Changing Patterns of Firewood Use on the Waimānalo Plain*

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Thomas S. Dye Carl E. Sholin

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Abstract

Wood charcoal identifications from 35 dated traditional Hawaiian fire-pits on the Waimānalo Plain are analyzed for evidence of change over time and difference across space. Plant taxa identified in the firewood are classified according to habit, origin, and elevational distribution. Early in traditional Hawaiian times, firewood was commonly brought to the plain from inland forests and fires were made primarily with native plants. Later, firewood was more likely to be collected locally, and it typically included both Polynesian-introduced and native plants. This change in behavior appears to have taken place in the fifteenth century. It was likely associated with a vegetational change in which the native lowland forest was replaced with a variety of useful plants, especially near Puhā Stream.

1 Introduction

Wood charcoal is ubiquitous in the archaeological record of traditional Hawai'i. It occurs as pieces of various sizes in the general matrix of almost all cultural deposits, where it is largely responsible for their diagnostic dark color. Most of the charcoal pieces in the general matrix are too small to be confidently isolated by eye or identified to taxon microscopically, but most deposits contain some larger pieces of wood charcoal in the general matrix that can be isolated and identified to taxon. This exercise is not particularly useful, however, because the event that produced a piece of wood charcoal deposited in the general matrix typically can't be identified. More useful for archaeological analysis is the wood charcoal recovered from features, such as *fire-pits*, that can be confidently identified as archaeological events. Not only are certain behavioral

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inferences relatively straightforward because the identified taxa are associated with a particular event, rather than a long-term process, but the event itself can be located precisely in space, and pieces identified as short-lived are suitable for dating with the ^{14}C method so the age of the archaeological event can typically be estimated with some confidence.

The analysis presented here is based on wood charcoal identifications from 35 fire-pits excavated over the last 15 years from four *site*s on the Waimānalo Plain. The wood charcoal in the fire-pits was initially identified so that *suitable dating material* could be selected (Dye and Pantaleo 2010). In addition to their use in dating, the wood charcoal identifications from the fire-pits are useful as a basis for inferences about changing patterns of behavior in traditional Hawai‘i. This focus on changing behavior differs from much of the recent literature on what has come to be called anthracology, which is primarily concerned with palaeoenvironmental investigation and using wood charcoal to reconstruct vegetation patterns at different times in the past (Scott and Damblon 2010; Allen and Murakami 1999; Huebert et al. 2010; Orliac 2000). The *synchronic* palaeoenvironmental goal of much anthracological work has led researchers to develop methods different from those used on the Waimānalo Plain (Théry-Parisot et al. 2010). Where anthracologists often collect charcoal from the general matrix in the hope of minimizing the effect of cultural selection (e.g., Orliac 2000), the work reported here uses only wood from short-term burning events because it emphasizes cultural selection at a particular point in time. Where anthracologists worry about the combustion process preserving woods differentially and distorting their representation in the assemblage (e.g., Huebert et al. 2010), the work reported here assumes that the combustion properties of the different kinds of firewood remained constant over the period of investigation, so that changes over time in the representation of a firewood taxon is indicative of behavioral changes rather than changes in the combustion qualities of wood.

The analysis of the wood charcoal from the fire-pits is carried out within the framework of a cognitive model for artifact analysis that divides the analytic process into three stages, named *acquisition*, *structuration*, and *reconstitution* (Djindjian 2001).

2 Acquisition of Materials

In the first stage of the analysis, the fundamental qualities inherent in the object of study are acquired. These fundamental qualities are what they are, regardless of what or how we think about them. They are the basic data, reported in the finest possible units of identification, location, and age so that others might find them maximally useful. Here, these fundamental qualities include the analyzed fire-pits, the wood charcoal identified from each of the fire-pits, and the conventional ^{14}C ages of the fire-pit use events.

The 35 dated fire-pits for which detailed wood charcoal identifications have been carried out were discovered over the last decade and a half during archaeological monitoring of construction excavations, subsurface inventory survey with a backhoe, and controlled archaeological data recovery excavations (table 1), all carried out in the context of cultural resources management at Bellows Air Force Station. Fire-pits discovered during

monitoring and inventory survey with a backhoe are typically recovered by excavating into the face of an open trench. In contrast, fire-pits discovered during data recovery are typically recognized at the base of a cultural deposit where their dark color contrasts strongly with the light-colored calcareous *sand* that represents the basal deposit of sites on the Waimānalo Plain. Typically, the entire plan of the fire-pit is exposed before materials are collected from it. In both cases, where the fire-pit is excavated out of the side wall of a trench and where it is excavated in plan, only a portion of the fire-pit *fill* is recovered. During archaeological monitoring and inventory survey with a backhoe a portion of the fire-pit is destroyed in the discovery process and in the case of data recovery excavations the top of the fire-pit is typically indistinguishable from the general cultural deposit and material is only recovered from the base of the fire-pit that extends below the general cultural deposit.

The analyzed fire-pits are all located on land used today for Bellows Air Force Station at the northern end of the Waimānalo Plain (fig. 1). Nineteen of the fire-pits were discovered in Sites 50–80–15–4851 and –4853, which flank Puhā (Waimānalo) Stream. The other 16 fire-pits were discovered at Sites 50–80–15–4856 and –4857 at the very northern end of the plain about 1.2 km from the stream. All of the analyzed fire-pits are located inland of the deepest and richest cultural deposits on the plain (see Dye and Pantaleo 2010:fig. 2). The reason for this is that the deep and rich coastal deposits were typically reworked so thoroughly by traditional Hawaiian habitation activities that it is difficult to identify and isolate charcoal associated with particular fire-pit use events (McElroy et al. 2006). Thus, the 35 analyzed fire-pits might yield an incomplete picture of traditional Hawaiian settlement on the Waimānalo Plain, one that focuses on events removed a short distance inland from the coastal settlement core immediately inland of the beach.

The wood charcoal from the fire-pits was identified by Gail Murakami at the International Archaeological Research Institute's Wood Identification Laboratory. Murakami identified wood charcoal pieces to taxon by comparing anatomical characteristics preserved in the charcoal with a reference collection of Hawaiian woods. Identified wood charcoal from each of the fire-pits is listed in the appendix. The sizes of the charcoal samples from the fire-pits varied considerably. The number of identified specimens ranges from 19 at fire-pit 900_2 to 3,049 at fire-pit 900_16, with a median of 121. Weights of identified specimens ranges from 0.29 g (gram) at fire-pit 900_21 to 93.85 g at fire-pit 900_16, with a median of 4.18 g. The *richness* of the samples varied, as well, from the single taxon identified at fire-pit 900_1 to the 24 taxa identified at fire-pit 900_18. Eight taxa were identified in the sample with median richness.

The number of specimens identified for each taxon ranges from 2 to 4,463. The most commonly identified taxon, by far, is *kukui*, *A. moluccana*, which typically appears in the fire-pits as charred nutshells but also as wood charcoal. One reason for the large number of identified specimens is that the nutshell is distinctive and easily identified. If it is present in a sample, then it is certainly identified and counted. However, the main reason for the large number of identified *kukui* specimens is fire-pit 900_16 (table 1), a feature that yielded an unusual charcoal collection in which 2,988 *kukui* nutshell pieces were identified. Next in abundance are three native plants probably used as kindling, *ʻilima*,

Table 1: Dated fire-pits on the Waimānalo Plain

Label	Site	Feature	Reference
119_7	50–80–15–4857	Context 7 fire-pit	Dye and Dye (2009)
119_16	50–80–15–4857	Context 16 fire-pit	Dye and Dye (2009)
273_58	50–80–15–4856	Context 58 fire-pit	Sholin et al. (2012)
308_159	50–80–15–4856	Context 89 fire-pit	Dye et al. (2012)
308_163	50–80–15–4856	Context 99 fire-pit	Dye et al. (2012)
308_175	50–80–15–4856	Context 95 fire-pit	Dye et al. (2012)
308_180	50–80–15–4856	Context 93 fire-pit	Dye et al. (2012)
900_1	50–80–11–4856	Feature 12	Lebo et al. (2009)
900_2	50–80–11–4856	Feature 17	Lebo et al. (2009)
900_3	50–80–11–4856	Feature 10	Lebo et al. (2009)
900_4	50–80–11–4856	Feature 5	Lebo et al. (2009)
900_5	50–80–11–4856	Feature 9	Lebo et al. (2009)
900_6	50–80–11–4856	Feature 4	Lebo et al. (2009)
900_7	50–80–11–4856	Feature 23	Lebo et al. (2009)
900_8	50–80–11–4856	Feature 22	Lebo et al. (2009)
900_9	50–80–15–4853	Feature 1	Desilets and Dye (2002:111)
900_10	50–80–15–4853	Feature 5	Desilets and Dye (2002:162)
900_11	50–80–15–4853	Feature 9	Desilets and Dye (2002:166)
900_12	50–80–15–4853	Feature 13	Desilets and Dye (2002:133)
900_13	50–80–15–4853	Feature 15	Desilets and Dye (2002:137)
900_14	50–80–15–4853	Feature 16	Desilets and Dye (2002:138)
900_15	50–80–15–4853	Feature 17	Desilets and Dye (2002:140)
900_16	50–80–15–4853	Feature 18	Desilets and Dye (2002:142)
900_17	50–80–15–4853	Feature 19	Desilets and Dye (2002:144)
900_18	50–80–15–4853	Feature 20	Desilets and Dye (2002:122)
900_19	50–80–15–4853	Feature 24	Desilets and Dye (2002:99)
900_20	50–80–15–4853	Feature 25	Desilets and Dye (2002:101)
900_21	50–80–15–4853	Unit BT-5, Feature 6	Addison (1997)
900_22	50–80–15–4853	Unit BT-23, Feature 9	Addison (1997)
900_23	50–80–15–4853	Unit BT-23, Feature 10	Addison (1997)
900_25	50–80–15–4853	Trench 5, Feature 1	Dye (1998)
900_26	50–80–15–4851	Trench 4, Feature 3	Dye (1998)
900_27	50–80–15–4851	Trench 4, Feature 2	Dye (1998)
900_28	50–80–15–4851	Trench 4, Feature 1	Dye (1998)
900_29	50–80–11–4856	Feature 22	Putzi and Dye (2005)

ʻakoko, and *ʻūlei*. The identified ki consists of wood charcoal and charred roots, the latter of which might be remains of food prepared in the fire-pit rather than a firewood. The most common firewoods are *ʻōhiʻa ʻai*, a Polynesian introduction, and five native trees: *hame*, *hao*, *lama*, *hau*, and *ʻōhiʻa lehua*.

Table 2: Summary of identified wood charcoal taxa

Taxon	Name	Habit	Origin	Low range*	Count
Aleurites moluccana	*kukui*	tree	Polynesian introduction	1	4463
unidentified		?	?	0	907

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Table 2: Summary of identified wood charcoal taxa

Taxon	Name	Habit	Origin	Low range*	Count
Sida fallax	*ʻilima*	shrub	native	1	708
Monocotyledonae		?	?	nil	612
Chamaesyce sp.	*ʻakoko*	shrub-tree	native	1	554
Osteomeles anthyllidifolia	*ʻūlei*	shrub	native	2	258
Cordyline fruticosa	*ki*	shrub	Polynesian introduction	5	234
Syzygium malaccense	*ʻōhiʻa ʻai*	tree	Polynesian introduction	200	229
Antidesma pulvinatum	*hame*	tree	native	30	224
Rauvolfia sandwicensis	*hao*	tree	native	100	204
Diospyros sandwicensis	*lama*	tree	native	5	197
Chenopodium oahuense	*ʻāheahea*	shrub-tree	native	1	195
Hibiscus tiliaceus	*hau*	shrub-tree	native	1	176
Metrosideros polymorpha	*ʻōhiʻa lehua*	tree	native	1	100
Abutilon sp.		shrub	native	1	98
Bobea sp.	*ʻahakea*	tree	native	100	85
Colubrina oppositifolia	*kauila*	tree	native	240	80
Canthium odoratum	*alaheʻe*	shrub-tree	native	10	73
Bidens sp.	*koʻokoʻolau*	shrub	native	1	70
Dodonaea viscosa	*ʻaʻaliʻi*	shrub-tree	native	3	69
Poaceae		grass	?	nil	50
Artocarpus altilis	*ʻulu*	tree	Polynesian introduction	0	48
Hedyotis terminalis	*manono*	shrub-tree	native	260	46
Saccharum officinarum	*kō*	grass	Polynesian introduction	0	34
Nestegis sandwicensis	*olopua*	tree	native	30	33
Acacia koa	*koa*	tree	native	60	29
Nothocestrum latifolium	*ʻaiea*	tree	native	460	27
latin{Gossypium tomentosum}	*maʻo*	shrub	native	1	22
Cocos nucifera	*niu*	tree	Polynesian introduction	1	21
Gossypium tomentosum	*maʻo*	shrub	native	1	19
Pittosporum sp.	*hōʻawa*	tree	native	150	15
Charpentiera sp.	*pāpala*	tree	native	110	12
Myoporum sandwicense	*naio*	tree	native	1	12
Palm sp.		tree	?	nil	12
Nototrichium sp.	*kuluʻī*	shrub-tree	native	1	11
Psychotria sp.	*kōpiko*	tree	native	15	9
Pandanus tectorius	*hala*	tree	native	1	8
Cheirodendron sp.	*ʻōlapa*	tree	native	310	5
Pteridophyta		fern	?	0	5
Wikstroemia sp.	*ʻākia*	shrub-tree	native	3	5
Scaevola sericea	*naupaka*	shrub	native	1	5
Pinus sp.		tree	alien	0	5
Myrsine sp.	*kōlea*	shrub-tree	native	215	3
Ilex anomala	*kāwaʻu*	tree	native	50	3
Pteridophyta		fern	?	0	2
Lagenaria siceraria		vine	Polynesian introduction	0	2

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Table 2: Summary of identified wood charcoal taxa

Taxon	Name	Habit	Origin	Low range*	Count
Senna sp.		tree	?	5	2
Hibiscus sp.	*aloalo*	shrub	native	70	2

* Elevation in meters above mean sea level.

The conventional ^{14}C ages of the 35 fire-pits are listed in table 3 and illustrated graphically in figure 2, which displays a panel for fire-pits at the northern end of the Waimānalo Plain near the boundary with Kailua Ahupua‘a and another panel for fire-pits near Puhā Stream. In the past, a failure to correct for the potential effects of *in-built age* by dating pieces of unidentified wood charcoal has yielded dates that are not archaeologically interpretable (Dye and Pantaleo 2010; Dye 2000). In contrast, the 35 fire-pit use events have been dated relatively precisely using identified, short-lived taxa to minimize in-built age. The dates returned by the dating laboratory range from 30 ± 60 at fire-pit 900_21 to 720 ± 4 at fire-pit 900_22. Three fire-pits returned median dates: fire-pit 900_14 with a date of 310 ± 60, fire-pit 900_26 with a date of 310 ± 40, and fire-pit 308_175 with a date of 310 ± 30.

3 Structuration

The second stage of the analysis, called structuration, refers to an *abstraction of a quality*, which is then used to classify and/or measure the acquired materials. In the present case, identification of wood charcoal to botanical taxon during the acquisition stage makes it possible to classify the materials based on qualities of the taxa observed by botanists. The particular qualities used in this analysis are *habit*, *origin*, and *elevational distribution*. These qualities and the classifications based on them are described below, followed by a series of maps and graphs that show their distribution over space and time.

3.1 Firewood Habit

Botanists use the term *habit* to describe the general appearance, growth form, or architecture of a plant. The classification used here assigns the identified taxa to one of six habits: tree, shrub-tree, shrub, vine, grass, or fern. Trees are perennial woody plants with a single main stem, or trunk, typically taller than 5–6 m (meter) at maturity. Shrubs have multiple stems and are shorter than trees, typically under 5–6 m. Shrub-trees are plants whose form can take on the characteristics of either a shrub or a tree. A vine is a plant with a climbing stem or runners. Grasses are plants with narrow leaves that grow from the base. Fern is not technically a habit, but refers instead to plants that have stems, leaves, and roots, but have neither seeds nor flowers. Ferns in Hawai‘i are typically low plants the size of shrubs. The wood charcoal identified in the fire-pits includes 23 taxa classified as trees, nine as shrub-trees, nine as shrubs, two as grasses, two as ferns and one as a vine. Two taxa were identified to a general level not diagnostic of habit.

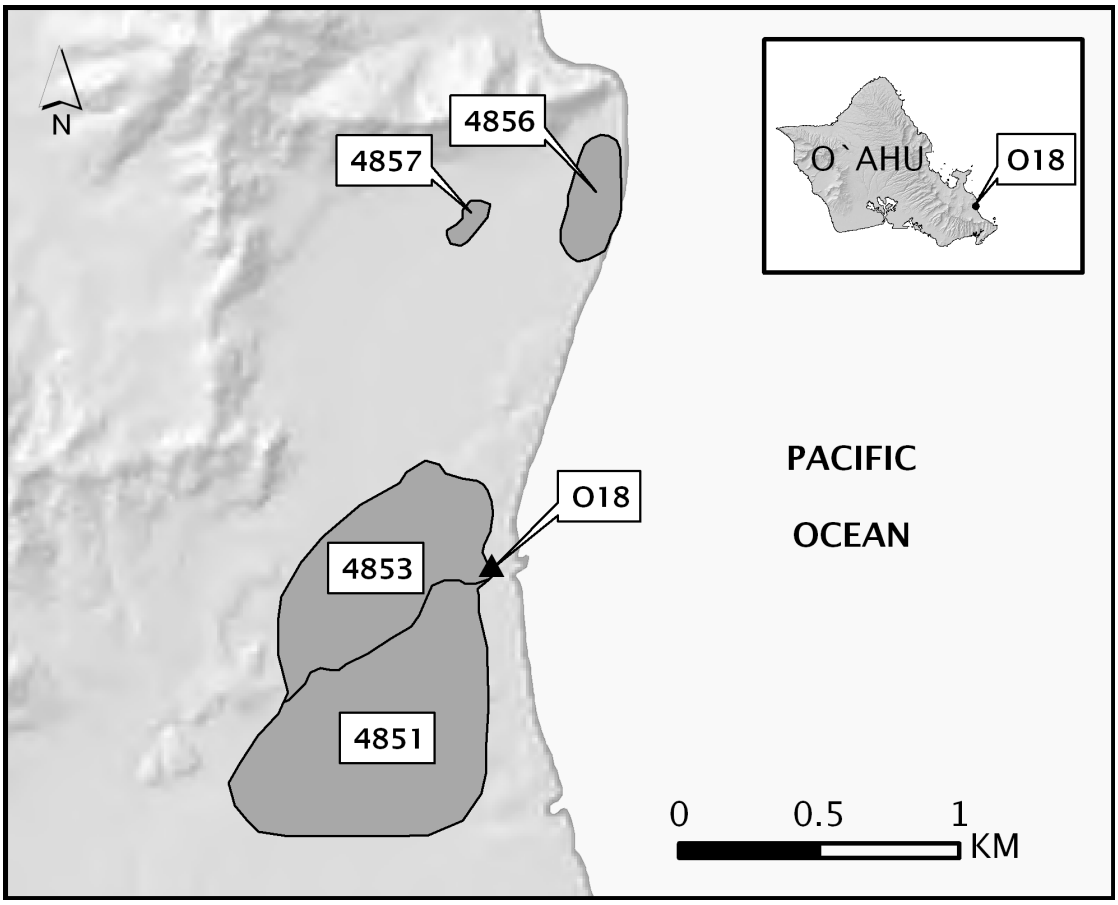

Figure 1: Locations of sites on the Waimānalo Plain.

A plot of the proportion of tree wood charcoal against fire-pit age shows a weak decline over time (fig. 3). This result is similar to the one reported by Dye (2010), which was based on the weight of identified charcoal, rather than the number of identified specimens, and included information from the 26 dated fire-pits available at the time.

Maps showing the proportion of tree wood charcoal in the fire-pits (fig. 4) show that tree wood charcoal is more common in fire-pits near the stream than it is in fire-pits at the northern end of the plain. Most of the fire-pits at the northern end of the plain were fueled with shrubs and shrub-trees; fire-pits with tree firewood are in the minority. In contrast, near Puhā Stream most of the fire-pits were fueled with some tree firewood and fire-pits that lack tree firewood are in the minority.

3.2 Locally-Collected Firewood

Botanists have also mapped the distributions of plants on the modern landscape, thereby establishing elevational ranges for them (Wagner et al. 1990). Given an accurate topo-

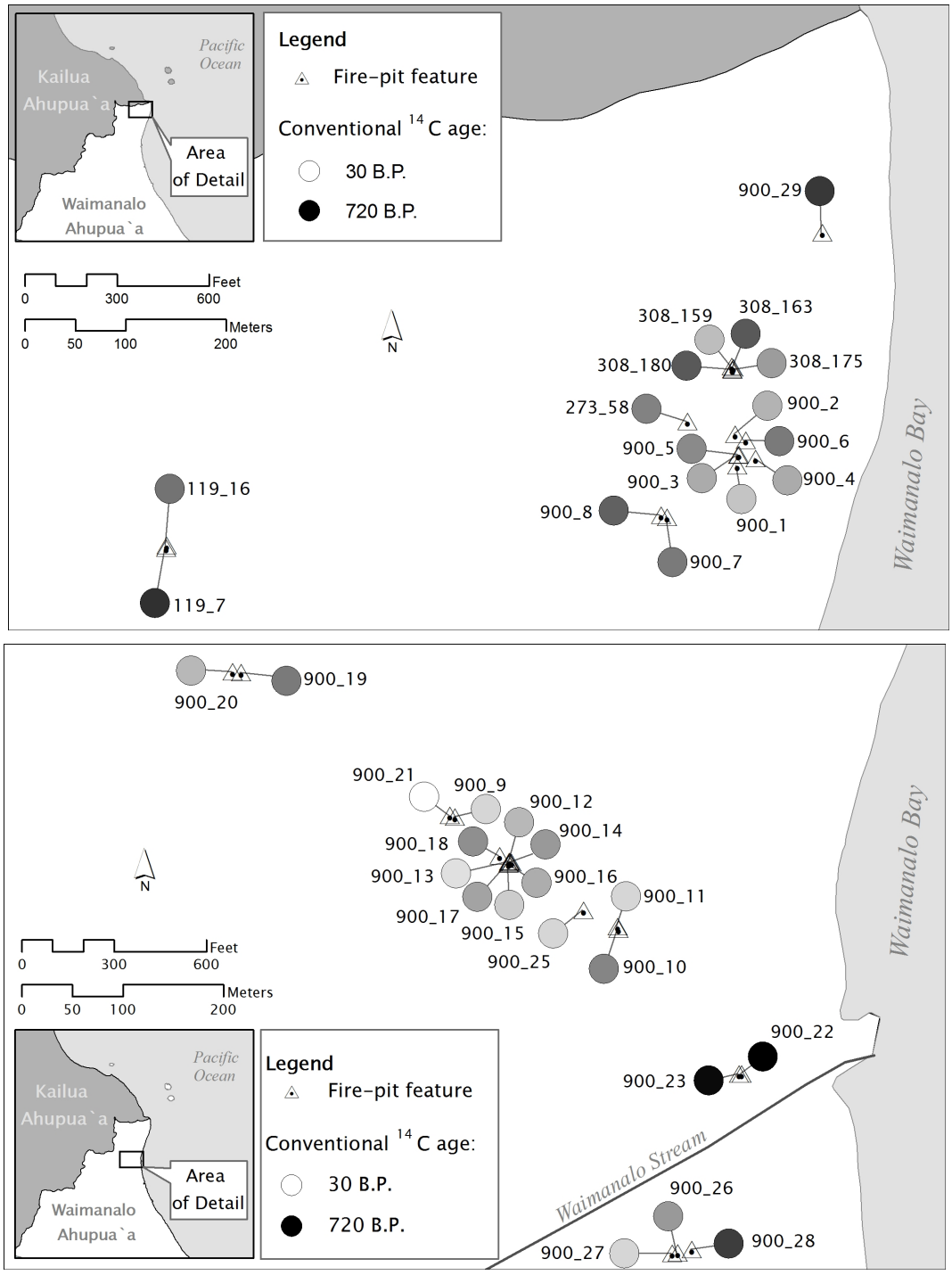

Figure 2: Conventional ^{14}C ages of fire-pits based on dates from short-lived taxa. See table 1 for the fire-pit labels and table 3 for ^{14}C dates. Note that the ^{14}C age is represented on a continuous gray scale, only the endpoints of which are shown in the legend.

Table 3: ^{14}C age determinations

Label	Laboratory #	^{14}C age
119_7	Beta-260904	580 ± 40
119_16	Beta-260905	400 ± 40
273_58	Beta-307650	370 ± 30
308_159	Beta-307651	220 ± 30
308_163	Beta-307654	470 ± 30
308_175	Beta-307653	310 ± 30
308_180	Beta-307652	470 ± 30
900_1	Beta-251242	200 ± 40
900_2	Beta-251246	240 ± 40
900_3	Beta-251244	250 ± 40
900_4	Beta-251245	260 ± 40
900_5	Beta-251243	350 ± 40
900_6	Beta-246786	380 ± 40
900_7	Beta-251248	390 ± 40
900_8	Beta-251247	450 ± 40
900_9	Beta-120317	140 ± 50
900_10	Beta-120318	150 ± 50
900_11	Beta-120319	350 ± 80
900_12	Beta-120320	230 ± 50
900_13	Beta-120321	110 ± 70
900_14	Beta-120322	310 ± 60
900_15	Beta-120323	170 ± 60
900_16	Beta-120324	250 ± 50
900_17	Beta-120325	270 ± 70
900_18	Beta-120326	330 ± 60
900_19	Beta-120327	400 ± 70
900_20	Beta-120328	220 ± 50
900_21	Beta-101869	30 ± 60
900_22	Beta-101871	720 ± 40
900_23	Beta-101872	680 ± 40
900_25	Beta-111022	150 ± 40
900_26	Beta-111023	310 ± 40
900_27	Beta-111024	140 ± 60
900_28	Beta-111025	540 ± 50
900_29	Beta-200230	550 ± 40

graphic model of O‘ahu Island, and assuming that the firewood identified in the wood charcoal was not imported from another island, the elevational data can be used as the basis for inferences about the firewood catchment area for each fire-pit. The lower bound

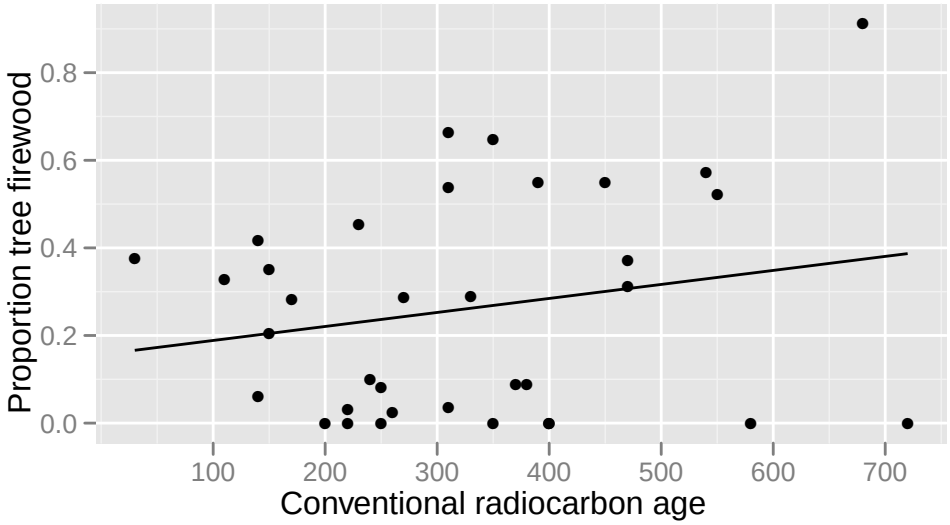

Figure 3: Proportion of tree wood charcoal over time.

of the observed elevational range for each identified taxon is also shown in table 2. Most of the plants identified in the fire-pits can be found today at elevations similar to the Waimānalo Plain which ranges from sea level to about 10 m above sea level. Thirty-two of the 48 identified taxa have lower elevational bounds in this range. Another ten taxa grow down to 10–150 m and thus might have been found in the Keolu Hills adjacent to the Waimānalo Plain. Six taxa are found today only at elevations greater than 150 m and these taxa must have come to the sites from more distant locations, the nearest of which would be the slopes of the Koʻolau range that mark the *mauka* boundary of Waimānalo Ahupuaʻa.

When the proportion of identified taxa with lower elevational bounds less than 10 m is plotted against the ^{14}C age of the fire-pit a clear pattern emerges in which the proportion of locally-collected firewood increases over time (fig. 5). Before 400 BP, fires made solely with locally-collected firewood were relatively rare and firewoods collected from the Keolu Hills and beyond were commonly brought to the plain. After 400 BP it became common to fuel fires using locally-collected firewood and both the frequency and amount of firewood imported to the plain appears to have declined.

When the proportion of locally-collected firewood is plotted on a map of fire-pit locations (fig. 6) it can be seen that there is no clear geographic pattern. Fire-pits fueled with a high proportion of locally-collected firewood are found near Puhā Stream and at the northern end of the plain. Similarly, fire-pits that burned relatively high proportions of non-local firewood are found in both places. These include fire-pits 900_9, 900_14, 900_23, and 900_28 near Puhā Stream and fire-pits 119_7, 273_58, 308_175, 308_180 and 900_209 at the northern end of the plain.

Perhaps the strongest evidence for a local origin of firewoods comes from the spatial

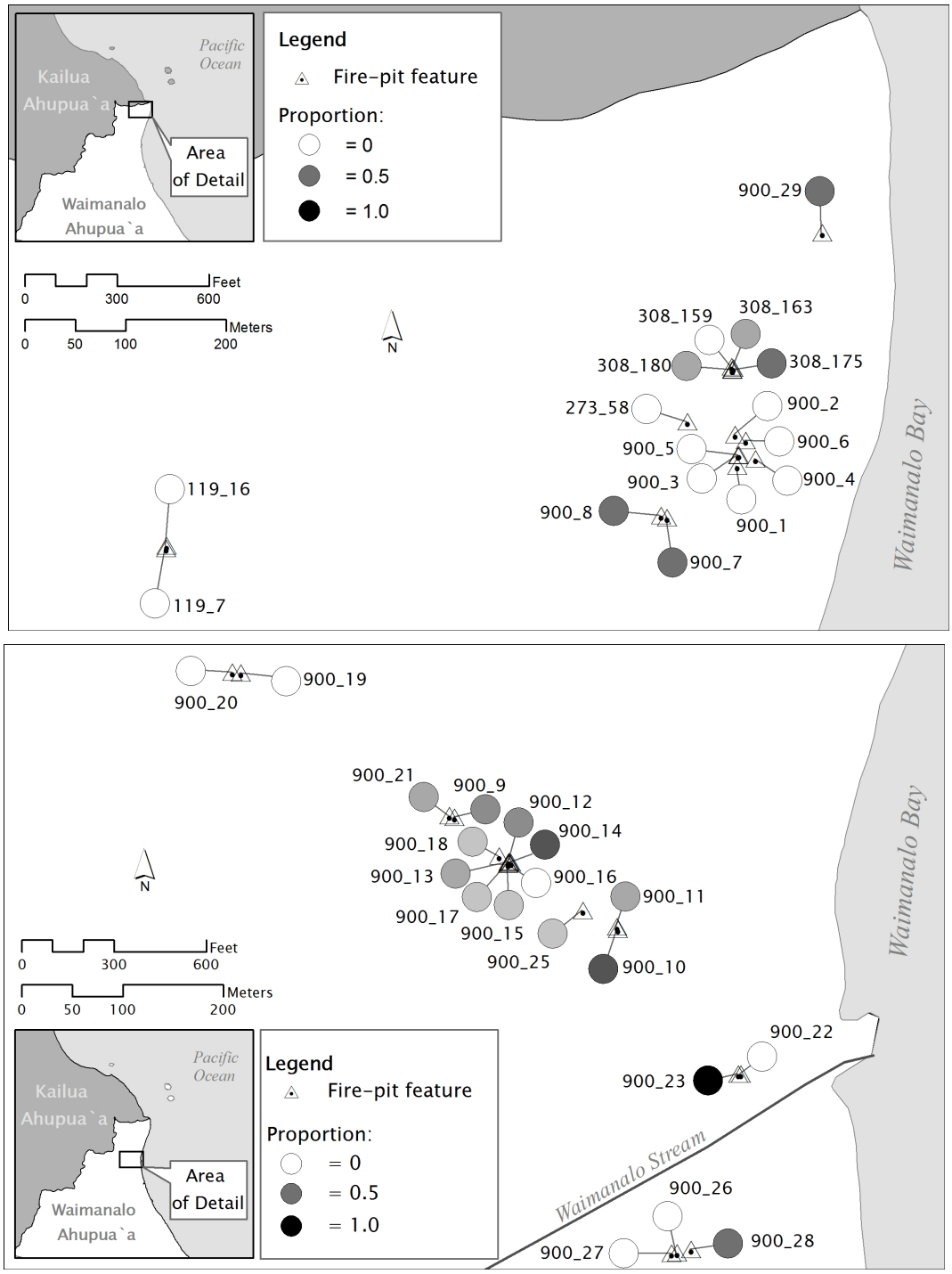

Figure 4: Proportion of identified wood charcoal from trees. See table 1 for the fire-pit labels. Note that proportion is represented on a continuous gray scale, only three values of which are shown in the legend.

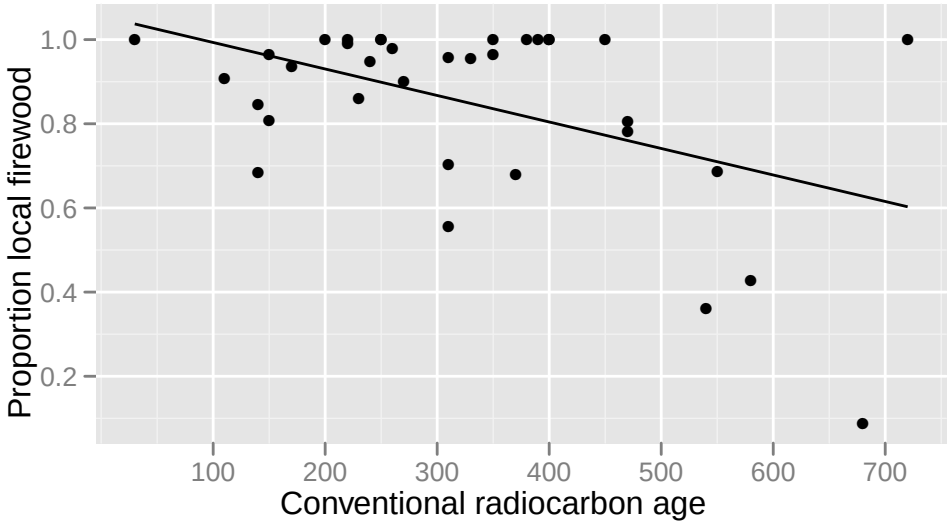

Figure 5: Proportion of locally-collected firewood over time.

distribution of *hau*. The *hau* tree, which today grows thickly along the banks of Puhā Stream, is found almost exclusively in fire-pits near the stream (fig. 7). Twelve of the 19 fire-pits close to the stream yielded pieces of *hau* wood charcoal. In contrast, only one of the 16 fire-pits at the northern end of the Waimānalo Plain, fire-pit 308_175, yielded *hau* wood charcoal. This evidence suggests that the catchment area for firewoods is typically small, within a few minutes walk of the fire-pit.

3.3 Polynesian Introductions Used as Firewood

The identified taxa can also be distinguished by the *origin* of the plant. The recovered materials include thirty-four native plants that botanists believe to be endemic or indigenous to the islands. Seven of the taxa are Polynesian introductions that on present archaeological evidence were brought to the islands from the Eastern Polynesian homeland over a period of three or four centuries (Dye 2011). The Polynesian introductions in the fire-wood charcoal include: i) the candlenut tree, *kukui*; ii) ti plant, *ki*; iii) breadfruit tree, *ʻulu*; iv) *mountain apple* tree, *ʻōhiʻa ʻai*; v) *coconut* palm, *niu*; vi) sugar cane, *kō*; and vii) bottle gourd, *ʻipu*. Pine wood is the lone alien taxon identified in the material from the fire-pits. It likely represents driftwood from the northwest coast of America (Strong and Skolmen 1963) that washed up on the beach near Site 50–80–15–4853, where the pine wood charcoal was recovered.

A plot of the proportion of Polynesian-introduced taxa against the ^{14}C age of the fire-pit indicates that the use of Polynesian-introduced taxa as firewood increased over time (fig. 8). Here, the proportion of Polynesian-introduced taxa is based on specimens identified as wood and excludes the nutshells of *kukui*. Before 400 BP, Polynesian-

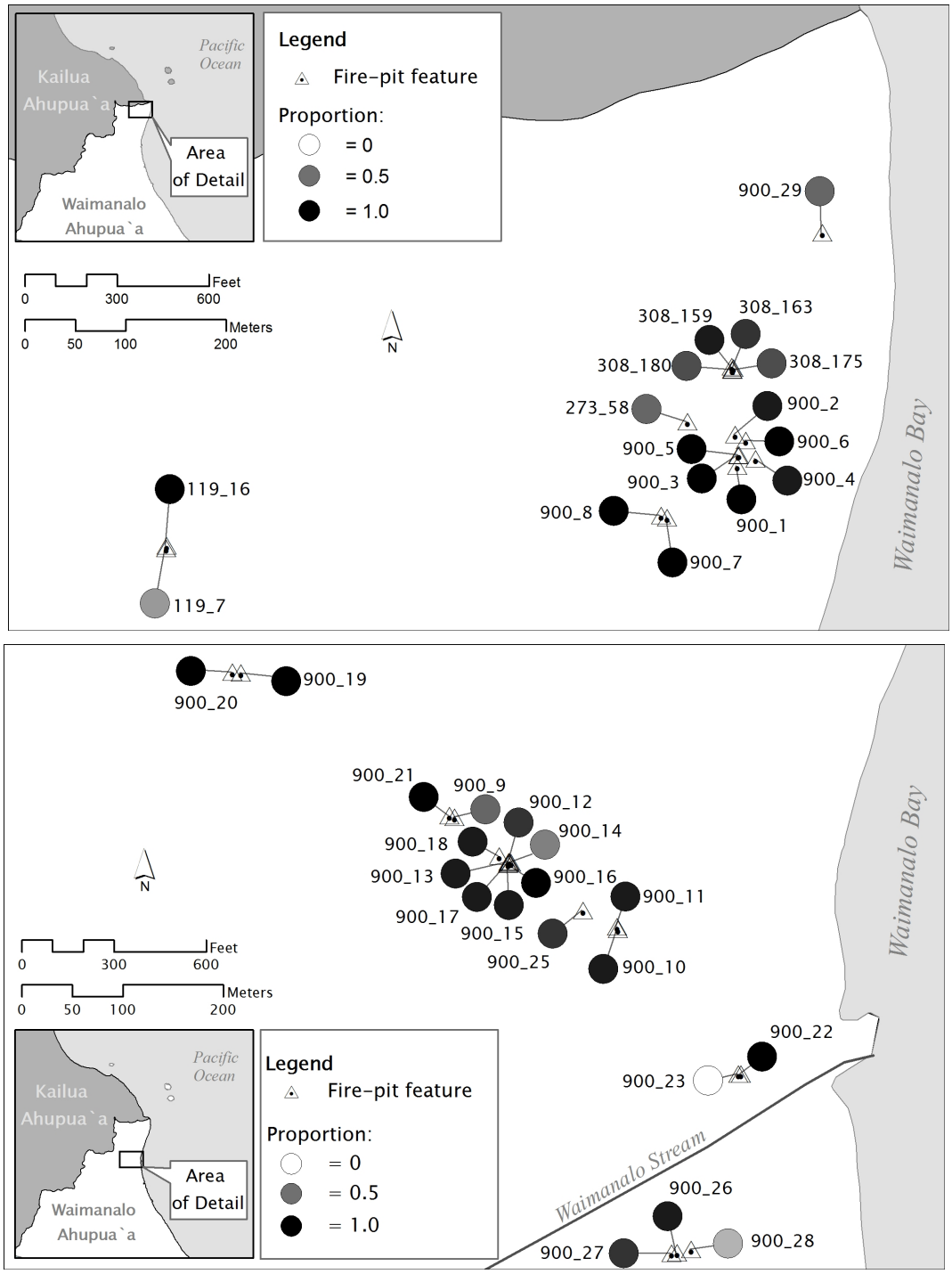

Figure 6: Proportion of identified wood charcoal collected locally near the fire-pit. See table 1 for the fire-pit labels. Note that proportion is represented on a continuous gray scale, only three values of which are shown in the legend.

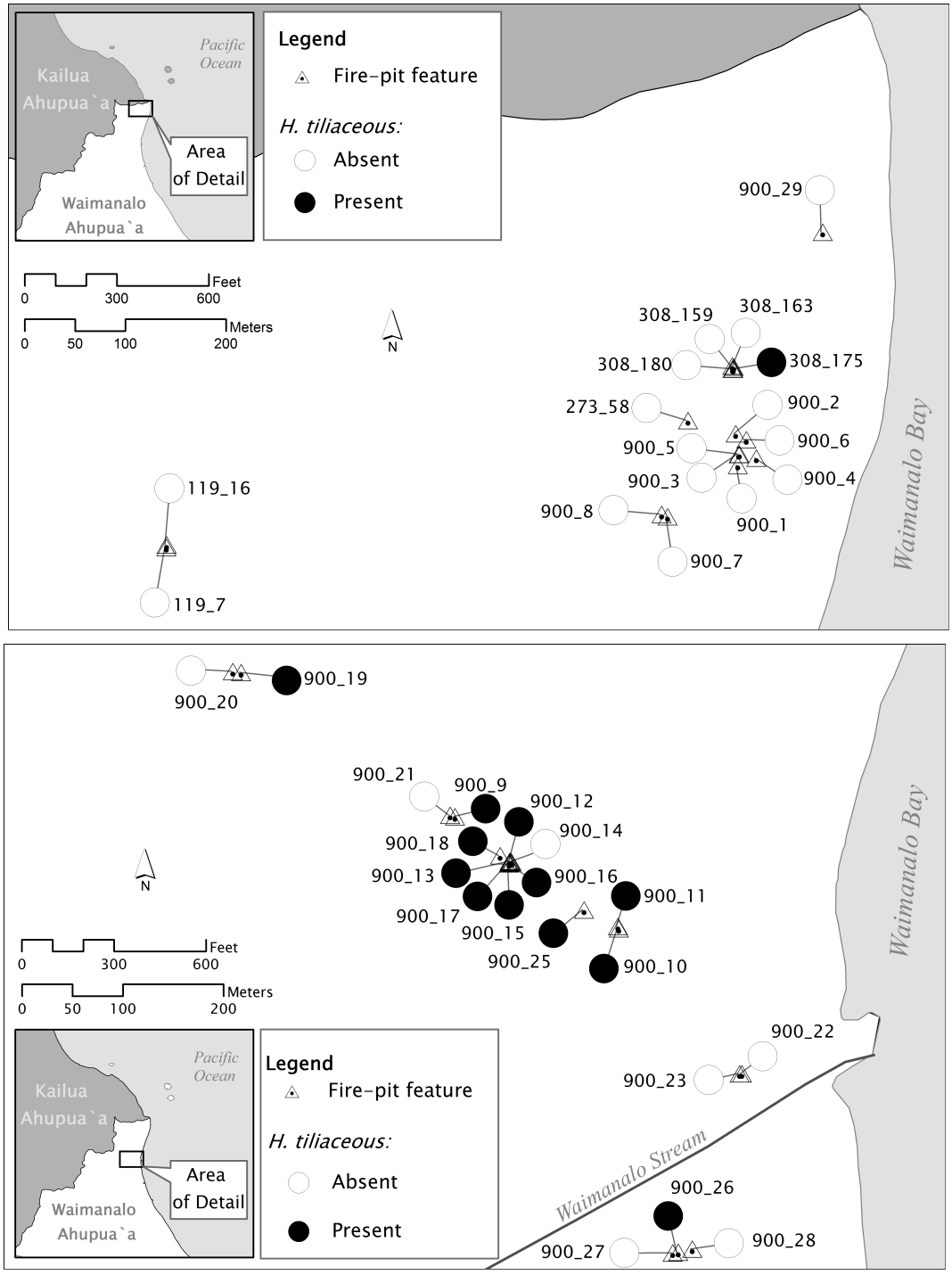

Figure 7: Distribution of *hau*, *Hibiscus tiliaceous*, wood charcoal. See table 1 on page 4 for the fire-pit labels.

introduced taxa were relatively rare in the fire-pits, typically less than 10 percent of the identified specimens. Afer 400 BP, wood from Polynesian introductions frequently made up the majority of identified firewood.

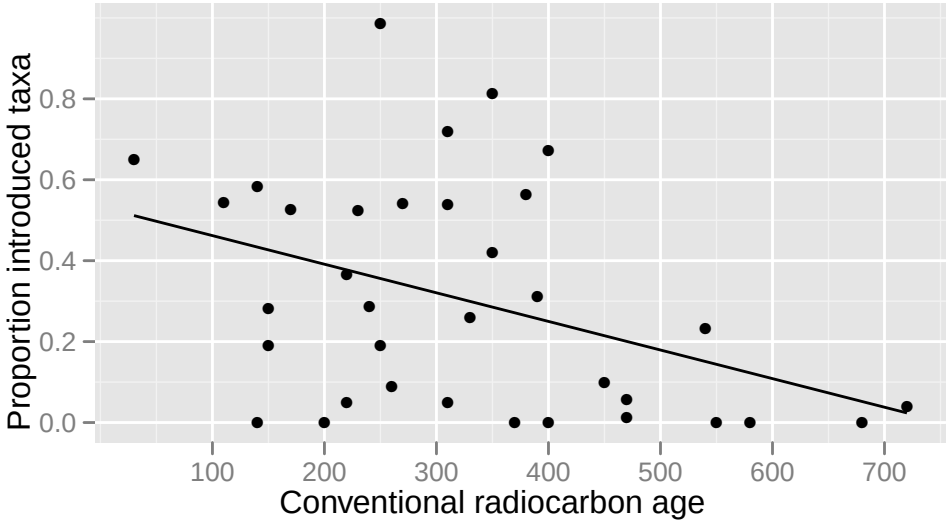

Figure 8: Proportion of Polynesian introductions over time.

When the proportion of Polynesian-introduced taxa is plotted on a map of fire-pit locations (fig. 9) a clear geographic pattern emerges. Most of the fire-pits near the stream yield relatively high proportions of Polynesian-introduced taxa. In contrast, fire-pits at the northern end of the plain are typically fueled primarily with native taxa and the incidence of Polynesian-introduced taxa is relatively rare.

4 Reconstitution

The final stage of analysis, called reconstitution, refers to a reason behind the structuration that inheres in the relationship between the results of acquisition and some phenomenon outside the acquired materials. The outside phenomenon might be a scientific law, or an historical explanation based on human intention and motivation. The goal of the reconstitution presented here is to propose changing patterns of behavior to account for the observed structure in the data and to situate these within the context of traditional Hawaiian social organization.

In a recent article, Dye (2010) compared the firewoods identified in fire-pits on the Waimānalo Plain with firewood identified from fire-pits on the elite Maui Island sites of Hale Kiʻi and Pihana Heiau (Kolb and Murakami 1994). Dye found that fire-pits on the Waimānalo Plain relied on shrubs and shrub-trees for firewood more than did the fire-pits from the elite Maui Island sites, which were rich in tree wood charcoal. He plotted the proportion of tree wood charcoal over time in the Waimānalo Plain fire-pits

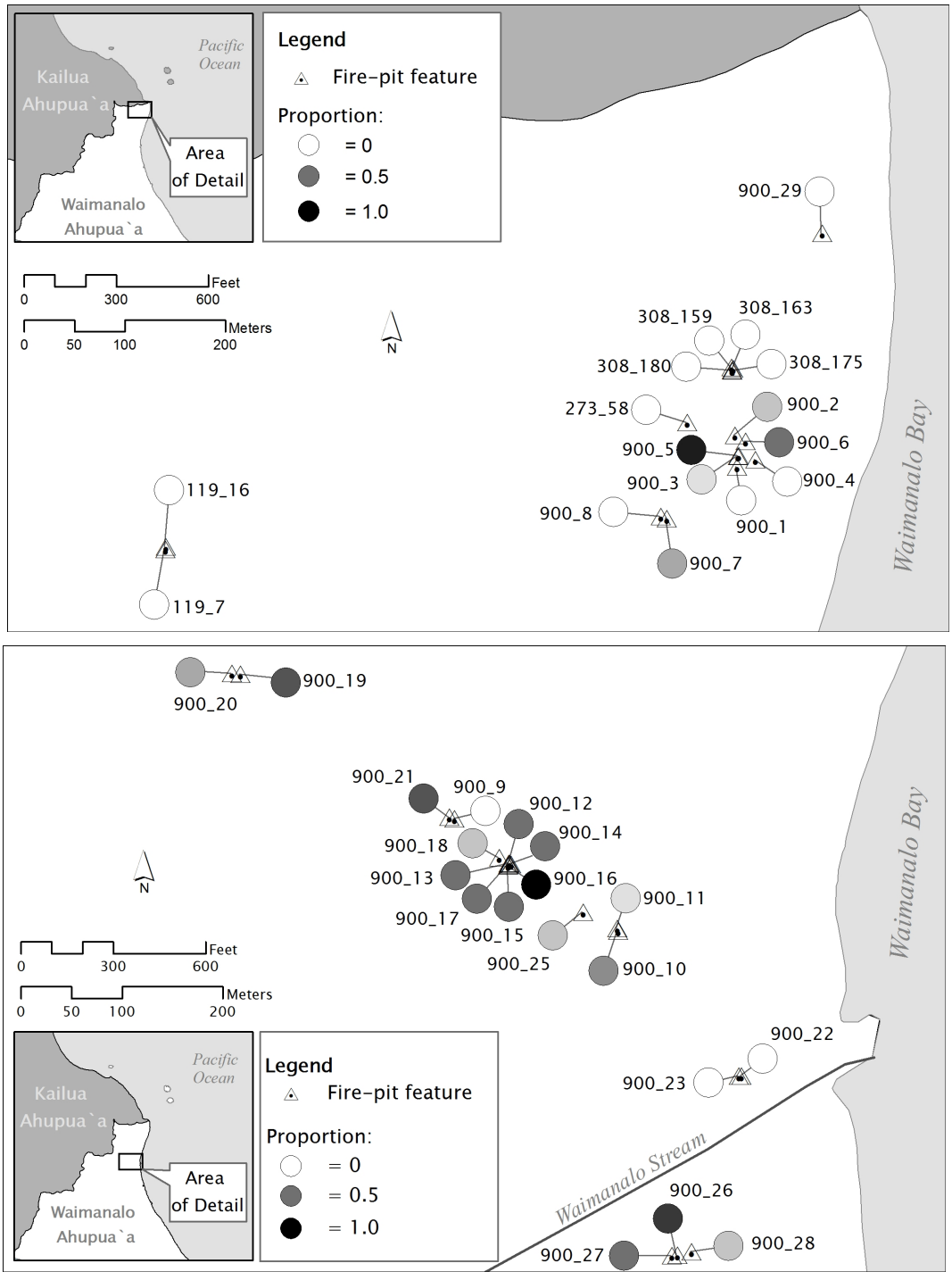

Figure 9: Proportion of identified wood charcoal from Polynesian-introduced taxa. See table 1 for the fire-pit labels. Note that proportion is represented on a continuous gray scale, only three values of which are shown in the legend.

and found evidence for a decline. This was explained as a consequence of the breakdown of traditional Polynesian lineage organization and a concomitant rise in the authority of *ali'i*, one result of which was a restriction in the ability of *maka'āinana* to gain free access to forests and tree firewood.

The decline over time in use of tree firewood is still evident with the augmented data set of fire-pits analyzed here. The hypothesis that this decline was due, at least in part, to a decline in the amount of tree firewood imported to the sites from inland locations is directly supported by the observed increase over time in locally-collected firewood. It appears that access to inland forests by people looking to collect firewood with which to build fires near the coast declined over time.

The hypothesis that this decline was due to assertions by *ali'i* of property rights over firewood in forests, a practice documented in the nineteenth century historical record, is difficult to assess with the fire-pit data. Coincident with the decline in access to inland forests is a shift to the use of firewoods introduced to the islands by Polynesians and presumably growing on the plain near the fire-pits. This appears to be an instance of the replacement of native lowland forest, perhaps one deficient in good firewood trees, with a landscape transported from the East Polynesian homeland of the Hawaiian people (Kirch 1984), relatively rich in good firewood. If this were the case, then the decline in access to inland forests might have been because the wood from them was no longer needed during the course of a normal day on the plain, rather than property rights claims of *ali'i*.

Regardless of the cause, however, a shift in behavior is clearly indicated by the data from the fire-pits. During the Early Period, prior to 400 BP, firewood was frequently carried onto the plain from inland forests, where it was burnt with some locally-collected wood. During the Late Period, after 400 BP, most firewood was collected locally from forests rich in introduced taxa that had been planted and maintained by *maka'āinana*. Bayesian calibration of the ^{14}C age determinations from Early Period fire-pits and Late Period fire-pits using the BCal software package (Buck et al. 1999) yields an estimate of the boundary between the two periods with a peak in the mid-fifteenth century (fig. 10).

5 Discussion and Conclusions

The wood charcoal identifications from 35 fire-pits on the Waimānalo Plain, which are related to precisely located and dated archaeological events, reveal patterns of change over time and space that can be associated with traditional Hawaiian fire-making behavior and local vegetation change.

The ability of the wood charcoal data to yield information on vegetation change augments environmental data from coring projects in several ways. According to the interpretation of the fire-pit data developed here, establishment of a managed, *anthropogenic* forest on the Waimānalo Plain was accomplished by the mid fifteenth century. This is quite a bit later than the forest changes documented in the pollen record of environmental cores, which appear to have taken place very shortly after Polynesian discovery and colonization of the islands (Athens et al. 2002). In contrast to the environmental changes documented in paleoenvironmental cores, which are often dated by interpolation

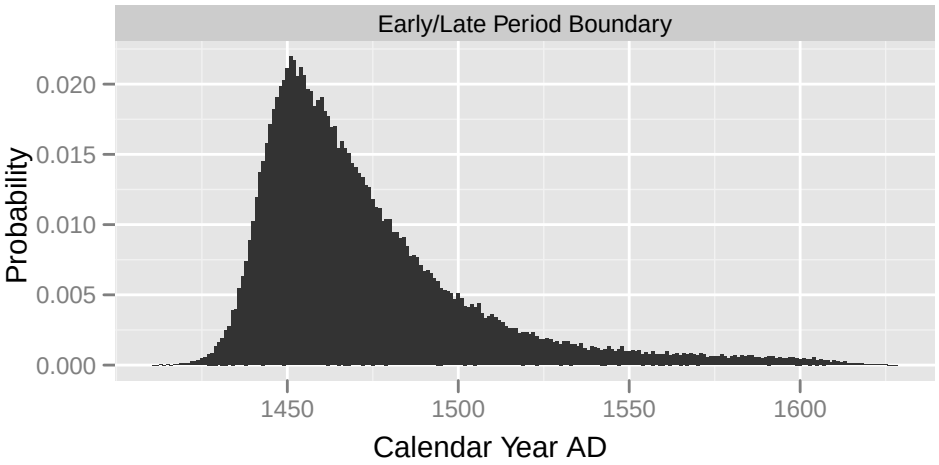

Figure 10: Age estimate of the boundary between Early and Late Periods. The 95% highest posterior density region is AD 1429–1537. The 67% highest posterior density region is AD 1440–1480.

without estimates of uncertainty (Athens et al. 2002:61), it is possible to estimate the date of the environmental changes recorded in the fire-pits relatively precisely with a posterior probability distribution that carries information about the uncertainty of the estimate. The temporal resolution made possible with the fire-pit data thus might add detail and precision to the broad patterns established by pollen analyses.

The very small catchment areas indicated by the wood charcoal analysis, and the ability to identify likely imports in the firewood, make it possible to track environmental change at an extremely fine geographic scale. The catchment areas indicated by the firewood data, which appear to be less than a kilometer, are orders of magnitude smaller than the catchment areas for *fossil* pollen deposits, which include wind-dispersed grains capable of traveling hundreds of miles from their sources. In the case of the Waimānalo Plain, efforts to establish useful plants appear to have concentrated near Puhā Stream, where fresh water was plentiful, and to have lagged a kilometer away at the northern end of the plain. This is a spatial resolution that other kinds of paleoenvironmental investigation in Hawai‘i have yet to achieve.

Finally, in the context of this special issue of *Hawaiian Archaeology*, it is appropriate to emphasize that the data analyzed in this paper were collected over a period of 15 years by eight different contract archaeology projects. The focus of these projects on acquisition of wood charcoal identifications yielded a consistent set of data capable of further analysis. This pattern of many small efforts coalescing into a larger result ought to be a common one in the cultural resource management industry, but it will not happen regularly until the industry lays aside the competition of the marketplace and warms to the camaraderie of pursuing shared goals.

A Charcoal identifications

Fire-pit	Taxon	Part	Count	Weight (g)
119_16	unidentified	bark	16	0.68
119_16	*Sida* cf. *fallax*	wood	16	0.24
119_16	unidentified	wood	5	0.12
119_16	*Chenopodium oahuense*	wood	3	0.04
119_7	cf. *Canthium odoratum*	wood	28	8.41
119_7	cf. *Chamaesyce* sp.	wood	13	2.09
119_7	cf. *Osteomeles anthyllidifolia*	wood	4	0.18
119_7	unidentified	wood	2	0.25
119_7	unidentified	bark	2	0.27
273_58	cf. *Canthium odoratum*	wood	14	0.6
273_58	*Nototrichium* sp.	wood	8	0.08
273_58	*Chenopodium oahuense*	wood	6	0.12
273_58	*Osteomeles anthyllidifolia*	wood	6	0.07
273_58	*Chamaesyce* sp.	wood	6	0.11
273_58	unidentified	wood	4	0.05
273_58	*Nestegis sandwicensis*	wood	2	0.07
273_58	*Diospyros sandwicensis*	wood	2	0.03
273_58	*Sida fallax*	wood	2	0.03
308_159	*Osteomeles anthyllidifolia*	wood	28	1.43
308_159	*Sida fallax*	wood	27	0.81
308_159	unidentified	wood	26	1.14
308_159	unidentified	wood	6	0.2
308_159	unidentified	bark	6	0.36
308_159	*Cordyline fruticosa*	wood	3	0.07
308_159	cf. *Senna* sp.	wood	2	0.07
308_159	cf. *Canthium odoratum*	wood	1	0.05
308_159	cf. Pteridophyta	stem	1	0.03
308_159	cf. *Chamaesyce* sp.	wood	1	0.02
308_163	*Osteomeles anthyllidifolia*	wood	32	1.27
308_163	*Chenopodium oahuense*	wood	26	1.31
308_163	*Sida fallax*	wood	18	0.55
308_163	cf. *Rauvolfia sandwicensis*	wood	17	0.64
308_163	*Nestegis sandwicensis*	wood	15	0.58
308_163	*Diospyros sandwicensis*	wood	14	0.84
308_163	cf. *Dodonaea viscosa*	wood	10	0.4
308_163	*Chamaesyce* sp.	wood	9	0.44
308_163	unidentified	wood	6	0.2
308_163	*Aleurites moluccana*	nutshell	6	0.44
308_163	unidentified	wood	5	0.23
308_163	cf. *Dodonaea viscosa*	wood	4	0.13

Continued on next page

Fire-pit	Taxon	Part	Count	Weight (g)
308_163	*Cordyline fruticosa*	wood	3	0.23
308_163	*Nototrichium* sp.	wood	2	0.05
308_163	unidentified	wood	2	0.05
308_163	*Nothocestrum latifolium*	wood	1	0.02
308_175	cf. *Rauvolfia sandwicensis*	wood	34	1.22
308_175	*Diospyros sandwicensis*	wood	23	1.68
308_175	cf. *Dodonaea viscosa*	wood	22	1.69
308_175	*Osteomeles anthyllidifolia*	wood	13	0.78
308_175	*Chenopodium oahuense*	wood	12	0.63
308_175	*Nestegis sandwicensis*	wood	7	1.07
308_175	*Aleurites moluccana*	nutshell	6	0.37
308_175	unidentified	wood	6	0.19
308_175	unidentified	bark	4	0.15
308_175	*Chamaesyce* sp.	wood	4	0.15
308_175	unidentified	wood	3	0.07
308_175	*Sida fallax*	wood	2	0.14
308_175	*Hibiscus tiliaceus*	wood	1	0.08
308_175	cf. Pteridophyta	stem	1	0.04
308_180	cf. *Rauvolfia sandwicensis*	wood	21	1.17
308_180	*Chenopodium oahuense*	wood	21	0.72
308_180	*Sida fallax*	wood	14	0.5
308_180	*Osteomeles anthyllidifolia*	wood	13	0.66
308_180	*Diospyros sandwicensis*	wood	10	0.23
308_180	*Chamaesyce* sp.	wood	5	0.09
308_180	unidentified	wood	5	0.1
308_180	unidentified	wood	4	0.14
308_180	unidentified	wood	3	0.07
308_180	unidentified	wood	1	0.02
308_180	cf. *Canthium odoratum*	wood	1	0.07
308_180	*Aleurites moluccana*	nutshell	1	0.06
308_180	unidentified	wood	1	0.03
308_180	cf. *Pandanus tectorius*	twig	1	0.04
900_1	*Sida* cf. *fallax*	wood	112	5.13
900_10	Monocotyledonae	root	80	1.01
900_10	Monocotyledonae	root	63	0.68
900_10	Monocotyledonae	stem	21	0.28
900_10	Monocotyledonae	stem	17	0.16
900_10	*Aleurites moluccana*	nutshell	10	0.37
900_10	*Metrosideros polymorpha*	wood	10	0.25
900_10	cf. *Sida fallax*	wood	9	0.09
900_10	cf. *Sida fallax*	wood	8	0.09
900_10	*Hibiscus tiliaceus*	wood	7	0.19

Continued on next page

Fire-pit	Taxon	Part	Count	Weight (g)
900_10	unidentified	wood	6	0.11
900_10	*Metrosideros polymorpha*	wood	5	0.06
900_10	*Chenopodium oahuense*	wood	4	0.08
900_10	*Chamaesyce* sp.	wood	4	0.08
900_10	*Ilex anomala*	wood	3	0.11
900_10	*Abutilon* sp.	wood	3	0.03
900_10	unidentified	wood	3	0.07
900_10	*Aleurites moluccana*	nutshell	3	0.09
900_10	unidentified	wood	3	0.12
900_10	*Pinus* sp.	wood	2	0.08
900_10	unidentified	bark	2	0.03
900_10	unidentified	bark	2	0.04
900_10	*Chamaesyce* sp.	wood	2	0.03
900_10	unidentified	parenchyma	1	0.02
900_11	cf. *Aleurites moluccana*	wood	112	0.74
900_11	Monocotyledonae	root	50	0.88
900_11	*Chenopodium oahuense*	wood	42	1.83
900_11	*Metrosideros polymorpha*	wood	41	4.19
900_11	Monocotyledonae	root	33	1.5
900_11	*Metrosideros polymorpha*	wood	23	1.73
900_11	Monocotyledonae	stem	13	0.25
900_11	Monocotyledonae	stem	12	0.17
900_11	*Sida* cf. *fallax*	wood	12	0.53
900_11	*Chenopodium oahuense*	wood	11	0.36
900_11	*Bidens* sp.	wood	9	0.35
900_11	*Bidens* sp.	wood	9	0.55
900_11	*Abutilon* sp.	wood	9	0.58
900_11	cf. *Syzygium malaccense*	wood	7	0.28
900_11	unidentified	bark	6	0.1
900_11	*Hibiscus tiliaceus*	wood	5	0.16
900_11	*Aleurites moluccana*	nutshell	5	0.06
900_11	*Metrosideros polymorpha*	wood	5	0.1
900_11	*Aleurites moluccana*	nutshell	5	0.14
900_11	*Sida* cf. *fallax*	wood	4	0.05
900_11	*Diospyros sandwicensis*	wood	4	0.16
900_11	unidentified	bark	4	0.09
900_11	cf. *Aleurites moluccana*	wood	4	0.09
900_11	*Abutilon* sp.	wood	4	0.07
900_11	*Syzygium malaccense*	wood	3	0.46
900_11	cf. *Dodonaea viscosa*	wood	3	0.38
900_11	unidentified	wood	3	0.33
900_11	cf. *Osteomeles anthyllidifolia*	wood	3	0.07

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Fire-pit	Taxon	Part	Count	Weight (g)
900_11	cf. *Psychotria* sp.	wood	2	0.01
900_11	*Diospyros sandwicensis*	wood	2	0.03
900_11	unidentified	parenchyma	2	0.03
900_12	*Aleurites moluccana*	nutshell	385	18.64
900_12	unidentified	bark	126	2.95
900_12	*Chamaesyce* sp.	wood	91	3.11
900_12	unidentified	wood	74	2.14
900_12	cf. *Antidesma pulvinatum*	wood	58	4.14
900_12	*Bobea* sp.	wood	52	1.97
900_12	*Aleurites moluccana*	nutshell	38	1.99
900_12	*Diospyros sandwicensis*	wood	36	1.46
900_12	*Sida* cf. *fallax*	wood	31	0.99
900_12	*Bidens* sp.	wood	26	0.61
900_12	Monocotyledonae	root	25	0.54
900_12	unidentified	bark	17	0.44
900_12	*Abutilon* sp.	wood	17	0.48
900_12	*Hibiscus tiliaceus*	wood	16	0.3
900_12	*Chamaesyce* sp.	wood	11	0.51
900_12	*Syzygium malaccense*	wood	11	0.41
900_12	*Osteomeles anthyllidifolia*	wood	10	0.31
900_12	Monocotyledonae	stem	10	0.3
900_12	Monocotyledonae	stem	9	0.15
900_12	cf. *Bobea* sp.	wood	9	0.16
900_12	cf. *Acacia koa*	wood	9	0.34
900_12	*Hibiscus tiliaceus*	wood	8	0.14
900_12	*Sida* cf. *fallax*	wood	7	0.33
900_12	cf. *Antidesma pulvinatum*	wood	6	0.36
900_12	unidentified	wood	5	0.19
900_12	*Abutilon* sp.	wood	4	0.05
900_12	Monocotyledonae	root	3	0.05
900_12	*Osteomeles anthyllidifolia*	wood	3	0.05
900_12	*Acacia koa*	wood	2	0.12
900_12	*Cocos nucifera*	nutshell	1	0.09
900_12	*Diospyros sandwicensis*	wood	1	0.03
900_12	cf. *Aleurites moluccana*	seed embryo	1	0.06
900_12	*Metrosideros polymorpha*	wood	1	0.14
900_13	*Aleurites moluccana*	nutshell	72	2.42
900_13	*Aleurites moluccana*	nutshell	63	2.92
900_13	unidentified	bark	27	0.61
900_13	unidentified	bark	23	0.67
900_13	*Chamaesyce* sp.	wood	20	0.64
900_13	*Sida* cf. *fallax*	wood	15	0.59

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Fire-pit	Taxon	Part	Count	Weight (g)
900_13	unidentified	wood	13	0.68
900_13	cf. *Antidesma pulvinatum*	wood	11	0.3
900_13	cf. *Bidens* sp.	wood	10	0.02
900_13	*Chamaesyce* sp.	wood	9	0.21
900_13	cf. *Antidesma pulvinatum*	wood	9	0.26
900_13	Monocotyledonae	root	7	0.08
900_13	*Diospyros sandwicensis*	wood	7	0.32
900_13	*Bidens* sp.	wood	6	0.27
900_13	cf. *Bobea* sp.	wood	5	0.31
900_13	cf. *Bobea* sp.	wood	4	0.08
900_13	*Hibiscus tiliaceus*	wood	4	0.04
900_13	Monocotyledonae	stem	3	0.04
900_13	*Hibiscus tiliaceus*	wood	3	0.11
900_13	*Sida* cf. *fallax*	wood	3	0.26
900_13	cf. *Scaevola sericea*	wood	3	0.07
900_13	cf. *Gossypium tomentosum*	wood	2	0.05
900_13	Monocotyledonae	stem	2	0.04
900_13	unidentified	wood	2	0.05
900_13	*Osteomeles anthyllidifolia*	wood	1	0.01
900_13	*Diospyros sandwicensis*	wood	1	0.05
900_14	*Syzygium malaccense*	wood	111	5.82
900_14	*Chamaesyce* sp.	wood	104	6.77
900_14	*Aleurites moluccana*	nutshell	74	2.59
900_14	*Syzygium malaccense*	wood	74	3.35
900_14	cf. *Antidesma pulvinatum*	wood	47	3.44
900_14	unidentified	bark	46	1.66
900_14	cf. *Antidesma pulvinatum*	wood	43	3.2
900_14	unidentified	bark	42	0.76
900_14	*Chamaesyce* sp.	wood	27	1.08
900_14	unidentified	wood	21	0.45
900_14	cf. *Syzygium malaccense*	wood	17	1.19
900_14	unidentified	wood	16	0.33
900_14	*Aleurites moluccana*	nutshell	15	0.73
900_14	*Sida* cf. *fallax*	wood	10	0.16
900_14	*Sida* cf. *fallax*	wood	7	0.26
900_14	unidentified	wood	6	0.32
900_14	cf. *Bobea* sp.	wood	4	0.13
900_14	cf. *Gossypium tomentosum*	wood	2	0.07
900_14	Monocotyledonae	stem	2	0.03
900_14	cf. *Acacia koa*	wood	2	0.03
900_14	*Diospyros sandwicensis*	wood	1	0.08
900_14	*Nototrichium* sp.	wood	1	0.01

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Fire-pit	Taxon	Part	Count	Weight (g)
900_14	cf. *Scaevola sericea*	wood	1	0.01
900_14	unidentified	wood	1	0.04
900_15	*Aleurites moluccana*	nutshell	51	1.64
900_15	unidentified	bark	24	0.2
900_15	*Chamaesyce* sp.	wood	22	0.61
900_15	cf. *Antidesma pulvinatum*	wood	8	0.33
900_15	*Diospyros sandwicensis*	wood	5	0.22
900_15	*Sida* cf. *fallax*	wood	4	0.05
900_15	*Hibiscus tiliaceus*	wood	4	0.02
900_15	Monocotyledonae	root	3	0.04
900_15	unidentified	wood	3	0.03
900_15	cf. *Scaevola sericea*	wood	1	0.01
900_15	*Chenopodium oahuense*	wood	1	0.01
900_15	*Osteomeles anthyllidifolia*	wood	1	0.01
900_16	*Aleurites moluccana*	nutshell	2988	92.76
900_16	*Sida* cf. *fallax*	wood	32	0.37
900_16	*Cocos nucifera*	nutshell	9	0.47
900_16	unidentified	wood	6	0.05
900_16	cf. *Gossypium tomentosum*	wood	5	0.07
900_16	*Hibiscus tiliaceus*	wood	4	0.04
900_16	Monocotyledonae	stem	3	0.03
900_16	unidentified	bark	2	0.06
900_17	*Aleurites moluccana*	nutshell	90	2.9
900_17	*Aleurites moluccana*	nutshell	74	2.52
900_17	*Chamaesyce* sp.	wood	30	0.63
900_17	*Chamaesyce* sp.	wood	28	0.83
900_17	*Hibiscus tiliaceus*	wood	25	0.74
900_17	unidentified	bark	25	0.58
900_17	unidentified	wood	23	0.66
900_17	unidentified	bark	22	0.27
900_17	cf. *Antidesma pulvinatum*	wood	16	1.42
900_17	cf. *Antidesma pulvinatum*	wood	13	0.41
900_17	unidentified	wood	12	0.3
900_17	Monocotyledonae	stem	9	0.14
900_17	Monocotyledonae	stem	9	0.14
900_17	*Hibiscus tiliaceus*	wood	8	0.13
900_17	*Sida* cf. *fallax*	wood	6	0.1
900_17	*Sida* cf. *fallax*	wood	6	0.08
900_17	cf. *Bobea* sp.	wood	6	0.26
900_17	unidentified	wood	4	0.07
900_17	unidentified	parenchyma	3	0.08
900_17	*Syzygium malaccense*	wood	2	0.17

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Fire-pit	Taxon	Part	Count	Weight (g)
900_17	*Syzygium malaccense*	wood	2	0.05
900_17	*Diospyros sandwicensis*	wood	2	0.02
900_17	*Abutilon* sp.	wood	1	0.02
900_17	*Cocos nucifera*	nutshell	1	0.03
900_17	cf. *Acacia koa*	wood	1	0.01
900_17	*Osteomeles anthyllidifolia*	wood	1	0.04
900_18	*Chamaesyce* sp.	wood	63	1.94
900_18	unidentified	bark	46	1.09
900_18	*Aleurites moluccana*	nutshell	43	1.12
900_18	*Sida* cf. *fallax*	wood	38	1.32
900_18	*Hibiscus tiliaceus*	wood	31	0.65
900_18	*Aleurites moluccana*	nutshell	30	0.78
900_18	*Aleurites moluccana*	nutshell	29	0.48
900_18	*Diospyros sandwicensis*	wood	26	1.27
900_18	*Dodonaea viscosa*	wood	22	0.68
900_18	unidentified	wood	22	0.47
900_18	unidentified	bark	21	0.47
900_18	*Sida* cf. *fallax*	wood	20	0.31
900_18	*Gossypium tomentosum*	wood	18	0.39
900_18	unidentified	bark	18	0.3
900_18	*Chamaesyce* sp.	wood	17	0.49
900_18	*Chamaesyce* sp.	wood	15	0.48
900_18	*Hibiscus tiliaceus*	wood	14	0.18
900_18	*Abutilon* sp.	wood	14	0.32
900_18	*Abutilon* sp.	wood	14	0.26
900_18	*Diospyros sandwicensis*	wood	14	0.33
900_18	unidentified	wood	11	0.2
900_18	unidentified	wood	10	0.14
900_18	*Metrosideros polymorpha*	wood	10	0.24
900_18	*Aleurites moluccana*	wood	9	0.13
900_18	*Artocarpus altilis*	wood	9	0.12
900_18	cf. *Psychotria* sp.	wood	7	0.23
900_18	*Sida* cf. *fallax*	wood	7	0.13
900_18	cf. *Pandanus tectorius*	wood	7	0.2
900_18	cf. *Antidesma pulvinatum*	wood	6	0.07
900_18	*Diospyros sandwicensis*	wood	6	0.25
900_18	*Aleurites moluccana*	wood	6	0.07
900_18	cf. *Dodonaea viscosa*	wood	6	0.22
900_18	unidentified	wood	6	0.08
900_18	cf. *Acacia koa*	wood	5	0.2
900_18	*Abutilon* sp.	wood	5	0.25
900_18	*Cocos nucifera*	nutshell	4	0.07

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Fire-pit	Taxon	Part	Count	Weight (g)
900_18	unidentified	stem/root	4	0.09
900_18	*Cocos nucifera*	nutshell	4	0.15
900_18	cf. *Acacia koa*	wood	3	0.07
900_18	*Metrosideros polymorpha*	wood	3	0.04
900_18	cf. *Acacia koa*	wood	3	0.08
900_18	*Osteomeles anthyllidifolia*	wood	3	0.06
900_18	*Pteridophyta*	stem	3	0.04
900_18	*Bobea* sp.	wood	2	0.04
900_18	*Dodonaea viscosa*	wood	2	0.23
900_18	*Chenopodium oahuense*	wood	2	0.02
900_18	*Pteridophyta*	stem	2	0.01
900_18	cf. *Syzygium malaccense*	wood	2	0.04
900_18	*Hibiscus tiliaceus*	wood	2	0.01
900_18	cf. *Bobea* sp.	wood	2	0.05
900_18	unidentified	parenchyma	1	0.01
900_18	*Osteomeles anthyllidifolia*	wood	1	0.11
900_18	unidentified	wood	1	0.01
900_18	*Artocarpus altilis*	wood	1	0.1
900_18	*Bobea* sp.	wood	1	0.05
900_18	*Chenopodium oahuense*	wood	1	0.3
900_18	*Gossypium tomentosum*	wood	1	0.06
900_19	*Aleurites moluccana*	nutshell	156	2.92
900_19	*Aleurites moluccana*	nutshell	30	0.66
900_19	*Sida* cf. *fallax*	wood	24	0.3
900_19	*Sida* cf. *fallax*	wood	18	0.44
900_19	*Aleurites moluccana*	nutshell	14	0.41
900_19	*Osteomeles anthyllidifolia*	wood	14	0.52
900_19	*Osteomeles anthyllidifolia*	wood	13	0.35
900_19	*Sida* cf. *fallax*	wood	12	0.19
900_19	*Osteomeles anthyllidifolia*	wood	9	0.09
900_19	unidentified	bark	7	0.06
900_19	unidentified	bark	5	0.1
900_19	unidentified	bark	3	0.04
900_19	unidentified	parenchyma	2	0.01
900_19	*Hibiscus tiliaceus*	wood	2	0.03
900_19	cf. *Bidens* sp.	wood	2	0.02
900_19	unidentified	parenchyma	1	0.02
900_19	cf. *Chamaesyce* sp.	wood	1	0.01
900_19	unidentified	wood	1	0.01
900_19	*Hibiscus tiliaceus*	wood	1	0.01
900_19	*Hibiscus tiliaceus*	wood	1	0.01
900_19	*Chenopodium oahuense*	wood	1	0.02

Continued on next page

Fire-pit	Taxon	Part	Count	Weight (g)
900_2	*Sida* cf. *fallax*	wood	7	0.09
900_2	unidentified	bark	5	0.09
900_2	*Aleurites moluccana*	nutshell	2	0.1
900_2	*Chenopodium oahuense*	wood	2	0.06
900_2	*Aleurites moluccana*	nutshell	2	0.04
900_2	cf. *Acacia koa*	wood	1	0.01
900_20	*Aleurites moluccana*	nutshell	23	0.8
900_20	*Sida* cf. *fallax*	wood	19	0.23
900_20	*Aleurites moluccana*	nutshell	18	0.56
900_20	*Osteomeles anthyllidifolia*	wood	14	0.48
900_20	*Chenopodium oahuense*	wood	11	0.26
900_20	*Sida* cf. *fallax*	wood	10	0.25
900_20	*Osteomeles anthyllidifolia*	wood	8	0.15
900_20	unidentified	bark	5	0.03
900_20	*Chenopodium oahuense*	wood	4	0.12
900_20	unidentified	bark	3	0.03
900_20	*Chamaesyce* sp.	wood	3	0.22
900_20	cf. *Bidens* sp.	wood	1	0.01
900_20	unidentified	parenchyma	1	0.01
900_20	*Chamaesyce* sp.	wood	1	0.01
900_21	Palm sp.	wood	12	0.15
900_21	cf. *Saccharum officinarum*	stem	12	0.01
900_21	*Chamaesyce* sp.	wood	6	0.07
900_21	Monocotyledonae	stem	3	0.04
900_21	*Sida* cf. *fallax*	wood	1	0.01
900_21	*Cordyline fruticosa*	wood	1	0.01
900_22	cf. *Osteomeles anthyllidifolia*	wood	24	0.65
900_22	Monocotyledonae	stem	1	0.01
900_22	*Cordyline fruticosa*	wood	1	0.02
900_22	unidentified	bark	1	0.01
900_23	*Colubrina oppositifolia*	wood	80	3.68
900_23	*Nothocestrum latifolium*	wood	26	0.29
900_23	cf. *Osteomeles anthyllidifolia*	wood	11	0.26
900_23	cf. *Antidesma pulvinatum*	wood	7	0.34
900_25	*Sida* cf. *fallax*	wood	106	6.22
900_25	*Cordyline fruticosa*	root	96	3.58
900_25	*Rauvolfia sandwicensis*	wood	82	5.18
900_25	*Chamaesyce* sp.	wood	35	1.54
900_25	*Abutilon* sp.	wood	24	1.22
900_25	*Chenopodium oahuense*	wood	23	1.71
900_25	*Hibiscus tiliaceus*	wood	23	1.32
900_25	cf. *Saccharum officinarum*	stem	19	0.44

Continued on next page

Fire-pit	Taxon	Part	Count	Weight (g)
900_25	*Bidens* sp.	wood	7	0.19
900_25	unidentified	wood	3	0.24
900_25	*Metrosideros polymorpha*	wood	2	0.08
900_25	*Aleurites moluccana*	nutshell	2	0.16
900_25	unidentified	tuber	2	0.12
900_25	*Diospyros sandwicensis*	wood	1	0.03
900_25	cf. *Aleurites moluccana*	kernel	1	0.01
900_25	*Lagenaria siceraria*	rind	1	0.1
900_25	unidentified	wood	1	0.09
900_26	*Cordyline fruticosa*	root	35	0.79
900_26	*Hibiscus tiliaceus*	wood	15	1.35
900_26	Poaceae	stem	12	0.11
900_26	*Cordyline fruticosa*	root	10	0.22
900_26	Poaceae	stem	4	0.03
900_26	*Cordyline fruticosa*	root	3	0.04
900_26	*Rauvolfia sandwicensis*	wood	3	0.34
900_26	cf. *Gossypium tomentosum*	wood	2	0.07
900_26	cf. *Saccharum officinarum*	stem	2	0.01
900_26	cf. *Saccharum officinarum*	petiole	1	0.01
900_27	cf. *Cordyline fruticosa*	root	52	1.73
900_27	Poaceae	stem	18	0.41
900_27	*Cordyline fruticosa*	root	15	0.43
900_27	Poaceae	stem	12	0.12
900_27	cf. *Gossypium tomentosum*	wood	11	0.37
900_27	*Cordyline fruticosa*	root	10	0.13
900_27	*Sida* cf. *fallax*	wood	10	0.42
900_27	*Sida* cf. *fallax*	wood	8	0.25
900_27	cf. *Canthium odoratum*	wood	7	0.13
900_27	*Rauvolfia sandwicensis*	wood	6	0.7
900_27	unidentified	wood	5	0.4
900_27	Poaceae	stem	4	0.08
900_27	*Sida* cf. *fallax*	wood	3	0.03
900_27	*Myrsine* sp.	wood	3	0.37
900_27	*Acacia koa*	wood	3	0.17
900_27	*Chenopodium oahuense*	wood	2	0.07
900_27	cf. *Canthium odoratum*	wood	2	0.16
900_27	unidentified	wood	1	0.01
900_27	unidentified	twig	1	0.01
900_27	unidentified	wood	1	0.05
900_27	*Rauvolfia sandwicensis*	wood	1	0.19
900_27	*Aleurites moluccana*	nutshell	1	0.04
900_28	cf. *Hedyotis terminalis*	wood	46	1.75

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Fire-pit	Taxon	Part	Count	Weight (g)
900_28	*Rauvolfia sandwicensis*	wood	40	1.9
900_28	*Artocarpus* cf. *altilis*	wood	37	2.61
900_28	*Canthium odoratum*	wood	20	0.96
900_28	unidentified	wood	12	0.66
900_28	*Nestegis sandwicensis*	wood	8	1.37
900_28	unidentified	wood	7	0.09
900_28	*Diospyros sandwicensis*	wood	5	0.21
900_28	cf. *Cheirodendron* sp.	wood	5	0.12
900_28	*Sida* cf. *fallax*	wood	2	0.31
900_28	unidentified	wood	2	0.12
900_28	*Hibiscus* sp.	wood	2	0.16
900_28	*Lagenaria siceraria*	rind	1	0.04
900_28	*Cocos nucifera*	nutshell	1	0.02
900_28	unidentified	wood	1	0.01
900_29	*Chamaesyce* sp.	wood	23	5.8
900_29	*Pittosporum* sp.	wood	15	5.87
900_29	*Myoporum sandwicense*	wood	10	1.64
900_3	*Sida* cf. *fallax*	wood	24	0.98
900_3	*Aleurites moluccana*	nutshell	5	0.15
900_3	*Chenopodium oahuense*	wood	3	0.02
900_3	*Sida* cf. *fallax*	wood	3	0.05
900_3	cf. *Chamaesyce* sp.	wood	2	0.02
900_3	cf. *Aleurites moluccana*	cf. kernel	2	0.005
900_3	*Chenopodium oahuense*	wood	2	0.06
900_3	cf. *Artocarpus altilis*	wood	1	0.01
900_4	cf. *Osteomeles anthyllidifolia*	wood	11	0.4
900_4	*Chenopodium oahuense*	wood	11	0.14
900_4	*Wikstroemia* sp.	wood	5	0.1
900_4	*Osteomeles anthyllidifolia*	wood	5	0.09
900_4	*Aleurites moluccana*	nutshell	4	0.17
900_4	*Chenopodium oahuense*	wood	4	0.08
900_4	cf. *Osteomeles anthyllidifolia*	wood	3	0.14
900_4	unidentified	parenchyma	1	0.005
900_4	cf. *Nestegis sandwicensis*	wood	1	0.01
900_4	unidentified	wood	1	0.02
900_4	*Chamaesyce* sp.	wood	1	0.01
900_5	*Aleurites moluccana*	nutshell	23	1.02
900_5	*Aleurites moluccana*	nutshell	12	0.65
900_5	*Sida* cf. *fallax*	wood	2	0.05
900_5	*Sida* cf. *fallax*	wood	2	0.07
900_5	*Sida* cf. *fallax*	wood	1	0.06
900_5	*Chamaesyce* sp.	wood	1	0.03

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Fire-pit	Taxon	Part	Count	Weight (g)
900_5	*Chenopodium oahuense*	wood	1	0.02
900_5	unidentified	wood	1	0.04
900_5	*Chenopodium oahuense*	wood	1	0.06
900_6	*Aleurites moluccana*	nutshell	37	2.32
900_6	*Sida* cf. *fallax*	wood	30	1.09
900_6	unidentified	wood	6	0.14
900_6	*Aleurites moluccana*	cf. kernel	2	0.03
900_6	*Chenopodium oahuense*	wood	1	0.03
900_6	cf. *Cocos nucifera*	wood	1	0.03
900_7	*Diospyros sandwicensis*	wood	11	0.54
900_7	*Aleurites moluccana*	nutshell	8	0.31
900_7	*Osteomeles anthyllidifolia*	wood	5	0.1
900_7	*Osteomeles anthyllidifolia*	wood	4	0.18
900_7	*Aleurites moluccana*	nutshell	1	0.05
900_8	*Diospyros sandwicensis*	wood	26	1.55
900_8	cf. *Osteomeles anthyllidifolia*	wood	18	0.64
900_8	*Cordyline fruticosa*	wood	5	0.12
900_8	unidentified	wood	4	0.16
900_8	*Myoporum sandwicense*	wood	2	0.49
900_9	Monocotyledonae	root	89	1.64
900_9	Monocotyledonae	root	72	0.67
900_9	Monocotyledonae	stem	51	0.58
900_9	Monocotyledonae	stem	22	0.28
900_9	*Sida* cf. *fallax*	wood	12	0.21
900_9	*Charpentiera* sp.	wood	9	0.09
900_9	*Sida* cf. *fallax*	wood	4	0.04
900_9	*Abutilon* sp.	stem	3	0.1
900_9	*Charpentiera* sp.	wood	3	0.23
900_9	*Pinus* sp.	wood	3	0.21
900_9	*Hibiscus tiliaceus*	wood	2	0.03
900_9	unidentified	bark	2	0.02

Glossary

anthropogenic Of, relating to, or involving the impact of man on nature.

coconut The palm, *Cocos nucifera*.

context A unit of stratification associated with a natural or cultural process or event.

detritus Material produced by the disintegration and weathering of rocks that has been moved from its site of origin, or a deposit of such material.

diachronic Of, or relating to, or dealing with phenomena as they occur or change over a period of time. See also synchronic.

fill Any sediment deposited by any agent so as to fill or partly fill a valley, sink, or other depression.

fire-pit A pit of varying depth, often bowl shaped at the base, usually identified by a concentration of charcoal and/or burned material in the fill, especially at the feature interface.

fossil An object of natural origin, such as a pollen grain, found in a geological or archaeological context.

habit A botanical term used to describe the general appearance, growth form, or architecture of a plant.

in-built age The age of a material when it was incorporated into the archaeological record.

mountain apple The tree, *Eugenia malaccensis*, a forest tree to 50 ft. high, that bears fruit resembling an apple. Traditionally the fruits were eaten both raw and pickled.

richness The number of classes in a collection or population, a measure of diversity.

sand Detrital material ranging in size from 0.5 mm to 2 mm in diameter. See also *detritus*.

shrub A plant with multiple stems and shorter than trees, typically under 5–6 m. See also habit.

shrub-tree Plants whose form can take on the characteristics of either a shrub or a tree. See also habit.

site The fundamental unit of archaeological investigation, a location that exhibits material evidence of past human activity.

suitable dating material An identified sample of wood charcoal, selected to include short-lived species, twigs, or sapwood collected from a context that is in a clearly defined association with a confidently identified traditional Hawaiian cultural feature.

synchronic Concerned with the complex of events existing in a limited time period and ignoring historical antecedents. See also *diachronic*.

tree A perennial woody plant with a single main stem, or trunk, typically taller than 5–6 m at maturity. See also habit.

Hawaiian Terms

ʻaʻaliʻi A native shrub or small tree, *Dodonaea viscosa*, with a variety of traditional uses. The fruit clusters and leaves were used in *lei* making; the hard, yellow-brown wood was used to make posts for thatched houses, spears, and bait sticks for fishing; the leaves were used in conjunction with alaʻa bark and puakala root to treat skin rash.

ʻahakea Native trees of the genus *Bobea*. The wood was used for *poi* boards and paddles. Its yellow color and wearability also made it desirable for the carved end covers and gunwales of outrigger canoes.

ʻāheahea A native shrub or small tree, *Chenopodium oahuense*. Traditionally the bark of the ʻaheahea was used medicinally, the leaves were eaten as greens, and the wood was used in fishhook construction and burned in fires.

ahupuaʻa Traditional Hawaiian land division, usually extending from the uplands to the sea.

ʻaiea All species of the endemic Hawaiian genus *Nothocestrum* of soft-wooded shrubs

and trees.

ʻākia Native shrubs and trees in the genus *Wikstroemia*, the bark from which was eaten as a source of fiber and whose roots, bark, and leaves were used to narcotize fish in saltwater ponds.

ʻakoko A member of the genus *Chamaesyce*, which includes 15 endemic shrubs and small trees.

alaheʻe A native large shrub or small tree, *Canthium odoratum*, whose hard wood was used to make digging sticks and adze blades.

aliʻi Chief, chiefess, officer, ruler, monarch, peer, head man, noble, aristocrat, king, queen, commander.

aloalo Native shrubs of the genus *Hibiscus*.

hala An indigenous tree, *Pandanus tectorius*, whose leaves were used for mat making, canoe sails, baskets, and thatching.

hale House, building, station, hall.

hame A native tree in the genus *Antidesma*, whose hard wood was used traditionally as anvils for preparing *olonā* fiber; a red dye was made from the fruit.

hao A native tree or shrub, *Rauvolfia sandwicensis*.

hau A native tree, *Hibiscus tiliaceous*, which was highly valued for a variety of uses: the bark was used for cordage; the light wood was used in canoe construction, to make floating containers, fishing floats, adze handles, fireworks, spears, and to mark fishing grounds; the wood was also rubbed together with *olomea* to make fire; and the flowers and the slimy sap were used medicinally. See also *olomea*.

heiau Traditional Hawaiian place of worship.

hōʻawa A native tree of the genus *Pittosporum*.

ʻilima An indigenous shrub, *Sida fallax*. Traditionally, the flower was used in *lei* making, both the flower and the root were used medicinally, the stems of the large plants were used as slats in house construction, and the stems of smaller plants were used in rough basketry.

ʻinamona Relish made of the cooked kernel of *kukui* mashed with salt. See also *kukui*.

ipu The gourd, *Lagenaria siceraria*.

kapa Tapa cloth, as made from *wauke* or *māmaki* bark.

kauila A native tree, *Alphitonia ponderosa*, whose hard wood was valued traditionally for spears and tools; it was also used as beams in house construction.

kāwaʻu A native tree or shrub, *Ilex anomala*. Hawaiians used the wood for saddle trees, for canoe trimmings, and as an anvil for *kapa* beating.

kō Sugarcane, *Saccharum officinarum*, was introduced to Hawaiʻi by Polynesian settlers, who cultivated it widely. The stalk was chewed between meals for its sweetness, brought on long journeys to ease hunger, and eaten in times of famine; juice from the stalk was fed to nursing babies, and used as a sweetening agent in medicinal herbal concoctions; the leaves were used as thatching for houses; the leaf midrib was used for plaiting braids that were made into hats; the stem of the flower was used to make darts for a child's game.

koa A tree, *Acacia koa*, one of the largest endemic trees in Hawaiʻi. Wood used for canoes, paddles, and surfboards.

kōlea A native tree in the genus *Myrsine*, the sap from which was traditionally combined with charcoal to make red dye; the wood was used for house construction and for making *kapa* beaters.

koʻokoʻolau A member of the genus *Bidens*, which includes twenty native and three naturalized species of shrub in Hawaiʻi. Hawaiians used the young tips of the plant to make a medicinal tea.

kōpiko A native tree belonging to the genus *Psychotria*. Traditionally, the wood of the *kōpiko* was used to make *kapa* anvils and used as firewood.

kukui The candlenut tree, *Aleurites moluccana*, introduced to Hawaiʻi by Polynesian settlers. The outer husk of the fruit or nut was used to make a black dye for tapa and tattooing; sap from the fruit was used as medicine to treat thrush, and used as a purgative; the hard shell of the nut was used in *lei* making; the kernel of the nut was the source of an oil that was burned for illumination and also used as a wood varnish for surfboards and canoes; the kernel was also chewed and spit on rough seas to calm the ocean and baked kernels were mixed with salt and chili pepper to make a relish (*ʻinamona*); the trunk was used to make canoes and floats for fishing nets; a reddish dye was made from the bark and/or root; a gum exuded from wounded bark was used to treat tapa; the flower was mixed with sweet potato to treat thrush; the leaves were used in a poultice for swelling and infection.

kuluʻī A native tree or shrub in the genus *Nototrichium*.

lama A small native tree, *Diospyros sandwicensis*, whose very hard wood was widely used as house construction material by traditional Hawaiians; also used to make implements.

lei Garland, wreath.

maika Ancient Hawaiian game suggesting bowling.

makaʻāinana Commoner, populace, people in general.

māmaki A small native tree, *Pipturus albidus*, also called *māmake*; the berry was used as a laxative, a dressing for wounds, and a tonic for general debility; the berry was fed to children to treat thrush; the bark was used to make tapa cloth.

manono A native shrub or small tree, *Hedyotis terminalis*.

maʻo A native shrub, *Gossypium tomentosum*, the leaf of which was traditionally used to make a green dye.

mauka Inland, upland, toward the mountain.

naio A native tree, *Myoporum sandwicense*, with hard, dark, yellow-green wood. The wood was used traditionally for the main timbers of houses.

naupaka A native low shrub, *Scaevola sericea*, from which the root was used medicinally and the fruit was occasionally eaten.

niu The coconut palm was widely used in traditional Hawaiʻi. The base of the trunk was used to make calabashes and drums; the trunk was used to make canoes and posts for houses; leaves were used for thatching, plaited to make baskets and fans, and used to beat the water to scare fish into nets; the base of the leaf was used to pound the banks of taro patches; the midribs of the leaves were used to make brooms, string kukui nut kernels for lights, make shrimp snares, and as musical instruments. The fruit's fibers were used to make sennit; the shell of the fruit was

used to make bowls, spoons, and knee drums; the flesh of the fruit was eaten at all stages of maturity and used in various dishes; milk and oil were made from the flesh, the oil was used on the body and hair, and also used to calm water; the water from the fruit was drunk.

ʻōhiʻa ʻai The mountain apple, *Syzygium malaccensis*, a forest tree growing up to 50 ft. high. Traditionally the trunk of the tree was used for house posts and rafters, enclosures for temples, and to carve idols. The fruit was eaten raw or dried. The bark was made into an infusion to remedy sore throats and a dye was also made from the bark.

ʻōhiʻa lehua A native plant, *Metrosideros polymorpha*, that ranges in habit from prostrate shrubs to tall trees and is distributed from sea level to 2,200 m elevation on all the main Hawaiian Islands.

ʻōlapa A native tree, *Cheirodendron trigynum*. Traditionally the bark of the tap root was used medicinally, the wood was used in spear construction, and the leaves were used in *lei* making. Also, the fruit, leaves, and bark were used to make a bluish *kapa* dye.

olomea A native shrub or small tree, *Perrottetia sandwicensis*, the wood of which was used in conjunction with the softer *hau* wood to produce fire by rubbing. See also *hau*.

olonā A native shrub, *Touchardia latifolia*, whose bark was valued as the source of a strong, durable fiber for fishing nets, for nets to carry containers, and as a base for ti-leaf raincoats and feather capes.

olopua The native tree, *Nestegis sandwicensis*, the hard wood from which was used for spears, adze handles, rasps, and digging sticks; it was also a preferred fire wood.

pāpala A native tree or shrub in the genus *Charpentiera*.

poi The Hawaiian staff of life, made from cooked taro corms, or rarely breadfruit, pounded and thinned with water.

ʻūlei The native shrub, *Osteomeles anthyllidifolia*. Traditionally this wood was used to make digging sticks, spears, and a musical bow.

ʻulu 1. Discoidal, smooth stone as used in *ʻulu maika* game; 2. breadfruit.

ʻulu maika Stone used in the *maika* game. See also *maika*.

wauke A small tree or shrub, *Broussonetia papyrifera*, whose bark was made into *kapa* cloth. The inner bark was used to make cordage, and the shoots were used to treat childhood diseases. The leaves, along with banana and taro leaves, were used ceremonially to wrap the bodies of *aliʻi* after death.

Abbreviations

BP Before present, used in ^{14}C dating where present refers conventionally to the year AD 1950.

Bellows AFS Bellows Air Force Station and Marine Corps Training Area Bellows (MCTAB) are facilities located on the southeast coast of Oʻahu in Waimānalo. The installation has military training and recreational facilities.

g The gram, a derived unit of mass in the International System of Units, equal to 10^{-3} kg. See also kg (kilogram).

kg The kilogram, a base unit of mass in the International System of Units, equal to the mass of the international prototype of the kilogram, which is approximately the mass of a cubic decimeter of water.

km The kilometer, a derived unit of length in the International System of Units, equal to 10^3 m. See also m.

m The meter, a base unit of length in the International System of Units, equal to the length of the path traveled by light in vacuum during a time interval of 1/299,792,458 of a second.

Bibliography

Addison, D. J. (1997, June). *Archaeological Subsurface Testing for the Removal of Pipeline Utilities Under the Installation Restoration Program at Bellows Air Force Station, Waimānalo, Koʻolaupoko District, Oʻahu, Hawaiʻi*. Draft report prepared for U.S. Army Corps of Engineers, Pacific Ocean Division. Honolulu: International Archaeological Research Institute.

Allen, M. S. and G. M. Murakami (1999). Lanaʻi island's arid lowland vegetation in late prehistory. *Pacific Science 53*, 88–112.

Athens, J. S., H. D. Tuggle, J. V. Ward, and D. J. Welch (2002). Avifaunal extinctions, vegetation change, and Polynesian impacts in prehistoric Hawaiʻi. *Archaeology in Oceania 37*, 57–78.

Buck, C. E., J. A. Christen, and G. N. James (1999). Bcal: An on-line Bayesian radiocarbon calibration tool. *Internet Archaeology 7*.

Desilets, M. E. and T. S. Dye (2002, January). *Archaeological Monitoring and Sampling During Bellows OU7 UST Removal Project Interim Remedial Action, Phase I, Bellows Air Force Station, Waimānalo, Koʻolaupoko, Oʻahu*. Prepared for U.S. Army Corps of Engineers. Honolulu: International Archaeological Research Institute.

Djindjian, F. (2001). Artefact analysis. In Z. Stančič and T. Veljanovski (Eds.), *Computing Archaeology for Understanding the Past*, Number 931 in BAR International Series, pp. 41–52. Oxford: Archaeopress.

Dye, K. P. and T. S. Dye (2009, November). *Pre-construction Archaeological Resource Survey for the New Civil Engineering Building, Bellows Air Force Station, Waimānalo, Koʻolaupoko, Oʻahu, Hawaiʻi, TMK: (1) 4–1–001:015*. Prepared for J. M. Waller Associates. Honolulu: T. S. Dye & Colleagues, Archaeologists.

Dye, T. S. (1998, September). *Archaeological Services in Support of the Final Environmental Impact Statement for Proposed Expansion of Military Training and the Construction of Improvements to Existing Recreational Resources at Bellows Air Force*

Station, Waimānalo, Hawai'i. Report prepared for Department of the Navy, Pacific Division, Naval Facilities Engineering Command. Honolulu: International Archaeological Research Institute.

Dye, T. S. (2000). Effects of ^{14}C sample selection in archaeology: An example from Hawai'i. *Radiocarbon 42*(2), 203–217.

Dye, T. S. (2010, October). Social transformation in old Hawai'i: A bottom-up approach. *American Antiquity 75*(4), 727–741.

Dye, T. S. (2011). A model-based age estimate for Polynesian colonization of Hawai'i. *Archaeology in Oceania 46*, 130–138.

Dye, T. S. and J. Pantaleo (2010). Age of the O18 site, Hawai'i. *Archaeology in Oceania 45*, 113–119.

Dye, T. S., C. Sholin, and K. Yeates (2012, February). *Archaeological Data Recovery at Site 50–80–11–4856 in Support of the Construct Recreational Cabins Project, Bellows Air Force Station, Waimānalo, Ko'olaupoko, O'ahu, TMK: (1) 4–1–015:001.* Prepared for Cape, Inc. Honolulu: T. S. Dye & Colleagues, Archaeologists.

Huebert, J. M., M. S. Allen, and R. T. Wallace (2010). Polynesian earth ovens and their fuels: Wood charcoal remains from Anaho Valley, Nuku Hiva, Marquesas Islands. *Journal of the Polynesian Society 119*(1), 61–98.

Kirch, P. V. (1984). *The Evolution of the Polynesian Chiefdoms.* New Studies in Archaeology. Cambridge: Cambridge University Press.

Kolb, M. J. and G. M. Murakami (1994). Cultural dynamics and the ritual role of woods in pre-contact Hawai'i. *Asian Perspectives 33*, 57–78.

Lebo, S. A., K. P. Dye, and T. S. Dye (2009, May). *Pre-Construction Archaeological Survey for New Recreational Lodging at Bellows Air Force Station.* Prepared for Earth Tech. Honolulu: T. S. Dye & Colleagues, Archaeologists.

McElroy, W. K., T. S. Dye, and E. H. R. Jourdane (2006, February). *Archaeological Monitoring and Investigations During Installation of Leach Fields at Bellows Air Force Station and Hickam Air Force Base, Waimānalo, Ko'olaupoko, and Moanalua, Kona, O'ahu.* Prepared for Shaw Environmental. Honolulu: T. S. Dye & Colleagues, Archaeologists.

Orliac, C. (2000). The woody vegetation of Easter Island between the early 14th and mid-17th centuries AD. In C. M. Stevenson and W. S. Ayres (Eds.), *Easter Island Archaeology: Research on Early Rapanui Culture*, pp. 211–220. Los Osos, CA: Easter Island Foundation.

Putzi, J. L. and T. S. Dye (2005, July). *Archaeological Monitoring Report for Replace Military Family Housing Projects Phase I at Hickam Air Force Base and Bellows Air*

Force Station, Hawaii. Prepared for Rim Architects. Honolulu: T. S. Dye & Colleagues, Archaeologists.

Scott, A. C. and F. Damblon (2010). Charcoal: Taphonomy and significance in geology, botany and archaeology. *Paleogeography, Palaeoclimatology, Palaeoecology 291*, 1–10.

Sholin, C. E., K. R. Yeates, and T. S. Dye (2012, March). *Archaeological Monitoring at Site 50–80–15–4856 in Support of the Construction of New Recreational Lodging at Bellows Air Force Station, Waimānalo, Koʻolaupoko, Oʻahu, Hawaiʻi, TMK: 4–1–001:015*. Prepared for Cape, Inc. Honolulu: T. S. Dye & Colleagues, Archaeologists.

Strong, C. C. and R. G. Skolmen (1963). Origin of drift-logs on the beaches of Hawaii. *Nature 197*, 890.

Théry-Parisot, I., L. Chabal, and J. Chrzavzez (2010). Anthracology and taphonomy, from wood gathering to charcoal analysis. a review of the taphonomic processes modifying charcoal assemblages, in archaeological contexts. *Palaeogeography, Palaeoclimatology, Palaeoecology 291*, 142–153.

Wagner, W. L., D. R. Herbst, and S. H. Sohmer (1990). *Manual of the Flowering Plants of Hawaiʻi*. Number 83 in B. P. Bishop Museum Special Publication. Honolulu: University of Hawaii Press and Bishop Museum Press.