Charcoal from archaeological contexts is potentially a direct source of information about past environmental conditions, and is especially important in tropical areas where organic materials tend to preserve poorly. The study of wood charcoal is also of particular value in reconstructing ancient vegetation patterns on Pacific Islands where the native flora has been substantially modified by centuries of human settlement and, more recently, by introduced European herbivores (e.g., Allen and Murakami 1999, Athens 1997, Lepofsky, Kirch and Lertzman 1996, Orliac 2000, Spriggs 1991, Wallace 1981). Further, charcoal and, less commonly, unburned wood from archaeological contexts aids understanding of past cultural activities, including patterns of fuel use, cooking practices, timber choices and ritual activities (e.g., Kahn 2008, Kahn and Coil 2006, Millerstrom and Coil 2008, Murakami 1983, Wallace 1989, and Wallace and Irwin 2004). However, despite its research potential and the routine recovery of large quantities of charcoal from archaeological excavations, Pacific archaeologists have until recently been mainly interested in its use for radiocarbon dating.

In this paper, we look at fuel remains from a fundamental component of the traditional Polynesian “kitchen”—the earth oven. Using a case study from the Marquesas Islands, East Polynesia (Fig. 1), we consider why particular woods may have been used as oven fuels and the degree to which archaeological oven samples provide useful profiles of local vegetation. Several methodological issues are also explored, including how to best quantify and compare wood charcoal assemblages, and the potential impact of sample size on certain measures of interest.
Figure 1. Location of Anaho Valley on Nuku Hiva Island.
Métraux 1971). In places where restrictions required men and women to eat separately a given household might have several ovens (Ferdon 1981: 86, Handy, Pukui and Handy 1972: 12-13). The typical household earth oven was located in the family dwelling complex, near or underneath a simple cooking shed, which was open on one or more sides. Ferdon (1981) describes the average Tahitian oven as a pit in the ground, several feet across and from one-half to two feet deep. Regional variations include ovens bounded by upright stone slabs on Rapa Nui (Métraux 1971), those built above ground and bounded by fresh banana trunks in Samoa (Buck 1930), and the use of shell or coral oven stones on atolls (Di Piazza 1998). When communal ovens were built for feasts, such as the Marquesan feikai mei pa’a (Handy 1923: 194, Pl. vii D), or to cook roots of *Cordyline fruticosa* (tī) (Fankhauser 1986), they could be extremely large.

Polynesian earth oven technology involved the use of heated stones and water to steam-cook food in closed pits (Fig. 2). Typically, a fire was kindled in the pit, cooking stones were added, and the rocks heated until glowing; in one experimental oven study, temperatures of 300° to 500°C were typical, though some ovens reached over 700°C (Orliac and Wattez 1989). After heating, the rocks were spread out, leaf-wrapped parcels of food placed on top, and the oven sealed to retain the heat and cook the food. Foods commonly prepared by this method were starchy fruits (breadfruit), tubers and roots (taro, yams and sweet potatoes), *Inocarpus fagifer* (ihi) nuts, processed food pastes, fish and meat including whole animals (e.g., Best 1923, Kirch and Green 2001: 143-62, Leach 1982). Starchy plants in particular were part of the daily traditional Polynesian diet in many places, and earth ovens provided an expedient way to render the complex carbohydrates of these foods easier to digest (Wandsnider 1997). Earth ovens also were an energy-efficient method of cooking whole animals and preparing large quantities of food for communal feasts (see also Thoms 2008, 2009). They were especially useful for long, slow cooking, as in the preparation of *tī* roots, where cooking might continue for two or three days (Fankhauser 1986).

In the Marquesas, oven pits were commonly located in established household food preparation areas (Ferdon 1993: 59, Handy 1923: 64). These were often one to two metres in diameter and up to two metres deep, but could be up to six metres in diameter in some cases (Handy 1923: 195). Ethnographic accounts (Handy 1923: 64, 195; Porter 1970) indicate that small stream boulders were used as cooking stones. A fire was often kindled in the pit using a “fire plough” process by which a short sharpened stick of *Hibiscus tiliaceus* (*hau*) was rapidly rubbed along a groove in a second piece of wood or the dry spathe of a coconut inflorescence, creating dust which ignited from the resulting heat (Linton 1923: 349). A fire might also be rekindled
from a bundle of coconut fronds left to smoulder for this purpose. With a fire alight, enough fuel was added to thoroughly heat the stones. Once heated, the oven might be cleared of stones and charred material (Handy 1923: 194, von Langsdorff 1813: 124) and lined with an even layer of stones. Hot stones were handled with tongs, preferably of *Thespesia populnea* (*mi‘o*, Pacific rosewood) or a dipper made of a stick threaded through a coconut shell (Handy 1923: 64). Typically, a thin layer of soil was spread over the hot stones and this was overlain by a bed of green sticks, *Hibiscus* leaf stems (petioles), or in more recent times, a bed of banana leaves or burlap bags, to prevent the food from coming into direct contact with the hot stones. Parcels of food were then placed in the oven. Additional heated stones were piled around these parcels, the oven sealed with *Thespesia* leaves and another layer of soil, and the food left to cook for some time.

While Marquesan ethnographies describe traditional kindling materials, they rarely mention the specific timbers that were used to heat oven stones. Handy (1923: 195) noted that the large *feikai mei pa‘a* ovens were fuelled
with large branches of *Inocarpus*, *Sapindus* and *Hibiscus*. On occasion, ethnographic documents from other East Polynesian high islands mention traditional fuel woods by name. *Hibiscus* was favoured for the widely-used fire plough (Ferdon 1981, Handy 1923, Malo 1903, Métraux 1971). *Artocarpus altilis* (breadfruit) logs were left smouldering in order to sustain cooking fires on Mangareva (Buck 1938). In the Marquesas, *Sapindus saponaria* (soapberry) was noted as a fuel typically supplied to vessels passing by the island of Tahuata in the early 19th century (Bennett 1970: 348). Generally, preferred fuel woods have physical properties that enhance their burning qualities. These include a high density, a low moisture content, the presence of extractives (e.g., oils and resins) and/or the ability to burn well when green (U.S. National Research Council 1980). Many Polynesian species that are considered “good fuels” also have these properties. Recent studies of tropical Polynesian economic trees (Elevitch 2006, Walter, Ferrar and Sam 2002, Whistler 2000) indicate that several mesic lowland taxa found in the Marquesas today are considered good sources of fuel elsewhere in the region, including *Alphitonia* spp., *Broussonetia papyrifera* (paper mulberry), *Casuarina equisetifolia* (ironwood), *Cordia subcordata* (island walnut), *Hibiscus tiliaceus*, *Inocarpus fagifer* (Tahitian chestnut), *Metrosideros collina*, *Pometia pinnata* (island lychee) and *Terminalia catappa* (Tropical almond).

**ARCHAEOLOGICAL EXPECTATIONS**

The present analysis was a pilot study aimed at exploring the potential of wood charcoal from Marquesan archaeological contexts to inform on past cultural practices and environmental conditions (Huebert 2008). It was also designed to evaluate two alternative models of fuel use. Shackleton and Prins (1992) argue that in many contexts fuel selection is largely opportunistic and based on the “principle of least effort”. In their view, charcoals recovered from fire features are likely to reflect whatever species were locally most common or accessible. Indeed, one of us (Wallace) had found that archaeological evidence derived from varied prehistoric fire features in New Zealand is consistent with this view. Alternatively, others (e.g., Carson 2002, Di Piazza 1998, Orliac 1997) have suggested that purposeful fuel selection may occur in some situations. Allen (2005), for example, argued that high quality fuel would be associated with earth oven use, given the benefits of efficiently heating oven stones. While her single site analysis showed this generally to be the case, it revealed that high quality fuels were associated with smaller hearths as well.

The present analysis was designed to test these two alternatives in the context of the Marquesas by examining fuel patterns within a single class of fire feature, the closed earth oven. It is argued that this specific type of fire feature potentially had demanding fuel requirements, related to the need to
reach and sustain high temperatures so as to thoroughly heat the associated cooking stones. The cost of insufficient heat was undercooked food, which could have been unpleasant for some traditional Polynesian foods, or socially unacceptable in certain contexts. In undertaking this preliminary analysis we recognise that ultimately other kinds of samples will be required to determine whether the patterns identified here are limited to ovens. Such work is underway (Huebert 2009). Further, additional variables will need to be considered to understand broad-scale Polynesian fuel practices. Factors such as population mobility, territory size, vegetation regeneration potentials and the diversity of available quality fuel species can all affect patterns of fuel use and the degree of human impact on local resources over the long term.

THE STUDY AREA

The Marquesas Islands are a remote archipelago of volcanic high islands in East Polynesia, located 1500km northeast of the Society Islands. Nuku Hiva, the largest island at 330km², is dominated by an ancient caldera. Ringed by peaks that reach up to 1224m, numerous deep valleys radiate outward from this caldera, extending to the coast (Brousse et al. 1978). Much of the coastline features sheer cliff faces, often with narrow coastal plains. The climate is mesic-tropical and rainfall is geographically marked. Windward localities receive up to 1500mm annually, while leeward coasts are significantly drier with minimums as low as 700mm (Cauchard and Inchauspe 1978). While the islands are well known for having extended droughts, which often resulted in localised famines (see for example, Robarts 1974), they also experience periods of excessive rainfall (Allen 2010, Ferdon 1993).

The Marquesas are home to a relatively diverse flora of approximately 320 plant species, 42 percent of which are endemic and persist mainly in the high cloud forest (Florence and Lorence 1997). The valley bottoms and lower valley slopes, by contrast, have a largely anthropogenic flora, the result of several hundred years of indigenous agriculture and the establishment of commercial coconut groves in the second half of the 19th century (Decker 1970). Feral ungulates have also contributed to the widespread destruction of the native Marquesan lowland vegetation (Decker 1970, Mueller-Dombois and Fosberg 1998: 447). As a consequence of these factors, little is known about the lowland flora prior to and during human settlement (but see Table 2 in Allen 2004, Millerstrom and Coil 2008).

This study draws on samples from Anaho, a broad amphitheatre-headed valley on the northeast coast of Nuku Hiva (Fig. 1). The northern to western valley slopes rise rapidly to nearly 300m, while a several hundred metre high peak dominates to the south. The valley opens onto a deep-set bay, which is home to one of the few coral reefs in the Marquesas (Aswani and Allen 2007,
Brousse et al. 1978). A few springs and intermittent streams are found here, one each in the northern and southern parts of the valley. Microclimate conditions within Anaho are varied, ranging from xeric (very dry) on the northern slopes to mesic (moderately wet) in the south, where waterfalls occasionally cascade down the cliff face. As a result, the valley flora is of mixed composition

Figure 3. Contemporary vegetation zones of Anaho Valley and the surrounding area (based on ORSTOM 1993 and Florence and Lorence 1997).
(Fig. 3). The strand zone around the head of the bay is dominated by aging, commercially planted coconut trees interspersed with *Thespesia populnea*, *Hibiscus tiliaceus*, *Morinda citrifolia* (noni), *Mangifera indica* (mango) and *Adenanthera pavonina* (pitipiti‘o). On the drier valley slopes *Sapindus saponaria* and *Xylosma suaveolens* (pi‘api‘au) dominate, while ridges are covered in low brush including the exotic *Leucaena leucocephala* (atiku) and grasses. In the mesic montane forests, on the higher ridges to the south, *Hibiscus* and *Pandanus* are prevalent (Florence and Lorence 1997).

Given the microhabitat variation found in the valley today, a vegetation mosaic was probably also present in the past. Lowland coastal species would have been the most proximate fuel sources but, given the relatively minimal distances between the coast, valley interior and exposed valley slopes, mesic montane and xeric species also would have been accessible, though these taxa may have been more time-consuming to acquire.

MARQUESAN CULTURAL SEQUENCE

While the timing and origins of Marquesan settlement remains unresolved, human populations were widely distributed throughout the archipelago by AD 1200, including Anaho Valley (Allen and McAlister in press). Polynesian settlers introduced domestic animals such as pigs, dogs and chickens to the islands, as well as numerous economically important plants. Transported tree crops, including breadfruit and coconut, were major components of the traditional Marquesan diet, as were starchy tubers such as taro, yams and bananas (Addison 2006, Crook 2007, Robarts 1974). The main protein sources were fish, shellfish, birds and pigs; the last was particularly important for special occasions (Ferdon 1993, Handy 1923: 196-99, Porter 1970: 113).

Early settlements were often situated along the coast (e.g., Sinoto 1979, Suggs 1961), and indications are that people placed their homes directly on the ground surface or on pebble or boulder pavements (e.g., Sinoto 1970, Suggs 1961). At the well-studied locality of Anaho Valley, Nuku Hiva Island, people occupied the northern coastal flat until c.AD 1650, leaving few architectural traces other than post-moulds, hearths and ovens. After c.AD 1650 they moved a few hundred metres inland, settling along the Teavau’ua Stream (Allen 2004). In this streamside locality most houses were apparently placed upon raised stone foundations (*paepae hiamoe*), a residential style that continued into the contact period (Allen 2009). While Suggs (1961) suggested that in many Marquesan valleys inland movement was related to inter-tribal warfare, the post-1650 relocation seen at Anaho is not to more defensible locations, but simply away from the immediate coast, suggesting other causal factors. One possibility would be unsettled coastal conditions (Allen 2010).
At the time of sustained European contact in the late 18th century most, if not all, Marquesans lived on these raised stone foundations (Crook 2007, Handy 1923). Marquesan society was stratified into commoners and elites of several types, including chiefs, warriors, priests and other specialists (Thomas 1990), and household size and complexity varied according to social standing (Ferdon 1993, Handy 1923, Suggs 1961). Distinctive stone architecture in use at this time included not only raised stone house foundations but also public assembly structures, called tohua, and religious and mortuary structures, known as meʻae (Linton 1925, Suggs 1961). While the chronology of these community structures is poorly known, many show evidence of substantial re-modelling (Suggs 1961), suggesting some antiquity. This contrasts with raised residential foundations which, at least at Anaho, do not appear until late prehistory (Allen 2009).

The higher status contact-period Marquesan households occupied compounds, which included a main house situated on a stone foundation (used for sleeping and other domestic activities), a family cooking shed, and sometimes a small sacred enclosure or platform (Handy 1923: 62-67). A separate structure called the fātaʻa was exclusively for men and included its own storehouse and cooking facilities. Less wealthy families maintained sleeping houses but had fewer and less elaborate secondary structures. A pit for preserved breadfruit or mā was often located nearby, as well as the family coconut, breadfruit, banana and paper mulberry trees (Addison 2006: 119-120; Ferdon 1993: 25, 58; Handy 1923: 62-67). Earth ovens were integral parts of these domestic units and important for cooking plant and animal foods that required high heat, long cooking or both.

**CONTEXTS OF WOOD CHARCOAL SAMPLES**

The samples used in this study derive from an on-going archaeological field programme that Allen has been directing in Anaho Valley. The wood charcoal samples come from features associated with two temporal contexts: (i) a relatively early subsurface occupation layer on the northern coastal flat of Teavauʻua, where stone architecture is lacking, and (ii) deposits associated with late prehistoric raised stone structures (paepae) which are widely distributed throughout the valley. Based on four determinations, the most likely age range for the subsurface occupation at Teavauʻua is AD 1450 to 1650 (Allen 2004, 2009). The more widely distributed occupational deposits associated with stone architecture are dated after 1650, based on 33 determinations (see Allen 2009). In assessing temporal change in fuel use at Anaho, these two contexts are contrasted as “early” versus “late”, although the earliest occupation at Anaho dates to about the 12th century AD (Allen 2009).
### Table 1. Details of oven features.

<table>
<thead>
<tr>
<th>Locality</th>
<th>Structure no. and unit</th>
<th>Feature no.</th>
<th>Charcoal sample no(s)</th>
<th>Estimated diameter (cm)</th>
<th>Depth (cm)</th>
<th>Portion excavated</th>
<th>Description</th>
<th>Feature contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal: Teavau’ua</td>
<td>TP-9</td>
<td>6</td>
<td>882</td>
<td>160</td>
<td>35</td>
<td>c. 2/3</td>
<td>Shallow, basin-shaped profile, oxidized sand at base</td>
<td>Angular &amp; rounded cobbles (numerous), underlain by dense charcoal and ash. Boulders mark periphery.</td>
</tr>
<tr>
<td>Coastal: Teavau’ua</td>
<td>TP-8</td>
<td>7</td>
<td>640</td>
<td>150</td>
<td>23</td>
<td>c. 1/4</td>
<td>Shallow, basin-shaped profile, oxidized sand at base</td>
<td>Angular cobbles (numerous), charcoal concentrated near base, two boulders mark periphery.</td>
</tr>
<tr>
<td>Coastal: Teavau’ua</td>
<td>TP-14</td>
<td>20</td>
<td>826</td>
<td>130</td>
<td>25</td>
<td>c. 1/4</td>
<td>Shallow, basin-shaped profile</td>
<td>Angular cobbles (numerous) and charcoal, two boulders mark periphery.</td>
</tr>
<tr>
<td>Coastal: Teavau’ua</td>
<td>SP-2</td>
<td>D-97</td>
<td>139 &amp; 146</td>
<td>uncertain</td>
<td>25</td>
<td>uncertain</td>
<td>Shallow, basin-shaped profile</td>
<td>Angular cobbles (several) and dense charcoal.</td>
</tr>
<tr>
<td>Lower Valley</td>
<td>Structure 13, Unit C14</td>
<td>3</td>
<td>4201 &amp; 4218</td>
<td>95</td>
<td>50</td>
<td>c. 3/4</td>
<td>Deep, u-shaped profile, strongly oxidized base</td>
<td>Rounded cobbles at top (numerous), dense charcoal below.</td>
</tr>
<tr>
<td>Coastal: local name unknown</td>
<td>Structure 8, TP-24</td>
<td>26</td>
<td>1049 &amp; 1054</td>
<td>150</td>
<td>35</td>
<td>c. 1/3</td>
<td>Shallow, basin-shaped profile</td>
<td>Angular cobbles (numerous) and dense charcoal.</td>
</tr>
<tr>
<td>Valley slope: Tepapa Uka</td>
<td>Structure 242, TP-38</td>
<td>29</td>
<td>4237 &amp; 4245</td>
<td>75</td>
<td>40-45</td>
<td>uncertain</td>
<td>Deep, u-shaped profile, no soil oxidation noted</td>
<td>Angular cobbles at top (few), modest amount of charcoal.</td>
</tr>
</tbody>
</table>

1 Features exposed in excavation were measured in plan view and profile (when available) and this information was used to estimate overall feature size. It was assumed that features had simple and regular geometric shapes. The quality of these estimates is likely to be proportional to the area excavated.
Figure 4. Anaho Valley with the Teavau’ua excavation area and the sampled stone structures indicated.
While there is a small amount of overlap in the calibrated age ranges of the two time periods discussed herein, this is considered inconsequential in the context of this comparison.

For the purposes of this analysis, ovens were defined as fire features with diameters exceeding 70cm and moderate to abundant amounts of fire-altered rock and charcoal. In cases where a large portion of the feature was excavated, or the feature was exposed in profile, oxidised bases and/or perimeters were observed, indicating *in situ* firing and high heat. These defining features of ovens are consistent with those used elsewhere (e.g., Allen 1992, 2005: 52-56; Orliac 1997; Orliac and Wattez 1989) and distinguish them from open fire features or hearths which tend to be smaller and lack the associated cooking stones. In the Anaho case it was not possible to determine with any certainty whether the ovens were single or multiple use features, although contemporary cooking practices suggest that any given pit and its oven stones might be used repeatedly for cooking.

**EARLY OVENS**

Four samples derive from subsurface ovens found from excavating in the Teavau’ua coastal flat around 100m inland of the modern shoreline (Fig. 4). This area was investigated through systematic shovel pits along transects and controlled excavations (Allen 2004). The oven features come from a delimited area where 8m² were opened for three-dimensionally controlled excavation. Three distinct occupation layers were identified and dated from the 13th century through the late 19th century (Allen 2004). Layer IIIb, the main cultural layer (c.AD 1450-1650), contains post-moulds and numerous burn features, including ovens and hearths, and concentrations of ash and charcoal. Food remains also were abundant; shellfish, fish, pig, dog and bird were represented. Pearlshell fishhooks in various stages of manufacture, basalt flaking debitage related to adze manufacture, and finished tools were recovered. The evidence suggests this was an area where a range of domestic activities were carried out although no formal pavements or stone structures were identified.

The ovens in the c.16th century occupation are similar in size, with a variance of less than 20cm in either depth or diameter (Table 1) and are situated within a few metres of one another. In most cases they also display an internal structure of fire-altered rocks in the top portion and charcoal and/or ash concentrated at the base (Fig. 5). The peripheries of some ovens were marked by small boulders. Nearby post-moulds indicate a structure was present.
Another three ovens from areas adjacent to raised stone house foundations were sampled (Table 1). The foundations are, as noted earlier, the typical form of late prehistoric domestic architecture, which ethnographic accounts suggest were used by much if not all of the populace. As a whole, the Anaho foundations date to the post-1640 period (Allen 2009). Structure 13 is a fairly typical stepped house platform, located close to Teavau‘ua Stream and about 270m inland from the shoreline (Fig. 4). This modest structure measures c.59m² and faces the stream. A large boulder alignment encloses about 20m² of flat ground to the front of the platform. A large oven (Efe-3) was uncovered here during an areal excavation (Fig. 6). A second oven (Efe-26)
was associated with a 97m² stepped house foundation, Structure 8 on Figure 4, roughly 150m from the shore. In this case the oven was located several metres seaward of the structure. A third oven (Efe-29) was associated with a residential compound located in the valley interior, on a narrow plateau high against the valley wall (Fig. 4). Efe-29 was closest to a simple 12m² platform (Structure 242) which was part of a multi-structure elite residential compound. Structure 242 probably was not a sleeping platform, since it is relatively small in area and un-stepped. A ritual function is possible for the foundation given its position within the complex and the massive boulders used in its construction. However, the presence of shell and two earthen breadfruit (mā) pits in the general vicinity indicate that this was generally a locality of food preparation.

In all three cases, small amounts of faunal remains were present in and around the ovens. Shellfish, pig bone and a possible breadfruit processing or storage pit were noted in the vicinity of Efe-3. An accumulation of fish and

Figure 6. Photo looking west at oven Efe-3 (indicated by arrow). The raised stone house foundation is on the left and the circular pit outlined by stones (centre) was probably used for breadfruit processing or storage.
bird bone was found in Efe-26 but this material was not charred or burned and it may post-date oven use. The inland feature, Efe-29, was located near to two large earthen food storage pits. Features Efe-3 and Efe-26 both had dense concentrations of fire-altered rock and charcoal. Efe-26 in particular is comparable to the previously described oven features from the coastal flat in both size and contents. In contrast, Efe-3 is comparatively narrow and fairly deep (Fig. 6). Efe-29, from the inland location, also was relatively small (c. 75cm in diameter) and contained less rock and charcoal than the other ovens. Some of this variability could relate to the difficulty of excavating pits in areas where the soil is hard, clayey and rocky.

**METHODS**

In the field, samples were collected with ~6.4mm (¼ inch) or 3.2mm (⅛ inch) screens, bulk-sampled from the centre of features during excavation, or bulk-sampled from profile walls once the excavation was completed. In some cases, multiple samples were taken from the same feature, sometimes from different depths, but all samples from any given feature were combined for interpretive purposes. In the laboratory, a 6.35mm geological sieve was used to separate the charcoal fragments from the sedimentary matrix. The overall weight and condition of each sample was recorded. Charcoal was identified by Huebert (2008) with the assistance of Wallace using procedures adapted from Leney and Casteel (1975). Each fragment was snapped to expose a transverse plane, and then cleaved to obtain tangential longitudinal and radial planes. These faces were observed under incident light using a high magnification (50-500x) compound microscope. Identifications were performed by comparing the specimen cellular anatomy to thin-sections made from specimens in the University of Auckland Wood Reference Collection created by Wallace and supplemented by Allen, which includes 248 taxa from the tropical Pacific and New Zealand. Additional anatomical information and a basic dichotomous wood identification key were drawn from Détienne, Jacquet and Orliac (1999). The entirety of each sample was identified (i.e., all charcoal retained in the 6.35mm sieve). Material that could not be positively identified to any taxon in the reference collection was assigned to a numbered “unknown” category (e.g., unknown 1). Fragments that lacked distinctive characteristics, or were too warped or fragile for identification, are classified as “unidentifiable” in the tables and figures that follow.

Charcoal is typically quantified in one of two ways, by count or weight. Counts are simply tallies of the number of fragments, while weight represents the total amount of material identified for each taxon. The choice of weights versus counts as the preferred quantification measure depends on a number of factors. Important considerations include the apparent degree of fragmentation...
in the samples and the variety of taxa and plant parts present. Samples may be unevenly fragmented owing to varying post-depositional and recovery conditions (Greenlee 1992). Some taxa do not preserve well (see Asouti and Austin 2005, Chabal 1992), and different plant parts may fragment to varying degrees. In these cases, the use of counts may over-inflate the importance of some taxa. Weights, in contrast, may be problematic if wood density varies widely between taxa or wood preservation conditions vary across sampling localities (see Di Piazza 1998: 151-52, Miller 1985: 4-5, Thompson 1994: 17-18). To explore the potential impact of these biases, the four most abundant taxa were quantified by both measures and Pearson’s correlation coefficient was used to evaluate the strength of the relationship.

In addition to the impact of quantification measures, wood charcoal results can also be affected by decisions made in the field as, for example, where in a feature the samples were taken. In consideration of these factors ratio level estimates (i.e., frequencies) may not always be appropriate (Grayson 1984) and ubiquity analysis provides an alternative way of evaluating taxonomic representation, one which makes relatively low level quantitative assumptions (Popper 1988: 60-64). This measure involves first assessing the presence or absence of a given taxon across a series of units or assemblages. Following this, taxonomic occurrences are used to establish the relative value of a taxon in the overall assemblage. For example, a taxon that occurs in half the assemblages analysed has ubiquity value of 0.5, while a taxon that is present in all of the assemblages has a ubiquity of 1.0. Ubiquity values are especially useful for comparing different sample groupings, for illustrating broad-scale changes in the use of a particular resource and for comparing samples that vary widely in size, taphonomic histories and other dimensions.

RESULTS

Wood Charcoal Identifications
Nine woody species, as well as coconut and other monocotyledon tissues, were identified in this assemblage of over 800 fragments (Tables 2 and 3). Five taxa matched material in the reference collection including Celtis pacifica, Cocos nucifera, Cordia subcordata, Sapindus saponaria and Thespesia populnea. Two distinct taxa were narrowed to possible matches, one to cf. Alyxia stellata and the second to cf. Maytenus crenata. The notation “cf.” is used to indicate some uncertainty in a given taxonomic identification; it suggests that the specimen in question compares well with a particular reference taxon but other taxa cannot be conclusively excluded. While fragments identified as Hibiscus generally matched the available reference specimens, the archaeological materials were morphologically varied and
Table 2. Ecological characteristics, biogeographic status and cultural uses of the identified taxa.

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
<th>Wood density and hardness</th>
<th>Ecological attributes, biogeographic status and Marquesan uses</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Alyxia stellata</em></td>
<td><em>meie</em></td>
<td>Heavy, N/A</td>
<td>Shrub with fragrant wood. Indigenous. Bark used to scent coconut oil.</td>
</tr>
<tr>
<td><em>Celtis pacifica</em></td>
<td><em>vainanini</em></td>
<td>Medium, Very hard</td>
<td>Tall spreading tree. Indigenous. Fragrant foliage.</td>
</tr>
<tr>
<td><em>Cocos nucifera</em></td>
<td><em>ʻehi, coconut</em></td>
<td>Varies considerably from core to periphery</td>
<td>Very tall woody monocot. Indigenous and/or Polynesian introduction. Food, fuel, building material and many other uses.</td>
</tr>
<tr>
<td><em>Cordia subcordata</em></td>
<td><em>tou</em></td>
<td>Heavy, Medium-hard</td>
<td>Spreading tree. Probably indigenous. Excellent burning properties. Many uses including carvings, drums and canoe parts.</td>
</tr>
<tr>
<td><em>Maytenus crenata</em></td>
<td><em>koinaina</em></td>
<td>Medium, N/A</td>
<td>Shrub or small tree. Endemic. No known uses.</td>
</tr>
<tr>
<td><em>Sapindus saponaria</em></td>
<td><em>kokuʻu, soapberry</em></td>
<td>Heavy, Medium-hard</td>
<td>Tall tree. Indigenous. Wood used for tapa beaters, other parts had medicinal and decorative uses, fruit used as soap.</td>
</tr>
<tr>
<td><em>Thespisia populnea</em></td>
<td><em>miʻo, Pacific rosewood</em></td>
<td>Medium-heavy, Medium-hard</td>
<td>Small to medium-size tree. Possible Polynesian introduction. Many uses including carvings, canoe parts, house posts. Ritually important.</td>
</tr>
</tbody>
</table>

---

* a Butaud *et al.* 2008, Detienne *et al.* 1999

more than one *Hibiscus* species could be represented. Two additional taxa were distinctive but could not be positively matched to any samples in the reference collection. The unidentified material represented 4.4 percent of the total weight of this assemblage.

**Comparison of Counts versus Weights**

As noted above, the four most abundant taxa were quantified by both counts and weights and the results compared (Fig. 7 a-d). In all cases, the two measures were statistically correlated. *Thespesia populnea*, with 476 fragments and 201gms, was the most abundant taxon. It has a weight-to-count correlation that is moderately significant (*r*=.87, *p*=.002), suggesting that neither measure is overly biased by taphonomic processes (Fig. 7a). Two outliers, however, are apparent. Sample 139 is excessively fragmented and sample 4201 has a single anomalously large fragment. In the remaining cases counts and weights are highly correlated.

Two samples (4237, 4245) from one oven were comprised almost entirely of *Sapindus saponaria*. This taxon has a highly significant weight-to-count correlation (*r*=.92, *p*=.001; Fig. 7b). *Sapindus* also was excessively

![Figure 7. Comparison of count and weight relationships for select taxa.](image)
fragmented in Sample 139 suggesting post-depositional processes have affected materials from this feature as a whole.

Two additional taxa were examined, although because there are few data points the relationship between counts and weight can only be tentatively assessed. Counts and weights of *Hibiscus* show a modest degree of correlation ($r=0.75$, $p=0.25$; Fig. 7c). Problematically, two of these samples contained only one *Hibiscus* fragment. A strong weight-to-count correlation ($r=0.99$, $p=0.01$; Fig. 7d) was also shown for undifferentiated monocot tissue, but only four samples were available for comparison.

The foregoing comparisons demonstrate that in this set of assemblages charcoal fragment counts and weights are strongly correlated for the two most abundant taxa. As such, either measure would be an appropriate quantification measure. However, given indications that at least some samples are quite fragmented, weights were deemed the best measure for inter-sample comparisons that follow.

**Types of Fuel**

Overall, in most samples, a narrow range of woody species was found (Table 3 over page). In an effort to identify the most common taxa across the series of samples, ubiquity values were calculated. With ubiquity values of .86, *Thespesia populnea* and *Sapindus saponaria* (Fig. 8) are the two most prevalent species. *Celtis pacifica* (.29), *Cocos nucifera* (coconut) wood (.29), *Alyxia* spp (.29) and *Hibiscus* sp(p) (.43) were each found in several samples. *Cordia subcordata*, *Cocos* endocarp, cf. *Maytenus crenata* and the unknown taxa were found in only one sample each. Most of the rare taxa occur within a single feature, Efe-26, where eight woody dicot species, plus *Cocos*, were recorded. This assemblage is unusually diverse considering that the two samples taken from this oven were among the smallest in this study. Efe-7 and Efe-29, in comparison, contained only one wood taxon each. This consistency in fuel species is notable given that even within this single functional category (i.e., ovens), some variability might be anticipated based on occupant status, site location and the types of food being cooked.

**Fuel Sources**

Casual observation indicates that most of the woody species identified in this study are still prevalent on the coastal flat and valley slopes of Anaho today. *Cocos nucifera*, *Hibiscus*, *Sapindus saponaria* and *Thespesia populnea* in particular are widely distributed throughout the valley. *Cordia subcordata*, found in one sample, occurs less frequently. *Celtis pacifica* has not been identified locally but is reported elsewhere in coastal Marquesan contexts (Decker 1970), often alongside *Sapindus*. Similarly, the endemic *Maytenus*
Table 3. Summary of wood charcoal identifications from Anaho ovens. Values presented are fragment counts followed by weight [in grams].

<table>
<thead>
<tr>
<th>Feature</th>
<th>Early (A.D. 1450-1650)</th>
<th>Late (post-A.D. 1640)</th>
<th>Total</th>
<th>Ubiquity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Efe. 6</td>
<td>Efe. 7</td>
<td>Efe. 20</td>
<td>Efe. D97</td>
</tr>
<tr>
<td>Sample No.</td>
<td>882</td>
<td>640</td>
<td>826</td>
<td>139, 146</td>
</tr>
<tr>
<td><strong>DICOTYLEDONS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Celtis pacifica</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cordia subcordata</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Hibiscus sp(p)</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Sapindus saponaria</em></td>
<td></td>
<td>12</td>
<td>12</td>
<td>50</td>
</tr>
<tr>
<td><em>Thespisia populnea</em></td>
<td></td>
<td>12</td>
<td>79</td>
<td>34</td>
</tr>
<tr>
<td><em>cf. Maytenus crenata</em></td>
<td></td>
<td>34</td>
<td>34</td>
<td>96</td>
</tr>
<tr>
<td><em>cf. Alyxia spp</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[.17]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feature</td>
<td>Early (A.D. 1450-1650)</td>
<td>Late (post-A.D. 1640)</td>
<td>Total</td>
<td>Ubiquity</td>
</tr>
<tr>
<td>---------</td>
<td>------------------------</td>
<td>-----------------------</td>
<td>-------</td>
<td>----------</td>
</tr>
<tr>
<td></td>
<td>Efe. 6</td>
<td>Efe. 7</td>
<td>Efe. 20</td>
<td>Efe. D97</td>
</tr>
<tr>
<td>Sample No.</td>
<td>882</td>
<td>640</td>
<td>826</td>
<td>139, 146</td>
</tr>
<tr>
<td>Unknown 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MONOCOTYLEDONS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cocos nucifera (wood)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cocos nucifera (endocarp)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other monocot</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. dicot wood taxa</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Monocot present</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
crienata was rarely observed in Anaho lowlands but it is likely to be present on the cliff faces and among the scrub vegetation of the southern valley slopes (Smithsonian 2009). The final woody taxon is potentially Alyxia stellata. This shrub was reported by Brown (1935) as an occasional find in well-drained lowland locations. Botanist J. Butaud (pers. comm. 2009) suggests that Alyxia wood could have been a by-product of processing the fragrant bark, which was used to scent coconut oil. A small amount of coconut shell

Figure 8. Trees, transverse sections of wood charcoal, and flowers of Sapindus saponaria (left) and Thespesia populnea (right). Photos (a) and (c) by Steven P. Perlman and (f) by Warren L. Wagner, courtesy of Smithsonian Institution. Photos (b), (d) and (e) by the authors.
also was found along with unidentified monocot tissue which looks similar to woody leaf petioles.

Although all of the recovered species are found today within walking distance of the archaeological sites, two vegetation habitats are represented. *Thespesia, Hibiscus*, and *Cocos* are all likely to have been available on the coastal flat and lower valley slopes, being typical lowland vegetation components. *Sapindus* and *Celtis*, in contrast, occur mainly in more arid settings and, in the case of Anaho specifically, on the northern valley slopes and along exposed ridge lines and plateaus. These xeric species would have required a little more effort to obtain, since they are somewhat further away and in more sloping areas. One exception is the case of the oven Efe-29 (near Structure 242 on Fig. 4) which is part of a complex situated in a more elevated and interior location, and not far from an exposed ridge line.

**Temporal Patterns in Fuel Use**

To consider the possibility of temporal change in fuel use, features from the two time periods outlined above were compared. Four ovens were analysed from the subsurface AD 1450-1650 occupation at Teavau‘ua and another three associated with late prehistoric raised foundations were examined. Importantly, all of the sites where these ovens occur occupy similar forest habitats. The only possible exception is one late period valley slope site (area of Efe-29) where the soils are rockier, the ground better drained, and xeric species might be slightly better represented. There are three dimensions of variability that are of interest here: variation in species composition, changes in the proportional contribution of different wood taxa over time, and changes in species richness.

The bulk of identified material is *Thespesia populnea* (Fig. 9). It appears more frequently than any other taxon by a substantial amount. Considering woody dicot species only (i.e., monocots removed) it represents 85 percent of the charcoal in ovens from the “early” occupation on the coastal flat where it has a ubiquity value of 1.0. In contrast it represents only 63 percent of the wood charcoal from late ovens where the ubiquity value is 0.67. The second most common taxon, *Sapindus saponaria*, occurs more frequently in late ovens. *Sapindus* represents 8 percent of the wood charcoal in the early Teavau‘ua ovens on the coastal flat where it has a ubiquity value of 0.75 and increases to 25 percent in late contexts where it is well represented in all three of the sampled features. Other wood taxa are rarer and/or more sporadic in their occurrence, and their presence or absence is not considered in detail.

Monocot tissues, including *Cocos* (coconut), occur in only one of the four early oven contexts (Table 3). However, these materials are present in all of the late ovens. This shift could reflect increased abundance in the
Figure 9. Frequency of wood charcoal taxa by weight.
area of monocots, such as coconut palms, *Pandanus* or *Cordyline*, which are all economically important taxa. It could also indicate a decline in the availability of woody tree species over time. Orliac (2000), for example, in examining charcoal from varied depositional contexts (including but not limited to ovens) found that on Rapa Nui the use of non-woody fuels such as grasses and twigs increased over time as woody vegetation declined, a process also indicated by local pollen records and ethnohistoric accounts (Bahn and Flenley 2003).

Potentially, the number of taxa present, or taxonomic richness, also may provide information on patterns of fuel use. For example, as favoured species are reduced, a wider array of taxa might be used. Given that sample size and species richness are often correlated (Grayson 1984), a first step was to examine the relationship between these two variables. The very low Pearson’s correlation coefficient ($r=-0.074$, $p=.875$) indicates that sample richness, or number of taxa, is not a function of sample size in this assemblage.

In most of the Anaho ovens only one to three taxa were identified (Fig. 10); when other species were observed, they generally were represented by extremely small amounts of material (Table 3). In the early Teavau’ua ovens there is little variation in the number of taxa found and only a few types of

![Figure 10. Taxonomic richness by oven feature.](image-url)
wood are present across all features. The richest early feature (D-97) with four dicotyledonous wood taxa is unremarkable in size or shape, and the bulk of material is comprised of the same two taxa found in most of the ovens in the area. The remaining taxa in this feature include *Hibiscus*, a common tree in the valley today, one species found today at higher elevations (cf. *Alyxia*) and a very small amount of *Cocos* wood. Late features have a similar number of taxa with one anomaly, Efe-26. This oven is the richest of the assemblage, with at least eight dicot wood taxa represented. Located near a large stepped house foundation (Structure 8), the oven is not appreciably different from any of the others in terms of morphology. However, it contained a modest amount of unburned fish and bird bone which could indicate secondary use as a refuse pit and might explain the particularly diverse charcoal assemblage.

Overall, there is little change in species composition across the seven ovens examined. Similarly, there is little variation in species richness; only one oven had more than four woody dicot taxa. There are two changes of consequence indicated across the two time periods examined here. First, there is a modest decline in the abundance of *Thespesia* and a modest increase in *Sapindus* as measured by both frequency and, more conservatively, ubiquity values. Second, it is notable that monocot tissues are present in only one early oven but occur in all late ovens.

**DISCUSSION**

Charcoal samples are potentially a rich source of information on past cultural activities and paleoenvironmental conditions. However, charcoal deposited on archaeological sites has passed through varied cultural selection “filters” (after Asouti and Austin 2005, Chabal 1992), including but not limited to functional requirements, energetic considerations, aesthetic preferences and ritual restrictions. Wood charcoal assemblages also can be affected by diverse formation and post-depositional processes because different species and plant parts have variable burning properties and preservation potentials. Moreover, analytical decisions related to sampling and quantification also can affect results and interpretations. Given the foregoing, it is unlikely that archaeological samples will accurately reflect the actual proportions of taxa in the local flora at any point in time. Nevertheless, steps can be taken to control for these kinds of biases, some of which have been implemented here. First, while recognising that earth ovens can be used for different purposes and for varying lengths of time, examination of a single functional class of fire features has allowed formation processes to be held relatively constant across the set of samples. By way of contrast, assemblages derived from ovens, hearths, occupational debris and dispersed charcoal in agricultural burn layers would be considerably more difficult to interpret without a
large number of samples. Second, two fundamental quantification measures (weights and counts) are compared to identify potential taphonomic biases across the samples, particularly those which contribute to fragmentation. Third, ubiquity (percent of occurrence) is used to compare spatial patterns across samples of different sizes and with potentially variable formation histories. And finally, the relationship between sample size and richness is formally evaluated as a prelude to cultural and environmental interpretations. With respect to interpretive aspects of the samples, three dimensions of potential variability were examined across the seven oven features: kinds of fuels used, the geographic sources of the woody species represented, and changes in fuel use over time.

Two native woody taxa, *Thespesia populnea* and *Sapindus saponaria*, were consistently the most abundant species across all seven ovens. Although sometimes one or the other dominated, typically one of these taxa formed the bulk of any given assemblage. Potentially, their prevalence could reflect natural abundances. However, neither is especially abundant in areas around the archaeological sites at present. The most common pre-European taxa in the lower valley today are *Hibiscus*, *Morinda* and *Cocos*. In addition, Handy (1923) early in the 20th century observed that Marquesan house gardens often included breadfruit, paper mulberry and coconut, and breadfruit is widely acknowledged as the most important economic species in late prehistory (e.g., Addison 2006, Ferdon 1993). Strikingly, none of these taxa are well represented in the Anaho ovens. In light of the foregoing, it seems unlikely that *Thespesia* and *Sapindus* were the most proximate fuel sources in the past.

Both *Thespesia* and *Sapindus* were, however, culturally valued, not just in the Marquesas but within the East Polynesian region at large. On Rapa Nui they are recorded in legend and song as plants carried to the island by legendary founding father Hotu Matua (Métraux 1971). *Thespesia populnea* wood is prized throughout the Pacific for carving, in part because of its durability, but also its attractive wood grain and pleasant scent (Elevitch 2006, Whistler 2000). In the Marquesas it was used for canoes and canoe accessories, bowls, utensils and statues, and in religious ceremonies (Brown 1935). While it is possible that these activities could have generated wood debris that was used for fuel, it is unlikely that such activities alone could produce the patterns observed across the entire series of habitation contexts sampled here.

The other important characteristic of these two species is that both are dense, hard woods which are long-burning and can reach high temperatures, characteristics which would have made them ideal oven fuels. A recent wood charcoal study in neighbouring Hatiheu Valley indicates that the Anaho findings are not atypical in the prevalence of these two taxa. Millerstrom and Coil (2008) examined multiple samples from two ovens and also found that
these two taxa accounted for a significant percentage of the charcoal ranging from 31 to 68 percent weight for *Thespesia* and 15 to 51 percent for *Sapindus* (Millerstrom and Coil 2008: 341-42, Table 2). This compares well with the proportions obtained in the present study where *Thespesia* constitutes 43 to 100 percent of the charcoal in seven of the eleven of the Anaho samples (some ovens having multiple samples) and *Sapindus* makes up 3 to 32 percent of the weight in six samples. The prominence of these two species in oven features, where sustained heat is a critical functional requirement, is consistent with the hypothesis that woods used in Marquesan ovens were purposely selected for their burning properties.

An important implication of the foregoing is that wood charcoal samples from ovens provide biased views of the wider vegetation and are, on their own, a poor basis for paleoenvironmental reconstructions. Although it is widely acknowledged that charcoal from cultural contexts is a fragmentary reflection of past environments (see Allen and Murakami 1999: 105, Asouti and Austin 2005, Chabal 1992, Miller 1985, Orliac 2000, Smart and Hoffman 1988, Thompson 1994), the biases associated with ovens in particular have not been widely recognised (but see Orliac 1997: 209-10). This is an especially important consideration in the Pacific where earth ovens are a widespread and abundant feature commonly sampled for charcoal. Based on the extensive experience of Wallace (e.g., 1981, 2002 and unpublished data) with prehistoric wood charcoal assemblages from New Zealand Māori sites, vegetation reconstructions are best built on evidence from a range of contexts. Charcoal from both primary (e.g., ovens, hearths and some post-moulds) and secondary depositional contexts (e.g., general occupational debris that has accumulated over time) will more accurately represent both the composition and abundance of the local vegetation (see also Chabal *et al.* 1999).

Most, if not all, of the wood represented in the Anaho ovens could have been locally sourced. With the possible exception of one taxon (cf. *Alyxia stellata*), the identified species are either found in Anaho today or are known from similar habitats elsewhere. Fuel wood for everyday use was probably gathered from the surrounding vegetation. *Thespesia* inhabits the coastal plain and valley slopes and is widespread today, although not abundant. *Sapindus*, in contrast, is common but grows mainly on the steeper, drier slopes and exposed ridge lines of Anaho, particularly to the north. However, as previously noted, neither species was likely to have been the most proximate fuel source, with other economic species probably growing in the immediate vicinity of domestic residences.

In considering non-local taxa, both natural and cultural processes can introduce species from other environmental zones. Trees from higher elevations may be uprooted and washed downstream during heavy rainstorms,
a common phenomenon in the Marquesas. Other taxa may arrive as driftwood, both from local intra-archipelago sources and from more distant ones (e.g., the South American coast). Materials may also enter features as by-products of other cultural activities. In the present case, Alyxia stellata is not found in the lowlands of Nuku Hiva today, but the bark had ornamental uses and could have entered the oven as a processing by-product. It is also possible that this shrub once had a wider distribution, as Brown (1935) has proposed. He suggests that Alyxia, along with other lowland species, may have disappeared in the recent past as the result of over-grazing by herbivores, particularly goats. Although definitive conclusions are not possible on the basis of these limited findings, the recovery of Alyxia from an Anaho oven highlights the potential of wood charcoal analyses to improve our understanding of changes in the Marquesan lowland vegetation since Western contact.

In general, the present samples suggest stability in the composition of the local vegetation. There are, however, some indications that human activities had an impact on the availability of at least one economically important tree species, namely Thespesia. During his early 20th century ethnographic study, Handy (1923: 65) reported the use of Hibiscus, Artocarpus, Casuarina, Calophyllum and Thespesia wood for bowls and containers, but noted the best and most commonly used were of the last. Linton (1923: 360) similarly found that Thespesia wood was a favoured raw material for carved utensils but the once plentiful supply of this economically valuable wood was almost exhausted. Sapindus, in contrast, was apparently an important fuel species that was widely available at Western contact. Crook (2007: 76) in the late 18th century observed that Sapindus “abounds so much that some of the Vallies are filled almost entirely with it, either in large timber, or underwood”. Several decades later, Bennett (1970) commented that it was often supplied to passing ships as fuel and early 20th century ethnographers noted its use as a fuel in large specialised ovens (Handy 1923). During his mid-20th century field study, Decker (1970) found that Sapindus was in demand by contemporary Marquesan bakers.

The Anaho oven findings add temporal depth to these observations. Thespesia is present in all four of the early ovens where it accounts for a significant percentage of the total (>50%). In the three later features, however, it is important in only one feature (Efe-3) and is altogether absent in another (Efe-29). At the same time, the ubiquity and abundance of Sapindus is greater in the later samples, along with monocot tissues, which generally are not long-burning fuels. Some caution is required in interpreting the available archaeological evidence as the number of samples is small and they could be affected by variables not well controlled here as, for example, the social status of the occupants, site proximity to certain sources, and the possibility
of specialised oven functions. Nevertheless, in line with the ethnohistoric accounts, a long-term decline in *Thespesia*, and the increasing use of alternative and possibly more costly (*Sapindus*) or less efficient (monocot species) fuels, is suggested and warrants further investigation.

Also of note are some of the potentially useful species that are not represented in the Anaho ovens. Woods selected for fuel are subject to various cultural factors which may not be well known or fully understood. Such factors may explain why several anticipated taxa were not seen in this assemblage. For example, *Cordia subcordata* was only found in small quantities despite its presence in the valley today and its reputation on other Pacific Islands as an excellent source of fuel (Walter *et al.* 2002: 150). Another species not represented, despite being distributed throughout the valley today and commonly used for fuel elsewhere (Elevitch 2006: 513-22), is *Morinda citrifolia*. Further research may ultimately identify why these and other potential fuel species are not represented in the Anaho samples. Some possibilities are sampling biases, limited availability in the past, difficulties in harvesting, or perhaps their importance in ritual or economic activities.

Other woods may not be represented because of physical properties that work against their preservation. Experimental combustion studies using tropical Pacific woods (Orliac and Wattez 1989) demonstrate that the amount of moisture at the time of burning and the nature of the combustion environment can impact on charcoal production and preservation. Some woods burn quickly to ash; *Hibiscus*, as previously mentioned, is a common lowland plant which easily ignites. However, it also tends to burn completely at relatively low temperatures, which may explain why it is so poorly represented in the Anaho features. Other woods may be locally abundant but not well represented in fire features because of their poor burning qualities. Orliac (1997:210) suggested that breadfruit is a poor quality fuel. In his Tahitian study of several thousand charcoal fragments from multiple oven features, he found that breadfruit charcoal was both infrequent and only occurred as twigs, despite trees being well represented in the immediate vicinity of the site.

*      *      *

A growing number of anthracology studies (i.e., studies of archaeological wood charcoal) demonstrate that wood charcoal has the potential to provide information on both Polynesian cultural activities in the prehistoric past and changing Pacific landscapes (e.g., Allen and Murakami 1999, Di Piazza 1998, Kahn and Coil 2006, Lepofsky *et al.* 1996, Millerstrom and Coil 2008, Murakami 1983, Orliac 1997, 2000). Importantly, however, the potential
impacts of formation and post-depositional processes, and analytical decisions about sampling and quantification, need to be considered alongside interpretive potentials. This study examines and attempts to control for some of these biases while also highlighting avenues for future methodological research.

Altogether over 800 fragments of charcoal, a relatively large assemblage by tropical Pacific standards, were identified from seven oven features dispersed throughout Anaho Valley. This assemblage includes samples from both coastal and inland locations over a time span of roughly 200 to 350 years. During this period, residences shifted from a concentration on the coast to a wider dispersal throughout the valley. However, in the features sampled, there was only modest variation in the types of wood used as fuels with two locally available species, *Thespesia populnea* and *Sapindus saponaria*, dominating. The prevalence of these two species, which are high quality fuels, is consistent with the idea that fuels used in the Anaho ovens were the result of selective rather than opportunistic behaviour. While additional samples from both ovens and other contexts are needed to fully evaluate the hypothesis of fuel selectivity, and exclude the possibilities of simple natural abundance and/or formation biases, it cannot be discounted on present evidence. Moreover, these findings are broadly consistent with studies elsewhere in the Pacific (Allen 2005: 52-56, Di Piazza 1998, Fankhauser 1986, Orliac 1997) which also have found a narrow range of species typify archaeological earth oven assemblages. An important corollary of these findings is that earth oven samples in isolation provide a poor basis on which to reconstruct ancient vegetation patterns; charcoal samples from a broader range of fire features and depositional contexts are critical to such an exercise.

The combined archaeological and ethnohistoric evidence also intimate that an important fuel species, *Thespesia populnea*, was reduced over time either through purposeful harvesting or more generally as a result of changes in the local vegetation. As a result, Anaho Valley residents may have travelled further and over more steeply sloping ground to secure another high quality fuel wood, *Sapindus saponaria*, or used alternative sources. This local archaeological trend is echoed in more general ethnohistoric accounts where *Sapindus* is widely documented as a post-contact fuel species, and Linton (1923: 360) lamented the decline of an important carving and craft timber (i.e., *Thespesia*). Human impact on local plant resources is not unexpected given the now well-documented anthropogenic effects on faunal resources and island landscapes (e.g., Kirch and Hunt 1997, Spriggs 1991, Steadman 2006). This study, however, may be the first archaeological analysis to suggest anthropogenic impact(s) on an important Pacific timber species which was once widely used for fuel, utilitarian, ornamental and religious purposes.
ACKNOWLEDGEMENTS

The field studies and radiocarbon dates were supported by grants to Allen from National Geographic Society, Wenner-Gren Foundation for Anthropological Research, Australian Institute of Nuclear Sciences and Engineering, Green Foundation for Polynesian Research, University of Auckland Research Committee and corporate support from Air Tahiti Nui. Hatiheu Mayoress, Yvonne Katupa, is thanked for her on-going support of the Marquesan research programme, and Patricia Frogier, Tamara Maric, Belona Mou, and Teddy Tehei for assistance with permits and collections. The University of Auckland Wood Reference Collection was created by Wallace from material collected from throughout tropical Polynesia. We are particularly grateful to Catherine Orliac and Kevin Butler for many of the French Polynesian reference samples. Jean François Butaud generously shared his knowledge of the Marquesan vegetation, Art Whistler his expertise on Pacific Island trees and ethnobotany, and Emilie Dotte her knowledge of anthracology. Andrew McAlister, Andrea Crown, David Addison, Victoria and Randy Wichman, and Patrick Allen assisted with sample collection and we are indebted to our friends and hosts, the Teikiehuupoko, Vaianui, and Puhetini families. Graphic support was provided by Andrew McAlister, Tim Mackrell, Seline McNamee, Mara Mulrooney, Peter Quin and Briar Sefton. Several photos in Figure 8 appear courtesy of the Smithsonian Institution. Thank you also to two helpful reviewers.

REFERENCES


Allen, M.S. and A. McAlister, in press. The Hakaea site, Marquesan colonisation, and models of East Polynesian settlement. Archaeology in Oceania.


Polynesian Earth Ovens and Their Fuels


Earth ovens are a key component of many traditional Polynesian societies, used by both households and larger community groups for daily and specialised cooking, now and in the past. As repositories of wood charcoal, they potentially offer an opportunity to date prehistoric activities, study cultural practices, and reconstruct the flora of past landscapes. In this study, over 800 fragments of wood charcoal from Anaho Valley, Nuku Hiva Island in the Marquesas Islands were analysed for information on fuel sources, cultural usage patterns, and the prehistoric lowland vegetation. The materials come from seven ovens distributed across the valley and date to two broad time periods: AD 1450-1650 and post-1640. Several methodological issues relevant to wood charcoal analysis are discussed and considered in relation to these assemblages prior to interpretation of the results. Examination of a single functional class of fire features (ovens) allows formation processes to be held relatively constant across the set of samples. Varied quantitative issues are explored, including measures of abundance and variability in sample size. *Thespesia populnea* (Pacific rosewood, *mi’o*) and *Sapindus saponaria* (soapberry, *koku’u*), two native hardwoods, are identified as dominants in this assemblage. This is perhaps not unexpected given that oven stones are heated to high temperatures, and good quality fuel is desirable for this purpose. As a corollary, charcoal derived from oven features is likely to offer an incomplete view of past vegetation, although it may reflect the dominant local vegetation. Finally, joint consideration of ethnohistoric and archaeological evidence suggests the possibility that anthropogenic impacts led to declines in an important economic species, *Thespesia populnea*.

**Keywords:** Wood charcoal, earth ovens, fuel wood, anthropogenic impacts, anthracology, Polynesia.
New Editions of

THE OLDMAN CATALOGUE OF MAORI ARTIFACTS and

THE OLDMAN CATALOGUE OF POLYNESIAN ARTIFACTS

The catalogues originally prepared by W.O. Oldman, the collector, and published and then reprinted by The Polynesian Society as Memoirs 14 and 15 have long been out-of-print. The original texts and plates of the new editions have been enhanced and corrected while retaining the flavour of the original. An introductory essay and finder-list have been added by Roger Neich and Janet Davidson. The volumes not only provide an overview of the collection, but also include essays on the history of the collections and listings of the items by their present location.

Available from:
The Polynesian Society,
c/- Māori Studies, The University of Auckland,
Private Bag 92019, Auckland. Email: jps@auckland.ac.nz

The catalogue illustrates and describes the Maori artifacts purchased by the New Zealand Government in 1948 from W.O. Oldman, arguably the foremost British collector of Oceanic artifacts in the late 19th and early 20th centuries. Most of the Māori items are now in the Museum of New Zealand/Te Papa Tongarewa in Wellington, but a substantial number are located in other New Zealand museums.
NZ $30 plus postage and packing

The catalogue illustrates and describes the Polynesian artifacts purchased by the New Zealand Government in 1948 from W.O. Oldman, arguably the foremost British collector of Oceanic artifacts in the late 19th and early 20th centuries. Most items in the collection were divided between the four major New Zealand museums (Wellington, Auckland, Canterbury and Otago), but a substantial number were allotted to provincial museums.
NZ $35 plus postage and packing
ISBN: 0-908940-06-8