wide, and were brought in using fork lifts on the opening day of the project, February 23, 1999. The opening ceremony included singing blessings for the project, and a symbolic gesture by the king's grandson, Hon. Sione Ikamafana Tuita, who made the first cut on a log with a traditional stone adze.(Figures 34 to 39).

The hull logs were split in half using a chainsaw with a 6 foot long bar. They were marked for cutting using a taut rope and spray paint. The chainsaw was then run down the middle of the painted line, forming a radial cut. From the viewpoint of standing on top of the log (Figures 40 to 42) it was better to cut with the grain by keeping the saw blade more horizontal with the outer surface of the log, than to cut vertically down into the log, causing the saw to cut more across the grain. The sawdust was finer when cut with the grain than when cut across the grain. I figured this out when one of the workers was cutting too deeply. Pulotu went up behind him and made some corrections in his technique. Afterwards I asked Pulotu if it was better to cut more gradually instead of directly cross-grain and he explained to me that yes, this was so.

When one side was cut as deep as possible, which was about halfway through the log, both log ends were cut all the way down to the under surface (Figure 43), then the log was rolled over with a forklift. The other side was cut through in the same manner. A line was painted across the now top surface with the line matching up to the two cut ends. Large rocks of limestone about 1 to 2 feet in diameter were wedged under the log to support it and keep it from rolling or splitting when not fully cut.

When the log was fully split, wedges were driven in between the log halves. The halves were then pried apart using a lever bar, and pulled apart using ropes with adequate numbers of men (Figures 44 to 46). A truck even had to be used to tug one of the limestone rocks back out from under the log.

Roughing In

The log halves were laid face up, and an outline of the desired hull shape was drawn on the upper face and log ends. Logs have their own widest and narrowest points. To get a complete hull segment out of a log, it is necessary to work within the narrowest confines of the log. Thus to determine the maximum possible width of the hull segment, a midline was first determined and marked down the entire middle of the log face. Both sides of the

Figure 34. Hauling the logs to the work site.

Figure 35. Pulotu directed positioning of the logs.

Figure 36. Blessings were sung for the Kalia Mileniume project during the opening ceremony.

hull were then marked symmetrically about this midpoint within the narrowest dips of the log's outer surface. The full curvature of the hull was then drawn on the end and carved in with a chainsaw (Figures 47 to 50).

About three passes of the chainsaw on each hull side rough cut the hull (Figures 47 and 48). The first cut on the side of the log was roughly perpendicular to the upper flat surface. The second and third cuts gradually formed the curve toward what was to become the canoe's lower surface. The outer surface was then smoothed and rounded with a few more finer cuts of the chainsaw to take off the rough edges.

Figure 37. Hon. Sione Ikamafana Tuita (King Topou IV's grandson) took the ceremonial first cut on log with a stone adze, opening the Kalia Mileniume project.

Figure 38. Tuione Pulotu, the King's grandson, and Minister Paunga posed in front of Tuione's canoe model.

Normally after the logs were split and squared, they were carefully placed for the upper surface to be parallel to the ground. A center line was cut 6" to 12" deep down the previously marked midline (Figure 51). A rough cut was also made to indicate the hulls intended thickness (Figure 52). Angled cuts were then made from either side of the midline to extract long wedges out of the center (Figures 53 to 54). This process continued, cutting gradually deeper and deeper perpendicular center cuts, then larger and larger angled cuts.

The intention of this technique was to extract as much usable lumber from the log as possible. The excess lumber was to be used to make paddles and other artifacts for use and sale. After as much good board feet of timber was extracted as possible, crosscuts were made in the remaining wood and large chisels on poles were used to break out the chunks of wood (Figures 55 to 57). The final result was a roughed in hull with a thickness of 3" - 4". This rough thickness allowed for error, the creation of flanges around the perimeter of the logs for joinery, and for the formation of comb cleats.

Connecting Hull Segments

The overall hull design consisted of five log halves (hull segments) lined up end to end to form a one hundred foot hull. For purposes of symmetry, each log that was split in half would be laid in corresponding positions on the hull, symmetrical to mid-ship. So with each hull segment numbered 1 through 5, the first log split into halves was placed as segments 2 and 4 on the hull. The second log split might have become segments 1 and 5 on the hull, and then one log half would be the middle segment 3 (Figure 58). Of course many of these decisions were simply based on the confines of the log's shape.

Before permanent joining could take place, the hull needed to be nearly fully assembled. The segments were temporarily fit together during construction. Segments 2 through 4 were laid horizontally along the ground (Figures 59 & 60), while end segments 1 and 5 (the prow segments) were inclined to a roughly 20° angle from horizon-

Figure 39. Proud master canoe builder Tuione Pulotu at right, with project manager Filipo in middle and crew member at left.

Figure 40. First cut to split log made from top as far down as possible.

Figure 41. Log halves to be used for the dugout segments of the hull's bottom.

Figure 42. Tuione Pulotu splitting a log.

tal (Figures 61 & 62). End segments were supported in the inclined position with braces. All segments were nailed together (Figure 63) so strakes could be form fit on top before permanently binding all the pieces together.

To make angled segments 1 and 5 meet at a continuous level on the topsides of the hull, two layers of strakes were added above segments 2 through 4 (Figure 58). Thus a complete hull was built. Four strakes were added on the first strake layer, and five strakes were added on the second strake layer. The middles of the strakes were positioned over the points where hull segments met one another to reinforce the hull segment binding (Figure 58). Thus at no point did strake ends join above the positions where segment ends joined. If joints were located above one another, this would have weakened the integrity of the hull. Strakes 1 and 5 of the second row met up with dugout segments 1 and 5 (Figures 62 & 64). The strake was then cut to an angle to meet flush at the prows.

The roughed-in thickness of 3” - 4” on each hull segment allowed for further refining, resulting in built in lips, or flanges, and comb cleats. With such a roughed-in thickness, the outer surface could also then be sculpted to fit the exterior curve and shape of the hull without worrying about puncturing a hole in the hull (Figure 64). Flanges were built on the inner surface along all edges of the hull segment (Figure 65). The flanges function by joining the segments together end to end, and by building up the sides of the hull. Glue

Figure 43. Pulotu cut through the end of the log.

Figure 44. Wedges were hammered in between the halves to finish the splitting and help pry the halves apart.

Figure 45. Log after split in half.

and lashings were used in the permanent connecting process.

Strakes

Southern Forest Products LTD. in Fiji milled the *A. vitiensis* necessary for the side strakes on the canoe. They were milled into slabs of two dimensions, either 6” x 24” x 20’ or 12” x 24” x 20’, and then shipped to Tonga. The wider strakes (8” or 12”) were intended to be received first in order to build a hull with greater tumblehome. The term tumblehome indicates that from the widest part of the hull (beam) to the hull’s topsides, the hull narrows, or curves inward. Stating there is no tumblehome would indicate vertical hull sides, with the topsides of the hull being about equal to the beam. Unfortunately the 6” strakes were the first to arrive. Tuione Pulotu decided to go on with the work even with limited strake width, so the completed hulls’ sides turned out to be more vertical with less tumblehome than originally planned (Figures 66 & 67).

Rough cut strakes were placed in position above the dugout hull segments (Figure 68). Marks were made for the creation of new comb cleats (Figure 69). Each set of cleats was made in a vertical row up the inside of the hull on the dugout segment, the first strake layer, and the second strake layer. The cleats were used to bind vertical running ribs to the inside of the hull. The strake was then thinned and lightened on its inner surface by scoring the strake with a chainsaw and removing the excess wood with adzes and chisels (Figure 70 & 71). Each rib and cleat set was horizontally spaced 5’ apart from the next, centered on the crossbooms. In the prows there were no crossbooms, but the ribs were still spaced 5’ apart.

In order to support the weight of the strakes on the walls of the dugout hull without cracking the hull bottom, ropes were looped in between one cleat on the windward side and one cleat on the leeward side. A piece of scrap wood was then stuck between the rope loops, and they were twisted in a tourniquet fashion (Figure 72). This tightened rope offered support and reinforced the integrity of the hull from the unbalanced strain of the strake.

The completed comb cleats were about 5” long, and about 2” to 3” wide. Drills with 1” bits and chisels were used to bore out a hole about 1” wide and 3”+ long within the comb cleat (Figure 73). Some cleats had two smaller holes,

Figure 46. Rolling the log half pictured at left in Figure 45 over on its side was a mammoth task.

about 1" in diameter, drilled in instead of one larger hole (Figures 74 to 76).

Permanent Hull Binding

Two layers of strakes were added above the dugout hull segments (Figure 77). Inside the hull there were no poles or stringers running horizontally (from prow to prow) to offer reinforcement between hull segments. Instead, the strakes provided that support. Strakes were fitted longitudinally with half the strake over one hull segment and half over the other hull segment (Figure 58). Thus, with the strakes overlapping segment joints, there

Figure 47. The log half was squared by cutting to the log's narrowest width.

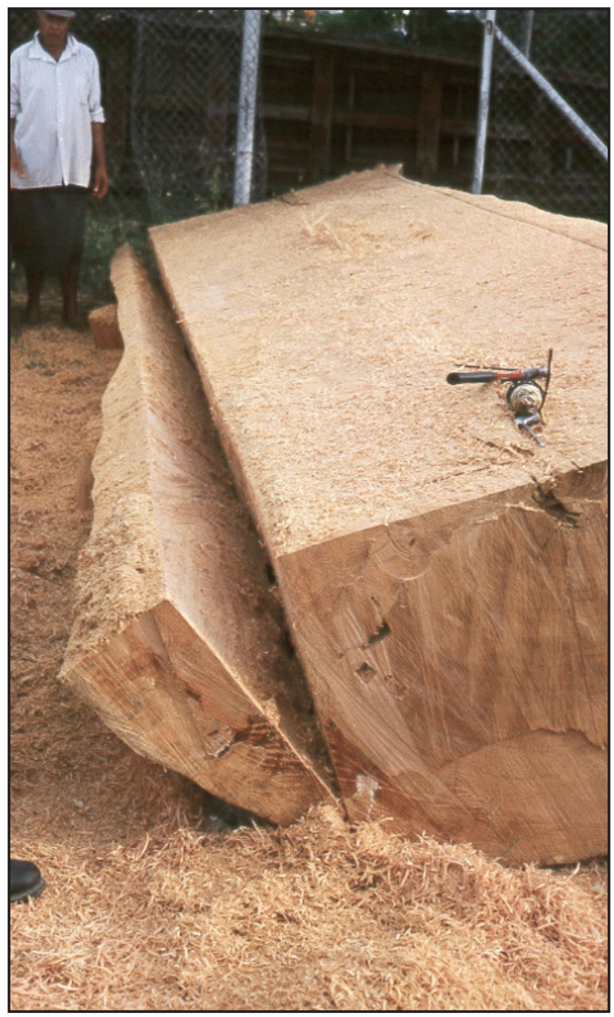

Figure 48. In the process of squaring the log.

Figure 49. Ribs and their lashings were sketched in.

Figure 50. Mr. Pulotu began to rough cut the hull thickness.

Figure 51. Making central cut in order to begin hollowing out the log.

Figure 52. Rough cut of hull thickness was made for entire length of a hull segment.

was natural reinforcement. Similarly, the second layer of strakes was laid above the first layer with their midpoints resting above the meeting points of the first strake layer. The final height of the hull including dugout segments, two layers of strakes, and one washstrake to just under the deck was 7' 7".

Gaps between the joining surfaces of the dugout hull and strakes were removed by sliding a chainsaw into the gap and running it back and forth horizontally to hit the high points, until a smooth, level fit was achieved between the two. Metal dowels were used between all joining hull and strake surfaces. Between the ends of each of the dugout hull segments, five dowels were evenly spaced out. The dowels were hollow and had a hole in the middle (Figure 78), so a glue gun could be used to insert glue into the hollow center of the dowel and have it come out both ends for superior binding. The segments were brought tightly together by cutting two rectangular holes in each segment end, about 2.5 – 3" wide and about 7" long, with the narrow side facing the segment end (Figure 79). Clamps were then placed in corresponding holes between hull segments in order to pull them together for glueing.

Strakes built up the sides, adding depth and overall size to the hull. The strakes were about 2 to 3 feet wide and about 15 to 20 feet long. They were fitted to lie flush on top of one another. The joint between strakes was reinforced with metal dowels about every 4 feet. Between the ends of the strakes, metal dowels were also used.

A gap of at least a quarter inch was left between hull segments and strakes in order to leave plenty of room for a good layer of 5200 Marine Glue, manufactured by 3M, along the full faces of the joining surfaces.

Holes were drilled through the flanges and sennit cord was lashed through these holes to connect the segments. In this way all of the lashings were only exposed on the interior surface of the hull (Figure 80). No lashings were exposed on the exterior of the hull in those areas likely to be submerged in the water, thus the lashings were protected from the elements. Only at the level of the washstrake

Figure 53. Wedge cut to hollow hull segment.

Figure 54. Board cut out of the center of the log.

Figure 55. The rest of the hull segment interior was roughed in by crosshatching with a chainsaw and then chipping out the cut sections with a chisel or adze.

Figure 56. Crosshatching with the chainsaw and chisel work.

Figure 57. Adze work refined the hull interior.

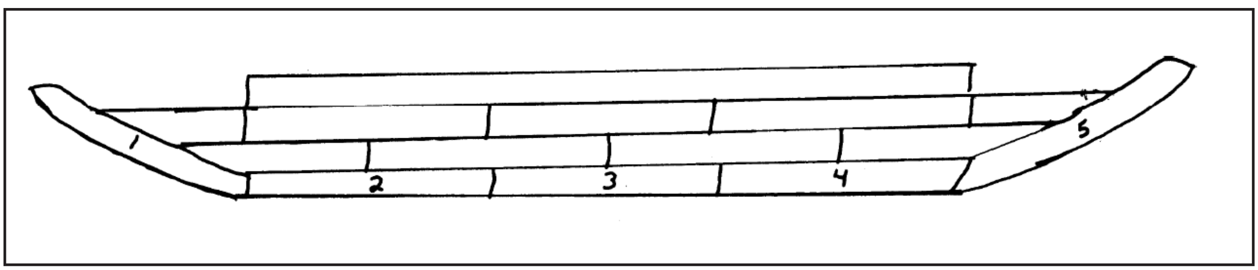

Figure 58. Placement of the dugout hull segments numbered 1 through 5.

lashings, about five feet above the hull bottom, were lashings exposed to the outside due to the use of battens to reinforce the connection of the washstrakes (uppermost strakes) to the hull (Figures 81 & 82).

(Here, the hull proper is considered the dugout log half and two layers of strakes; the washstrakes are the level of strakes above the hull proper.) The washstrakes were tacked to the strakes below, and then glued in place with 3M 5200 Marine Glue. The battens were nailed in place.

One inch holes, matching up on the upper and lower sides of the batten, were drilled in the strakes. Lashings were made binding the batten, washstrake and hull strake (Figures 81 & 82). In order to seal the drilled holes after the lashings were completed, wooden dowel plugs made of Australian cedar (*T. australis*) were tapped into the holes.

The washstrakes were usually made of two strakes, in upper and lower positions. The lower washstrake functioned as a place for the crossbooms to rest on. Its measure ranged from about 23” to 24” in height. The batten was connected to its lower surface, joining it to the hull and reinforcing its structural stability from the stresses of the crossbooms. The upper washstrake measured from 7” to 9 1/2” high amidship, possibly dependent on the height of the crossbooms.

Twelve crossbooms were used. Four were made of the thicker 8” x 12” **tamanu** (*C. vitiense*) beams. The eight

Figure 59. Hull segments 2 through 4 were laid out horizontally along ground.

Figure 60. Hull segments laid out in place.

Figure 61. Prow segments were laid at about a 20° angle from horizontal.

thinner crossbooms of unknown species were 8” x 6”. These booms were placed with the greater width upright and the narrow width horizontal. They were spaced out 5 feet apart from one another along the central 55 feet of the hull and the deck was installed over the top of them. The crossboom arrangement from one end to the other was as follows: one large, three small, one large, two small, one large, three small, and one large (Figure 112).

Ribs

Comb cleats served to bind ribs into the hull. These ribs were spars used to support the strakes. They were added only after the hull had been built. Corresponding to each crossboom, ribs made of **tamanu** (*C. vitiense*) were directly attached. The ribs served to insure the connection of the crossbooms to the hull. Thus there were twelve pairs of ribs connected to crossbooms along each hull. Each set of ribs was spaced five feet apart from the next (Figure 83). After these twelve sets of ribs were inserted, the builders had run out of **tamanu**, and therefore in the prows, **dakua** (*A. vitiensis*) was used to build the ribs, which were also spaced every five feet from where the crossbooms ended to the tip of each prow (Figure 84). Tuione Pulotu indicated that it was alright to use weaker wood for the prows’ ribs because the prows would not receive as much stress as the midship areas, where the crossboom forces and torsion would be between the two hulls.

Figure 62. The prow as viewed from inside. The bottom piece was dugout hull segment #2 (2); the top middle piece was dugout hull segment #1 (1); and the upper left and right pieces were strakes (s).

Where lashings went over the ribs, chainsaws were used to slightly groove the ribs and provide a surface to contain the lashings and prevent slippage (Figure 85). Each rib, one on the windward side and one on the leeward side, was usually made of three pieces. A shoulder piece was lashed on to the crossboom, and two pieces were run along the strakes down to the floor of the hull. These three rib pieces were scarfed or joined together (Figure 86). The ribs were lashed to the comb cleats with sennit cord which was purchased from Fiji.

Prows and Yard Rail

The prow’s point is often called the cutwater, and sometimes called the **manu** in Polynesia. Each cutwater was made with its own solid piece of *A. vitiensis* (Figures 87 & 88). Behind the cutwater, two halves comprised the endcover which topped off the prow (Figures 89 & 90).

A piece of *T. australis* was placed in between the two endcover halves, which according to Pulotu, was meant to offer a little “style”[4]. Be-

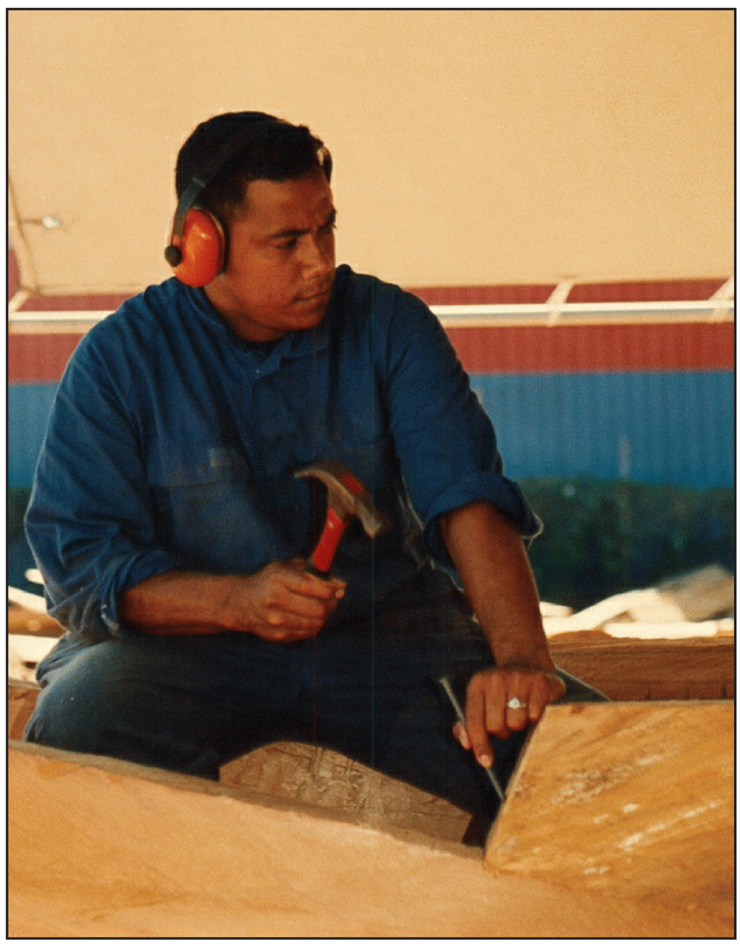

Figure 63. The segments were tacked in with nails.

[4] The way the pieces were put together, a red “T” was formed in the middle of each prow. When I was casually talking to Tuione Pulotu about the prow, he cleverly said it formed a “T for Tuione” and then laughed. Later I was interviewing him with my video camera

Figure 64. The strake exterior surface was trimmed to be flush with the hull segment.

tween the deck and the top of the end cover, a washstrake called the breakwater was positioned facing toward the prow (Figures 89 & 90).

On the **katea**, the larger of the two hulls, runners were fashioned on the windward side for the purpose of guiding the lines, called stays, which support the mast fore and aft. These were large tubes which were cut into the side of each prow, and spaced about three feet apart. Three runners were positioned on one prow and four on the other (Figure 91). The runners were intended to be built-in to the sides of the end covers, but the wood on one prow partially rotted and was planed down to attach new runners (Figures 92 to 95).

The yard groove was placed about 5' 6" in from the tip of each cutwater on the **katea** prows. It was fashioned as an independent piece, and a cleat was built-in. The cleat was used for lashing down the foot of the sail's yard into the groove when under sail (Figures 96 to 97).

The distance from the tip of the cutwater to the breakwater varied because the hulls were not perfectly symmetrical. On the **katea**, prow 1 was measured as 24' 5" from the tip of the manu to the breakwater, and prow 2 was measured 23'8" between the same points.

On the **hama**, the prows with the longer and shorter ends were reversed, so prow 3 was 15'11" long from tip to breakwater, and prow 4 was 14'6" between the same points. Thus, when one would stand on the windward side of the canoe and sight it from the tip of the **hama** cutwater to the **katea**, the **katea** prow 1 looked significantly longer than **katea** prow 2.

The last significant piece on the prow was the yard rail which led from the leeward side of the yard groove up to the deck. The yard rail continued over the entire length of the deck on the leeward side, and then led back down to the yard groove on the other prow (Figures 98 to 102). The yard rail was used as a track to rest the crux of the yard and boom of the

about the prow and I kept trying to ask him what the T stood for, but he wouldn't answer me. Finally he replied "What? What do you want me to say? I tell you, the T stands for Tonga!"

Figure 65. Finishing touches were made on the comb cleats (c). Notice the flanges (f) or thick lips where dugout hull segments (d) and strakes (s) met. Also note the tourniquet style ropes (t) between hull bottom comb cleats which were used to temporarily reinforce sides while placing strakes above.

Figure 66. The leeward side of the **katea** is shown here. Note the relatively straight vertical contour of the hull, with very little tumblehome and an abrupt curvature to the bottom.

sail, in order to run the sail from one yard groove to the next during the shunting maneuver. The deck was scored with a chainsaw in order to prepare to install a post for the yard rail. A footing was chiseled out for each yard rail post. All posts were installed directly over a crossboom, thus there were twelve posts for the yard rail.

Main Deck, Hut, and Lookout Deck

The deck was made of *T. australis*. 25 planks were placed side by side to span the 22' wide deck. The planks ranged from 8" to 14" wide and 2" thick. The length of the deck was 61'. The distance between the two hulls at midship was 9'11". The beam of the **hama** (outrigger hull) at midship was 4' 1", and the beam of the **katea** (main hull) at midship was 4' 8.5". The total beam of the Kalia Mileniume was 18' 8.5", calculated by adding the distance between the two hulls, plus the beams of the **katea** and **hama**. This left a little over 1.5 feet of deck left overlapping the outer sides of each hull. Around the "port and starboard" sides there was a toe rail built.

Above each crossboom, notches were chiseled out of the deck plank to a depth of about half the plank's thickness in order to screw and lash it down. This method kept the lashings recessed. Before the lashings were made, the planks were screwed into the crossbooms with metal screws. Then holes were drilled through the plank for lashings to go down, around the crossboom, and back up. Wire was used to make a very large "needle" for passing

Figure 67. Windward side of the **hama** is shown here, with a view of the batten, the washstrake above, and the crossbooms.

Figure 68. The strake was in position above two adjoining hull segments for the purpose of marking where the comb cleats should be built.

Figure 69. The position for the comb cleat was marked with the strake on the hull.

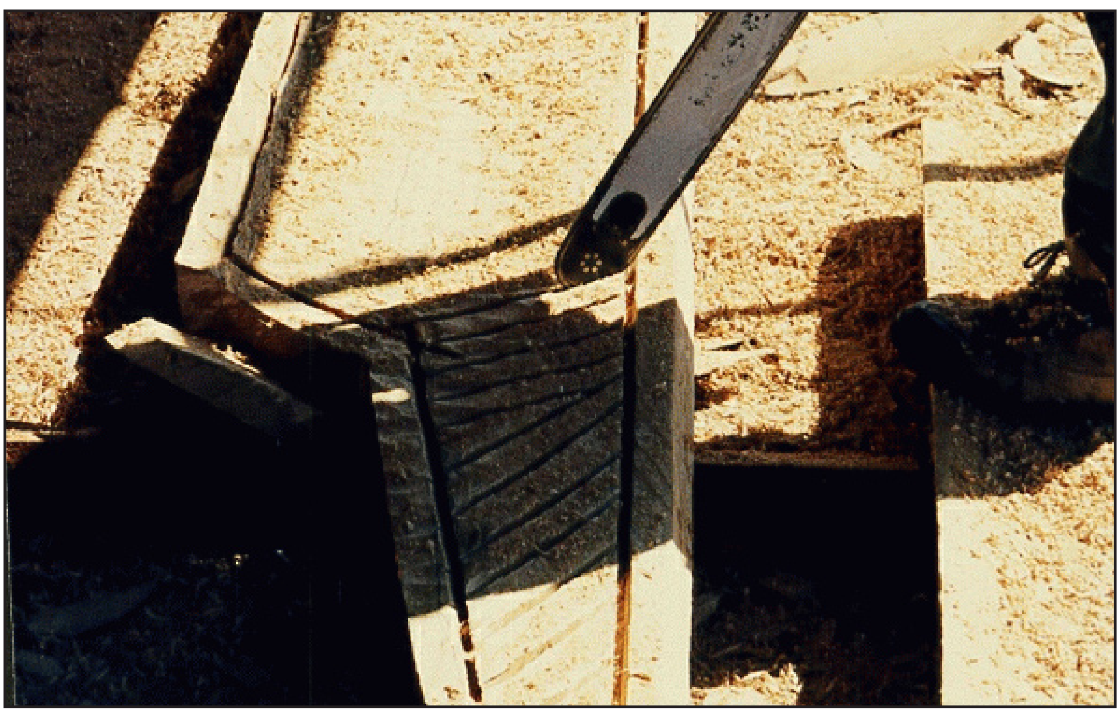

Figure 70. The inner surface of the strakes were scored with the chainsaw.

Figure 71. The strake was hollowed out. Comb cleats were left built in.

Figure 72. Tourniquet style ropes temporarily reinforced the hull segments.

Figure 73. The comb cleat was drilled.

the sennit cord up and down through the drilled holes. (Figures 103 to 106).

There were four hatches built for entry into the hulls. They were positioned approximately 13 feet in from the ends of the deck nearest the prows. Their openings were about 2.5 feet to 3.5 feet wide and a little over 4 feet long. (Figures 107 & 108). Hatch covers which were simply wooden boxes built out of decking, were made to cap each hatch, and could be lifted off completely when not in use.

Figure 74. Comb cleat with "**kalia**" inscribed.

To prevent water from entering the hulls, all planking laid above canoe hulls was caulked with 5200 Marine Glue manufactured by 3M. Planking not over the hulls was left uncaulked so that water could drain from the deck. The main deck was coated with Thompson's Water Sealant ®, using a hand pumped sprayer. Other exposed wood above the hull was also sprayed with the water sealant, including an extra heavy coating on the mast steps. In addition, all sennit lashings, both inside and outside the hull were sprayed with water sealant.

The **kalia** was a "double-decker" with the main deck positioned just over the two main hulls and a lookout deck built right above the hut (Figures 109 to 111). The hut or **fale** with interior dimensions 7' wide and 13'6" long was roughly centered

Figure 75. Comb cleats lined up between adjoining strake and hull segment.

Figure 76. Comb cleat.

Figure 77. This illustration of the hull shows the multi-layer hull construction with dugout hull segments on the bottom (d), two layers of strakes (s), and the batten (b) which reinforced the joint between the second strake layer and the upper washstrakes (w). There were two planks which made up the washstrake. All twelve crossbooms (c) can be seen running between the two hulls.

Figure 78. Glue gun used to insert glue into the metal dowels end of the metal dowels.

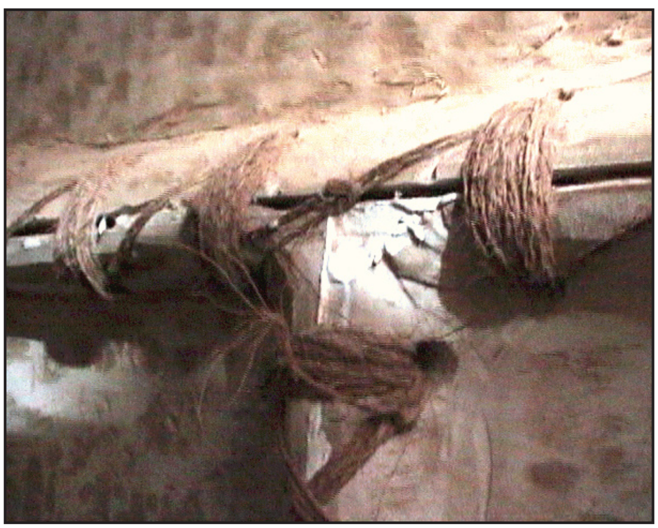

Figure 80. Paired holes drilled through the flanges with their lashings.

on the deck, one foot closer to the windward side, leaving a little more deck space on the leeward side. The lookout deck built above the hut stood 7' above the main deck. All posts and crossbeams used in the construction of the lookout deck were neatly lashed together, as well as nailed or screwed.

The roof on the **fale** was positioned underneath the lookout deck. It was curved and made of a lattice work. The curved

Figure 79. A rectangular patched hole used for clamping was next to Pulotu's back foot

Figure 81. Interior view of a lashing between the second strake layer and washstrake layer. 1" holes which were drilled through hull to the exterior. The batten was on the exterior side and bound to the hull by this lashing.

roof faced the windward side, leaving the open face on the leeward side. Thatching for the roof was made of whole pandanus leaves placed side by side and pinned together with a long skewer (Figures 112 to 116).

Three nice sheets of plywood made from *A. vitiensis* were placed on the floor inside the **fale** (Figure 117). One berth was made on the left side of the **fale**, and on the right side, it was planned to cut a hole to serve as a toilet. I was not there to witness the toilet constructed.

The two mast steps were made of a block of *T. grandis* split in half. Two wedges were cut out of each block,

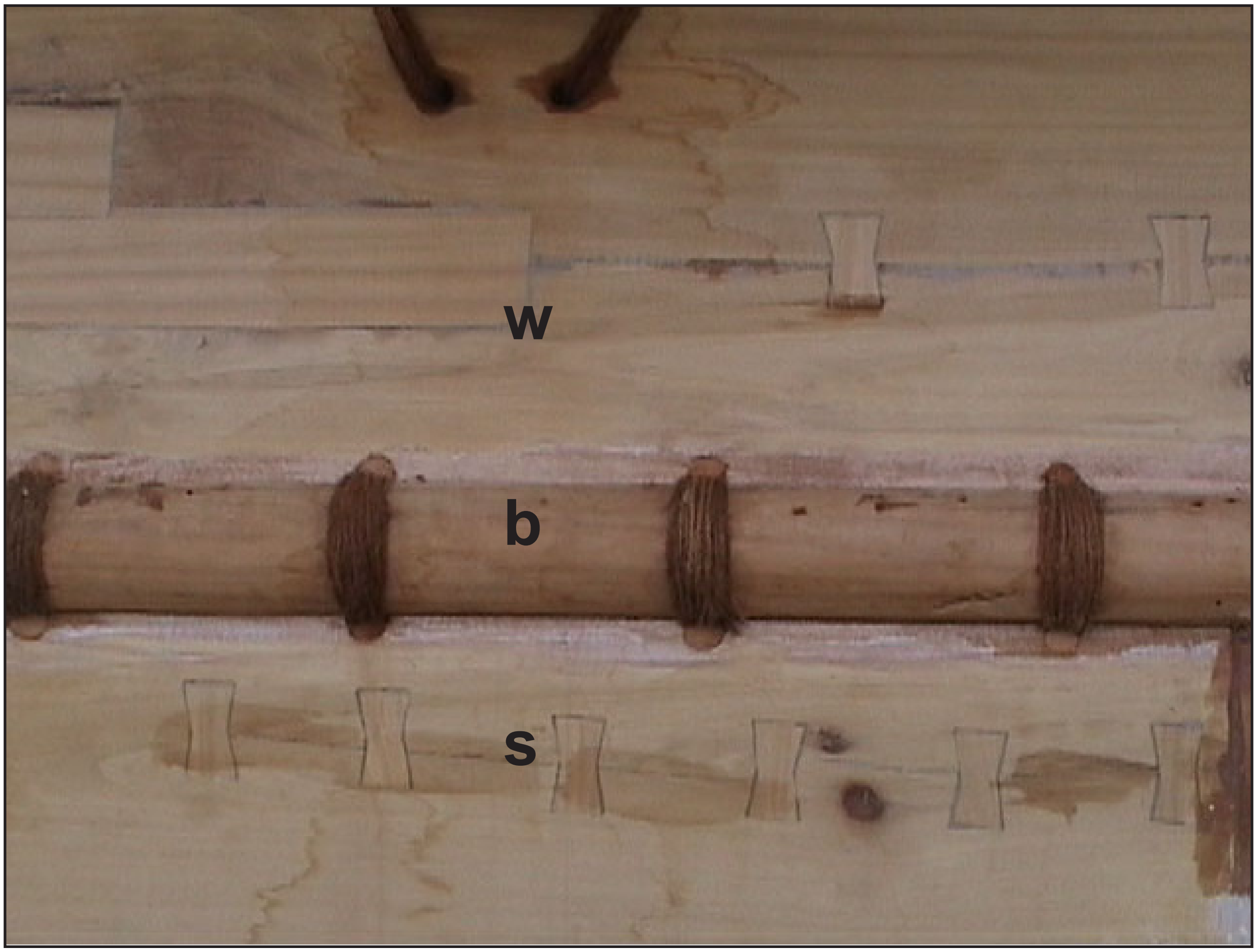

Figure 82. View of exterior with lashings emerging. The batten (b) was bound over the area where the second strake layer (s) and washstrake layer (w) met. Plugs filled in the holes where the lashings came out.

leaving a convex middle area where the concave end of the mast would rest. A side piece was left on either side of the step so it could be lashed down to the deck (Figures 118 to 121).

Each mast step was placed over the large hull, just above the windward gunnels (Figures 108 & 122). It was necessary to place them above a crossboom, so they could be securely lashed down. Two yard grooves were then placed in the middle of the deck between the two mast steps. These would be used as a “phantom prow.” The rear sail’s yard was tucked in to the middle of the deck, while the sail in front of it was tucked in to the leading prow (Figures 108 & 123).
On the windward side of the deck were placed two large cleats (about waist height in dimension), one opposite each mast. The cleats functioned as props to raise the mast shrouds above the **fale** to prevent their entanglement. (Figure 124).

Masts (Fanā)

The masts, called **fanā**, were made of laminated *A. vitiense*. Two **fanā** were made for the Kalia Mileniume. The five laminations were cut and planed by Tonga Timber Products, LTD, and the wood came from Southern Forest Products, LTD, Fiji. The masts were about 42’ long with a diameter of 7 1/2”. They were made of five laminates, glued, and nailed together with copper nails. Copper was used because it planed down easy when the mast was shaped from the laminates. The grain of the wood ran lengthwise, from top to bottom. The claws of the topmast spanned two feet across at their widest point (Figures 125 to 127). At the claw and cleat areas, the grain of the middle laminate ran 90° to the rest of the mast’s grain. These were critical areas of high stress which required reinforcement. Cleats were positioned on the mast about 3 1/2’ down from the top of the mast and about 9 1/2’ down. The shrouds and stays, used to hold the mast upright, were tied around the mast and rested on the upper surface of

Figure 83. Ribs (r) are shown here connected to the crossbooms (c).

Figure 84. View into the prow from roughly 25 feet back from the prow tip. The two sets of ribs in foreground were made of *Calophyllum vitiense* and three sets of ribs up in the prow were made of *Agathis vitiensis* wood.

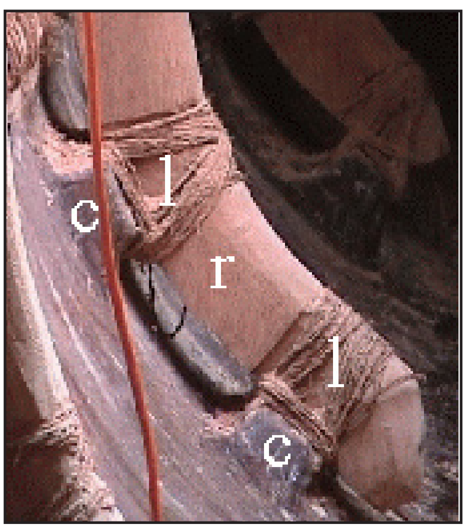

Figure 85. A rib bottom (r) is shown here lashed (l) into two comb cleats (c) in the hull bottom.

Figure 86. Note the angled scarfing (s) of the upper rib piece to the lower rib piece. Lashings were placed over these joints, here to join the ribs to the comb cleats behind.

Figure 87. Fenga Fanguna made the cutwater piece for the prow.

Figure 88. Fenga Fanguna shaped the cutwater (c) to fit the prow.

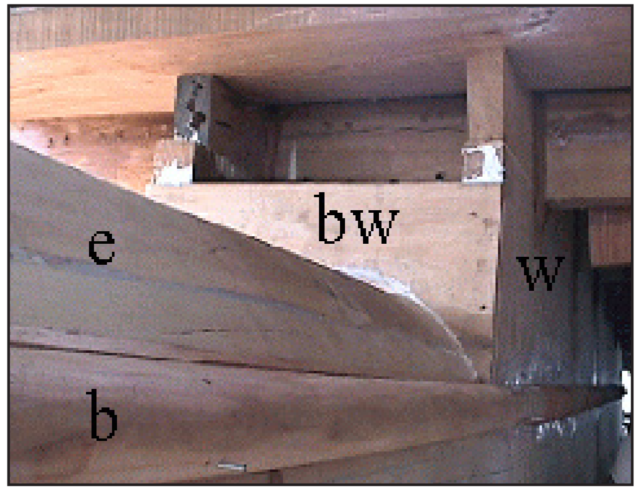

Figure 89. The breakwater (bw) wraps around at the same level as the washstrake (w). Also notice the prow's endcover (e) and the length of the batten (b).

Figure 90. Viliami Kolomatangi placed the last piece of the breakwater into position.

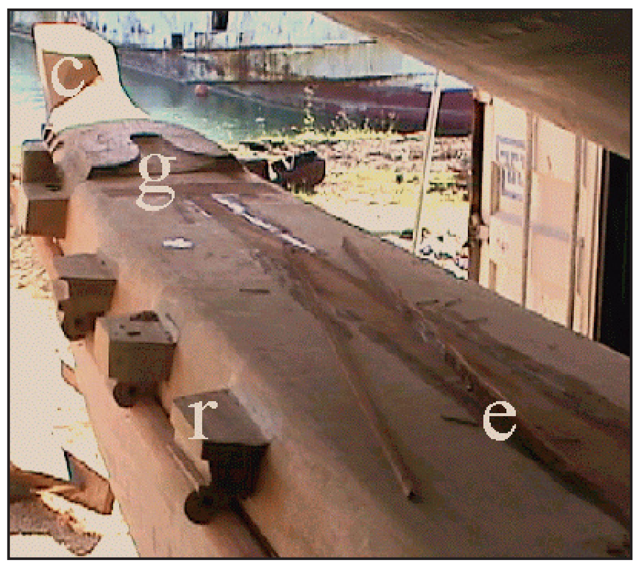

Figure 91. The cutwater (c) is seen at the point of the prow, followed by the yard groove (g). The runners (r) for the mast shrouds are aligned along the left (windward) side. The upper surface of the prow is called the end-cover (e).

Figure 92. These roughed-in runners on **katea** prow deteriorated.

Figure 93. This rotten wood on the end cover was unsuitable for making a runner.

Figure 94. A new runner was sculpted to replace the rotten wood.

Figure 95. New runners were placed in position.

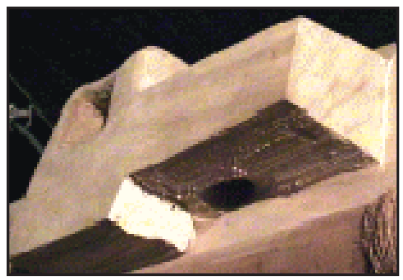

Figure 96. On this prow of large **kalia** the middle hole is the front runner. The upper left hole is the cleat to lash the foot of the yard to the groove. The yard groove is just above these.

Figure 97. The mast stay (rope) was in use through the runners of the small **kalia**. Note the built in cleat above the first runner which was later used to lash the foot of the yard down.

Figure 98. Placement of yard rail post.

Figure 99. The first yard rail was placed from the tip of the prow to the deck.

Figure 100. The yard rail ran along the leeward side of the **katea**.

Figure 101. View of the prow shows the positioning of the yard rail in relation to the runners.

Figure 102. Note the rail posts on the leeward side of the **katea** and how they rise and fall. This makes it easier to lift the foot of the sail's yard from the rail to the yard groove and back.

Figure 103. Holes were drilled for lashing the deck planks to the crossbooms.

the cleats. Holes were drilled in the cleats as a secondary site for running halyards used to haul up sails or other items if needed (Figure 128).

A concave, half circle was cut out of the bottom of the mast to be the mast foot. This point was designed to be mounted on the mast step to allow the mast to be pivoted from prow to prow, depending on where the sail was stepped. Standing rigging consisted of six shrouds and two stays for each mast. Four of the shrouds were placed at corners on the deck. Two shrouds were positioned directly windward and leeward of the mast. The two stays ran through the runners on the prows and operated to slant the mast from one prow towards the other. On the small **kalia**'s mast, two halyards were used to haul the sail up, and on the large **kalia**'s masts there were three halyards per sail (Figures 129 to 133).

The decision to built a shunting canoe with two masts was partially inspired by a Tongan man in Hawai'i by the name of Emil Wolfgramm. Wolfgramm told me he saw a photo of an 'uvean, two masted shunting canoe. He took the picture to a well known Hawaiian artist who drew up a set of plans for a **kalia** which included two masts. The artist preferred not to receive credit for his drawings. These drawings were taken by Mr. Wolfgramm to Mr. Pulotu (Wolfgramm 2001).

Sails (La)

The sails were made out of woven pandanus mats, with a weave between a quarter to half an inch thick. Tuione Pulotu made an attempt at procuring a sedge material called **kuta**, *E. dulcis* from Vava'u in September 1999 in order to make the sails, but was unsuccessful. He said that there was not enough **kuta** there, and the people in Vava'u didn't think they would be able to supply the necessary amount of plant material.

Tuione Pulotu described the sail for the small canoe. "Pandanus mats were woven by sections and then the sections were sewn together. Each section is three feet wide, and you overlap the edge about 8". Then you sew it with string. It is '**haole**' [foreign] string! If you use a wider mat, when the wind pushes on it, the weave spreads wider apart. So if we use narrower mats, there are more overlapping areas, and where they overlap is where the strength is."

Figure 104. Holes were drilled near the edges of the planks..

Figure 105. Deck planks ran parallel with the hulls. Here deck planks were being lashed to the crossbooms..

I did not witness the fabrication of the sails for the Kalia Mileniume. However I did see the plans for factory-made sails as drawn by Tony Harold of Sails Specialty LTD of Auckland New Zealand. They depicted two lateen sails, each with a sail area of 1065 square feet, for a combined sail area of 2130 square feet for the entire Kalia Mileniume. Unfortunately they were too expensive and were not ordered for the **kalia**. I am presenting this data as an estimate on the size of the pandanus sails made and used for the completed Kalia Mileniume.

Paddles (Fohe)

One **fohe uli**, or stearing paddle, was 28'5" long. The blade of the paddle was 16' long and 2' wide, the arm of the paddle had a diameter of 8", and the grip at the end was 10" x 8". The paddles were made out of solid pieces of *A. vitiensis*. The tip of the blade was beveled for a distance of two feet from the end to maximum blade width. The blade itself had a maximum thickness of about 6" down the middle. The blade design for the Kalia Mileniume was unlike that of traditional blades, according to Tuione Pulotu, because this blade was make with a rocker or curve in it to ease steering. (Figures 134 & 135).

Patches and Repairs

Great effort was made to remove rotten areas of the hull. When asked about why these areas existed, Tuione Pulotu explained that normally the wood

Figure 106. This view underneath the deck shows nearly all the crossbooms and both hulls. Note the deck lashings visible on the crossbooms.

Figure 107. This worker entered a hatch carrying a rib for fitting and installation. Note the hatch cover just in view at the top.

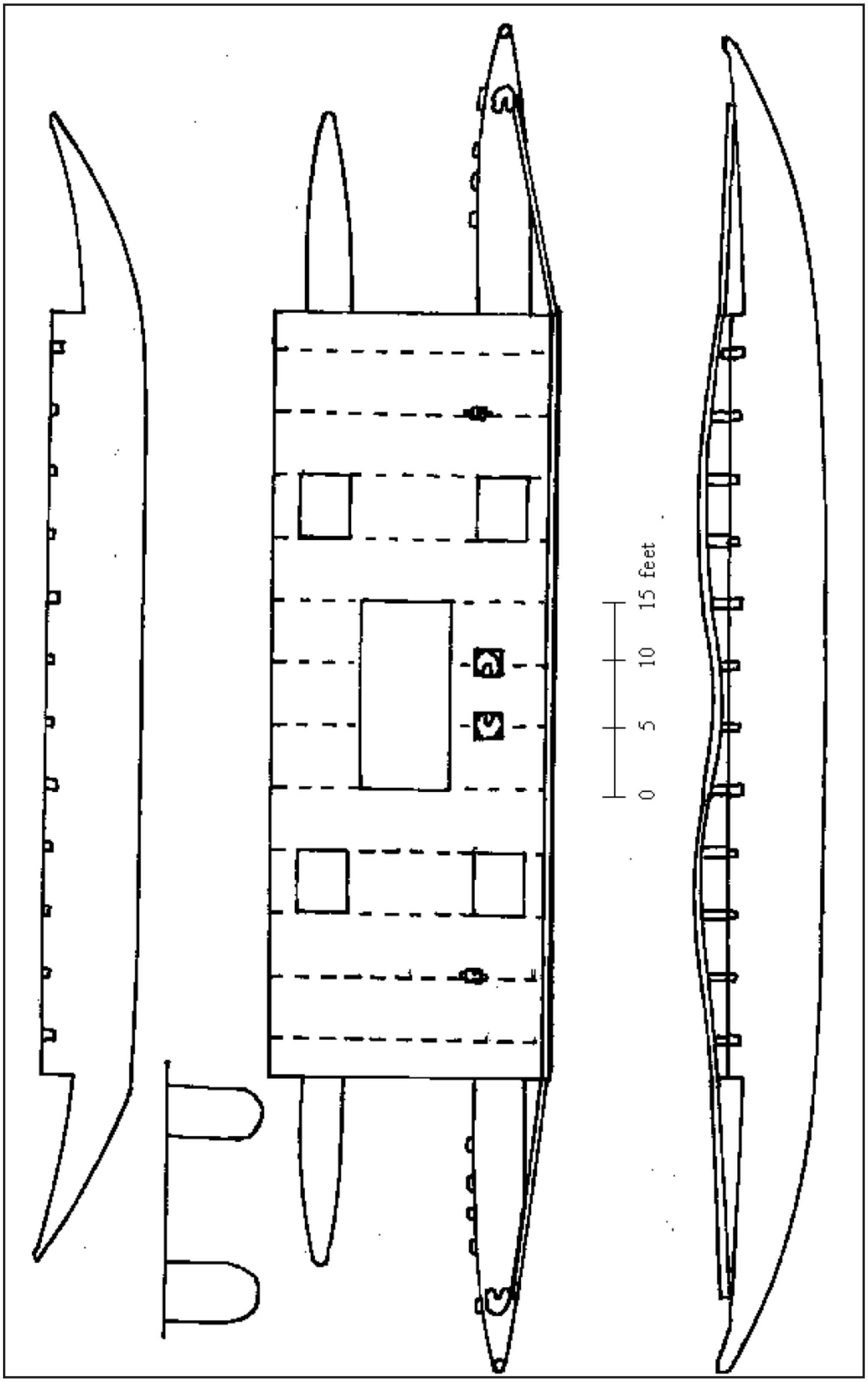

Figure 108. Scale drawing of completed Kalia Mileniume drawn by Mark Nickum.

Figure 109. Outrigger hull, **fale** and lookout deck. From the lookout deck, the captain would stand nearly 15 feet above the water line.

Figure 110. Curved shape of the windward side of the **fale**. Note spears ready for action.

Figure 111. Lookout deck

Figure 112. Lashing post on windward side of lookout deck to cross post.

Figure 113. Lashing through holes drilled on either side of the support post.

Figure 114. Lashings were made as tight as possible.

Figure 115. Two pairs of holes on back of the cross post where the wire needle passed the lashings through..

Figure 116. Rows of pandanus leaves pinned together with skewers for roof of **fale**.

should have been given a year to dry in a covered area. Instead these logs sat out exposed to the elements after harvest, in transit, at the wharf, and on the work site. With the sun beating down, the wood tended to crack in places. This allowed water to enter the wood more easily and contributed to the deterioration of the wood. Large areas of the dug-out hull segments required removal of deteriorated wood followed by replacement with fresh wood (Figures 136 to 141). Some weakened areas of the hull were then fiberglassed over in order to strengthen the area. The strakes underwent checking or splitting, which required inserting butterfly joints to reinforce their integrity and prevent further splitting (Figures 142 & 143).

Figure 117. My Tongan family sitting inside the **fale** on the birth and plywood floor.

Figure 118. Two wedges were cut out to make the step for the foot of the mast.

Figure 119. Two side pieces were shaped to provide recessed areas for lashing the mast step down to the deck.

Figure 120. The last detailed trimming was done by hand with a mallet and chisel.

Figure 121. The finished mast step.

Figure 122. The mast step was placed above a crossboom and lashed by the left and right pieces of the mast step.

Finishing Touches

The finishing touches involved thatching the **fale**, applying the bottom paint, varnishing the rest of the hull, and raising the masts. By coincidence, a friend of mine, Kate Thompson, from the University of Hawai'i, Mānoa, School of Nursing, is a sailor. She went to Tonga a few weeks after my final visit in order to go on a sailing trip in Vava'u. She has been kind enough to let me include a few of her pictures of the completed Kalia Mileniume (Figures 144 to 148).

Hull Profile Measurements

Measurements include the contour of each hull cross-section, the beam, the distance from deck underside to hull bottom, and rise of the hull bottom from the baseline (bottom of the hull at midship). "North" faces windward, with each station E or W of midship.

Figure 123. Placing one of the two yard grooves for the middle of the deck into place.

Discussion

The results of this thesis are descriptions of the architectural design, construction techniques, and timber species utilized for building the Kalia Mileniume. Here, the authenticity of the Kalia Mileniume is evaluated in light of the traditional approach to canoe construction described in the section "Introduction to the **Kalia**". There are three central hypotheses (questions) that are addressed herein: 1) Was the architectural design of the Kalia Mileniume true to that found in the literature and extant canoes? 2) Were the timber species used consistent with those used in Fiji between 1773 to 1874? 3) To what degree were modern materials used for fastenings, caulking, preservatives, and other purposes?

First the major features of the Kalia Mileniume are discussed in comparison with the ethnographic literature. Then, the hypothesis questions are addressed. Finally some issues about changing Pacific culture are discussed.

Figure 124. Large cleat on windward side of the **hama**, one for each mast. Its purpose is to prop the shroud which is tied to the crossboom on this side over the **fale** so there is no obstruction to the shroud when under sail.

Hulls and Strakes

The final hull length for the Kalia Mileniume was 108'. This was in keeping with hulls recorded in Fiji of 102' (Wilkes 1845:167), and two Fijian **drua** of 99' and 118' (Williams 1858:75).

The great length of the two Kalia Mileniume hulls was achieved by joining five dugout logs. This was necessary because the shipping regulations for the logs shipped from Fiji to Tonga required that the logs be no longer than 30'. Using multiple dugout logs for the hull bottom was partially consistent with Paris's drawings of a **kalia**. These drawings depicted three segments joined to form the main hull of a 51' Tongan **kalia** (Dumont d'Urville 1830-34). Paris's cross-sectional drawing shows the hull bottom seg-

Figure 125. The top of the mast shows the five laminates.

Figure 126. Shape of the claw with Tuione Pulotu standing in front.

Figure 127. Three holes were to be drilled into the claw for the halyards.

Figure 128. Cleat on the side of the mast for use in tying on the shrouds.

Figure 129. Claw of the small **kalia** mast.

Figure 130. Two halyards on the small **kalia** ran through the drilled holes in the middle of the claw. The left stay runs to one prow and the right stay runs to the other prow. These were used to tilt the mast one way or the other depending on the point of sail (Figure 133) The middle shroud ran to the windward side, and the shroud not visible behind the mast ran to the leeward side.

Figure 131. Two halyards were tied on to the sail's yard in preparation for hoisting the sail.

Figure 132. The lower four shrouds just above the two cleats on the mast ran one to each corner of the deck.

ment as constructed from two halves which were joined at the bottom midline of the hull. Several layers of strakes were then attached above this hull bottom. Thus full dugout logs were not used on the **kalia** depicted by Paris, but joining several segments was the technique utilized, as opposed to one large dugout log for the entire hull (Dumont d'Urville 1830-34).

Joining several full dugout segments was recorded in the Cook Islands, where two, and sometimes three, dugout logs were joined to form a single hull (Hiroa 1944:178).

The Kalia Mileniume segments were each butted end to end, with flanges at the ends of each segment. These flanges permitted rows of holes to be drilled for lashings. Each hole matched a corresponding hole in the next hull segment's flange, and each hole only pierced through the flange and not down to the exterior hull surface. Consequently, no lashings were exposed to the elements, permitting a longer lifetime for the lashings.

The multi-segmented hulls built in the Cook Islands did use butt joints, but according to Hiroa's diagrams (1944:179) there were no flanges where the segments connected. The segment ends were the same thickness as the rest of the hull segment. Angled or oblique holes were drilled for the lashings closest to the midline of hull. Those lashings were thus recessed and not exposed to the outer surface of the hull where they would drag on coral, rock, and sand. All other lashings running up the sides of the dugout logs were exposed to both the inner and outer hull surface by holes drilled clear through (Hiroa 1944:179).

Figure 133. Note the tilt of the mast towards the front prow. In this configuration the foot of the sail yard would be tucked into the right prow and the canoe would be sailing to the right.

Lashings which go clear through both sides of the attached hull segments may provide more structural strength, particularly if traditional adhesive and caulking are not as strong as modern epoxies and glues. Lashings emerging on both surfaces could have equalized tension and pressure, and the

Figure 134. Fohe uli blade. The first 2' from the tip of the paddle blade were tapered until the maximum width of the blade was reached.

Figure 135. Blade and handle of paddle. The blade was 16' in length overall.

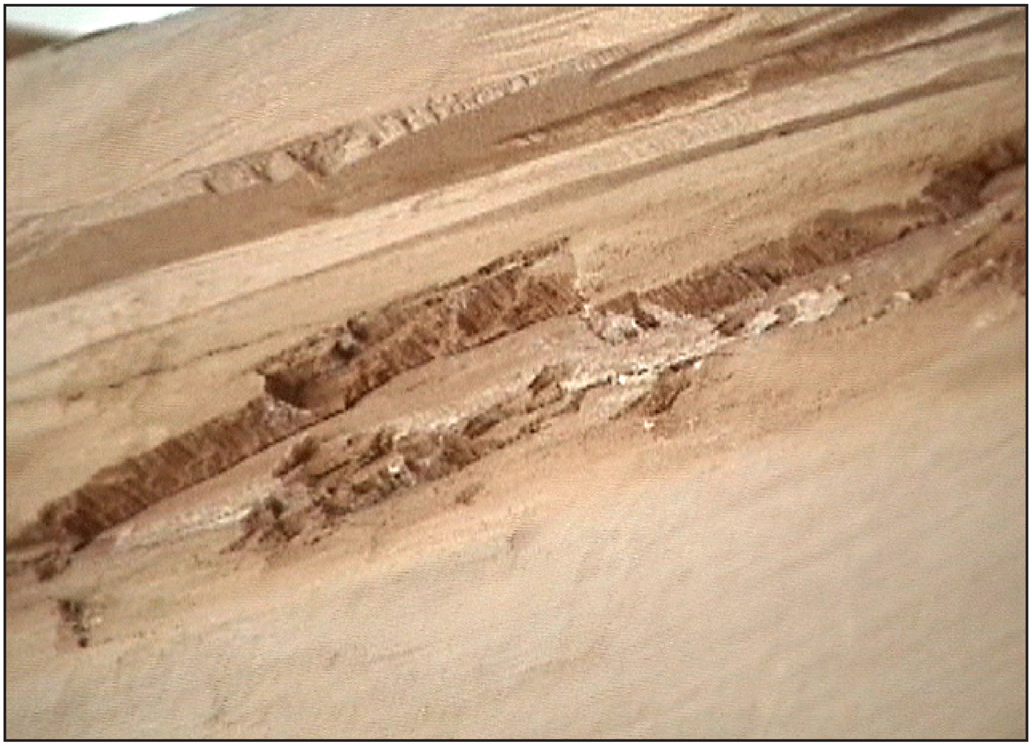

Figure 136. The outer surfaces of the hull tended to deteriorate.

Figure 137. Removal of the rotten material was done with chisels.

Figure 138. After the rotten wood was removed, good wood was glued in its place with epoxy.

Figure 139. Several patches were visible on this prow.

Figure 140. At least an inch in depth was removed from one of the endcovers by grinding it away with a chainsaw.

Figure 141. View of a large soft area to be replaced. New boards for use in the replacement were visible on the ground.

Figure 142. Butterfly plugs were used to prevent further split or checking.

Figure 143. Butterfly plugs gripped the wood across the grain to hold it together.

Figure 144. Here can be seen one mast which was raised and the hulls with their bottom paint and waterline painted on.

Figure 145. The main hull extended beyond the outrigger hull.

Figure 146. The mast was stepped in place using shrouds and stays. The yard rail can be seen on the right side.

Figure 147. The almost completed **fale** was outfitted with pandanus thatching on the back.

Figure 148. Top of the mast with three halyard lines. The placement of yard grooves can be seen amidship on the leeward side of the **fale**, where they are positioned directly over the windward side of main hull and over the middle two crossbooms 6 and 7.

tendency for the strakes or hull segments to bend in one direction or the other would be minimized. However, the opposite may be true. Bindings lashed entirely inside the hull via interior flanges, might increase leverage and keep the hull segments from bending outward at their point of connection. The contradictory evaluations above are speculations not based on practical sailing experience. At any rate, it could be interpreted that the primary role of the flanges was to provide wood to drill recessed holes for interior lashings. Thus, while flanges may offer some structural advantage by strengthening the edges of hull segments and strakes, this may not be the primary role.

The flanges built around the perimeter of the Kalia Mileniume strakes and the way they were lashed together were consistent with Paris's Tongan **kalia** drawings (Dumont d'Urville 1830-34), and detailed descriptions of ʻuvean canoes (Burrows 1937:113), Fijian **drua** (Williams 1858:74), Samoan **ʻalia** (Krämer 1994:292), and other types of Samoan canoes (Hiroa 1930:387). It was possible to drill through the flanges while keeping all exposed holes on the interior side of the hull. No mention in the literature was found of flanges built into dugout hull segments, although I assume this would have been the case since flanges appear to have been normal features around the edges of most strakes in the **kalia** complex.

The Samoans built their canoes starting with a keel instead of a dugout log, for both their small bonito canoes (Hiroa 1930:383) and their large **ʻalia** (Krämer 1994:292). The Samoan canoe keel is a middle piece which runs along the bottom of the canoe from one prow to the other. The Samoans were known to be very talented at plank work for their canoes. Their carpenters were even taken by the Tongans from Samoa to Lau in order to build canoes there. Why, though, would they not use dugout logs for the bottom? Was there a shortage of particular trees in Samoa? Maybe they were just more conservative with their trees and tried to utilize more board feet of timber from each log, instead of wasting timber by digging or burning it out in the hollowing process.

One common technique for form fitting the strakes and hull pieces to one another, was to paint one of the two surfaces to be joined, with mud or another substance, press the two surfaces together, and then cut or shave down the high points indicated by the paint mark. In this way a nice tight fit was achieved (Hiroa 1930:385, Feinberg 1988:40). Now, with chainsaws, the joining process has been simplified. On the Kalia Mileniume it was only necessary to lay the strakes in position, slip a chainsaw in between the joining surfaces, and run the saw back and forth between the surfaces until a nice clean fit was achieved.

No mention in the literature was found of the techniques used to clamp hull segments together in preparation for binding them. For the Kalia Mileniume, rectangular holes were cut close to the ends of the hull segments in order to insert clamps and pull the segments together in preparation to glue and lash. This aspect of the Kalia Mileniume construction may be a novel technique for Polynesian canoe building that was developed or incorporated by Tuione Pulotu. However, some sort of clamping or wedging technique would have been necessary in the past.

Table 1. Table of Offsets for Outrigger Hull - Midship and 4’ E of Midship. All Measures in Feet-Inches-Eighths.

	Station Position			
	Midship - Outrigger Hull		**4’ E of Midship - Outrigger Hull**	
Beam	4-1-0		No data - Est. 4-0-0	
Rise of Bottom from Baseline	0-0-0		0-0-0	
Hull side measured	**Windwrd**	**Leeward**	**Windwrd**	**Leeward**
Underside of deck to bottom	7-6-6	No data	7-7-0	7-7-2
Washstrake Total Width	2-7-0	2-6-6	No data	2-6-6
Upper Washstrake Width	0-8-0	0-7-4	No data	0-7-2
Lower Washstrake Width	1-11-0	1-11-2	No data	1-11-4
Point on sheer line above hull bottom from which measure taken	Distance from sheer line to hull side			
	Windwrd	**Leeward**	**Windwrd**	**Leeward**
4'	0-0-0	0-0-0	0-0-1	0-0-2
3'	0-0-0	0-0-0	0-1-4	0-0-0
2'	0-2-0	0-0-4	0-2-2	0-1-1
1' 9"	0-2-4	0-1-0	0-3-2	0-1-6
1' 6"	0-3-0	0-1-6	0-4-0	0-2-3
1' 3"	0-3-6	0-2-4	0-5-0	0-3-1
1'	0-5-0	0-3-6	0-6-2	0-4-2
9"	0-6-0	0-5-0	0-7-4	0-5-5
6"	0-8-0	0-6-6	0-9-4	0-7-4
3"	0-11-4	0-9-4	1-1-0	0-11-2

Table 2. Table of Offsets for Outrigger Hull - 8’ and 12’ E of Midship. All Measures in Feet-Inches-Eighths.

	Station Position			
	8’ E of Midship - Outrigger Hull		**12’ E of Midship - Outrigger Hull**	
Beam	No data - Est. 4-0-0		3-10-0	
Rise of Bottom from Baseline	0-0-0		0-0-0	
Hull side measured	**Windwrd**	**Leeward**	**Windwrd**	**Leeward**
Underside of deck to bottom	7-7-4	No data Est. 7-7-4	7-7-0	7-6-3
Washstrake Total Width	2-7-4	No data Est. 2-7-4	2-7-6	2-6-5
Upper Washstrake Width	0-7-6	No data Est. 0-7-6	0-7-5	0-7-0
Lower Washstrake Width	1-11-6	No data Est.1-11-6	2-0-2	1-11-5
Point on sheer line above hull bottom from which measure taken	Distance from sheer line to hull side			
	Windwrd	**Leeward**	**Windwrd**	**Leeward**
4'	0-0-2	0-0-0	0-0-2	0-0-0
3'	0-1-6	0-0-2	0-1-2	0-0-1
2'	0-3-2	0-1-1	0-2-5	0-1-3
1' 9"	0-3-7	0-1-5	0-3-1	0-1-7

Point on sheer line above hull bottom from which measure taken	Distance from sheer line to hull side			
	Windwrd	**Leeward**	**Windwrd**	**Leeward**
1' 6"	0-4-5	0-2-2	0-3-4	0-2-4
1' 3"	0-5-4	0-2-7	0-4-3	0-3-4
1'	0-6-6	0-4-0	0-5-4	0-4-6
9"	0-8-4	0-5-2	0-6-5	0-5-7
6"	0-11-2	0-7-4	0-8-4	0-7-6
3"	1-2-4	0-11-6	0-11-6	0-11-4

Table 3. Table of Offsets for Outrigger Hull - 16' and 20' E of Midship. All Measures in Feet-Inches-Eighths.

	Station Position			
	16' E of Midship - Outrigger Hull		**20' E of Midship - Outrigger Hull**	
Beam	3-9-4		3-7-0	
Rise of Bottom from Baseline	0-0-0		0-0-0	
Hull side measured	**Windwrd**	**Leeward**	**Winwrd**	**Leeward**
Underside of deck to bottom	7-6-7	7-6-4	7-6-4	7-6-4
Washstrake Total Width	2-7-6	2-6-4	2-7-2	2-6-4
Upper Washstrake Width	0-7-2	0-7-0	0-6-5	0-7-2
Lower Washstrake Width	2-0-4	1-11-4	2-0-5	1-11-2
Point on sheer line above hull bottom from which measure taken	Distance from sheer line to hull side			
	Windwrd	**Leeward**	**Winwrd**	**Leeward**
4'	0-0-3	0-0-1	0-0-1	0-0-2
3'	0-1-3	0-0-0	0-1-0	0-0-0
2'	0-2-5	0-0-6	0-2-4	0-0-3
1' 9"	0-3-0	0-1-2	0-3-0	0-1-0
1' 6"	0-3-4	0-1-7	0-4-2	0-1-7
1' 3"	0-4-3	0-2-7	0-5-1	0-3-6
1'	0-5-2	0-4-1	0-5-2	0-4-1
9"	0-6-3	0-5-4	0-6-4	0-5-5
6"	0-8-6	0-7-4	0-8-7	0-7-7
3"	1-0-2	0-10-4	1-0-0	1-0-3

Table 4. Table of Offsets for Outrigger Hull - 24' and 28' E of Midship. All Measures in Feet-Inches-Eighths.

	Station Position			
	24' E of Midship - Outrigger Hull		**28' E of Midship - Outrigger Hull**	
Beam	3-5-4		3-2-0	
Rise of Bottom from Baseline	0-2-4		0-4-2	
Hull side measured	**Windwrd**	**Leeward**	**Windwrd**	**Leeward**
Underside of deck to bottom	7-4-0	7-4-0	7-1-6	7-2-0
Washstrake Total Width	2-7-0	2-6-6	2-6-4	2-6-6
Upper Washstrake Width	0-6-2	0-7-1	0-6-1	0-7-0
Lower Washstrake Width	2-0-6	1-11-5	2-0-6	1-11-6

Point on sheer line above hull bottom from which measure taken	Distance from sheer line to hull side			
	Windwrd	**Leeward**	**Windwrd**	**Leeward**
4'	0-0-2	0-1-0	0-0-1	0-0-0
3'	0-0-3	0-0-0	0-1-4	0-0-0
2'	0-1-6	0-0-5	0-3-1	0-0-1
1' 9"	0-2-1	0-1-0	0-3-4	0-0-3
1' 6"	0-2-3	0-1-4	0-3-6	0-0-6
1' 3"	0-3-0	0-2-2	0-4-2	0-1-3
1'	0-3-5	0-3-2	0-5-0	0-2-2
9"	0-4-5	0-4-3	0-6-0	0-3-3
6"	0-6-3	0-6-1	0-8-0	0-5-6
3"	0-9-2	0-9-0	0-11-2	0-8-6

Table 5. Table of Offsets for Outrigger Hull - 32' E and 8' W of Midship. All Measures in Feet-Inches-Eighths.

	Station Position			
	32' E of Midship - Outrigger Hull		**8' W of Midship - Outrigger Hull**	
Beam	2-10-4		4-0-6	
Rise of Bottom from Baseline	0-8-0		0-0-4	
Hull side measured	**Windwrd**	**Leeward**	**Windwrd**	**Leeward**
Underside of deck to bottom	* 4-4-4	* 4-3-6	7-6-2	7-6-0
Washstrake Total Width	**	**	2-7-2	2-7-6
Upper Washstrake Width	**	**	0-8-2	0-8-0
Lower Washstrake Width	**	**	1-10-6	1-11-6
Point on sheer line above hull bottom from which measure taken	Distance from sheer line to hull side			
	Windwrd	**Leeward**	**Windwrd**	**Leeward**
4'	0-0-0	0-0-0	0-0-0	0-0-0
3'	0-1-0	0-0-0	0-0-0	0-0-0
2'	0-2-5	0-0-1	0-1-5	0-0-2
1' 9"	0-2-7	0-0-3	0-2-2	0-0-6
1' 6"	0-3-2	0-1-1	0-2-5	0-1-2
1' 3"	0-3-5	0-1-6	0-3-2	0-2-2
1'	0-4-2	0-2-2	0-4-0	0-3-4
9"	0-5-2	0-3-2	0-5-4	0-5-0
6"	0-7-1	0-5-3	0-7-4	0-7-4
3"	0-9-6	0-8-0	0-10-6	0-11-4

* 32 Ft E of Midship was a station beyond the end of the deck. Therefore this measure was made from the "middle of the batten to the hull bottom."

** No washstrake present here beyond the underside of the deck.

Table 6. Table of Offsets for Outrigger Hull - 16’ and 24’ W of Midship. All Measures in Feet-Inches-Eighths.

	Station Position			
	16’ W of Midship - Outrigger Hull		24’ W of Midship - Outrigger Hull	
Beam	3-9-2		3-3-6	
Rise of Bottom from Baseline	0-0-0		0-1-4	
Hull side measured	**Windwrd**	**Leeward**	**Windwrd**	**Leeward**
Underside of deck to bottom	7-7-0	7-6-6	7-5-2	7-4-6
Washstrake Total Width	2-8-2	2-9-2	2-8-6	2-9-6
Upper Washstrake Width	0-9-0	0-9-2	0-8-6	0-10-2
Lower Washstrake Width	1-11-2	2-0-0	2-0-0	1-11-4
Point on sheer line above hull bottom from which measure taken	Distance from sheer line to hull side			
	Windwrd	**Leeward**	**Windwrd**	**Leeward**
4'	0-0-0	0-0-0	0-0-0	0-0-0
3'	0-0-0	0-0-0	0-0-0	0-0-0
2'	0-0-6	0-0-3	0-0-4	0-0-1
1' 9"	0-1-3	0-0-6	0-1-0	0-0-4
1' 6"	0-2-2	0-1-3	0-1-4	0-0-7
1' 3"	0-3-5	0-2-2	0-2-4	0-1-3
1'	0-5-1	0-3-4	0-3-5	0-2-3
9"	0-6-4	0-5-0	0-5-0	0-3-4
6"	0-8-4	0-7-0	0-7-1	0-5-2
3"	0-11-0	0-10-0	0-10-6	0-7-7

Table 7. Table of Offsets for Outrigger Hull - 28’ and 30’ W of Midship. All Measures in Feet-Inches-Eighths.

	Station Position			
	28’ W of Midship - Outrigger Hull		30’ W of Midship - Outrigger Hull	
Beam	3-1-5		2-9-7	
Rise of Bottom from Baseline	0-2-1		0-2-4	
Hull side measured	**Windwrd**	**Leeward**	**Windwrd**	**Leeward**
Underside of deck to bottom	7-4-4	7-4-0	No data	No data
Washstrake Total Width	2-8-6	2-9-2	No data	No data
Upper Washstrake Width	0-9-1	0-10-4	No data	No data
Lower Washstrake Width	1-11-5	1-10-6	No data	No data
Point on sheer line above hull bottom from which measure taken	Distance from sheer line to hull side			
	Windwrd	**Leeward**	**Windwrd**	**Leeward**
4'	0-0-0	0-0-0	0-0-0	0-0-0
3'	0-0-0	0-0-0	0-0-0	0-0-0
2'	0-0-3	0-0-2	0-0-4	0-0-4
1' 9"	0-0-6	0-0-4	0-0-7	0-1-1

Point on sheer line above hull bottom from which measure taken	Distance from sheer line to hull side			
	Windwrd	**Leeward**	**Windwrd**	**Leeward**
1' 6"	0-1-2	0-0-7	0-1-4	0-1-2
1' 3"	0-1-6	0-1-2	0-2-2	0-1-6
1'	0-2-5	0-1-5	0-3-2	0-2-5
9"	0-3-7	0-2-6	0-4-1	0-3-4
6"	0-5-5	0-4-5	0-5-4	0-5-0
3"	0-8-4	0-7-6	0-7-6	0-7-4

Table 8. Table of Offsets for Outrigger Hull - 32’ and 34’ W of Midship. All Measures in Feet-Inches-Eighths.

	Station Position			
	32’ W of Midship - Outrigger Hull		**34’ W of Midship - Outrigger Hull**	
Beam	2-8-4		2-5-0	
Rise of Bottom from Baseline	0-5-0		1-2-0	
Hull side measured	**Windwrd**	**Leeward**	**Windwrd**	**Leeward**
Underside of deck to bottom	No data	No data	No data	No data
Washstrake Total Width	No data	No data	No data	No data
Upper Washstrake Width	No data	No data	No data	No data
Lower Washstrake Width	No data	No data	No data	No data
Point on sheer line above hull bottom from which measure taken	Distance from sheer line to hull side			
	Windwrd	**Leeward**	**Windwrd**	**Leeward**
4'	0-0-0	0-0-0	*	*
3'	0-0-0	0-0-0	0-0-0	0-0-0
2'	0-0-2	0-0-3	0-0-0	0-0-6
1' 9"	0-0-6	0-0-6	0-0-1	0-1-0
1' 6"	0-1-3	0-1-2	0-0-3	0-1-2
1' 3"	0-2-3	0-1-7	0-0-6	0-1-5
1'	0-3-5	0-2-6	0-2-1	0-2-2
9"	0-5-0	0-4-1	0-3-6	0-3-3
6"	0-7-0	0-6-5	0-5-4	0-5-0
3"	0-10-3	0-8-1	0-8-6	0-7-6

* This station was beyond the deck’s overlap and had no washstrakes present, and with the one foot rise of the hull bottom, so there was no sheer line at 4’.

Table 9. Table of Offsets for Outrigger Hull - 36’ and 38’ W of Midship. All Measures in Feet-Inches-Eighths.

	Station Position			
	36’ W of Midship - Outrigger Hull		**38’ W of Midship - Outrigger Hull**	
Beam	2-1-4		2-0-6	
Rise of Bottom from Baseline	1-10-3		2-7-0	
Hull side measured	**Windwrd**	**Leeward**	**Windwrd**	**Leeward**
Underside of deck to bottom	No data	No data	* 2-2-2	No data
Washstrake Total Width	No data	No data	**	**
Upper Washstrake Width	No data	No data	**	**
Lower Washstrake Width	No data	No data	**	**
Point on sheer line above hull bottom from which measure taken	Distance from sheer line to hull side			
	Windwrd	**Leeward**	**Windwrd**	**Leeward**
4'	***	***	***	***
3'	***	***	***	***
2'	0-0-0	0-0-3	0-0-0	0-0-0
1' 9"	0-0-1	0-0-5	0-0-0	0-0-0
1' 6"	0-0-1	0-0-7	0-0-1	0-0-1
1' 3"	0-0-3	0-1-1	0-0-2	0-0-5
1'	0-0-7	0-1-6	0-0-4	0-1-0
9"	0-1-6	0-2-4	0-1-3	0-1-4
6"	0-3-2	0-4-2	0-2-6	0-3-1
3"	0-5-2	0-7-2	0-4-6	0-6-0

* This station was beyond the end of the deck. Therefore this measure was made from the “middle of the batten to the hull bottom.”
** No washstrake present here beyond the underside of the deck.
***This station was beyond the deck’s overlap and had no washstrakes present. Coupled with the rise of the hull bottom, there was no sheer line at these points.

Table 10. Table of Offsets for Outrigger Hull - 40’ and 41’ W of Midship. All Measures in Feet-Inches-Eighths.

	Station Position			
	40’ W of Midship - Outrigger Hull		**41’ W of Midship - Outrigger Hull**	
Beam	1-8-6		1-4-4	
Rise of Bottom from Baseline	No data		No data	
Hull side measured	**Windwrd**	**Leeward**	**Windwrd**	**Leeward**
Underside of deck to bottom	* 1-7-0	* 1-7-0	* 1-1-2	* 1-1-2
Washstrake Total Width	**	**	**	**
Upper Washstrake Width	**	**	**	**
Lower Washstrake Width	**	**	**	**
Point on sheer line above hull bottom from which measure taken	Distance from sheer line to hull side			
	Windwrd	**Leeward**	**Windwrd**	**Leeward**
4'	***	***	***	***
3'	***	***	***	***

Point on sheer line above hull bottom from which measure taken	Distance from sheer line to hull side			
	Windwrd	**Leeward**	**Windwrd**	**Leeward**
2'	***	***	***	***
1' 9"	***	***	***	***
1' 6"	***	***	***	***
1' 3"	0-0-0	0-0-0	***	***
1'	0-0-3	0-0-0	***	***
9"	0-1-1	0-0-7	0-0-0	0-0-0
6"	0-2-5	0-2-1	0-1-0	0-0-6
3"	0-4-6	0-4-2	0-2-4	0-2-6

* This station was beyond the end of the deck. Therefore this measure was made from the "middle of the batten to the hull bottom."
** No washstrake present here beyond the underside of the deck.
***This station was beyond the deck's overlap and had no washstrakes present. Coupled with the rise of the hull bottom, there was no sheer line at these points.

Table 11. Table of Offsets for Outrigger Hull - 42' W of Midship and Main Hull - 20' E of Midship. All Measures in Feet-Inches-Eighths.

	Station Position			
	42' W of Midship - Outrigger Hull		**20' E of Midship - Main Hull**	
Beam	0-10-4		4-8-6	
Rise of Bottom from Baseline	No data		0-1-2	
Hull side measured	**Windwrd**	**Leeward**	**Windwrd**	**Leeward**
Underside of deck to bottom	* 0-6-4	* 0-6-4	7-4-2	7-3-6
Washstrake Total Width	**	**	1-11-6	1-11-6
Upper Washstrake Width	**	**	****	****
Lower Washstrake Width	**	**	****	****
Point on sheer line above hull bottom from which measure taken	Distance from sheer line to hull side			
	Windwrd	**Leeward**	**Windwrd**	**Leeward**
4'	***	***	0-0-0	0-0-0
3'	***	***	0-0-0	0-0-0
2'	***	***	0-1-6	0-2-4
1' 9"	***	***	0-2-4	0-3-4
1' 6"	***	***	0-3-4	0-4-6
1' 3"	***	***	0-4-4	0-6-2
1'	***	***	0-6-2	0-7-7
9"	***	***	0-8-2	0-10-0
6"	***	***	0-11-0	1-0-2
3"	***	***	1-2-0	1-3-4

* This station was beyond the end of the deck. Therefore this measure was made from the "middle of the batten to the hull bottom."
** No washstrake present here beyond the underside of the deck.
*** At 42-7-4 W of Midship, Outrigger Hull, the prow ends
**** One single washstrake on main hull, not composed of upper and lower washstrake.

Table 12. Table of Offsets for Main Hull - Midship and 20’ W of Midship. All Measures in Feet-Inches-Eighths.

	Station Position			
	Midship - Main Hull		**20’ W of Midship - Main Hull**	
Beam	4-8-4		4-4-0	
Rise of Bottom from Baseline	0-0-0		0-1-0	
Hull side measured	**Windwrd**	**Leeward**	**Windwrd**	**Leeward**
Underside of deck to bottom	7-5-4	7-5-0	7-4-4	7-5-0
Washstrake Total Width	1-11-2	1-10-4	1-10-0	1-10-0
Upper Washstrake Width	*	*	*	*
Lower Washstrake Width	*	*	*	*
Point on sheer line above hull bottom from which measure taken	Distance from sheer line to hull side			
	Windwrd	**Leeward**	**Windwrd**	**Leeward**
4'	0-0-0	0-0-0	0-0-0	0-0-0
3'	0-0-0	0-0-0	0-0-1	0-0-3
2'	0-1-6	0-2-4	0-2-2	0-3-2
1' 9"	0-2-4	0-3-4	0-2-6	0-3-7
1' 6"	0-3-4	0-4-6	0-3-4	0-4-5
1' 3"	0-4-4	0-6-2	0-4-6	0-5-4
1'	0-6-2	0-7-7	0-6-0	0-6-6
9"	0-8-2	0-10-0	0-7-7	0-8-3
6"	0-11-0	1-0-2	0-10-4	0-11-2
3"	1-2-0	1-3-4	1-3-1	1-2-7

* One single washstrake on main hull, it is not composed of an upper and lower washstrake.

Table 13. Table of Offsets for Main Hull - 28’ and 34’ W of Midship. All Measures in Feet-Inches-Eighths.

	Station Position			
	28’ W of Midship - Main Hull		**34’ W of Midship - Main Hull**	
Beam	4-4-0		3-10-4	
Rise of Bottom from Baseline	0-4-0		0-10-0	
Hull side measured	**Windwrd**	**Leeward**	**Windwrd**	**Leeward**
Underside of deck to bottom	7-2-0	7-2-2	**	**
Washstrake Total Width	1-9-0	1-10-0	***	***
Upper Washstrake Width	*	*	***	***
Lower Washstrake Width	*	*	***	***
Point on sheer line above hull bottom from which measure taken	Distance from sheer line to hull side			
	Windwrd	**Leeward**	**Windwrd**	**Leeward**
4'	0-0-0	0-0-0	0-0-0	0-0-0
3'	0-0-0	0-0-1	0-0-0	0-0-0
2'	0-2-4	0-3-7	0-1-6	0-0-7
1' 9"	0-3-0	0-5-0	0-2-6	0-1-6

Point on sheer line above hull bottom from which measure taken	Distance from sheer line to hull side			
	Windwrd	**Leeward**	**Windwrd**	**Leeward**
1' 6"	0-3-7	0-5-3	0-3-4	0-2-6
1' 3"	0-5-1	0-6-1	0-4-7	0-3-7
1'	0-6-4	0-7-2	0-7-0	0-5-1
9"	0-8-3	0-9-6	0-8-6	0-7-0
6"	0-11-1	1-0-4	1-0-7	0-10-2
3"	1-2-2	1-3-4	1-7-0	1-2-2

* One single washstrake on main hull, it is not composed of an upper and lower washstrake.
** Station beyond the end of the deck.
*** No washstrake present here beyond the underside of the deck.

Table 14. Table of Offsets for Main Hull - 40' W of Midship. All Measures in Feet-Inches-Eighths.

	Station Position	
	40' W of Midship - Main Hull	
Beam	3-6-6	
Rise of Bottom from Baseline	1-11-0	
Hull side measured	**Windwrd**	**Leeward**
Underside of deck to bottom	*	*
Washstrake Total Width	**	**
Upper Washstrake Width	**	**
Lower Washstrake Width	**	**
Point on sheer line above hull bottom from which measure taken	Distance from sheer line to hull side	
	Windwrd	**Leeward**
4'	0-0-0	0-0-0
3'	0-0-0	0-0-0
2'	0-1-2	0-0-4
1' 9"	0-1-7	0-1-1
1' 6"	0-3-0	0-1-7
1' 3"	0-4-4	0-3-0
1'	0-6-4	0-4-2
9"	0-9-1	0-6-4
6"	1-2-3	0-10-3
3"	1-5-2	1-3-0

* Station beyond end of deck.
** No washstrake present beyond end of deck.

The metal dowels which were placed on all sides and ends of the Kalia Mileniume dugout segments and strakes are unprecedented in the literature. No wooden dowels or other similar structures were mentioned in the literature. This may be surprising, although the difficulty level is probably higher for drilling paired holes straight and deep enough for dowels, as opposed to paired holes suitable for lashings. This would all depend on the kind of modern or traditional tools used for drilling.

Battens were used between the washstrake layer and the hull. Although there was no mention in the reviewed literature of a practical purpose for the battens, it seems possible that the battens served two purposes, perhaps first for style and aesthetics, and possibly second as an added structural reinforcement for the washstrake, since the crossbooms rested on them. Tuione Pulotu said they were added on to the Kalia Mileniume because they were used traditionally, and because they were beautiful.

The hulls of the Kalia Mileniume were not perfectly symmetrical from prow to prow. However, the hulls were essentially symmetrical at the waterline, and it would seem that for sailing performance, the waterline is the essential place for symmetry.

Hull and strake thickness was about two to three inches on the Kalia Mileniume. This originally appeared thin to me. However, they can be compared with Samoan, Fijian, and Hawaiian canoes. On smaller Samoan canoes, the strakes ranged from one quarter to one half inch thick, with the flanges at the edges being kept at the original plank thickness of 1.5 inches or slightly less (Hiroa 1930: 388-389). When I examined the Kabaran **camakau** in Laie, the hull thickness at places was about a quarter inch, and there was a hole in it. The Hawaiian canoe, Hawai'i loa, originally had a fairly thick hull of 8 inches on the bottom and 6-7 inches on the sides according to Mr. Wallace Froiseth (pers. comm. April 11, 2001), but it was eventually reduced to 3 inches. These examples indicate that the hull thickness of about 3 inches chosen by Tuione Pulotu for the Kalia Mileniume is within the range of similar wooden hulled canoes built with traditional designs in mind.

Hull profile measurements were collected to be used for scale drawings that may someday be drawn by a professional naval architect. The measurements were intended to permit calculation of hull displacement and canoe carrying capacity. It would also be possible for a professional to construct a computerized model using the measurements of this canoe on a program such as AutoCAD. Then hydrodynamic and other modeling tests could be made. It is my sincere hope that individuals with these skills and talents will be able to contribute in these ways to further knowledge of the Kalia Mileniume and other canoes.

Overall, it is concluded that the construction of the Kalia Mileniume hulls was consistent with the published literature. The hull length of 108', the joining of multiple dugout hull segments, the flanges on the inside of the strakes, the method of lashing, and the hull thickness, are all relatively consistent with traditional **kalia** and other Polynesian canoes that have been previously documented.

Timber Species

Agathis vitiensis was not confirmed in the literature as a wood choice for the **kalia**, although Hocart's (1929:128) confirmation of Fijian kauri use on the **camakau** is a possible indication for its use historically as a timber for the **kalia**. It is possible that the great **kalia** were built of *A. vitiensis*, but since this timber species is softer and potentially more perishable than *I. bijuga*, all may have perished before the ethnographers saw them. Also many of the early accounts of canoes written by explorers and ethnographers include no mention of timber species in their reports.

Of all the *A. vitiensis* herbarium sheets recorded from the Bishop Museum, Honolulu (Appendix D) were from either Viti Levu or Vanua Levu in Fiji. No *A. vitiensis* specimens were collected from Lau, Fiji, where the **kalia** were predominantly made. Perhaps some fresh collecting in Lau is necessary to see if *A. vitiensis* exists in Lau.

It may be that *I. bijuga* and *Calophyllum* spp.which grew in the strand flora were more readily available than *A. vitiensis*, which grew at higher elevations. Therefore these coastal species were naturally used more often as canoe timbers. If this was the case, then the Samoan method of keel and planking may have been more likely used for building large canoes. It was and is very difficult to find timber of the right diameter to be able to make the bottom of the hull out of a full dugout log instead of a keel and planking. This also may be why the 51 foot Tongan **kalia** depicted by Paris (Dumont d'Urville 1830-34) which was composed of three bottom hull segments, showed each bottom segment as being a composite of two halves instead of one full dugout log.

What is the common name choice for *A. vitiensis* in Tonga? In Fijian, *A. vitiensis* is known as **dakua** or **dakua makadre**. **Dakua makadre** specifies *A. vitiensis* while **dakua salusalu** specifies *Podocarpus vitiensis* Seem. (Tuisawau 2000). For the Maori, the genus *Agathis* is known as **kauri**. Other *Agathis* species across the Pacific are also known as **kauri**, and *A. vitiensis* is sometimes called Fijian **kauri**. However, this is only in recent times, and probably because of the dominance of New Zealand foresters. There is some question as to what it is called in Tonga. It is likely that traditionally it did not have a Tongan name because its range did not extend beyond Fiji. The closest known botanical collections of *A. vitiensis* to Tonga were collected from Kandavu, Fiji (Smith 1979:114). A review of the Bishop Museum herbarium's collection of *A. vitiensis* shows that all specimens are either from Viti Levu or Vanua Levu, Fiji (Appendix D). Thus it would be an interesting project to collect the flora of the Lau Group in Fiji, in order to see if *A. vitiensis* was potentially available where the predominance of Tongan **kalia** were built.

Now *A. vitiensis* can be found planted on the island of Tongatapu and perhaps elsewhere in Tonga. Tuione Pulotu said “we [Tongans] call it **dakua**”. Mataliku Branch Manager Samuela M. “Manu” Pomelile (2000) of Tonga Timber Limited has said it is called **kauri** in Tonga. Pomelile’s usage of the name **kauri** is probably due to his long time connection with the timber industry and he thus uses the industry’s standard name for this timber. I would interpret **dakua** as being the most likely traditional name for *A. vitiensis* for Tonga, however it is possible that most Tongans wouldn’t have had familiarity with this Fijian plant, and wouldn’t have had a common name for it at all. Probably only the Tongan canoe makers and warriors who voyaged to Fiji would have been familiar with *A. vitiensis*.

In today’s world of mass production, it is commonplace to use a great quantity of a single product. The Kalia Mileniume only included four timber species. Three of these were supplied by the timber industry (*A. vitiensis*, *C. vitiense*, *T. australis*), and the fourth (*T. grandis*) was only an incidental tree found growing on Tongatapu by the canoe builder.

The process of searching the island of Tongatapu for suitable timber and incorporating this single *T. grandis* tree in the **kalia** was probably more akin to the way canoe builders of the past would have selected timber. Canoe builders of the past would have known their island environment well. When resources were restricted to the single island where construction was taking place, the builder would most probably have made use of a wider diversity of timber species, particularly if their timber supply was dwindling. The greater the diversity of timber species used for different canoe components, the less likely the builder would be to deplete the preferred major timber species. At the time of the **kalia**, Tonga had already depleted its major supply of timber suitable for canoe construction. This is why they arranged Tongan settlements on Fulaga and Kabara in the Lau Group of Fiji to build canoes (Derrick 1946:121).

The risk of depleting timber supplies (or perhaps they already had depleted their timber resources) may be one explanation why the Cook Islanders (Hiroa 1944:178), ‘uveans (Burrows 1937:112), and Futunans (Burrows 1936:154), seemed to utilize so many more timber species (Appendix B) in comparison to the Kalia Mileniume. It is important to note, however, that Burrows seemed to incorporate more botanical detail in his reports than many of the other Bishop Museum ethnographers who were cited herein. And of course all of the species listed by Burrows and Hiroa were not used on every canoe.

Each species had different qualities, and the fine-art of building and sailing the canoes would have required a life time of experience to learn and implement. Choosing timber was certainly a matter of tradeoffs. For each tree cut down, that was one tree not available for other uses. Wood products were highly valued in Tonga due to their lack of wood resources (Kaeppler 1978:248). Wood products were so valued, in fact, that products such as canoes, wooden bowls, wooden neck rests, slit gongs, and sandalwood were often given to Tongans by Fijians as gifts of marriage (Kaeppler 1978:248).

Using the timber choices of *A. vitiensis* and *C. vitiense* on the Kalia Mileniume was most likely due to geographic availability and cost. Development of the timber industry has permitted the building of the massive Kalia Mileniume with an amazingly small diversity of timber species. Interestingly, for the hulls of the new 57’ canoe, named Iosepa, which was built on Oahu, Tuione Pulotu (2001) shipped eight *A. vitiensis* logs to Hawai‘i from the same timber company in Fiji which provided the timber for the Kalia Mileniume. This clearly shows the suitability of this wood for hull construction and Mr. Pulotu’s preference for its use. (The Iosepa was launched on November 3, 2001.)

Outrigger Booms, Ribs, and Deck

The four thickest outrigger crossbooms were made of *C. vitiense* and the eight thinner ones were made of an unknown timber, both unknown to myself and the canoe builder, Tuione Pulotu. Southern Forest Products (Fiji) LTD ran out of the *C. vitiense* and assured that this other variety of wood would serve the purpose. These crossbooms were spaced every five feet.

On a Fijian **drua** which was 44’ long three stout stringers were lashed underneath and perpendicular to the crossbooms to add rigidity (Hornell 1936:320). This was not done on the Kalia Mileniume, and I was very curious about this at the time of construction. However in retrospect, each 2” thick plank of the deck was perpendicular to the crossbooms and screwed and lashed to each crossboom. This solidly affixed platform should provide strong rigidity to keep the crossbooms spaced at their proper intervals and prevent the hulls from moving too independently of one another. (This is most important when waves and ocean swells drive one hull up and drop the bottom out from underneath the other. This action puts a twisting or torque between the two hulls which could pull them apart.)

Also interesting to the Kalia Mileniume design was the relationship between the crossbooms and the ribs. Each of the 12 crossbooms was connected to a corresponding pair of ribs. On a Fijian **drua** which Hornell observed in 1925, the ribs and crossbooms were interdigitated along the length of the hull, thus not being connected to one another (1936:321). This was of course only a single **drua** observation and it is unknown if this feature was representative of other canoes in the **kalia** complex or not.

The 51’ Tongan **kalia** drawn by Paris from the Dumont D’Urville voyage from 1826-1829 (Dumont d’Urville 1830-34) indeed depicted the ribs as being lashed to the crossbooms. For the Samoan **‘alia** I was unable to find details about the positioning of the ribs in relation to the crossbooms (Hiroa 1930, Krämer 1994).

The essential question here is: how do these two different styles of rib placement affect the canoe, its sailing, and its durability (if at all)? From one point of view it is best to have the ribs connected to the crossbooms, because then the crossbooms are more securely connected to the canoe hull, and subsequently there would be less likelihood of the hulls separating from one another. From another point of view it is better to have the ribs separate from the crossbooms. If the crossbooms do start to pull away from the hulls, perhaps the independent ribs, which may be attached to the deck, would help to reinforce the connection of the two hulls. It is hard to know which plan is superior without testing.

When asked about the placement of the ribs in relation to the crossbooms, Tuione Pulotu indicated that the job of the ribs was to hold the hulls to the deck and crossbooms. Therefore the ribs are connected to the crossbooms, or else they are not able to serve their purpose.

Most lashings in Polynesia were made from sennit cord, and true to form, the Kalia Mileniume was also lashed together with sennit cord. One exception was for the lashings binding the crossbooms to the ribs of the hull. These lashings were made with 3 millimeter nylon line, and then lashed over with sennit for asthetics.

The decks of the Kalia Mileniume were built from planks of *T. australis* which is originally from (Indo-Malaysia to Australia). Thus it would not have been a traditional material choice for deck planking. According to Tuione Pulotu, it was chosen as the wood for the deck because it was a light-weight and durable wood capable of withstanding the weather. In this case availability and cost were also issues in the selection of timber.

Patches and Repairs

Patching canoe hulls was a common activity in Samoa (Hiroa 1930:381,404) and Fiji (Thompson 1940:184) and this did not detract from the perceived value and sailing capability of the canoe. Patching was necessary for the completion of the Kalia Mileniume. Much effort was expended patching rotten portions of the underside of the hull. A conservative estimate is that between 10-25% of the under surface of the dugout hull segments required patching. This was accomplished by chipping out rotten wood and replacing it with good wood. The strakes, however, required less patchwork, but they did need “butterfly plugs” where the wood split with the grain. This was undertaken because the dugout segments were built predominantly with the softer sapwood of the *A. vitiensis*. Sapwood is produced on the exterior area of the tree trunk, which is the widest portion of the tree. Consequently, it was the part of the log utilized to build the widest possible hull. Considering how the timber was milled (quarter sawn), the strakes on the sides were most likely built of wood that was a cross section of both sap and heart wood. The heartwood seemed to check or split more than the sapwood as it seasoned, but it seemed to rot less.

Perhaps this explains why Samoans built their **‘alia** out of planks and a slender keel piece instead of using dugout segments. Maybe it did not have to do with availability of timber, but had more to do with the ability of the wood to withstand the elements and thus resist disintegration or rot. It would be interesting to build two canoes, one with dugout hull sections which utilize sapwood, and one canoe with a keel piece and heartwood planking. Over time those variations could be used to test the longevity of each canoe, the intensity of maintenance and upkeep, and to see if there really is a difference in rot resistance between sapwood and heartwood. The sailing properties of the two designs could also be tested.

There must have been tradeoffs involving the two different techniques. The plank built canoe probably would have taken on more water through the caulking than the dugout hull. This would have been a problem on longer voyages. Thus if your canoe was built for longer voyages or for exploration, you might build one with dugout hulls (sapwood) even if the canoe didn’t last as long as the plank built style. If, however, you were building a canoe which you wanted to last for a very long time for shorter distance sailing within your chieftanship or for battles with neighbors, perhaps a longer lasting canoe would outweigh the tradeoff of having one that leaked more.

Some of the wood on the end covers of the main **katea** (hull) also rotted away during construction. Runners, or line guides for the lines supporting the mast fore and aft, were originally built all as one piece roughed into the end covers. When these began to deteriorate, the original runners were cut off and new runners were made out of separate pieces of wood for attachment to the end cover. It remains to be seen how strong these pieces will be if the Kalia Mileniume is used extensively on the open ocean.

After construction of the Kalia Mileniume was complete, a few sections of the hull exterior were fiberglassed to improve the integrity in weaker areas which had been patched. However the entire hull was not fiberglassed.

Masts and Sails

There were two sails on the Kalia Mileniume, which made it necessary to position a set of yard grooves amidship on the deck. Each sail spanned about half the length of the main hull, thus two yard grooves were placed amidship for the sails. The yard rail rises up from the prow to the deck, and then curves back down to the middle of the deck, making it easier to lift the sail off the rail and place it in the proper groove. Raising the sail up along the incline of the rail is facilitated by the fact that the mast leans toward the yard groove in which the sail is placed. During the shunting maneuver, the mast is lifted upright and then leaned down toward the new groove. While the sail is walked from one groove to the next, the mast is at its highest position in the middle, and works to lift and support the weight of the sail over the rail and back down to the new groove.

The lines which support the mast during this maneuver run through the afore mentioned runners on the prow, so one prow line was let out while the other one was taken in, thus shifting the mast into its new position.
The masts on the Kalia Mileniume bring up some very interesting issues regarding canoe authenticity. First, they were built of laminated *A. vitiensis*, and second, there were two masts on this shunting canoe.

The normal mast construction for a Fijian **camakau** according to Hornell (1936:314) was for the crescent shaped form at the top of the mast, the **ndomondomo**, to be made of hard **vesi**, *I. bijuga*, and for the main section to be of the tough, springy wood of the **ndamanu**[5], *Calophyllum* spp. Of course these were solid pieces of wood, not hollowed or laminated, which were scarfed (joined) together (Hornell 1936:312). In comparison the masts for the Kalia Mileniume were laminated with five one inch layers of A. vitiensis, which is a softer, gymnosperm wood. The masts for the two smaller 40’ **kalia** were made out of two solid pieces of *A. vitiensis*, one piece for the upper **tomotomo** and the other for the main part of the mast. These were joined together much as the afore mentioned Fijian **camakau** mast. Both masts for the smaller **kalia** were broken during training sails.

It makes sense to use a lighter timber for masts of such great size as the 42’ long, 7 ½” thick masts of the Kalia Mileniume. The technology of using five laminates allows for the grain of the wood to run in different directions and provide for a stronger mast, which is less likely to have weak points. European masts were large and weighty, but they were also stationary. Recall that the sailors of the **kalia** had to heft the mast from leaning toward one leading prow to leaning toward the other leading prow during the shunting maneuver.

While there were tacking canoes plying the seas of Polynesia with two masts, I found no mention anywhere in the literature of a shunting canoe with two masts. The **Kalia** Mileniume is certainly among one of the first. The ‘uvean two masted **kalia** which Emil Wolfgramm has seen is also one of the first, if not the first of which I have been made aware (Wolfgramm 2001).

The masts of both 40’ **kalia** snapped in half while under sail. I witnessed one of these masts break when the canoe flipped upside down while sailing. In this incident the crew had the sheets (lines) of the sail tied down. Normally the sheets are cleated in such a way so that they can be easily released. When the big puff of wind came up and began to roll the canoe over, the crew was unable to release the sheets in time. Perhaps they should have followed Thompson’s warning. “In stormy weather the man who holds the sheet watches the outrigger and the sail constantly. If he does not slacken the sail at a gust, the float rises out of the water and the canoe is in danger of capsizing,” (Thompson 1940:176).

Another contributing factor to these incidents was that the masts were too weak. It might have been better to use the *C. vitiense* or *I. bijuga* wood for these masts instead of the *A. vitiensis*, particularly since these masts were not laminated, as was done with the masts of the Kalia Mileniume.

The art of sail making has been disappearing in the Pacific over time. The weave of the pandanus leaves may be the key. The weave needs to be tight enough to be sturdy and flexible enough to stretch. Sailors from the Lau Islands in Fiji even said that they preferred mat sails to canvas sails because the mat enables wind to pass through, and therefore the masts were not easily strained or broken (Thompson 1940:176). Not enough sailing took place while I was in Tonga to enable observations of mat sails under a variety of conditions.

Perhaps the weave of pandanus leaf strips previously used for mat sails was a loose weave for just this reason. If the weave was loose and a heavy wind developed, the pandanus strips would spread apart, leaving gaps to allow air pressure to pass through. However, if the wind was lighter, the stretched out sail would catch more of the wind. For the masts of the two 40’ **kalia**, the weave was possibly too tight and the sail too heavy. The wind would not have been allowed to pass through this kind of weave in order to reduce stress on the mast. This may have played a role in the masts breaking and/or the canoe flipping.

[5] “The **ndamanu** (*Callophyllum burmannii* Wight and other species) is not the same tree as the Polynesian **tamanu** (*C. inophyllum*),” (Hornell 1936:314).

Reflections on Interview Methodology

Most often the interviews consisted of stating observations of the **kalia**, followed by asking a question about the observation. This succeeded in eliciting the majority of key information about the construction of the **kalia**; however, ease of scientific reproducibility was perhaps not sufficiently addressed in the methodology.

Of the many interesting results of these interviews, it was learned that Tuione Pulotu had studied much of the canoe architecture from books written in English. Thus knowledge by both Pulotu and his crew of the Tongan names for canoe components was limited.

Some questions were very leading. When interviewing logging manager Amena Tuisawau, he was asked, “Who are the landowners? Are they usually the villages?” Luckily in this instance, it turned out to be correct and interesting information about Fiji’s land ownership hierarchy was elicited (Appendix B).

Sometimes I would observe things which just seemed obvious, opening them up for discussion. For instance, “Look at the hole in that **camakau** hull. The hull seems thin there.” This was often done rather than thinking about appropriate, reproducible, methods at each step, and reflecting that methodology in my behavior and question set.

The Hypotheses

In the introduction, three hypotheses were proposed. Each one will be briefly discussed here in light of the above discussion.

1. The architectural design of the Kalia Mileniume is true to the structures and canoe anatomy recorded in the literature, old photographs, and extant canoes.

This was strongly supported. The master canoe builder, Tuione Pulotu, successfully designed and constructed a Tongan voyaging canoe which was consistent overall with recorded tradition. The design of the hull, the multiple dugout logs used, the design of the strakes, the lashings, and many other traits were all consistent. Table 15 more thoroughly compares consistent and inconsistent traits in the architecture of the Kalia Mileniume.

2. The timber species used are consistent with the timber choices which were available in Fiji between the years of 1773 to 1874.

This was not strongly supported. *A. vitiensis* was used to build canoe hulls (for the **camakau**) in Fiji, but no records were found that linked *A. vitiensis* to the **kalia** complex of canoes. *Calophyllum* spp. were most certainly used for various canoe parts including masts and outrigger crossbooms. *T. australis* was most likely not used as part of the canoe building tradition in Western Polynesia. This is a recent agroforestry introduction within the twentieth century. *T. grandis* was also a timber most likely not available in Fiji between the dates specified. It was introduced to Fiji in the late nineteenth century and first listed in Thurston’s 1886 Catalogue (Smith 1991:179).

Table 16 lists timber species used historically from Lau, the Cook Islands, Futuna, Samoa, Southern Lau, and ‘uvea, and timber species used on the Kalia Mileniume. The complete listings of historical canoe plant species can be seen in Appendix B. Timber species used historically were selected from those used for sailing canoe hulls, end covers, crossbooms, and other sizeable, structural timber components.

3. There will be the use of modern materials for fastenings, caulking, preservatives, and other purposes.

This hypothesis was clearly supported. For example, metal dowels and 3 millimeter nylon twine were used for fastenings; epoxy and 3M 5200 Marine Glue were used for fastening and caulking; Thompson’s Water Sealant was used as a preservative; and fiberglass was used on the exterior of selected hull portions to reinforce, strengthen, and protect.

Loss of Traditional Knowledge

Kalia voyaging canoes have not existed in living memory of the Tongan people (Paunga 1999). Thus the men selected as sailing crew for the **kalia** had to relearn the arts of seamanship and navigation for their people, much as the first crew of the Hokule‘a had to start from “scratch.” With the loss of extant **kalia** and the cessation of voyaging in traditional canoes, a majority of the technical language associated with canoes, their components, and sailing procedures was also lost. This was evident time and again when I pointed to a yard groove in the prow, or a yard rail running to it, and asked a sailing crew member what the Tongan name was for these canoe components. I invariably was met with a sheepish grin and an “I don’t know” answer. Once when asking Tuione Pulotu the Tongan name for a particular part, he said, “I don’t know; I have only read about these things in English.” After reflecting upon this loss of technical terminology, I photocopied and distributed a list of Tongan canoe terms recorded by Hornell (1936:273). These terms were provided to Hornell by an old canoe carpenter from Lifuka, Ha‘apai, Tonga. The sailing crew seemed very pleased with this list. I’m not sure if they began using these terms or not, since my last field expedition to Tonga was almost completed at that point.

As with any revival, the tradition needs to be practiced on an ongoing basis in order to live again. As of this writing (October 2001) the Kalia Mileniume was last taken for a

Table 15. Consistent and inconsistent traits in the architecture of the Kalia Mileniume.

Consistent traits	Inconsistent traits
1. Hull segment butt joints	1. Metal dowels
2. Sennit cord lashings	2. Nylon lashings (minimal use)
3. Use of iron adze	3. Use of chainsaw
4. Use of butterfly plugs to keep cracks in wood from splitting further	4. Use of epoxy, glue, and some fiberglass
5. Overall length	5.
6. Interior flanges for lashings to be protected from exterior exposure	6.
7. No additional lateral reinforcement besides overlapping strakes	7.
8. Hull and strake thickness of 3”	8.
9. Battens	9.
10. Ribs and comb cleats	10.
11. Patching rotten wood with fresh wood	11.
12.	12. Two masts on a shunting canoe
13.	13. Use of laminations for mast.

short sail on January 1, 2001. However, no sailing program seems to be continuing. Four men from the construction work crew remained with the **kalia**, in order to look after and protect it. Only time will tell how well they will accomplish their tasks.

Canoes and Cultural Economics of Work

The overall architecture of the Kalia Mileniume both inside and out is highly consistent with the traditional architecture for the **kalia** as described in the literature. A few modern materials and techniques have found their way into the construction, including the use of chain saws, drills, metal dowels, marine adhesives, resin, and fiberglass on small sections for reinforcement. However, the majority of hull construction, ribs, crossbooms, and decking are all constructed of wood.

Some may consider fiberglassing portions of the hulls’ exterior as cultural blasphemy, but I think it is necessary to take a step back and consider the “economics” of today’s life in Tonga vs. the “economics” of pre-contact Tongan lifestyle before siding with this view. In the past, daily life, community relationships, fishing, trade, inter-island contact, power, and political control were all dependent upon the canoe. Coastal villages would have their own small outrigger canoes for fishing and community affairs, and powerful chiefs, nobles, and royalty would have their own voyaging canoes for dealing with trade of a greater scale, reciprocity, war, and matters of state. The Tongan culture and lifestyle was therefore highly dependent upon the canoe. The canoe was an integral part of who they were and how they came to be a united chieftainship. When not in use, the canoe was hauled out of the water, sheltered, and maintained. Caulking would be replaced, **kafa** or sennit lashings repaired, hulls kept clean, damaged wood replaced, and cracks and other hull imperfections repaired. Canoe upkeep was an ongoing and continual process in a society for whose existence, livelihood, and power structure largely revolved around the sea and voyaging.

Today in Tonga much of life is different. Motorboats take fishermen out to sea and back, their catch being sold daily out of their boats at the wharf to people using cars, trucks, vans, and bicycles. Instead of trade taking place predominantly between Tonga, Fiji, and Samoa by canoe, now goods are imported to Tonga mostly from Australia and New Zealand, and the rest of the industrial world. These goods are brought to Tonga on freight ships carrying hundreds of containers at a time. People travel within the Tongan Islands by ferry and sometimes on Royal Tongan Airlines. It is common for many Tongan families to have children who have emigrated to Australia or New Zealand.

While many things in Tonga have changed, some have stayed the same. Most Tongan families today have an allotment of about seven acres in the **uta** or bush. This land is allotted to them by the noble of their village. Often the families’ bush allotment is not connected to their homes. It can be several miles away. In the **uta** they plant **kumala** (sweet potatos), **ufi** (yams), **talo** (taro), bananas, and sometimes keep **pulu** (cows), while the family’s **puaka** (pigs) and **moa** (chickens) are generally kept around the house. In this way most families maintain at least a partially subsistence-based lifestyle[6].

[6] Many family members, both men and women, find it unnecessary to seek employment. Roughly 24% of Tonga’s potential labor force was involved in formal employment

Table 16. Comparison of timber species used historically to build Western Polynesian canoes and timber species used to construct the Kalia Mileniume.

Timber Species Used Historically to Construct Western Polynesian Canoes	Timber Species Used to Construct the Kalia Mileniume
1. *Alphitonia zizyphoides* (Spreng.)A.Gray	1. *Agathis vitiensis* (Seem.) Benth. & Hooker f.
2. *Artocarpus altilis* (G) Fosb.	2. *Calophyllum vitiense* Turrill
3. *Barringtonia* sp.	3. *Tectona grandis* L.
4. *Barringtonia asiatica* (L.) Kurz	4. *Toona australis* (F.Muell.) Harms
5. *Calophyllum inophyllum* L.	
6. *Dysoxylum* sp.	
7. *Dysoxylum richii* (A.Gray) C.DC.	
8. *Elaeocarpus* sp.	
9. *Erythrina indica* Lam.	
10. *Erythrina* sp.	
11. *Eugenia* sp.	
12. *Glochidion ramiflorum* J.R.& G.Forst.	
13. *Guettarda speciosa* L.	
14. *Hernandia* sp.	
15. *Hibiscus tiliaceu*s L.	
16. *Intsia bijuga* (Colebr.) O. Kuntze	
17. *Kleinhovia hospita* L.	
18. *Macaranga harveyana* (Muell.Arg.) Muell.Arg or *Macaranga stipulosa* (Muell Arg.) Muell. Arg.	
19. *Pometia pinnata* J.R. & G. Forst.	
20. *Rhus taitensis* Guillemin	
21. *Spondias dulcis* Forster f.	
22. *Terminalia catappa* L.	
23. *Terminalia richii* A. Gray	
24. *Thespesia populnea* (L.) Sol.	

Table 17. Traditional Materials vs. Modern Materials.

Traditional Materials	Modern Materials
1. Lashings	1. Metal Dowels
2. Sennit cord	2. 3 mm Nylon line
	3. Epoxy
	4. 3M 5200 Marine Glue
	5. Thompson’s Water Sealant
	6. Fiberglass

What has changed is what was once a core feature of traditional Tongan identity, voyaging on Tongan canoes. Life has now shifted towards capitalism[7], Christian faiths, and a more land based society for which the lore and life of the sea is no longer a pervasive influence. Few Tongans have heard of a **kalia**, let alone understand the significant role it played in the formation of the Kingdom of Tonga.

With the above characteristics of the modern Tongan lifestyle in mind, is fiberglassing weaker portions of the Kalia Mileniume hulls really "cheating?" When thought of in the modern economic, resource availability context, this is clearly not the case. With people gainfully employed and villages no longer focused on fishing, chieftainships and political power are no longer dependent upon the canoe. There is no longer the available man power, economic motivations[8], or political authority available to provide for the constant hauling out and maintenance required for a wooden canoe of this nature. Now that the 108' **kalia** has been launched, it will most likely remain in the water, hauled out only on rare occasions for maintenance. There was barely enough money to build the canoe and surely will be even less to maintain it.

Thus, in light of today's cultural confines and newly incorporated capitalist ways of life, I believe that fiberglassing selected portions of the bottom of the **kalia** in order to insure Tonga's investment was a vital and fair decision. The entirety of the two hulls and crossbeams joining them were built using traditional wood sources and traditional architectural design. In a society which has now greatly turned away from the sea, this **kalia** seeks to remind the Tongan people of their heritage and revive a deep sense of pride in some of their unique and compelling origins. If the **kalia** was to be short lived and not properly protected, it would not have much of a chance to fulfill this mission and destiny.

Conclusions

Ethnobotany of Canoe Construction in Western Polynesia

A small hand-full of ethnographers who worked in Western Polynesia documented the ethnobotany of canoe construction as a small portion of their overall work. Varying degrees of information were documented including common plant names, scientific plant names, construction procedures based solely on interviews, construction procedures based on observation of canoe construction and interviews, and sometimes statements about continuity of canoe building tradition. Information recorded was rarely standardized and rarely scientifically reproducible. Informants were often not identified. Ethnographic methods for documentation were rarely discussed. This body of ethnographic and ethnobotanical information along with the content of this thesis form a solid basis for future ethnobotanical research on canoe construction in western Polynesia.

Burrows (1936, 1937) documented Futunan and 'uvean canoes, and he consistently documented both the common and scientific plant names. Burrows (1936:155) did include a several page description of the construction procedures of a Futunan canoe, which seems to be the tran-

as of 1994 (original source: Central Planning Dept. Kingdom of Tonga. Citation and statistic found in http://www.undp.org.fj/tonga/to_ccf.htm).

[7] Capitalism however certainly hasn't completely taken over Tongan culture and ideology. An example which drove this point home for me occurred when a member of the family I was staying with passed away. For the funeral, four cows were slaughtered in my family's backyard. One of these cows was contributed by my family, and other cows were contributed by siblings of the lady who died, and other family members. The cow my family donated belonged to my family for what I would assume to be a long time. A cow in Tonga is worth about $T1000. My family still owed roughly $T1000 on their house loan. Each month $T100 is owed on their house loan, which is a sizeable chunk of their monthly income. An average salary is about $T 50 a week. One would think that in a more "capitalist" society, a family might choose to sell their cow and pay off the house, freeing them of debt. But in Tongan society other traditions, "the Tongan way," still prevails. Funerals are very important events in Tonga, and proper plans are made well ahead of time. Clearly, I think, the cow was being kept for just such an event. The cows were not slaughtered until the third day of the funeral proceedings. The first night of the funeral for this lady my family estimated that 700 people came. The family spent about $T 3000 on the food for the first night of the funeral. (That is 60 weeks of work on the average wage!) The third day, four cows were butchered in my family's backyard and all of the meat was doled out and gone by the time I returned around 8:00 P.M. that evening.

[8] In order to support the canoe builders, gardens were once planted in advance of the canoe construction project to feed the workers. Gardens are no longer planted in the **uta** by villages for the purpose of feeding the canoe builders. This very thing was in fact a sore subject early on in the Kalia Mileniume Project. As finances were being sorted out in the beginning, some days lunch for the workers only consisted of drinking coconuts (**niu**), bread (**ma**), and Fanta orange soda. One worker who quit early on in the process indicated that they were not receiving their wages yet, and they weren't even being well fed. Luckily this situation changed for the better after time had passed.

script of an interview. Burrows (1937:112) also mentioned that in ‘uvea, there were seventy men who were still recognized as master builders of canoes and houses.

Hiroa (1930, 1944) documented Samoan and Cook Islander canoes, and consistently documented the common plant names, but not the scientific names. His accounts and diagrams of canoe construction are very detailed, and seem to be based on interview and observation of already completed canoes, though this is not explicitly stated.

Thompson (1940) documented canoes of Southern Lau, and consistently documented the common plant names, and included some of the scientific names. Thompson (1940:175) witnessed the processes of construction, of sailing, and of paddling canoes on Kabara, Fulaga, and Ongea. Therefore her descriptions were based on interview and direct observation of canoe construction techniques and also seem to be from a continuous canoe building tradition.

The first ethnobotanists to conduct a study of canoe construction were Banack & Cox (1987). They contracted for the construction of a **camakau** on Kabara, Fiji, and witnessed its construction from beginning to end. The people on Kabara came from a continuous canoe building tradition. Banack & Cox documented the construction procedures and all plant species utilized (both common and scientific names). This appears to be the first comprehensive ethnobotanical documentation of the process of canoe construction, witnessed in its entirety by the researcher, with a complete documentation of all plant species used. This study was a landmark in the ethnobotanical documentation of canoe construction in the region of Fiji and Western Polynesia.

Future Ethnobotanical Research

Traditional architecture was heavily focused on in this thesis. There have been many limitations on gathering ethnobotanical information from the construction of the Kalia Mileniume. The Kalia Mileniume was built with materials provided by the timber industry, and it was built by canoe builders who have not come from a continuous canoe building tradition. This leaves a lot of lingering questions. What range of species would have been utilized under traditional island conditions? What preferred timber species would have been utilized? How would coastal strand timbers have been managed? What overall land management strategies, if any, would have been practiced? What materials would have been used for glues, caulking, and sealing, and how would they have been prepared? How were the sails properly woven? The body of ethnographic and ethnobotanical literature discussed in this thesis forms the basis for future ethnobotanical research on canoe construction in western Polynesia.

Target sites for future ethnobotanical research on the **kalia** complex of canoes seem to be the Lau Group in Fiji, and ‘uvea. It is preferable to document canoe construction from a continuous tradition of canoe building. Banack & Cox (1987) documented the construction of a **camakau** on Kabara, therefore it is likely there are still craftsmen there who could be contracted to build a **drua**. Also the flora of Lau should be collected in order to aid in determining what timber species may have been available for **kalia** construction in the region where most of the **kalia** were historically built. To what extent was *A. vitiensis* available in Lau? Bishop Museum specimens of *A. vitiensis* are only from the locations of Viti Levu and Vanua Levu, Fiji (Appendix D).

Of the seventy master craftsmen cited as being in ‘uvea according to Burrows (1937:112) perhaps some of these families still have a continuous canoe building tradition in living memory. If so, it may be possible to contract a **kalia** to be built by an ‘uvean craftsman. What little ethnobotanical knowledge still exists in these areas may only have been transmitted by word of mouth and not by actual hands-on training. So it is imperative to document this knowledge now before it is lost.

It would also be of great interest to go to ‘uvea to track down the two masted **kalia** which Emil Wolfgramm (2001) described as having seen from a photograph. Since it was an ‘uvean double masted **kalia** which may have been the inspiration for using two masts on the Kalia Mileniume, it is possible that ‘uvea was the first and perhaps only place to have innovated a two masted shunting canoe. This topic deserves more exploration.

Future Experimental Research

In the future it would be of scientific and cultural interest to be able to offer Tuione Pulotu and other canoe builders a forum for building sailing canoes and exploring many unanswered questions about canoe design and construction.

The first project could be to build two double hulled voyaging canoes of the same carrying capacity, somewhere between thirty and fifty feet long, although they could be shorter since we will be dealing with novice canoe sailors. One canoe could be a shunting canoe (Tongan **kalia**) and the other could be a tacking canoe (similar to the Hawaiian **wa‘a kaulua** upon which the design for the Hokule‘a was based).

According to literature sources, shunting canoes are more efficient at sailing to windward than tacking canoes (Clunie 1991). We could test this idea. Are shunting canoes more efficient to windward than tacking canoes? A shunting canoe’s sail and mast are placed over the larger hull and centered between the two prows, while a tacking canoe’s mast is placed slightly forward in the middle of the deck between the two hulls. The sails of shunting canoes thus place more force over the main hull, while tacking canoes place more force on the center of the deck. Using canoes of the same carrying capacity would provide the experimental control. The canoes would be compared on the basis of how closely and fast they sail into the wind. The overall net distance gained would be calculated to determine which canoe design has the greater ability to sail to windward.

For further experimental comparison, other canoes could be built with varying curvature of the hull bottom from a V-shaped bottom to a U-shaped shaped bottom. Asymmetrical hull sides could also be tested in comparison to symmetrical hull sides. I am referring here to the Marshall Islands canoes on which the hulls are shaped somewhat like the foil of an airplane wing.

Another experimental possibility could be to build and compare plank built versus dugout hulls. Large diameter, hard, durable timber trees may have been difficult to obtain during the era of the **kalia**. If that was the case, and a large diameter hull was desired, the canoe builder would either have started with a keel piece, and built up the hull with planks of durable, hard timber, or would have used softer woods that grow faster to greater diameters. Under these conditions and timber choices, a plank canoe might have a longer life span than a softer wood, dugout canoe, but the plank canoe might also take on more water, depending on the caulking techniques used. Perhaps for shorter distance travel to trade or do battle with enemies, a plank built canoe would have been the best compromise, but for long distance travel a dugout hull would have been preferred. These are interesting tradeoffs that could be explored experimentally.

An ethnobotanical study would be to build and record various aspects of several smaller sailing canoes constructed out of different timber species. For example hulls and planks could be made of *Artocarpus altilis* (Parkinson) Fosberg [Marshall Islands)], *Acacia koa* A. Gray [Hawai‘i], *A. vitiensis* [Fiji], *I. bijuga* [Fiji] *Calophyllum* spp., [Polynesia], Sitka Spruce [*Picea sitchensis* (Bong.) Carr.], Cedar [*Juniperus scopulorum* Sarg.], (*P. sitchensis* and *J. scopulorum* driftwood in Hawai‘i from Pacific Northwest), and marine grade plywood. Over the years, comparisons about their length of life, maintenance regimes, and performance under sail could be quantified and evaluated, with the controls of similar canoe design and the same environmental conditions. A similar study could be conducted with canoes made of the same species of timber but taken to different environments.

In addition, traditional bottom paints, caulking techniques, binding and lashing techniques, and different maintenance regimes could be tested comparatively. How long does a canoe last that is perpetually in the water throughout its whole life versus a canoe that is always taken out of the water and stored in a covered canoe shed between uses? If a canoe is kept out of the sun is it better protected from cracking, or is it more prudent to submerge the hull under water to keep it from cracking?

It would be useful for the accuracy of these experiments to bring the few remaining canoe builders who come from a continuous building tradition to Hawai‘i. They could be interviewed, provided materials to build their canoes, and perhaps have a valuable exchange among themselves. (Some purists may not like the idea of traditional cultural exchange such as this, because it may tend to change cultural approaches to canoe building, however it would certainly be an exciting meeting of canoe construction masters.) The few that are left reside in the Marshall Islands; Federated States of Micronesia; Lau, Fiji; the Santa Cruz Islands, Solomon Islands; and possibly ‘uvea.

It would be useful to develop a standardized list of material strength requirements for traditional canoe components. Most of this information should be available from naval architects who design and build modern multi-hull sailboats. It should be possible to find information about stress tests conducted on masts, sails, hulls, keels, and rigging. This would be used as baseline data for each canoe component. Then we could test each of the canoe components built out of their traditional materials. For instance, if this had been done on the smaller **kalia**’s masts (both masts broke during sea trials), we should have been able to determine that the *A. vitiensis* timber was not strong enough to be used for mast construction.

There are many more hypotheses to test. Building more canoes in order to test these hypotheses would lead to a deeper understanding of Pacific Island voyaging history. Pacific migrations are truly awesome historical events and they deserve our utmost respect. The revival in Polynesian voyaging canoe construction going on today is a credit to Polynesia and their cultural heritage.

Final Thoughts and Reflections

Polynesian canoes have been constructed in many shapes and sizes, with differing rigging styles, different means of construction, different availability of materials, and a whole host of different uses. There were the **popao** paddling canoes of Tonga and Samoa, used for fishing and other nearby coastal purposes. Even today these small canoes can be seen sitting in the water in areas of Tonga such as Ha‘apai. Today in Hawai‘i there are fiberglass paddling canoes which usually seat six paddlers for recreation, exercise, and competition.

Rarer than these small canoes, were voyaging canoes. Voyaging canoes were special. They had a much more dramatic impact on the psyche of a culture. Small paddling and sailing canoes could almost be considered a mundane, though critical part, of daily life for island peoples of the past. These canoes were instrumental in helping people make their livelihood from the ocean. The voyaging canoes however did not belong to the average person. They belonged to chiefs and kings, rulers of high import, means, and political influence.

Large voyaging canoes were symbols of statehood, power, military prowess, strength, and cultural pride. People's cultural identity to the nation with which they belonged were in no small part dependent upon large, strong canoes which sailed great distances, often for use in dramatic exploits between themselves and nearby islands. These voyaging canoes were also the vehicles which allowed for the spread of Polynesians and their culture over a vast expanse of the Pacific realm.

Today in Hawai'i much of this identity has been revived with the work of the Polynesian Voyaging Society. Elsewhere in Polynesia people are also reviving their voyaging canoe heritage. Many people I spoke to in Tonga had never heard of the **kalia** before the advent of the Kalia Mileniume project. Building this canoe in Tonga has reminded some Tongans, and educated others, of their cultural heritage.

I was given a tapa cloth poster before I left Tonga. On this poster was scribed "God and Tonga are my Inheritance." I was given two of these and I gave one to a good Tongan friend who now lives in Hawai'i. This is a great quote, but over the years I feel much of what it once meant to be Tongan has changed. Culture is dynamic and evolves. Tonga has entered the modern world. It is slowly becoming like the rest of the world, a nation of commercial consumers. I see little fault in this, nor do I see it as a tragedy. I am not so idealistic. But I think it is possible to make these changes while still maintaining the knowledgeable feeling of pride in what makes Tonga a unique part of the rest of the world.

I spoke with one of the crew members in Tonga who was being trained as a sailor aboard the **kalia**. I asked him why he was doing this, and how he felt about the project. He told me he was proud to be part of the crew. As a sailor aboard the **kalia**, he felt he was making a unique contribution to Tonga, to keep some of their past alive. He also told me Tuione Pulotu was a hero for building the **kalia** and bringing it back to Tonga.

Of course, all who were involved in the project were modern day Tongan heros. These heros included the builders themselves, those who contributed money, be it large donations or just driving by the canoe site and handing the workers 20 **pa'anga** to go buy lunch. Also those who came by the canoe to help work for a few hours, prepare a meal, or just enjoy the experience, they were all heros in their own way, because that was what the project was about - bringing Tongans together from all walks of life and recreating a piece of the past for them all to share in a common experience.

The **kalia** was important historically to all of Western Polynesia. It was the key vehicle of the Tongan Maritime Chiefdom. As the story of the **kalia** is publicized, both Pacific islanders and the world at large will find out about the **kalia**, and it may create a cultural icon for people to identify with Tonga. It will also help generate interest in learning about challenges facing Tonga and the Pacific islands culturally, economically, and environmentally. A cultural symbol can help draw human interest into an otherwise obscure area of the world. The pyramids of Egypt, the Incan ruins in Peru, the Great Wall of China, the Kremlin in Russia, the Statue of Liberty in the United States, these are a few examples of cultural icons which help us identify with a place. Often when we think of these places, icons make us wonder what the nation is like, what the people are like, and may encourage us to educate ourselves. Icons may motivate research projects which may lead to improved international relations and cross-cultural understanding.

The Hokule'a helped build a new bridge among Polynesian peoples. Over the years it has brought people from Hawai'i, Tahiti, the Cook Islands, Tonga, Samoa, New Zealand, and Rapa Nui (Easter Island) together to share their common ancestry. All have shown respect, gratitude, and thanksgiving toward one another during the voyages of the last 25 years. Goodwill which can cross such a wide span of geography and bring people together from far reaches is a unique and special thing.

Each new generation in all places must make their home, their nation, and their life their own. Tonga now has recovered a piece of its cultural heritage which once was lost to every single living Tongan. All Tongans can now see, interact with, and be a part of their cultural heritage, and understand what the Tongan Maritime Chiefdom once really was, a powerful, far-reaching Polynesian nation. The Kingdom of Tonga can be proud of the Kalia Mileniume and most certainly can be proud of who they are now as a people.

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Appendix A: Interview Transcripts of Tuione Pulotu

The following interviews were conducted with Tuione Pulotu (2000) unless otherwise indicated. The text in bold italics represents Mark Nickum's dialogue and the normal font represents Mr. Pulotu's responses.

Tuione, in your proposal you asked to have a year for the timber to season.

Yes, all the timber we received should have been covered and left to dry, but instead it was left outside in the sun, so it cracked, and then the water got in. That is what happened to the wood.

The boat was skinnier than I expected. The timber from Fiji came in 4, 6, and 8, inch thicknesses. The wider wood would have allowed to curve the strakes out further. But because of the money problem, the 6 and 4 inch strakes came in first, so we used the 4 inch strakes for the outrigger and the 6 inch strakes on the main hull. I wasn't able to curve the hulls out as far as I had planned because we didn't the thickness expected, thus less tumblehome. The 8 inch thick strakes came in December 1999. So we used that in place of the 4 inch for the top portion of the hull (the washstrakes) to connect the iako to. We had to cut the 8 inch strakes down to 4. I did order extra.

We got 4 larger beams for the iako. I ordered 5 of the larger timbers (8" x 12") the rest were 8" x 6". We ordered an extra thicker one in case one was curved.

What is going on here where they are chiseling away such a large area of the hull?

What happened is we just discovered a few days ago that there is a soft spot in the wood on the outrigger. The guys have been working on it for a few days now to take out the softer part of the wood and replace it. After that we are going to put on fiberglass cloth on both the outside and the inside. I have some reinforcement cloth to line the inside and outside of the soft spot to make it strong. There was another problem on the outside of the hull, because the glue we ordered was white [3M 5200 Marine Glue]. It showed too much on the wood. So above the waterline we took the saw and took out a thin layer of the white glue. We went in a quarter of an inch, then went in and mixed the glue with some sawdust so it wouldn't be so white on the outside. The glue is by 3M. It is a rubberized glue so it stays soft. On a big boat that is made out of pieces, when the boat hits rough water, the pieces will move, and somewhere it will break, so we changed to this glue so that there is still some play between the seems so the movement won't damage the wood. I sent some pieces of **dakua** to New Zealand to the glue company and the guy called back and told me it worked ok. The guy recommended to give a space between strakes of about an eighth of an inch in order to allow room for a full layer of glue. We also put some metal dowels at all those joints. On 20 feet length we have about 4 or 5 dowels. The dowels came from a company in Japan. It came with its own glue, which was like an epoxy. We pumped the epoxy into the bolt, and used the 3m glue on the outside. After doing this the first day I decided this conflicted with the idea of using the softer glue in the joints. So the next day I told the guys to get rid of the hard glue and use the 3M glue on everything, including the dowels. I think it was good that we did this so there is still some give around the dowels.
The logs were sitting for a long time over in Fiji and here at the wharf, so water got into the wood and started rotting it.

What can you tell me about the crossbeams? What are they called?

The **kiato** were milled in Fiji. At first I wanted to use **vesi** for the **kiato**, it is a stronger wood and is better in the water for water use, but the company told us that they could supply us with the wood, but then they told us they were having problems getting logs to provide the sizes we ordered. Then I asked if they could supply us with **tamanu**, in Viti Levu there is no **vesi**, but in Vanua Levu there is **vesi**.

Can you tell me how the battens were made?

We used red cedar. It is a softer wood with a different color to separate the hull from the other part of the boat, which is called **faka'oa** and is the upper part of the boat. That is the only area in the hull where the sennit work comes through to the outside. The rest of the sennit work all stays on the inside. So what we do is put enough sennit for the purpose of holding the thing. Just in case the glue comes apart, we still have the sennit. Then we shaped some pieces of red cedar to plug the holes. The sennit work that you see now from the **kiato** down is not enough sennit. We are going to add some more. We left the holes open so that when we get some more sennit we will add more to make it stronger. There are three things holding the **kiato** to the **faka'oa**, the glue, the ribs which reach all the way up, and the sennit.

Can you tell me about the lamination of the masts?

I mentioned that we did have some extra wood. The 8 inch wood that came late from Fiji. That is what we used, we took it to the mill. They cut it and planed it for us to use on the masts. (Tonga timber). We still have to make some laminations for the boom of the sail. We ran out of glue to glue it at the moment.

How many pieces were put together for the mast?

There are five of them all together. In this area where we have these here, we cross grain the center piece to make it stronger (indicated the top of the mast where the claw is, and two other locations where large thick cleats were built up for drilling holes for ropes to go through). Then after that we shaped it. The whole thing was solid. Otherwise it will be too weak here where we drill the holes for holding the mast off. Otherwise there is no way this area would be strong enough.

<u>So what happened to this mast here? What is this mast made of? (Indicated broken mast of small **kalia**)</u>

It is made of **dakua**. This is why we are laminating the other masts. This was one thickness of wood and when you use one thickness you don't know where the wood is soft or where it will break. This mast was made of two pieces, a top and bottom half. It broke here where we glued them together.

<u>Can you tell me about the sail?</u>

This sail was for the small canoe. It was woven of pandanus, woven into a mat, into sections and we sow it together. Each section is three feet wide, and you overlap the edge about 8 inches. Then you sew it with a string. It is "**haole**" string! If you use a wider mat, then the wind pushed on it and the weave spreads wider apart, wider apart, so if we use narrower mats then where they are overlapped is where the strength is.

<u>How are you making the sails for the big **kalia**? What kind of material will you be using?</u>

We will be getting regular sail material from New Zealand for when we sail out of Tonga, but in Tonga we will be using these mat sails.

<u>The runners on the prows here are all solid?</u>

Here there is rot, so we have to take it out and replace it. In this area of the hull we were having a lot of problems with rot and ended up replacing a lot of it (left when facing windward on **katea** prow, windward side).

<u>In Tongan, what are the runners called where the rope goes through?</u>

I don't know.

<u>Well, when you call to the men, what do you call them?</u>

I didn't read these things in Tongan you know!
<u>What are you using for the yard rails?</u>

Tamanu. **Tamanu** all the way. And for the part that supports the rails we are using **dakua**, because we didn't have enough **tamanu** to cover it.

<u>I noticed on the hulls of the small **kalia** that the ribs are only on the leeward side of the hulls. Can you explain that a little?</u>

Because it is a whole log, one piece of wood, you just need enough to hold the deck down.

<u>So the main purpose of the ribs is to hold the deck down?</u>

Yeah.

(Interview with Viliami and another worker)
<u>Is this the mast that broke this week?</u>

Yes.

<u>So how did you fix the break? Do you understand?</u>

We glued it.

Did you cut off the broken part of the mast? Yes.

<u>Is it straight?</u>

No.

<u>Is it diagonal? [I indicated with hand a diagonal cut like other scarf joints]</u>

Yes.

<u>What is the reinforcement you are screwing in made of?</u>

Dakua.

(Back with Tuione Pulotu)
<u>Can you show the metal dowel and glue system to me?</u>

This dowel you pump the glue in from the end. You use an electric glue gun. You put this [tube of glue] in. The gun has an electric motor on it, you plug the dowel into the tube, and squeeze the glue in. For the other dowel, there is a hole in the middle for squeezing the glue in.

<u>What is the dowel with the hole in the end for?</u>

When you have a butt joint like this [for instance the horizontal lines on an "F" butting into the vertical line] you drill a hole here [from the back of the "F" through to the perpendicular piece] and insert the dowel.

<u>What is the dowel with the hole in the middle for?</u>

For when two pieces meet together end to end, and you can squeeze the glue into the middle of the dowel and it spreads to either end.

(Looking over the hulls.)
How often do you put the dowels in along the washstrake?

The twenty footer we put four or five, it depends.

What about where you butt it together?

Like the butt joints on the bottom sections? [made a curve shape with hand to indicate dugout bottom sections] Four, no five [confirmed five with another worker.]

I saw you did some different things here than you had on your original plans. What do you call these big cleats in Tongan? [big cleats, two, one on either side of **fale** on the windward side over the outrigger hull].

I don't know. That's to tie the rope. They used to use it when there was one mast. It kept the ropes clear of the house. The rail on the top is high, if they put the ropes directly to the **'iako** it would hit the house.

Do you tie the ropes on to the cleat, or do you tie them on to the **kiato** and have the go over the cleat?

We tie it directly to the **kiato** to have it be strong.

I also noticed when I was looking over some of the plans of the tongiaki, that there are some fore and aft beams underneath the crossbeams, under the deck.

On the end of the tongiaki's platform there was a piece that came up in between. They did that to carry the floor. If you notice at the end of the boat, there were some vertical beams over the prows, and a horizontal beam between those. The deck was extended beyond the washstrakes and the beams that ran fore and aft were used to support the deck.

On your original plans you had eight hatches going in. Now you just have four.

It is deep enough so that if you put any long things in the hull, there is enough room to get it in and out. Since the depth of the hull is deep enough, you can move things in and out.

When they are out on the seas and something happens with the masts or they need to make other repairs, are they going to be taking spare wood and spare materials for that?

They are taking stuff inside the boat, like extra steering oars, and we are also going to have some long sticks just in case they have to push the boat off the reef.

Are there going to be sculling oars?

Yes, that will be the last thing.

Are all the beams made out of **tamanu** or are some made of **dakua** wood? Because some look like they are whiter, like this one.

How come you have to see that? <grin> There is another kind of wood here. It is not **dakua**.

What kind of wood is it?

I forget the name but it came from Fiji. When I called up to get the wood, it was raining in Fiji and they couldn't get back to the forest then to get some more **tamanu**. The long one. The 24 footer. So he asked me if they could substitute this wood. So he told me about this wood that they had available which they could cut the rest of the crossbooms out of. He said that it was as strong as the **tamanu**, except he said they would treat it for bugs because the bugs like to eat it.

So it is one, two, three, four ...

Five...

All the four big crossbooms are what?

Tamanu.

So how many are not?

Seven. There was another **tamanu** of this small size but it was too crooked.

Did you guys laminate the masts yourself?

Yes.

So how did you get the copper dowels in?

What copper dowels? Oh, they are nails. Instead of clamping it, we just put the glue on and nailed it with the copper nails. We used the copper nails because you can still plane it without damaging anything.

And then again here where it is important to have extra strength [at the cleats and claw of the mast] the middle laminates go cross-grained.

Yes, that will help to keep the thing from breaking off.

I still need to make three holes for the rope here, to pull the sail [pointing to the hook of the mast]. The sail is so heavy I'm going to put three ropes so it will be easy to pull the thing up.

I noticed on the small canoe's mast there were two holes at the claw of the mast, and there were two ropes that

<u>looked like they were used to haul the sail up. Do you only use one of the ropes?</u>

A small one like that you only need one rope, but because the material we use for the sail is so heavy, I put two holes and two ropes to help make it easier to haul the sail up.

<u>So then you can get a couple of guys on either one, and...</u>

On this one [for the Kalia Mileniume] I'm going to make three so three guys can pull up the sail, just in case we need the extra rope.

<u>Are all the mast laminates made out of **dakua** wood?</u>

Yes, it is all **dakua** wood.

<u>What kind of glue did you use to laminate the big mast?</u>

We used epoxy glue. It was from the West System.

<u>On some of the small patches - but not too many - there is no wood. What did you use as filler?</u>

It is just epoxy glue. Also where the white glue here shows through [3M 5200 between the seams of the strakes] we will take the outer layer off and fill it in to make it look nicer so that the seams don't stand out so much.

The normal **fohe** [steering paddle] the Tongans used had a straight blade. The one I'm making I'm going to have a little curve on the end. The curve will help so that when you have to steer, you don't have to push it too much. You just put it out.

<u>I also noticed the other day before they went sailing on the small **kalia** that you made a little adjustment on where the **fohe** goes in.</u>

Because when we made that one, it was for another handle, and when we put that fohe in, it did not sink deep enough to hold the fohe in place. So when they were sailing, the paddle jumped out of the hole. So I had to deepen the groove so it would sit properly.

<u>Did you make any other adjustments on the small **kalia**?</u>

No.

<u>Here on the smaller **kalia** you can see on the ends of the crossbooms sticking out beyond the hull you have a board running along nailed into all the ends to bind all the **kiato** together. Are you going to do that here on the big **kalia**?</u>

I'm still deciding what to do here. Either cut them all to the same length, or leave the four big ones sticking out and then just run the board in between the bigger **kiato**, connecting the boards to the smaller **kiato**.

<u>Where will you be placing the two yard grooves that have to be amidships on the deck?</u>

I'll probably place it here [he placed the loose yard groove into position on the deck], but it depends, I'll have to measure it. My mast is going to go over here [he kicked the mast step into position] Then I'll measure the distance from the mast to the prow, and then place the yard groove for the deck at the same distance away. [He place both yard grooves into approximate position] So right above the middle two **kiato**. The railing [for the yard] comes down and comes to the floor of the deck here to make it easy to lift the sail up and place it into the groove.

<u>Where does the block and tackle thing you were talking about go for the mast shrouds that lead from the deck?</u>

I'll have to drill a hole through the deck here, and drill a hole through the **kiato** and then drill a hole back up through the deck. Then run the rope through and put the block on it [one eyed pulley]. Then the rope for the mast will run through the block and up to the mast. There will be one for each mast.

<u>In the **fale** you've got a nice birth here. What kind of plywood did you use for the floor?</u>

Just **dakua** plywood.

<u>Really, where from?</u>

From Fiji! Fijian plywood. Nice stuff (Said with enthusiasm). It is half inch. I put that on top there just to block the water from splashing up.

<u>Are you going to put some sealing or any kind of a coating on the deck?</u>

Oh yeah, I just bought some stuff. It just came a couple weeks ago. Thompsons water sealer. Five gallons from Hawaii. I'm going to spray the hole deck with it. I'm going to spray all of the sennit work, and the mat sail. That will protect the from having water get into it.

<u>Down here beyond where the **kiato** are, there are how many sets of ribs?</u>

There are three. But see these are just to hold the pieces together and to support the pieces of wood for the prow. But it doesn't have anything to do with holding the top to the bottom [deck to the hulls] because the prow doesn't have any pressure on it.

Appendix B: Interview Transcripts of Amenatave Tuisawau

The following interviews were conducted with Amenatave Tuisawau at Southern Forest Products (Fiji) LTD. on June 7, 1999. The text in bold italics represents Mark Nickum's dialogue and the normal font represents Mr. Tuisawau's responses.

<u>Where do you find **dakua**?</u>

You can find **dakua** in all of our tenured lands, but not the size the King of Tonga wanted of course. I'd say 1 in 100 **dakua** are that size.

<u>You said you log all the different species. About how much of that would you say is *Agathis*?</u>

Oh, out of an area like this, you'll get about 10% of that area under production will be *Agathis*, and the rest will be mixed species. *Myristica* species, *Endospermum macrophyllum* Pax & K.Hoffm., mixed species. Fiji has the largest number of commercial species in the Pacific. Compared to Papua New Guinea, Vanuatu and Solomons. They have a smaller number but big sizes. We have a lot of species, but not as big of sizes as PNG, Solomons, Malaysia. *Agathis* falls into Class 1 species.

<u>What does that mean?</u>

Class 1 means they are in high demand. You have *Agathis vitiensis*, *Podocarpus vitiensis*, *Dacrydium*.

<u>What was the common name for *Dacrydium*?</u>

yaka

<u>Oh yeah, I remember reading about **yaka**.</u>

Are you getting all that on video?

<u>Yes. I'll show you how it turned out when we're done. I mainly use it to help me remember what we have talked about.</u>

Regarding the availability of *A. vitiensis*, and where they are available. This is an example of a forest types map. It is different than the map of Viti Levu we have been looking at here. The areas where the dots are indicate good commercial forest for logging. The solid green areas indicate non-commercial forest lands. *A. vitiensis* are available in the commercial forest lands. We have a lot of *A. vitiensis* available in Fiji. And this is one of the best production areas available here on this map.

This is Viti Levu Sheet 17. You can get these maps from the Forestry Department. So for us as loggers these are the sorts of areas we target. These areas in red with the names have already been logged. These areas without names we are slowly working our way toward.

<u>How long has logging been going on in this area?</u>

It is an old concession area, but only part of it was logged by Viti Timber and it was transferred to Fiji Forest Industries, under the name of Kamuna Evenvai, together with an Australian company, and then they sold it to Fenning Timbers, and then it expired again last year. And now it was put on retainer by the Native Land Trust Board. We work directly with the land owners, and now we are logging there. It is not only us there. We are logging it with several other companies. It is an annual license. We have a good relationship with landowners and we give them a good value for their high value resource.

<u>So who are the landowners? Are they usually the villages?</u>

The villages. They are the villages. Our land system is owned 80% by landowners so that's all native owned.

<u>I see, so that means it is owned by the villages?</u>

The villages. So if you go into the villages, the small land owner units are known as **matangali**. One block of land will be one **matangali**. One **matangali** can be 5 or 6 villages. They have one chief, and he is the **turanga matangali**. He is the head of that **matangali**. One **matangali** can be owned by 5 or 6 villages. When you have 4 or 5 **matangali**, they all come under the head of what you call an **ayavusa** and the chief of the village is the chief of the **ayavusa**, and he is the **turanga ayavusa**.

<u>I see, so do you work with the **turanga ayavusa** then?</u>

Yes. To have logging consent, in the **matangali**, the **turanga ayavusa** has to sign, and then the **turanga matangali** and all the **matangali** has to sign.

<u>So who makes up the Native Land Trust Board?</u>

The Native Land Trust Board is part of the government, but it runs separate from the government.

<u>So do they get a little bit of money then for each license?</u>

Yes. All the logging here has been done for royalties that are paid to the Native Land Trust Board. All of the commercial species are divided into three classes. Class 1, the most highly demanded species, we pay royalties of 37 dollars a cubic meter. Class 2 is 36 dollars per cubic meter. Class 3 is 13 dollars per cubic meter. That goes straight to the Native Land Trust Board.

As the logs come out of the bush, they are measured.

The Native Land Trust Board gets 25% out of that as their earnings. And 75% goes to the land owners and is paid out every 6 months. The Forestry Department gets 6 dollars per cubic meter.

The land may be leased for other purposes, for agriculture or something. And again, 25% goes to the Native Land Trust Board and 75% goes to the land owners every six months.

So that is how the organization is run. It is probably the best way of running native land, compared to the other islands of the Pacific, the Solomon Islands, Vanuatu. Sometimes the landowners get cheated by other companies.

This system was the brain child of one of Fiji's great chiefs. He was highly educated, known as Ratu Skuna. He was the one who made the idea of the Native Land Trust Board.

<u>Is there a book about him or something?</u>

Yes, yes.

<u>Yes, I think I have seen it.</u>

And we have all of our boundaries surveyed and mapped properly, so there will be no dispute. So we credit that man for setting this up. He organized for surveyors to come from Britain. So all these forests have been surveyed properly.

This is the Native Lands Commission Map. See these lines, these are all land owner units, **matangali**. And they were all surveyed.

<u>When were they surveyed?</u>

Let's see, 1931 and 1935. In the bush they have mounds marking the locations. If you look at this point here, there is a mound there. A big soil mound. Sometimes boundaries are straight lines, or they follow ridges, or they follow creeks. So in case we have boundary disputes, we can go in and check. For us as loggers it is very important that we have all the boundaries marked before we go in. Some of the land owners know their boundaries very well. It has been transferred to them from their grandfathers and great grandfathers. So we just go up to them and they say, "Oh yeah, our boundaries, you just go from that mountain to that one, and along the creek."

<u>Are there forestry reports that are made each year on quantity of resources remaining?</u>

Yes, the Forestry Department does good work monitoring forest coverage in Viti Levu. By divisions and on a national level. They do annual reports. If you want to the latest report you should go to the Division of Forestry in Nausori.

This order from the president came in through the head quarters of the Forestry Department in Suva. Go ask for Jiko [Jiko is the last name]. He is the Deputy Conservator of Forests. He is the second in charge there.

<u>In terms of particular timber species, comparing *Agathis vitiensis* to *Intsia bijuga*, how do you think *Agathis vitiensis* compares in terms of how heavy, how dense, rot resistant to being in the ocean or on land, or pest resistance to insects and things? Do things come to mind about preferences you would have if you were building a canoe or building something similar to this?</u>

Yes. I come from an island in between Viti Levu and Vanua Levu, and we also do a lot of seafaring, but we don't have *Agathis*, but we use a lot of *Intsia bijuga*. Our canoes are not as big as the one needed for the king of Tonga. That must be a giant canoe for the king of Tonga, because he asked for the biggest sized *Agathis* to build those canoes. You ask me for my traditional knowledge, even to my grandfather's time, he just used *Intsia bijuga*. *Intsia* does not grow to as large a size as *Agathis*. If you asked me based on my traditional knowledge, I would go for *Intsia*. They are very easily worked. They are hard. They are what we used. We used *Intsia* for canoes, war clubs, traditional bows, spears, blades. If you go back to the cannibal days, to the bows and arrows, the clubs, and the fork, they used *Intsia*. We have never used *Agathis* for canoes. However probably if you asked people from areas where *Agathis* was available. As far as I know, *Agathis* is also a good timber, workable. It can be used for tables, couches, buildings. This is the first time in my life I have seen anyone use *Agathis* for canoes. *Agathis* is a very workable timber. It is the number one timber in Fiji, the one we export the most. It is used mainly for interior of houses. As far as canoe making, I don't know. But I think you have seen the canoes, how are they coming.

<u>Yes, they are looking beautiful...</u>

We used a lot of *Intsia* for boat building. For small boats. For paddling canoes and launches we used *Agathis vitiensis*.
<u>Did you say *Agathis vitiensis*?</u>

Yes, *Agathis*. I am building a small boat now out of *Agathis*. I just got the log down there now.

[Uses for *Agathis vitiensis* as listed on a Fiji forestry poster in Amena's office included the following "Furniture, veneer and plywood, boat planking and decking, masts and spars, oars, kitchen equipment, vats and tanks, panelling, bench tops, fabricated and machined items including bowls, novelties, handles, carvings, picture frames; In framing grades, light construction."]

Appendix C: Plant Species Used for Western Polynesian Canoes

Table C1. **Camakau** of Kabara, Lau, Fiji. Modified from Banack & Cox 1987:154-155.

Scientific Names	Family	Local names	Major Uses in Canoe
Intsia bijuga (Colebr.) O.Kuntze	Fabaceae	**vesi**	main hull, maststep, masthead, outrigger booms, oars
Planchonella pyrulifera (A.Gray) Lam ex van Royen	Sapotaceae	**bau levu, bau**	end covers, deck platform, washstrakes, booms, rail
Macaranga graeffeana Pax & Hoffm.	Euphorbiaceae	**gadoa, gadoa vula**	float
Artocarpus altilis (Parkinson) Fosb.	Moraceae	**uto**	alternate wood for float
Barringtonia edulis Seem.	Barringtoniaceae	**uko**	alternate wood for float
Calophyllum amblyphyllum A.C. Smith & S.Darwin	Clusiaceae (Guttiferae)	**damanu**	mast, sail yard and boom
Memecylon vitiense A.Gray	Melastomataceae	**kaukaukata, kaukata**	connectives securing the float to booms (stanchions)
Vavaea megaphylla Wright	Meliaceae	**sevua**	outrigger booms, battens
Cordia subcordata Lam.	Boraginaceae (Ehretiaceae)	**nawanawa**	inserted ribs, rail supports, can be used for mastshore
Tournefortia argentea (L.f.) Johnston	Boraginaceae	**yevo**	inserted ribs
Dysoxylum richii (A.Gray) C.DC	Meliaceae	**makota**	alternate wood for inserted ribs
Hernandia nymphaeifolia (Presl.) Kubitzki	Hernandiaceae	**evuevu**	bailer
Alphitonia franguloides A.Gray	Rhamnaceae	**selavo**	stringers
Cryptocarya hornei Gillespie	Lauraceae	**duvuduvu**	alternate wood for stringers
Acacia simplicifolia (L.f.) Druce	Fabaceae	**tatagia**	foot of sail boom and yard
Unidentified		**tugasele**	skulling oar, batten
Palaquium sp.	Sapotaceae	**bau vudi**	alternate wood for deck
Myristica castaneifolia A.Gray	Myristicaceae	**male**	alternate wood for deck
Thespesia populnea (L.) Soland.ex Correa	Malvaceae	**malomalo**	alternate wood for minor pieces
Maniltoa floribunda A.C.Smith	Fabaceae	**cibicibi**	alternate wood for minor pieces
Canarium harveyi Seem. var. harveyi	Burseraceae	**yagai / malayagai**	**yagai** - Fijian glue, **malayagai** - deck platform
Calophyllum inophyllum L.	Clusiaceae (Guttiferae)	**tilo**	eaves used to prevent frictions under lashings; mastshore

Scientific Names	Family	Local names	Major Uses in Canoe
Mammea odorata (Raf.) Kosterm.	Clusiaceae (Guttiferae)	**veitau**	alternate species for leaves under lashings
Cocos nucifera L.	Arecaceae	**niu magimagi, niu gani bulu**	sennit mesocarp fibers used to fill joints and holes
Hibiscus tiliaceus L. ssp. *tiliaceus* Borss.	Malvaceae	**vau**	rigging rope
Pandanus tectorius Parkinson	Pandanaceae	**kie**	sail
Ventilago vitiensis A.Gray	Rhamnaceae	**kadragi**	vines used as rope to pull canoe
Agathis vitiensis (Seem.) Benth. & Hook	Araucariaceae	**dakua**	alternate for Fijian glue
Scaevola sericea Vahl	Goodeniaceae	**vevedu**	leaves used to cover sennit cooking in underground oven
Crinum asiaticum L.	Amaryllidaceae	**viavia**	leaves used to cover sennit cooking in underground oven
Ochrosia oppositifolia (Lam.) K. Schum.	Apocynaceae	**vavaoa**	pounding block to bean sennit

Table C2. Cook Islands canoes modified from Hiroa 1944.

Scientific Names	Family	Cook Islands Names	Canoe Type	Canoe Part (English)	Canoe Part (Cook Islands)
Calophyllum inophyllum L. *	Clusiaceae	**tamanu**		hull	**takere**
Unidentified		**puka**		hull	**takere**
Spondias dulcis Forster f. *???* *	Anacardiaceae	**vi** (mango)	hull	takere	
Artocarpus altilis (Parkinson) Fosberg **	Moraceae	breadfruit		gunwale strake	
Barringtonia sp.	Lecythidaceae	**‘utu**		end covers	
Calophyllum inophyllum L. *	Clusiaceae	**tamanu**		stern piece	
Thespesia populnea (L.) Solander *	Malvaceae	**miro**		stern piece	
Cordia subcordata Lam. ***	Boraginaceae	**tou**		stern piece	
Calophyllum inophyllum L. *	Clusiaceae	**tamanu**		end covers	
Hibiscus tiliaceus L. *	Malvaceae	**‘au**		end covers	
Unidentified		**puka**		end covers	
Mangifera indica L. ****	Anacardiaceae	mango		end covers	
Hibiscus tiliaceus L. *	Malvaceae	**‘au**		outrigger float	**ama**
Calophyllum inophyllum L. *	Clusiaceae	**tamanu**		outrigger booms	**kiato**
Casuarina equisetifolia J.R.&G.Forst. *****	Casuarinaceae	ironwood		outrigger booms	**kiato**

Scientific Names	Family	Cook Islands Names	Canoe Type	Canoe Part (English)	Canoe Part (Cook Islands)
Hibiscus tiliaceus L. *	Malvaceae	**‘au**	small canoe	mast	
Calophyllum inophyllum L. *	Clusiaceae	**tamanu**	vaka **katea**	stringer	**‘au**
Calophyllum inophyllum L. *	Clusiaceae	**tamanu**	vaka **katea**	outrigger booms	**kiato**

List developed from: Hiroa 1944.
* = scientific name deduced from common names located in Whistler 1984.
** = scientific name determined from common name located in Smith 1981:207.
*** = Hiroa listed **tou** as either *Cordia* or *Pipturus*. It is most likely *Cordia subcordata*.
**** = scientific name deduced from common names located in Smith 1985:450.
***** = scientific name deduced from common names located in Smith 1981:253.

Table C3. Futunan canoes modified from Burrows 1936.

Scientific Names	Family	Futunan Names	Canoe Part (English)	Canoe Part (Futunan)	Comments
Calophyllum sp.	Clusiaceae	**tamanu**	hull (underbody)	**fa vaka**	Timber most prized for canoe underbodies
Calophyllum inophyllum L.	Clusiaceae	**tsilo**	hull (underbody)	**fa vaka**	Timber most prized for canoe underbodies
Alphitonia zizyphoides (Spreng.) A.Gray	Rhamnaceae	**toi**	hull (underbody)	**fa vaka**	
Guettarda speciosa L.	Rubiaceae	**afa**	hull (underbody)	**fa vaka**	
Syzygium sp.	Myrtaceae	**angai**	hull (underbody)	**fa vaka**	
Pometia pinnata J.R. & G. Forst.	Sapindaceae	**tava**	hull (underbody)	**fa vaka**	
Syzygium?	Myrtaceae	**kolivai**	hull (underbody)	**fa vaka**	
Hernandia	Hernandiaceae	**pipi**	hull (underbody)	**fa vaka**	
Erythrina indica **	Fabaceae	**ngatae**	hull (underbody)	**fa vaka**	
Hernandia peltata ***	Hernandiaceae	**puka**	hull (underbody)	**fa vaka**	
Dysoxylum Bl.	Meliaceae	**ma’ota**	hull (underbody)	**fa vaka**	
Entada scandens ****	Leguminosae	**tsipi**	hauling line		**tsipi** is a liana used in hauling the log
Glochidion ramiflorum J.R. & G. Forst.	Euphorbiaceae	**masame**	washstrake	**oa**	(stararboard=**oa matau,** port=**oa o ama**) **sau**
Unidentified		(bamboo)	battens	**kofe**	

Scientific Names	Family	Futunan Names	Canoe Part (English)	Canoe Part (Futunan)	Comments
Artocarpus altilis (Z) Fosb.	Moraceae	(breadfruit)	caulking		gum of breadfruit used for caulking with old bark cloth
Parinarium glaberrimum *****	Chrysobalanaceae	**ifi-ifi**	caulking		gum used to make watertight
Dysoxylum Bl.	Meliaceae	**ma'ota**	end covers	**puke**	
Glochidion ramiflorum J.R. & G. Forst.	Euphorbiaceae	**masame**	end covers	**puke**	
Barringtonia asiatica (L.) Kurz	Lecythidaceae	**futu**	end covers	**puke**	
Cananga odorata (Lam.) Hook.F.&Thoms.	Annonaceae	**mosokoi**	outrigger float	**ama**	
Hibiscus tiliaceus L.	Malvaceae	**fau**	outrigger float	**ama**	
Artocarpus altilis (Z) Fosb.	Moraceae	breadfruit	outrigger float	**ama**	
Pipturus argentea Wedd.	Urticaceae	**samasama**	outrigger booms	**kiato**	(long boom=**kiato loa**, short boom=**kiato** mutu
Randia cochinchinensis (Laur.) Merr .*	Rubiaceae	**ola**	outrigger stanchions	**tukituki**	**ola** is extremely dense, hard wood
Dysoxylum Bl.	Meliaceae	**ma'ota**	paddle	**foe**	
Glochidion ramiflorum J.R. & G. Forst.	Euphorbiaceae	**masame**	paddle	**foe**	
Cananga odorata (Lam.) Hook.F.&Thoms.	Annonaceae	**mosokoi**	paddle	**foe**	

List developed from: Burrows 1936 for Samoan five-part canoe. All authorities derived from Smith 1979-1991 except *Artocarpus altilis* which is derived from Whistler 1984.
* = scientific name located in Whistler 1984 based on common name listed by Burrows 1936.
** = *Erythrina indica* Lam. considered by Smith 1985:204 to be *Erythrina variegata* L.
*** = *Hernandia peltata* considered by Smith 1981:110 to be *Hernandia nymphaeifolia* (Presl) Kubitzki
**** = *Entada scandens* Benth. considered by Smith 1985:57 to be *Entada phaseoloides* (L.) Merr.
***** = *Parinarium glaberrimum* considered by Smith 1985:48 to be *Atuna racemosa* Raf.

Table C4. Samoan canoes modified from Hiroa 1930.

Scientific Names	Family	Samoa Names	Canoe Type	Canoe Parts (English)	Canoe Parts (Samoan)	Comments
Litsea samoensis (Chr.) A.C.Smith *	Lauraceae	**papaon-go**	**paopao**	hull		
Hernandia moerenhoutiana Guillemin *	Hernandiaceae	**pipi**	**paopao**	hull		
Hibiscus tiliaceus L. *	Malvaceae	**fau**	**paopao**	hull		
Artocarpus altilis (Park.) Fosb. *	Moraceae	**‘ulu**	**paopao**	hull		
Calophyllum neo-ebudicum Guillaumin *	Clusiaceae	**tamanu**	**paopao**	hull		
Cananga odorata (Lam.) Hook. f. & Thoms.*	Annonaceae	**mosooi**	**paopao**	hull		
Thespesia populnea (L.) Sol. *	Malvaceae	**milo**	**paopao**	outrigger booms	**‘iato**	
Hibiscus tilaceus L. *	Malvaceae	**fau**	**paopao**	outrigger float	**ama**	
Casuarina equisetifolia L. *	Casuarinaceae	**toa** (iron-wood)	**paopao**	stanchions (pegs)		pegs joining **‘iato** to **ama**
Unidentified			**paopao**	braid lashings	**li**	lashings of **‘iato** to **ama**
Thespesia populnea (L.) Sol. *	Malvaceae	**milo**	**paopao**	branched boom		outrigger boom made of a branch the right size to form connecting peg contigu-ously
Unidentified				canoe shed	**afolau**	
Intsia bijuga (Colebr.) O. Ktze. *	Fabaceae	**ifilele**	**va’a alo**	keel	**ta’ele**	
Terminalia catappa L. *	Combretaceae	**talie**	**va’a alo**	keel	**ta’ele**	
Hibiscus tiliaceus L. *	Malvaceae	**fau**	**va’a alo**	hull planks		lower tier pieces/sections of the hull which attach to the keel
Artocarpus altilis (Park.) Fosb.		**‘ulu uvea**	**va’a alo**	caulking		**‘ulu uvea** = breadfruit va-riety
Artocarpus altilis (Park.) Fosb.		**puou**	**va’a alo**	caulking		**puou** = breadfruit variety
Casuarina equisetifolia L. *	Casuarinaceae	**toa** (iron-wood)	**va’a alo**	stanchions (pegs)		pegs joinging **‘iato** to **ama**
Hibiscus tiliaceus L. *	Malvaceae	**fau**	**va’a alo**	outrigger float	**ama**	
Artocarpus altilis (Park.) Fosb.	Moraceae	breadfruit	**va’a alo**	bow piece	**pale**	

Scientific Names	Family	Samoa Names	Canoe Type	Canoe Parts (English)	Canoe Parts (Samoan)	Comments
Kleinhovia hospita L. *	Sterculiaceae	**fu'afu'a**	**va'a alo**	stern piece	**taumuli**	
Macaranga harveyana or *stipulosa* (Muell.Arg.) Muell. Arg. *	Euphorbiaceae	**pata**	**va'a alo**	gunwale (right side)	**oa**	Lau **pata** applies to both *Macarangea harveyana* and *M. stipulosa* *
Hibiscus tiliaceus L. *	Malvaceae	**fau**	**va'a alo**	gunwale (left side)	**oa**	
Securinega flexuosa (Muell. Arg.) Muell. Arg *.	Euphorbiaceae	**poumuli**	**va'a alo**	outrigger booms	**'iato**	
Kleinhovia hospita L. *	Sterculiaceae	**fu'afu'a**	**va'a alo**	bow cover	**tau**	
Barringtonia asiatica (L.) Kurz *	Lecythidaceae	**futu**	**va'a alo**	stern cover	**velo**	
Terminalia richii A. Gray *	Combretaceae	**malili**	**taumualua**	bow / stern pieces		(**taumua** = bow, **lua** = two) two bow shaped ends and NO OUTRIGGER
Intsia bijuga (Colebr.) O. Ktze. *	Fabaceae	**ifi lele**	**taumualua**	hull		(**taumua** = bow, **lua** = two) two bow shaped ends and NO OUTRIGGER
Unidentified		**fatau**	**taumualua**	hull		(**taumua** = bow, **lua** = two) two bow shaped ends and NO OUTRIGGER
Broussonetia papyfera Ventenat **	Moraceae	**lau u'a**	**'alia**	caulking		**lau u'a** bark cloth smeared with breadfruit gum used as caulking between upper and lower planks
Thespesia populnea (L.) Sol. *	Malvaceae	**milo**		paddle		**milo** favorite wood for pad-dles
Pometia pinnata Forst. *	Sapindaceae	**tava**		paddle		
Inocarpus fagifer (Park.) Fosb. *	Leguminosae	**ifi**		paddle		
Garuga floribunda Dec. *	Burseraceae	**manaui**		paddle		
Hibiscus tiliaceus L. *	Malvaceae	**fau**		bailer	**tata**	
Unidentified		**fue**	**paopao**	anchor	**taula**	**fue** vine which lasts longer in the water was used as a rope

* = scientific name located in Whistler 1984 based on common name listed by Hiroa 1930.
** = scientific name located in Christophersen 1935 based on common name listed by Hiroa 1930.

Table C5. Southern Lau canoes modified from Thompson 1940.

Scientific Names	Family	Lauan Names	Canoe Type	Canoe Parts (English)	Canoe Parts (Lauan)	Comments
Intsia bijuga (Colebr.) Kuntze *	Fabaceae	greenheart (**vesi**?)	**camakau**	hull (underbody)		
Unidentified		**mbau**	**camakau**	hull (underbody)		
Dysoxylum richii (A. Gray) C. DC. **	Meliaceae	**makota**	**camakau**	hull (underbody)		
Unidentified		**wangiri**	**camakau**	hauling ropes		vines used for haulling log
Crinum asiaticum L. ***	Amaryllidaceae	**viavia**	**camakau**	hauling ropes		vines used for haulling log
Smilax vitiensis (Seem.) A. DC.	Smilacaceae	**kandrangi**	**camakau**	hauling ropes		vines used for haulling log
Unidentified		**sielavu**	**camakau**	rollers		wood used for rollers when hauling log
Homalanthus nutans ****	Euphorbiaceae	**mauamaua**	**camakau**	hauling		wood inserted into the stern of the hull for hauling purposes
Unidentified		**tapo**	**camakau**			sticks
Flagellaria gigantea Hook. F.	Flagellariaceae	**walaki**	**camakau**			vines wrapped around stern when hauling
Intsia bijuga (Colebr.) Kuntze *	Fabaceae	greenheart (**vesi**?)	**camakau**	strake (narrow)	**kapikapi**	long narrow strip (**kapikapi**) inserted between the hull and washstrake
Unidentified		**mbau**	**camakau**	strake (narrow)	**kapikapi**	
Unidentified		**vaivai**	**camakau**	strake (narrow)	**kapikapi**	
Unidentified		**mbau vuntchi**	**camakau**	endcover (headboard)	**mua levu**	
Unidentified		**mbau vuntchi**	**camakau**	endcover (sternboard	**mua lailai**	

Artocarpus altilis (Park.) Fosb. *****	Moraceae	(breadfruit)	**camakau**	outrigger float	**cama**	breadfruit pre-ferred on Kabara
Unidentified		**ngandoa**	**camakau**	outrigger float	**cama**	**ngandoa** pre-ferred on Ongea
Artocarpus altilis (Park.) Fosb. *****	Moraceae	(breadfruit)	**camakau**	outrigger booms	**i kaso**	
Unidentified		**ndamanu**	**camakau**	mast	**i vana**	length equalls at least half the length of the ca-noe
Intsia bijuga (Colebr.) Kuntze *	Fabaceae	greenheart (**vesi**?)	**camakau**	masthead		
Pandanus sp.	Pandanaceae	pandanus	**camakau**	sail	**i latha**	
Eleocharis dulcis (Burm.f.) Trin.ex Henschel ******		**kuta**	**camakau**	sail	**i latha**	
Intsia bijuga (Colebr.) Kuntze *	Fabaceae	greenheart (**vesi**?)	**camakau**	paddle (steering paddle)	**uli**	steering paddle is called **fohe uli** in Tonga - MN
Unidentified		**yangai**	**camakau**	calking		**yangai** pitch used to caulk seems of patches in hull
Dysoxylum richii (A.Gray) C.DC. **	Meliaceae	**makota**	**wangga vothe**	hull (underbody)		
Dysoxylum richii (A.Gray) C.DC. **	Meliaceae	**makota**	**takia**	hull (underbody)		
Unidentified		**puko**	**sauthoko (drua)**	hearth	**mata ndra-vu**	firehearth made of puko wood
Intsia bijuga (Colebr.) Kuntze *	Fabaceae	greenheart (**vesi**?)	**sauthoko (drua)**	hull (large hull)	**kata**	
Unidentified		**mbau**	**sauthoko (drua)**	hull (small hull)	**cama**	

List developed from: Thompson 1940.
* Scientific name determined from Fijian common name in Smith 1985:134.
** Scientific name determined from Fijian common name in Smith 1985:559.
*** Scientific name determined from Fijian common name in Smith 1979:157.
**** *Homalanthus nutans* Pax is considered by Smith 1981:560 to be *Omalanthus nutans* (Forst. F.) Guillemin
***** Scientific name determined from Fijian common name in Smith 1981:207.
****** Scientific name determined from Fijian common name in Smith 1979:239.

Table C6. Lauan **Camakau** canoes modified from Gillett *et.al*. 1993.

Scientific Names	Family	Lauan Names	Canoe Part
Dysoxylum richii (A.Gray) C.DC.	Meliaceae	**makota**	hull hardwood
Calophyllum amblyphyllum A.C.Sm & S.Darwin	Clusiaceae	**damanu**	hull hardwood
Intsia bijuga (Colebr.) Kuntze	Fabaceae	**vesi**	hull hardwood
Maniltoa floribunda A.C.Sm.	Fabaceae	**cibicibi**	hull hardwood
Planchonella pyrulifera (A.Gray) Lam ex van Royen	Sapotaceae	**bau, bau levu**	strakes, dug-out, stanchions, decks
Burckella richii (A.Gray) Lam	Sapotaceae	**baucana**	stanchions
Palaquium fidjiense Pierre ex Dubard	Sapotaceae	**bauvudi**	mast, strakes
Calophyllum amblyphyllum A.C.Sm & S.Darwin	Clusiaceae	**damanu**	mast, strakes, spars, ribs, mastbrace
Calophyllum inophyllum L.	Clusiaceae	**dilo**	hull ribs
Argusia argentea (L.f.) Heine	Boraginaceae	**evo**	bailer, hull ribs
Memecylon vitiense A.Gray	Melastomataceae	**kaukata**	stanctions
Dysoxylum richii (A.Gray) C.DC.	Meliaceae	**makota**	stanchions
Cordia subcordata Lam.	Boraginaceae	**nawanawa**	bailer, mast brace
Alphitonia zizyphoides (Spreng.) A.Gray, *Alphitonia franguloides* A.Gray	Rhamnaceae	**selavo**	strakes, sculling paddle
Manilkara vitiensis (Lam & van Olden) Meeuse	Sapotaceae	**tugasele**	mast, bailer, hull ribs
Intsia bijuga (Colebr.) Kuntze	Fabaceae	**vesi**	hull, steering and sculling paddles, strakes

Table C7. ‘uvean canoes modified from Burrows 1937.

Scientific Names	Family	‘uvean Names	Canoe Type	Canoe Part (English)	Canoe Part (‘uvean)	Comments
Elaeocarpus sp.	Elaeocarpaceae	**tongovao**	**vaka tafaanga**	hull (under-body)	**fakahekaheka**	
Dysoxylum sp.	Meliaceae	**maota**	**vaka tafaanga**	hull (under-body)	**fakahekaheka**	
Erythrina indica **	Fabaceae	**ngatae**	**vaka tafaanga**	hull (under-body)	**fakahekaheka**	wood considered light but soft
Rhus taitensis Guillemin	Anacardiaceae	**tavai**	**vaka tafaanga**	hull (under-body)	**fakahekaheka**	
Calophyllum inophyllum L.	Clusiaceae	**fetau**	**vaka tafaanga**	hull (under-body)	**fakahekaheka**	wood considered tough but heavy
Parinarium glaberrimum ***	Chrysobalan-aceae	**ifi-ifi**	**vaka tafaanga**	caulking	**mono**	joints calked with small sticks of **ifi-ifi** crushed and driven in.
Hibiscus tiliaceus L.	Malvaceae	**fau**	**vaka tafaanga**	caulking	**mono**	bast of *H.tiliaceus* used for calking - esp. holes about lashings which surface to out-side of hull
Inocarpus edulis J.R. & G. Forst.	Fabaceae	**ifi**	**vaka tafaanga**	caulking	**mono**	gum made of the crushed fruit of ifi, smeared outside and inside to further tight-en joints
Randia cochinchinensis (Lour.) Merr. *	Rubiaceae	**ola**	**vaka tafaanga**	stanchions	**tutuki**	**ola** is a hard wood
Cananga odorata (Lam.) Hook.F.&Thoms.	Annonaceae	**mohokoi**	**vaka tafaanga**	outrigger float	**ama**	**ama** usually made of soft, light wood of **mohokoi**, though **fau** may also be used
Hibiscus tiliaceus L.	Malvaceae	**fau**	**vaka tafaanga**	outrigger float	**ama**	
Unidentified			**vaka tafaanga**	strakes	**fono**	
Unidentified			**vaka tafaanga**	washstrake	**oa**	
Unidentified			**vaka tafaanga**	bow cover	**puke mua**	
Unidentified			**vaka tafaanga**	stern cover	**puke muli**	

Scientific Names	Family	‘uvean Names	Canoe Type	Canoe Part (English)	Canoe Part (‘uvean)	Comments
Unidentified			**vaka tafaanga**	outrigger booms	**kiato**	
Unidentified			**vaka tafaanga**	stringers	**fakamanuka**	
Unidentified			**kalia**	hull (main hull)	**katea**	
Unidentified			**kalia**	hull (outrigger hull)	**hama**ni	
Unidentified				sail	**la**	
Unidentified				mast	**fana**	
Unidentified				mast step	**tuulanga la**	

List developed from: Burrows 1937.
* = scientific name located in Whistler 1984 based on common names listed by Burrows 1937.
** = *Erythrina indica* Lam. considered by Smith 1985:204 to be *Erythrina variegata* L.
*** = *Parinarium glaberrimum-sensu* Christophersen considered by Smith 1985:48 to be *Atuna racemosa* Raf.

Appendix D: Bishop Museum *Agathis vitiensis* Specimens.

Location (Island or Province)	Locality	Collector	Coll #	Date
Island of Viti	Mt. Korumbaba	Paul A. Cox	886	10-31-85
Vanua Levu: Cakaudrove Province	Yanawai River Region	John M. Miller	1190	10-23-87
Vanua Levu: Macuata	Korotari	I.T. Kuruvoli	15229	02-06-67
Vanua Levu: Mathuata	Summit ridge of Mt. Numbuiloa, east of Lambasa	A.C. Smith	6480	Oct29-Nov6, 1947
Vanua Levu: Mbua.	Southern Slope of Mount Seatura	A.C. Smith	1640	04-28-34
Vanua Levu: Thakaundrove	Natewa Peninsula: Hills W of Mbutha Bay;	A.C. Smith	836	12-21-33
Viti Levu, Fiji		H.E. Parks	20859	May-July, 1927
Viti Levu: Ba	Tavua, E slopes of Yoo, c. 2 mi W of Nandarivatu	Grady L. Webster & Richard Hildrety	14169	07-12-68
Viti Levu: Colo-north province	Nadarivatu-Sigatoka river	John W. Gillespie	4283	12-10-27
Viti Levu: Mba (Ba?)	Mandrongo, Nausori Highlands	Grady L. Webster & Richard Hildreth	14286	07-16-68
Viti Levu: Nadarivatu (Colo-north province)	Nadarivatu, valley of the Sigatoka river	John W. Gillespie	3730	11-14-27
Viti Levu: Nadroga & Navosa	Nausori Highlands, Ba	I.T. Kuruvoli	13330	10-05-63
Viti Levu: Nadroga & Navosa	Nausori Highlands, Ba	J.W. Parham, D.K. & I.K.	13321	09-05-63

Location (Island or Province)	Locality	Collector	Coll #	Date
Viti Levu: Naitasiri prov. Suva	past Tamairia village, 6 miles from Suva	John W. Gillespie	2173	08-08-27
Viti Levu: Naitasiri provi: Suva	past Tamairia village, 7.5 mi. from Suva	John W. Gillespie	2132	08-09-27
Viti Levu: Naitasiri province	Naitasiri province: Waindina River Basin	L.H. MacDaniels	1051	03-29-27
Viti Levu: Naitasiri province	Suva	John W. Gillespie	2027	08-06-27
Viti Levu: Naitasiri:	Colo-i-Suva	Eroni Vukicea		06-30-50
Viti Levu: Namosi prov	SE of Namosi Village	John W. Gillespie	2841	09-08-27
Viti Levu: Namosi prov.	Naitaradamu mountain, just below the summit	John W. Gillespie	3244	09-28-27
Viti Levu: Nandronga & Navosa (form. Tholo North)	Rairaimatuku Plateau	A.C. Smith	5497	Aug 4-7, 1947
Viti Levu: Ngaloa (Serua pencilled in)		O.Degener & E.Ordonez	13624	Nov20-Dec31, 1940
Viti Levu: Rewa province	Korobaba mountain: near summit	John W. Gillespie	2224	08-11-27
Viti Levu: Serua	Hills between Waininggere and Waisese Creeks	A.C. Smith	9400	Nov30-Dec23, 1953
Viti Levu: Serua:	Hills E of Navua River, near Nukusere	A.C. Smith	9090	Oct29-Nov2, 1953
Viti Levu: Serua: N. of Namboutini		Forest Dept. (E. Damonu	579	03-22-63
Viti Levu: Serua: N. of Ngaloa	Geloa Viti Timber Co	Forest Dept. (E. Damanu)	580	03-22-63
Viti Levu: Suva (Rewa:)	Botanic Garden, Suva	L.H. MacDaniels	1130	04-11-27