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Lāna'i Island's Arid Lowland Vegetation in Late Prehistory[1]

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ABSTRACT: Native Hawaiian dryland forests, important from both ecological and cultural perspectives, are among the more poorly known Hawaiian vegetation types. Wood-charcoal assemblages from archaeological features offer one means for investigating not only the composition of these diverse forests, but also the timing and mechanisms of their demise. Representing short-duration events, and relatively localized catchments, wood-charcoal assemblages provide different information from time-averaged, regional-scale pollen records. Analysis of the wood-charcoal evidence from the traditional Hawaiian settlement of Kaunolū, southwestern Lāna'i, suggests that arborescent dryland forest species once extended into the island's arid lowland regions. Moreover, many dryland forest taxa apparently persisted in this region until sometime after abandonment of the Kaunolū settlement in the mid-1800s. We suggest that although Native Hawaiians may have contributed to forest loss, ultimately some other mechanism, most likely exotic herbivores, transformed the southern coast of Lāna'i into the arid grasslands seen today.

HAWAIIAN DRYLAND FORESTS were remarkable for their floristic diversity (Fosberg 1936, Rock 1974, Mueller-Dombois 1981). Relative to mesic and wet forests, they contained considerably more species, many of which are now rare or extinct (e.g., Baker and Allen 1976, Athens 1997). Rock (1974: 15) remarked that "not less than 60 percent of all the species of indigenous trees growing in these islands can be found in and are peculiar to the dry regions or lava fields of the lower forest zone." These forests also were home to many highly specialized endemic Hawaiian birds, several of which are also now rare, locally extirpated, or extinct (Munro 1960, Olson and James 1984:776). Olson and James (1984:776), commenting on dry lowland areas in particular, noted that "fossil [bird] evidence conclusively shows not only that many prehistorically extinct species once flourished in the lowlands, but also that virtually all extant species occurred there as well." For Native Hawaiians, the dryland forests provided many of the Islands' finest woods, extremely hard and close-grained species prized for tools, weapons, timbers, and ritual practices (Malo 1951:20–23, Apple 1971, Rock 1974:15). As the foregoing suggests, understanding the temporal-spatial distributions of these dryland forest species has importance for a variety of scientists interested in historical ecology. However, dryland forests are among the more poorly known Hawaiian vegetation types (Gagné and Cuddihy 1990), particularly on Lāna'i Island, where early written accounts are limited and palynological records are not yet available.

In this study we used archaeological wood-charcoal assemblages to consider the distribution, composition, and demise of arborescent native vegetation in the Lāna'i Island lowlands, particularly along the southern coast. The relatively late age of the

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archaeological contexts allowed us to evaluate change across the late prehistoric to early historic temporal boundary and the potential role of Native Hawaiians in effecting local vegetation change.

Historical Records of Hawaiian Dryland Forests

Historically, some of the most detailed information on Hawaiian dryland forests comes from the botanical studies of Joseph Rock (1974). In 1910, he extensively surveyed native forests of Hawai'i Island and used climatic variables to define key botanical regions. However, by that time many arid regions had been converted to pasture or seriously reduced by herbivores. Moreover, Rock found the species-rich dryland forests of Hawai'i Island to be limited to small areas between 1000 and 2000 ft (305–610 m) elevation at Pu'uwa'awa'a (North Kona District), South Kona, and Kīpuka Puaulu (Ka'ū District). He suggested that this rich forest type had been gradually dissected and partially destroyed by lava flows.

More recently, insights into the distribution and composition of lowland forests generally have been provided by palynological studies. Several lengthy vegetation records, some exceeding the period of human occupation, are now available for lowland regions of O'ahu Island (Athens et al. 1992, 1997, Athens and Ward 1993*a*, Athens 1997). Athens (1997:259) argued that the leeward lowland forests of O'ahu were dominated by an upper story of *Pritchardia*, with a "high diversity of secondary and lower-story species." He suggested that the lowland forests of O'ahu disappeared in a matter of centuries after human colonization and by A.D. 1400–1500 there was essentially nothing left; by the time of European contact the native lowland forest was "absolutely gone" (Athens 1997: 261). Athens opined that the native forest associations seen by early botanists may have had little resemblance to those before human occupation.

Although not representing the same time depth, archaeological wood-charcoal assemblages are available for a broader geographic area (e.g., the sample of Table 1) than is the case for pollen cores. They differ from the O'ahu palynological samples in some important respects. In particular, the wood-charcoal assemblages record arborescent taxa in many arid lowland areas during the period of Hawaiian occupation and suggest that they were present in sufficient abundances to make their way into varied cultural features on a regular basis. Several interpretations are possible. Perhaps different vegetation histories occurred in the areas represented by pollen versus wood-charcoal assemblages. Alternatively, the O'ahu pollen records, lacking the benefit of calibration by modern vegetation analogs, may overestimate certain taxa (e.g., *Pritchardia*) and, by extension, the magnitude of vegetation change. In our view, the differences are most likely attributable to the distinct temporal and spatial scales represented by the two kinds of data, as well as the differing biases that affect them. Pollen assemblages are time-averaged records of regional vegetation change, potentially biased by taxonomic differences in pollen productivity, differing pollen dispersal mechanisms, and/or the secondary pollen transport. Wood-charcoal assemblages, in contrast, represent more localized and temporally discrete floral records. Although they may overcome some of the biases inherent in palynological records, they are affected by factors of cultural selection. Potentially useful in this regard is the opportunity for rare species to be recorded if they are culturally important, as might be the case with xeric hardwood species. From an anthropological perspective, wood-charcoal assemblages also provide information on cultural patterns of wood use.

The foregoing suggests that pollen and wood-charcoal assemblages provide complementary but only partially overlapping vegetation records. Both are necessary for fully understanding local environments and in particular their relationship with human activities. Ideally, the two kinds of analyses would proceed in tandem, but so far these efforts have been limited (but see Wickler et al. 1991, Athens et al. 1997).

TABLE 1

SUMMARY OF OTHER WOOD CHARCOAL STUDIES FROM ARID HAWAIIAN ENVIRONMENTS

	SITE LOCALITY							
TAXA Rainfall (mm)	Kohala 1[a] 1,270	Kalaupapa[b] 1,016	Kohala 2[c] 630	Kaho'olawe inland[d] 635	Wailuku[e] 460	Kamiloloa[f] 250	Kaunolū[g] >250	Kaho'olawe coast[d] >250
Cultivated								
Artocarpus	+	+					+	+
Cordyline	+	+	+			+		
Cocos			+					
Dioscorea			+					
Ipomoea	+	+	+			+		+
Lagenaria			+			+	+	+
Saccharum	+		+					+
Coastal								
Abutilon		+						
Chamaesyce	+	+	+	+		+	+	+
Chenopodium	+	+	+	+	+	+	+	+
Cordia							+	
Dodonaea		+	+	+	+	+	+	+
Erythrina						+		+
Metrosideros	+	+	+			+	+	+
Osteomeles								+
Scaevola	+	+				+	+	
Senna		+						
Sesbania						+		
Sida		+	+				+	+
Reynoldsia							+	+
Dryland								
Acacia koaia					+	+	+	
Bidens						+		
Bobea							+	
Colubrina		+						
Diospyros		+		+	+	+	+	+
Flueggea						+		
Myoporum						+		+
Myrsine							+	+
Nestegis		+						+
Nothocestrum				+		+	+	+
Nototrichium	+			+		+	+	+

Rauvolfia		+						+
Santalum				+			+	+
Sophora			+		+		+	+
Styphelia					+		+	
Mesic								
Acacia koa						+	+	+
Aleurites	+					+	+	+
Canthium		+				+		+
Coprosma			+					
Hedyotis						+		
Ilex						+		
Perrottetia	+							+
Psychotria				+		+		+
Syzygium	+	+			+		+	
Tetraplasandra	+		+			+		

[a] Murakami (1994*a*).
[b] Murakami (1994*b*).
[c] Murakami (1994*c*).
[d] Graves and Murakami (1993).
[e] Kolb and Murakami (1994).
[f] Murakami (1993).
[g] This report.

The Vegetation History of Lāna'i and Agents of Change

Although O'ahu has been the subject of intensive palynological study and wood-charcoal assemblages are available for most of the Hawaiian Islands, Lāna'i (Figure 1) remains understudied. The island also was largely overlooked by early botanists (Fosberg 1936:119), who more commonly remarked on the magnitude of forest loss and extent of erosion. Serious attention was not paid to Lāna'i until 1911, when George C. Munro (1960), general ranch manager and amateur ornithologist and botanist, initiated a program to save the island's remaining native flora and fauna. Similarly, palynological records for the island are lacking, and other wood-charcoal studies are not yet available. Overall little is known about the flora of Lāna'i, either before the advent of Polynesian colonists or at the time of European contact.

Of particular interest here is the impact of Native Hawaiians on the dryland vegetation of Lāna'i during the late prehistoric and early post-European period. The role of people in the demise of the native Hawaiian flora generally seems undeniable (e.g., Kirch 1982, Cuddihy and Stone 1990, Athens 1997), but the timing and character of human impact is less certain. Before Western contact, Native Hawaiians reduced lowland forests as they opened areas for gardening, carved out settlements, and at least occasionally set range fires (e.g., Kirch 1982, Athens and Ward 1993*a*, Graves and Murakami 1993). Within the last two centuries, large tracts of land have been converted to pastures, plantations, and housing developments. Throughout the period of human settlement, dryland forests in particular have been vulnerable, being more susceptible to fire and easier for introduced browsers and grazers to penetrate relative to wetter vegetation types. In addition, some components of these highly diverse forests may always have been localized and rare, and thus more vulnerable to extinction and extirpation (see Gagné and Cuddihy 1990:72). Because many of these rare elements also are hardwoods, the potential for their representation in cultural contexts is enhanced.

Athens (1997) took the position that Native Hawaiians had both transformed and then fully depleted native lowland forests, at least on O'ahu Island, by the time of Western contact. More generally, Olson and James (1984) argued that "by removing such [arid lowland] habitats from the Hawaiian Islands, the Polynesians wrought a greater change in the total biota of the archipelago than has been accomplished by all post-European inroads in the wet montane forests." Contrasting with this above, Hobdy (1993) and Ziegler (1989) recently opined that native vegetation on Lāna'i remained largely intact until the introduction of herbivores. Spriggs (1991:108), in evaluating Hawaiian impact on Kaho'olawe, took a moderate view, suggesting that although herbivores and overgrazing, not Native Hawaiians, were responsible for large-scale erosion and denudation of the island, Native Hawaiians may have cleared vegetation for agriculture and firewood and transformed a diverse dry forest into an open savanna of grassland and trees. More recently, Graves and Murakami (1993:33) argued that "there is absolutely *no* indication from our analyses of the wood charcoal data that the dramatic loss or diminishment of woody taxa from Kaho'olawe was a prehistoric phenomenon." Thus, there is a wide range of opinions on the scale, intensity, and timing of human impact on native lowland forests and we might not expect each region to have been affected uniformly (see also Athens 1997). Wetter windward coastal areas, for example, may have been impacted earlier, and arid lowlands may have been affected later but more severely. On Lāna'i, direct evidence on the timing of forest decline and the role of Native Hawaiians versus introduced animals has been largely lacking. In this regard, the wood-charcoal samples reported here are particularly important and offer an avenue for examining the dynamic interrelationships between people and the landscape in more detail than previously possible.

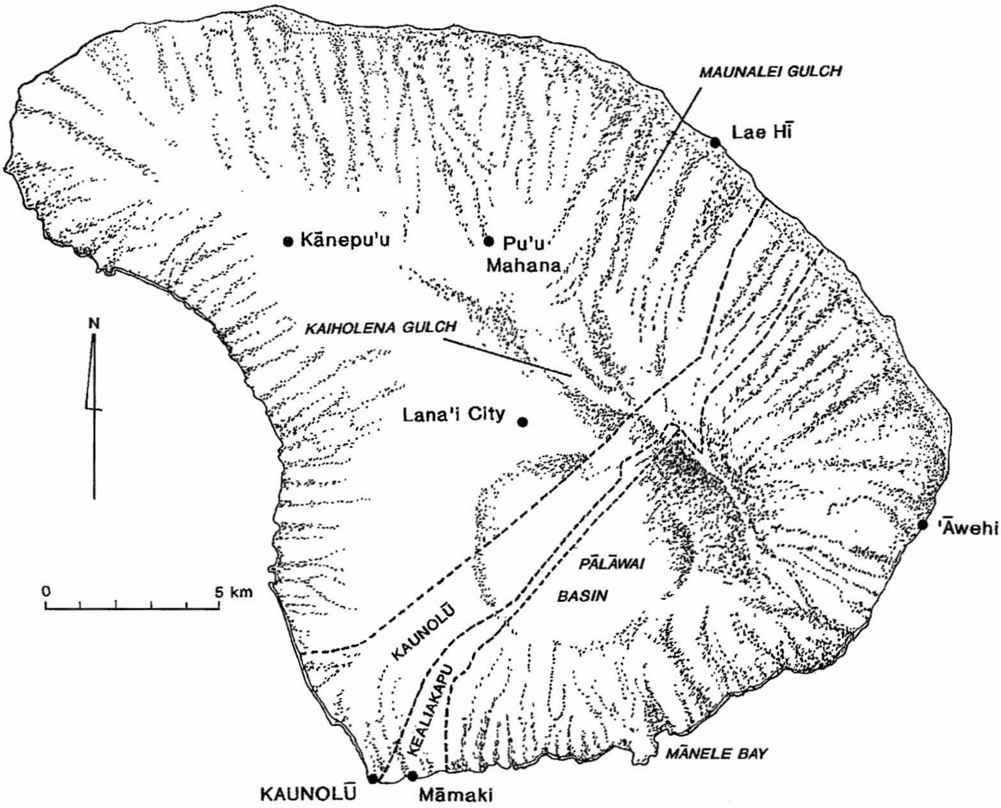

FIGURE 1. Map of Lāna'i Island and localities named in text.

THE LĀNA'I WOOD-CHARCOAL STUDY

Environmental and Cultural Context

Lāna'i is one of the smaller Hawaiian islands, with less than 365 km^2 area. A northwest-trending rift zone forms the backbone of the island, and a second rift zone extends southwest, just north of Kaunolū. The summit of the island, Lāna'i Hale, rises to 1027 m, and an associated collapsed caldera forms a prominent upland plateau at about 610 m elevation. Pālāwai Basin, lying between 305 and 460 m, is also part of this old caldera, now filled with lava flows and alluvium (Macdonald and Abbott 1974: 338).

Climatically, Lāna'i lies in the rainshadow of Maui. It is a poorly watered island, especially along the leeward coast, where the annual rainfall is typically below 250 mm (Armstrong 1983). When Munro first drew attention to Lāna'i, much of the native vegetation was under siege from introduced animals, including cattle, sheep, deer, goats, and pigs. It was through Munro's efforts that the dryland forest at Kānepu'u, what some have called the finest example of this forest type in Hawai'i, was saved from near total destruction. Hobdy (1993; see also Gagné and Cuddihy 1990) offered a simple model of the island's pre-Polynesian vegetation, based on botanical collections, relict vegetation, and historical accounts. Coastal and strand plants were predicted for the immediate coastal environs. Inland from the coastal strand, Hobdy suggested that an arid grassland dominated by *Heteropogon* and *Panicum* and a low shrub and forb community dominated by *Dodonaea* and *Lipochaeta* once existed. Above 305 m elevation, he (1993) proposed that the unique dryland forest of Kānepu'u was once more widespread (see also Warshauer 1976 *in* Ziegler 1989, Gagné and Cuddihy 1990:73). Today, Kānepu'u is the largest remaining stand of dryland forest on the island (Ziegler 1989) and in addition to the enclosure at 520 m, scattered remnants of forest extend ca. 4 km to the east and down to an elevation of 457 m. Patches of native dry forest are also known from some of the lower gulches between Maunalei and 'Āwehi on the northeastern coast (Steve Perlman *in* Ziegler 1989:19, Harris et al. 1991).

In addition to the dry forests, another important arid vegetation type was historically known from the Pālāwai and Miki Basins. This consisted of a unique *Chamaesyce celastroides* forest, now destroyed by goats and cattle (Hobdy 1993 based on Munro 1960). Rock (1974:85), however, suggested that the inland plateau may have once been covered with a xerophytic vegetation similar to that seen today at Kīpuka Puaulu on the lower slopes of Mauna Loa in Hawai'i Volcanoes National Park. Rock also mentioned, without detail, the interesting xerophytic vegetation in the valleys of Mahana, Kō'ele, and Kaiholena, as well as a dry forest on the western end of Lāna'i.

Archaeological excavations on Lāna'i have been limited compared with those on other islands. Currently, human settlement on the island dates to ca. the eleventh century A.D., based on a radiocarbon determination of A.D. 1035–1250 (two sigma; calibrated using Klein et al. 1982) from Mānele Bay on the southern coast (Athens and Kaschko 1988). The settlement of Laehī on the north coast dates to a slightly later period, A.D. 1282–1436 (two sigma) (Graves and Ladefoged 1991), and occupation at Kaunolū is no earlier than the fourteenth century (see below). Although earlier settlement of the island is possible, these dates are broadly consonant with more general models of Hawaiian settlement that predict relatively late occupation of drier environments, beginning around the fifteenth century A.D. (e.g., Kirch 1984, Hommon 1986). Thus, from the evidence at hand, anthropogenic influences on Lāna'i are likely to have occurred over at least a 700-yr period.

Kaunolū Excavations and Sample Selection

The traditional Hawaiian community of Kaunolū (Figure 2) is located on the southwestern coast of Lāna'i and covers an area of ca. 0.5 km^2 between the coast and 70 m elevation. Kaunolū village has the unusual position of straddling two traditional land units, or *ahupua'a*: Keāliakapu and Kaunolū. The more western *ahupua'a* of Kaunolū extends across the entire island, to the northeastern coast, whereas the eastern land unit of Keāliakapu terminates near the summit of the island (see Figure 1). Kaunolū was one of the first Hawaiian settlements to be mapped as an integrated community by archaeologist Kenneth Emory in the early 1920s. Based on its well-preserved architectural features, associations with historic personages, and diversity of feature types, the settlement was recently designated a National Historic Landmark.

In 1991, Bishop Museum archaeologists returned to Kaunolū with funding from Castle and Cooke, Ltd., to carry out a modern archaeological mapping program and construct an interpretive trail (Dixon et al. 1992). With the small remaining portion of the original grant, M.S.A. initiated test excavations at the settlement in November–December of 1993. Approximately 6 m^2 were opened at 11 sites over the course of six working days. The primary objective was to collect radiocarbon samples and to construct a chronology for the settlement.

The available radiocarbon dates indicate that the majority of Kaunolū's architectural features were in use during the late prehistoric to early historic period (e.g., ca. A.D. 1600 to 1850). According to Emory (1969:51), Kaunolū was abandoned by 1875. The historic assemblages examined thus far, however, suggest that abandonment occurred earlier, at least at some sites. In two excavated contexts, sites A6-78 and A6-94, small amounts of glass, chert, and metal

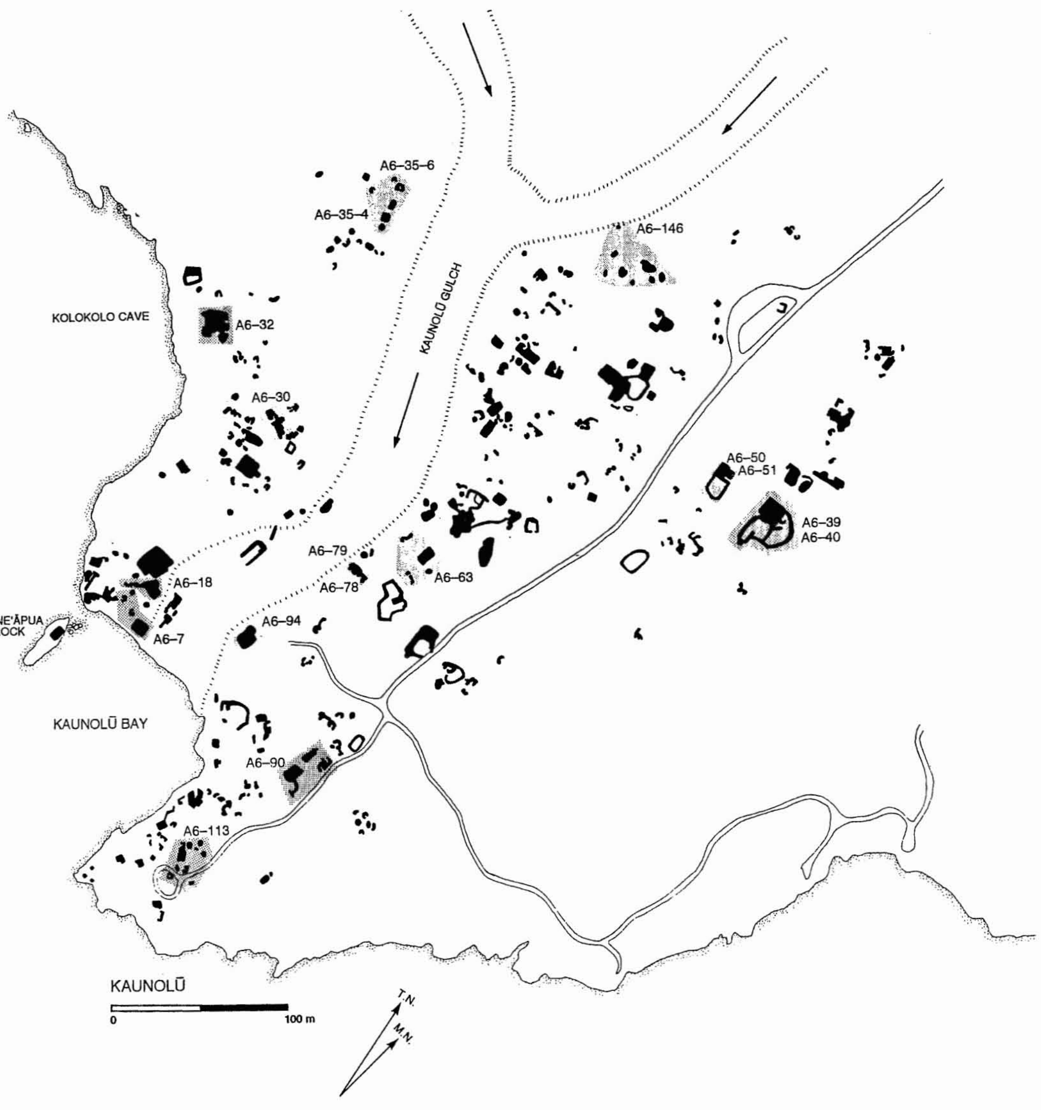

FIGURE 2. Settlement of Kaunolū, Lāna'i Island.

indicate historic occupation, but these materials are never abundant. Similarly, no unambiguous historic-period fauna were recovered. Emory (1969: 5–10) suggested that notable interaction with Euro-Americans did not occur on Lāna'i until the 1840s, when missionaries became increasingly active on the island. He also reported a major population decline between 1838 and 1846 that he attributed to emigration. Our excavation findings, coupled with the more general historic accounts, suggest that Kaunolū was probably largely deserted by the mid-1800s. According to Emory (1969: 51), the last resident left the nearby Māmaki settlement around 1900.

Today the vegetation of Kaunolū consists of scattered *Prosopis pallida*, *Leucaena leucocephala*, and *Sida fallax*, with a mixture of exotic and native grasses and herbs. A brief botanical reconnaissance of the area in 1982 also noted two additional native shrubs, *Gossypium tomentosum* (*Ma'o*) and *Abutilon incanum* (*Ma'o*) (P. Higashino, pers. comm., 1994). No other native arborescent species have been recorded from the area.

The samples reported here came from two sites: a large residential complex designated A6-78 (Figure 3) and a small overhang shelter (feature 13) assigned to site A6-146. Samples from the larger complex were selected because they offered a stratigraphically defined temporal series with the potential to record important changes in species composition or relative abundances. The single sample from the small shelter was selected because this site provided what was believed to be the earliest secure date from Kaunolū. As such, this second sample had the potential to provide a snapshot of the local vegetation coincident with initial human use of the area.

Site A6-78 overlooks the eastern bank of Kaunolū Gulch. The site consists of terraces, enclosures, and platforms typical of a residential complex occupied on either a permanent or an extended basis. The wood-charcoal samples were secured by systematic, stratigraphically controlled excavations in a large (1.0 by 1.25 m), rectangular, stone-lined hearth, designated feature 3 in Figure 3.

Excavation within the hearth revealed six stratigraphic layers, indicated by roman numerals (Figure 4). In most cases, the excavators followed the natural stratigraphy and their excavation levels (arabic numerals) are identical to the stratigraphic layers. However, layer I, a thin surficial organic accumulation, was excavated with layer II as a single level (I & II/1) because layer I was not visible except in profile. Layer III, a relatively thick stratum, was excavated as two levels: III/2 and III/3, to maintain fine stratigraphic control.

Three small, flat pieces of metal, two from layer I & II/1 and a third from layer III/2 suggest that the most recent use of the site occurred in the historic period. A layer IV radiocarbon sample (BETA-69106) produced a one sigma range of A.D. 1890 to 1910 (see Table 2). This seems like an unacceptably late age for this subsurface layer given the entirely traditional artifact and faunal assemblages. The two sigma range for this sample indicates a potential age between A.D. 1680 and 1930. The one sigma range for the layer V sample (BETA-69107) is between A.D. 1510 and 1670. As with layer IV, the associated material culture and faunal remains are traditional. Although the layer IV date is problematic, a late prehistoric to early historic age for the stratigraphic series as a whole conforms with both the evidence from this site and from the settlement at large.

Feature 13 of site A6-146 is situated in the eastern slope of Kaunolū Gulch, roughly 360 m from the coast. This overhang shelter is adjacent to a residential complex of terraces, platforms, and enclosures, but use of this feature was probably temporally and functionally unrelated to these other structures. A rough alignment of small boulders encloses an area ca. 2.25 m long by 1.15 m wide. The area under the overhang is 40 cm deep with a maximum interior height of 40 cm. Overall, the small size of the shelter and simplicity of associated architecture suggest that it was used as a temporary camp site.

Consistent with the foregoing, excavations revealed a single occupation associated with the shelter (Figure 5). Layer I is a thin organic accumulation on the surface of the shelter floor. Layer II, the location of the identified wood-charcoal sample of Table 3, consists of a pit of 10 cm depth with ash, small amounts of charcoal, and fire-altered rocks. This feature was interpreted as a hearth and most likely represents a single event. Layer III contained small amounts of charcoal, shell, and two basalt flakes. It is probably contemporaneous with the pit; however, this temporal relationship is ambiguous given the origination of the pit at the layer I/III boundary (see Figure 5). A sample of charcoal (BETA-69111) from directly under the pit (at the layer II/III boundary) was dated to A.D. 1425–1954 (two sigma) with a most probable age range of A.D. 1424–1675. This is the earliest secure date from the Kaunolū settlement as a whole, and as such is one of the reasons we selected this site for wood-charcoal analysis. Layer IV is culturally sterile.

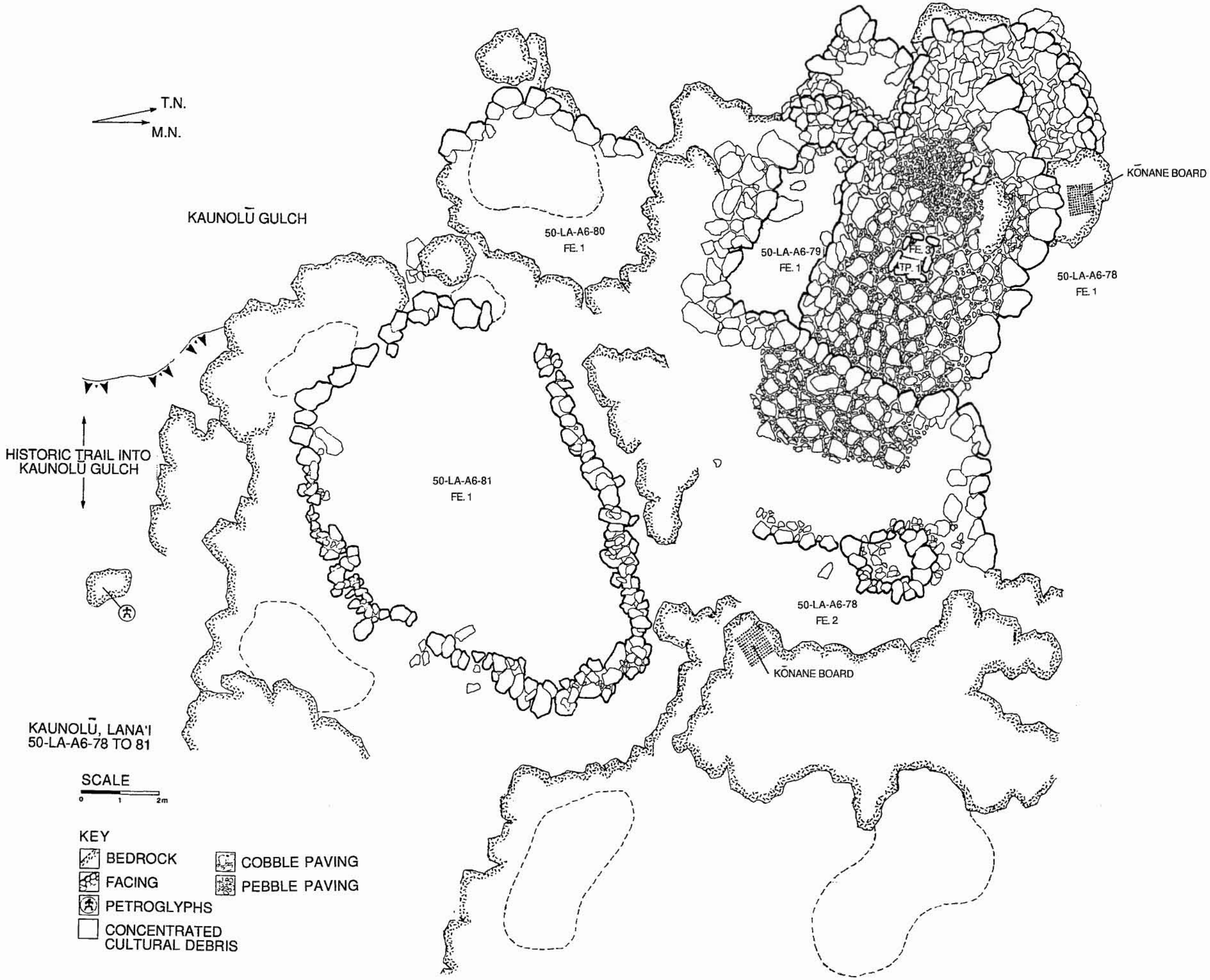

FIGURE 3. Site A6-78, Kaunolū settlement, Lāna'i Island.

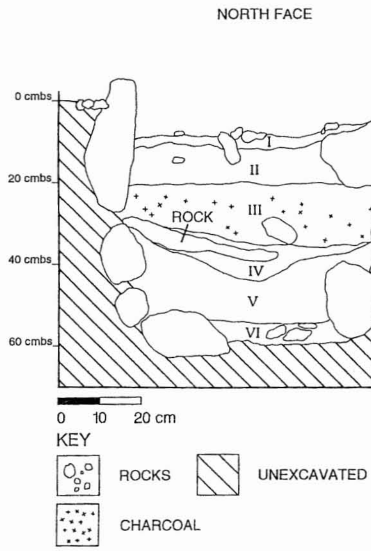

FIGURE 4. Profile of excavation at site A6-78; wood-charcoal samples from layers I and II, layer III (upper and lower level), and layer IV.

Methods

The wood-charcoal samples were initially sorted into groups based on common anatomical features, as observed under a dissecting microscope (American Optical Stereoscan) at 40×. Taxa with distinctive structures that were well known to G.M.M. were identified without further processing. For more ambiguous or unknown groups, representative specimens were impregnated with Spurr's epoxy resin (after Smith and Gannon 1973), polymerized in embedding capsules, thin-sectioned on a sliding microtome, and then observed in more detail. Identifications were made using the Pacific Islands Wood Collection housed in the Department of Botany, University of Hawai'i at Mānoa, and the published literature. The former contains over 200 species of Hawaiian woody plants, including both Polynesian introductions and native dryland taxa.

Results: Systematic Review of Wood-Charcoal Taxa

Twenty-five woody taxa, along with *Lagenaria* rind, *Aleurites* nutshells, fern, and parenchyma tissue were identified by G.M.M. from the five samples (Table 2). Twenty-one of the woody taxa were identified at least to the generic level and most to species; another four taxa were distinctive but did not compare well with any particular specimens in the reference collection.

The ecological interpretations provided here are based largely on the currently known distributions of the identified taxa, as described in the botanical literature. The systematic review that follows discusses the known biogeographic distributions of each taxon, relevant ecological characteristics, ethnographically documented uses of the woods, and other key archaeological occurrences.

FAMILY AMARANTHACEAE

Nototrichium sandwicense (*Kulu'ī*) (A. Gray) Hillebr.

The endemic genus *Nototrichium* consists of two species (Wagner et al. 1990: 193–194), of which *N. sandwicense* is most likely represented at Kaunolū. Both species occur as shrubs to small trees, ranging in height from 1 to 6 m. Rock (1974: 141) noted that *N. sandwicense* may become more arborescent with elevation. It occurs as a scattered to sometimes common element, being found in open dry forests, on exposed ridges, and on lava fields, from 0 to 75 m elevation. Rock (1974: 141) remarked that it is peculiar to very dry regions and sometimes occurs as a "straggling shrub where nothing else can live." *Nototrichium sandwicense* is distributed across all of the Hawaiian Islands. Rock (1974: 143) described the wood as "coarsely grained and very light," but no ethnographically reported uses could be found.

FAMILY ARALIACEAE

Reynoldsia sandwicensis A. Gray (*'Ohe*)

This endemic Hawaiian tree ranges up to 30 m in height and typically occurs in dry to occasionally mesic forests between 30

TABLE 2

Distribution of Taxa in Percentage Weight (Top) and Number of Identified Specimens (Bottom)

	PROVENIENCE				
TAXON	A6-78-3 I & II/1	A6-78-3 III/2	A6-78-3 III/3	A6-78-3 IV/4	A6-146-13 II/2
Acacia koa			0.8	3.1	
			4	8	
Acacia koaia	11.7	32.5	11.6	0.2	
	8	48	40	1	
Aleurites moluccana			0.3	1.4	3.6
			1	1	1
Artocarpus altilis				0.4	
				2	
cf. *Bobea* sp.			0.7	0.2	
			1	1	
Chamaesyce spp.	55.7	38.0	58.1	52.8	89.1
	57	72	205	122	22
Chenopodium oahuense	0.7	5.3	6.0	11.2	
	1	10	23	34	
cf. *Cordia subcordata*		1.0			
		2			
Diospyros sandwicensis				0.6	
				1	
Dodonaea viscosa		9.2	12.7		
		7	36		
Lagenaria siceraria			0.1	0.2	
			1	3	
Metrosideros polymorpha			0.2	20.3	
			4	28	
cf. *Myrsine* sp.				0.2	
				2	
Nothocestrum sp.	18.4				
	15				
Nototrichium sandwicense	1.0	0.9	1.6	2.6	
	1	1	7	3	
cf. *Reynoldsia sandwicensis*		0.1			
		1			
Santalum sp.		0.9			
		1			
Scaevola sericea	1.5	3.5	0.2	0.2	1.6
	2	22	2	2	1
Sida cf. *fallax*		2.9	0.4	2.8	3.8
		4	3	6	2
Sophora chrysophylla	3.5		3.6	1.6	
	4		10	3	
Styphelia tameiameiae		0.2	1.6		
		1	4		
Syzygium malaccense	0.2	1.9	0.2	0.3	
	1	4	1	1	
Bark	0.6	1.5			
	1	2			
Fern				0.4	
				1	
Parenchyma			0.2		
			1		
Vine				0.2	
				1	

TABLE 2 (continued)

	PROVENIENCE				
TAXON	A6-78-3 I & II/1	A6-78-3 III/2	A6-78-3 III/3	A6-78-3 IV/4	A6-146-13 II/2
Unknown 1		0.2	1.5	1.3	
		1	6	1	
Unknown 2	3.9	0.4	0.2		
	5	1	1		
Unknown 3	2.8	1.5			
	4	2			
Unknown 4					1.9
					2
Totals: % weight	100%	100%	100%	100%	100%
NISP	99	179	350	221	28

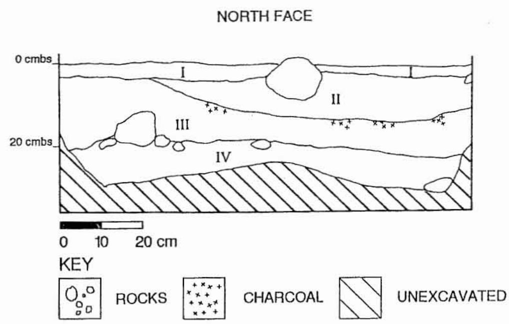

FIGURE 5. Profile of excavation at site A6-146; wood-charcoal sample from layer II (pit feature).

and 800 m (Wagner et al. 1990:231). Rock (1974:351) observed that it was peculiar to very dry lowland areas, often being found on *'a'ā* lava fields; on Lāna'i he noted it in the company of *Santalum freycinetianum* on the slopes above Mānele and Kalama (Rock 1974:353). It is found on all of the main Hawaiian Islands except for Kaho'olawe and Kaua'i. This is one of the few dryland species with a soft wood, which is white and has prominent resin ducts. Native Hawaiians used the resin for "various purposes" and the wood for stilts (Rock 1974:353).

FAMILY BORAGINACEAE

Cordia subcordata Lam. (*Kou*)

This indigenous shrub or small tree was brought to the Hawaiian Islands by the original Polynesian colonists. It typically grows in dry lowland and coastal areas and is known from all of the main islands except for Moloka'i and Kaho'olawe (Wagner et al.

TABLE 3

RADIOCARBON DATES FROM KAUNOLŪ

SITE	LAYER/ LEVEL	BETA- LAB. NO.	^{14}C AGE YR B.P.[a]	$\delta^{13}C$	^{14}C ADJ AGE	CAL AGE A.D.[b]
78-3	IV/4	69106	80 ± 60	−27.5‰	40 ± 60	1680–1750
						1810–1930
78-3	V/5	69107	310 ± 70	−26.8‰	280 ± 70	1460–1690
						1730–1810
146-13	III	69111	350 ± 80	−24.9‰	350 ± 80	1420–1670
						1780–1800

[a] Conventional radiocarbon age after Stuiver and Polach (1977).
[b] Calibrated age A.D. at two sigma as provided by Beta Analytic, Inc. (1993).

1990: 392–394). Rock (1974: 415) observed it growing wild along the beach at Mānele; he also noted that it was often planted by Native Hawaiians near their dwellings.

The wood is soft but durable (Rock 1974: 417) and has the advantage of not imparting a distinctive flavor to foods (Wagner et al. 1990: 394). For these reasons it was often used traditionally for bowls and other utensils (Malo 1951: 22).

FAMILY CHENOPODIACEAE

Chenopodium oahuense (Meyen) Aellen (*'Āheahea*)

This endemic shrub sometimes reaches treelike proportions. *Chenopodium oahuense* is occasional to common today in dry habitats, including coastal dry forests. It is found on all of the main islands except Kaho'olawe (Wagner et al. 1990: 538). Despite its historic extirpation from Kaho'olawe, both the seeds (Allen 1992) and wood charcoal (Graves and Murakami 1993) have been recovered from lowland archaeological sites of that island. Based on its archaeological occurrences and distributions elsewhere, Allen (1992: A2, A13, A25–26) suggested that *Chenopodium* was a colonizer in fallow agricultural fields and may have been encouraged by Native Hawaiians because of its edible foliage (see Malo 1951: 23, Buck 1964: 6) and use as a fuel.

FAMILY CUCURBITACEAE

Lagenaria siceraria (Molina) Standley (Bottle Gourd)

The bottle gourd is an annual vine that was introduced to Hawai'i by Polynesian colonists. It grows well in warm, relatively dry environments. Gourds were cultivated for their fruits, which were used for various kinds of containers, including receptacles for food and water (Neal 1965: 812–813).

FAMILY EBENACEAE

Diospyros sandwicensis (A. DC) Fosb. (*Lama*)

An endemic tree, this taxon ranges from 2 to 10 m in height (Wagner et al. 1990: 585–587). It occurs as a scattered to dominant vegetation element in some types of dry to mesic forest, but also in wet forests. Its range extends from 5 to 1220 m elevation and the species is known from all of the main islands except Kaho'olawe and Ni'ihau.

Diospyros is a relative of ebony and the wood is very hard and close-grained (Rock 1974: 395). It was used for "building houses for the gods," sacred enclosures (Rock 1974: 395), *hula* altars (Wagner et al. 1990: 587), and tool handles (Buck 1964).

FAMILY EPACRIDACEAE

Styphelia tameiameiae (Cham. & Schlechtend.) F.v. Muell. (*Pūkiawe*)

This indigenous plant is typically a low shrub, but is sometimes treelike in form. It occurs as a scattered to common vegetation element across a broad range of habitats from 15 to 3230 m elevation (Wagner et al. 1990: 590–591). These habitats include mesic to open areas at low elevations, montane wet forests, fog-swept alpine shrublands, bogs, and, more rarely, windward coastal localities. Ethnographic accounts indicate that the smoke from this plant was used to cleanse and remove sacredness from chiefs, allowing them to mingle with commoners (Wagner et al. 1990: 591).

Archaeologically, it has been recovered from hearth features on religious structures (e.g., *heiau*) (Kolb and Murakami 1994), suggesting a similar function in the prehistoric past. It is notable that *Styphelia* has thus far been uncommon in domestic contexts in comparable environmental settings (see Table 1). Somewhat speculatively, its presence in the A6-78 site at Kaunolū could reflect an association with a person of high rank.

FAMILY EUPHORBIACEAE

Aleurites moluccana (L.) Willd. (*Kukui*)

A Polynesian introduction, trees of this species reach heights of 10 to 20 m. The plant is now common in mesic valleys, ranging in elevation from 0 to 700 m (Wagner et al. 1990: 598). It is found on all of the main islands except for Kaho'olawe, where it nevertheless shows up in coastal wood-charcoal assemblages (Graves and Murakami 1993). Although the wood is soft, many parts of the tree had traditional uses and the trunks in particular were often made into canoes (Malo 1951: 22).

Chamaesyce spp. (*'Akoko*)

In Hawai'i this genus is represented by 22 species, including both endemic and historically introduced taxa (Wagner et al. 1990: 602–617). The exotic species are largely herbaceous in character. The 15 native species range in size from large shrubs to small trees, reaching heights of up to 9 m. *Chamaesyce celastroides* is "by far the most variable and widespread of all Hawaiian *Chamaesyce*," with several varieties (Wagner et al. 1990: 606), and is most likely the taxon represented in the Kaunolū archaeological samples. Wagner et al. reported that it is occasional to common in coastal vegetation and mesic forests between 0 and 1800 m. It is found on all of the major islands.

This species is extant on Lāna'i and was once a dominant vegetation component in the Pālāwai Basin (Hobdy 1993: 205). The genus is notable for its abundant latex. According to Hillebrand (1981: 396) the wood was "much used for firewood," a statement well supported by archaeological evidence. *Chamaesyce* wood charcoal is typically abundant and widespread in archaeological sites of dryland areas (see Table 1). Graves and Murakami (1993) found that it occurred in all of the Kaho'olawe proveniences examined. In 10 of 14 assemblages, it represented more that 50% of the wood charcoal.

FAMILY FABACEAE

Acacia koa A. Gray (*Koa*)

This endemic tree reaches heights of 35 m and at Western contact was often a dominant component of the vegetation in dry to wet forests (Wagner et al. 1990: 641). It ranges from 60 to 2060 m elevation and is found on all of the main islands except Kaho'olawe and Ni'ihau.

Traditionally, the wood was used for house posts, a variety of wooden tools and containers, and for canoes. Extirpated from Kaho'olawe today, the wood is found in prehistoric firepits on the island (Graves and Murakami 1993).

Acacia koaia Hillebr. (*Koai'a*)

This species has recently been placed with *A. koa* by Wagner et al. (1990: 641–642). They noted, however, that plants referred to as *A. koaia* are a rarer form of the endemic Hawaiian *Acacia* that is found in drier and more open habitats on Moloka'i, Lāna'i, and Maui. The wood of *A. koaia* is substantially harder, the plant tends to have a gnarled habit, and its wood anatomy is distinctive (in Wagner et al. 1990: 642).

Based on its crystalliferous strand parenchyma, Murakami (1983) tentatively identified *A. koaia* wood from three mid-elevation sites of the Waimea-Kawaihae Road Corridor. More recently, the wood has been identified from *heiau* contexts on Maui Island (Kolb and Murakami 1994). The hard wood was once used to make spears, fancy paddles, and bark-cloth (*kapa*) beaters (Pukui and Elbert 1986: 157).

Sophora chrysophylla (Salisb.) Seem. (*Māmane*)

An endemic shrub or tree, this taxon reaches up to 15 m in height. It occurs as a scattered vegetation component, from 450 to 3240 m, in dry shrubland and mesic forests, and more rarely in wet forests (Wagner et al. 1990: 706). *Sophora chrysophylla* is found on all of the main islands today except for Ni'ihau and Kaho'olawe. Although extirpated from Kaho'olawe, wood charcoal from *Sophora* has been found in both lowland and upland sites on the island (Graves and Murakami 1993). The wood of this species is exceptionally hard and durable (Rock 1974:189) and was used for a variety of tools (Malo 1951:224) and for house posts (Buck 1964:83).

FAMILY GOODENIACEAE

Scaevola sericea Vahl (*Naupaka*)

This pan-Pacific shrub grows up to 3 m tall and is particularly common in coastal settings (Wagner et al. 1990:788). It occurs on all of the main Hawaiian Islands.

Neal (1965:820) wrote that beach *naupaka* is used medicinally and the greens are eaten in other parts of the world. Although the wood is described as "durable," no Native Hawaiian uses of it are documented by Neal or in the other standard references used herein. However, the bark was used medicinally (Handy and Handy 1972:238).

FAMILY MALVACEAE

Sida fallax Walp. (*'Ilima*)

This shrub is widespread throughout the Pacific. It ranges in height from 0.2 to 1.5 m and is common on rocky or sandy coasts, in open arid lava fields, and in dry to mesic forests at elevations from 0 to 1980 m (Wagner et al. 1990:897). *Sida fallax* is one of the few indigenous woody plants still found in the Kaunolū vicinity today. The entire plant had many uses for Native Hawaiians.

FAMILY MORACEAE

Artocarpus altilis Park. Fosberg (*'ulu*)

Artocarpus (breadfruit) is a Polynesian introduction that was historically recorded on all islands except Kaho'olawe. Typically these trees grow to heights of 10 to 20 m (Hillebrand 1981:407) and bear fruits after 5 to 7 yr (Neal 1965:303). They prefer warm, moist habitats. The wood was used in house construction and for canoes, the bark for cloth (Malo 1951:21, Neal 1965:303, Rock 1974:117).

FAMILY MYRSINACEAE

Myrsine sp. (*Kōlea*)

Twenty endemic trees and shrubs compose this genus (Wagner et al. 1990:934). One of the more common species is *M. lessertiana*, which reaches heights of 8 m and occurs on slopes, ridges, and in open forest sites primarily in mesic to wet forests and margins of bogs, but also in dry forests. *Myrsine lanaiensis* is another common species. This small tree reaches heights of 3 to 6 m. It typically occurs in dry to mesic forests, from 300 to 1000 m elevation, primarily on the leeward sides of all of the main islands.

The wood of *M. lessertiana* is pinkish and mottled. It is "not very hard" but was used traditionally for house posts and beams (Rock 1974:377). The charcoal made a black bark-cloth dye (Malo 1951:21), and a red dye was extracted from the bark (Buck 1964:187).

FAMILY MYRTACEAE

Metrosideros polymorpha Gaud (*'Ōhi'a*)

Metrosideros polymorpha is an endemic species but a widespread genus (Wagner et al. 1990:967). It ranges from small shrubs to tall trees and inhabits a range of ecological settings, from sea level to 2200 m. The species occurs on all of the main islands today except for Ni'ihau and Kaho'olawe. *Metrosideros* has been found in Kaho'olawe wood-charcoal assemblages, suggesting that it might have once grown here (Graves and Murakami 1993).

The wood is dark reddish, durable, hard, and equal in strength to oak (Rock 1974: 333). It was traditionally used for making idols, spears, posts and rafters, bark-cloth mallets, and for fuel (Malo 1951:20, Rock 1974).

Syzygium malaccense (L.) Merr. & Perry (*'Ōhi'a 'ai*)

This Polynesian introduction ranges in height from 8 to 25 m. Today it is naturalized at low elevations and found in mesic to wet sites, but is most common in mesic valleys between 200 to 310 m elevation (Wagner et al. 1990:975). Hillebrand (1981:128) reported *S. malaccense* on all of the main islands.

According to Rock (1974:321), this species had an important role in Hawaiian and Polynesian legends and was regarded as sacred. This sacred nature is exemplified in, or possibly the result of, use of the wood for idols and temple enclosures. In addition to its sacred function, the wood also served utilitarian purposes, being used for house posts, rafters, and canoe parts. The fruits were eaten and the bark used medicinally. Archaeological occurrences date its introduction to some time before the fifteenth century A.D. (see Kolb and Murakami 1994).

There is also an endemic *Syzygium*, *S. sandwicensis* (*'Ōhi'a hā*), a tree or shrub that grows from 3 to 25 m in height. On Lāna'i, this taxon occurs primarily on ridges and slopes in mesic to wet forests and bogs between 230 to 1220 m. The wood of this species is hard and durable and was used as a fuel and for house construction (Malo 1951:21, Rock 1974:323).

FAMILY RUBIACEAE

Bobea sp. (*'Ahakea*)

Bobea is an endemic genus with four species (Wagner et al. 1990:1114–1118). It typically occurs as a tree and only rarely as a shrub. *Bobea elatior* is the most widespread species, occurring in mesic valleys and mesic to wet forests between 250 to 1100 m elevation. It occurs on several islands, including Lāna'i. *Bobea sandwicensis* is another widespread member of this genus, found in dry to mesic forests from 100 to 1220 m.

The wood of *Bobea* is yellow and durable. It was used ethnographically for *poi* boards, paddles, and canoe gunwales (Malo 1951:20, Rock 1974:439). This is the first record of its use as firewood.

FAMILY SANTALACEAE

Santalum sp. (*'Iliahi*)

This highly variable native tree is represented by four native Hawaiian species (Wagner et al. 1990:1220). *Santalum ellipticum* typically varies from 1 to 5 m in height and is most often found scattered on ridges, slopes, or in gulches of dry shrublands and forests. It is most often found from sea level to 560 m elevation, but Wagner et al. (1990: 1221) reported a single individual from ca. 2140 m elevation in the saddle area between Mauna Loa and Mauna Kea on Hawai'i Island. It is common on lava fields and in other rocky contexts, such as the environment around Kaunolū. The species was once found on all of the main islands. *Santalum freycinetianum* is another sandalwood that is also known from the dry forests of Lāna'i. This species may reach over 15 m in height.

Sandalwood has a pleasant scent and was commercially sought after in Hawai'i during the late 1700s and early 1800s (Wagner et al. 1990:1222). Although little is written about traditional Hawaiian uses of sandalwood (see Malo 1951:21), the powdered wood was used to scent sheets of bark cloth (Buck 1964:209).

FAMILY SAPINDACEAE

Dodonaea viscosa Jacq. (*'A'ali'i*)

This pantropical shrub to small tree typically ranges in height from 2 to 8 m (Wagner et al. 1990:1227–1228). In the Hawaiian Islands, it is scattered to dominant, between 3 to 2350 m, often occurring in open sites such as ridges and lava fields, but also on coastal dunes, in lowland shrubland communities, and in dry mesic and wet forests. It is found on all of the Hawaiian Islands.

The black heartwood of *Dodonaea* is extremely hard, dense, and heavy (Rock 1974:279). According to Buck (1964:83), the trunks were used for house posts.

FAMILY SOLANACEAE

Nothocestrum sp. (*'Aiea*)

Nothocestrum is an endemic genus with four species, two federally listed as endangered (Wagner et al. 1990:1262–1264). It ranges from large shrubs to trees up to 10 m tall. Among the likely candidates for the Kaunolū wood charcoal is *N. latifolium*, which occurs in dry to mesic forests and was noted by Rock (1974:421) as growing between 460 and 1530 m elevation in the Ka'a Desert of western Lāna'i. The soft wood was used in making canoes (Malo 1951:21) and for fire-making, and the slender branches for thatching sticks (Pukui and Elbert 1986:10).

DISCUSSION

Analytical Issues

In using the five Kaunolū archaeological samples to reconstruct the late prehistoric to early historic vegetation of Kaunolū we recognize the potential limitations of a small number of samples and largely restrict our discussion to a consideration of the species present rather than their relative abundances. A recent study of wood-charcoal assemblages by H. A. Lennstrom (unpubl. data), for example, has shown how variable wood-charcoal samples may be, both in the case of multiple samples from single hearths and with samples from multiple features within a single site. In the former case, the variability may occur because fragments of individual timbers are not necessarily homogeneously distributed throughout the feature. Taxonomic differences across features at a single site may reflect variable feature functions or the changing availability of fuel resources. Lennstrom's study underscores the difficulty of obtaining a reliable and valid sample of the local vegetation; valid information on taxonomic abundances in particular requires a number of wood-charcoal samples from multiple contexts.

Nominal (presence/absence) assessments also require some constraint, because a number of cultural factors may structure the formation of an archaeological assemblage. Most notable are cultural preferences for particular kinds of firewood, the possibility of long-distance transport of fuels, and the occasional discarded artifact originally from another environment. Ethnographic sources (e.g., Malo 1951:21, 22–23, Hillebrand 1981:396) and examination of other wood-charcoal assemblages (Table 1) suggest some of the woods that may have been favored fuels. *Chamaesyce celastroides* is one such known preferred firewood. In contrast, cultural restrictions may limit the contexts in which a given species occurs or altogether preclude its representation in the archaeological record, as discussed for *Styphelia* and *Diospyros* (see those sections).

In light of the foregoing the samples we studied, representing two spatially discrete localities and at least three distinct time periods, allowed an initial assessment of the extent and composition of dryland vegetation in this region, as well as the role of Native Hawaiians in late prehistoric to early historic vegetation change. In time, additional wood-charcoal records from both Kaunolū and other sites along this southern coast will assist in evaluating the reliability and validity of these records. In the interim, we draw on wood-charcoal assemblages from similar environmental contexts elsewhere in the archipelago (Table 1) to evaluate the validity of the species associations found at Kaunolū.

Assemblage Composition and Ecological Associations

One of the most remarkable aspects of these assemblages is the high species diversity represented in such small samples. Altogether 22 taxa were recovered from only two site localities and less than 100 g of charcoal. Both Polynesian introductions and native species are represented among the suite of 21 woody taxa. Plants introduced by Polynesian settlers include *Aleurites* (candlenut), *Artocarpus* (breadfruit), *Cordia* (*kou*), *Lagenaria* (bottle gourd), and *Syzygium* (mountain apple). *Lagenaria* is represented by fruit rind fragments, but the other four all occur as wood charcoal. Wood from 17 native taxa was recovered and, although all are known historically from Lāna'i, many are quite rare today. The four distinctive but unidentified taxa also most likely represent natives and quite possibly are rarer dryland species not included in the Pacific Islands Wood Collection (the basis for most identifications).

In Table 3, the 22 Kaunolū taxa are organized by the vegetation zones they potentially represent. Typical coastal taxa include *Cordia*, *Scaevola*, and *Sida*—all three occur today at other coastal localities, such as Mānele Bay to the southeast, and *Cordia* was often cultivated. *Lagenaria* and sweet potato are the two domesticates most likely to have been grown in this arid environment, so recovery of the former is not unexpected. Woody taxa like *Chenopodium*, *Chamaesyce*, *Dodonaea*, and *Metrosideros* are also known to occur in arid coastal contexts. According to Rock (1974:9), *Reynoldsia* was a common species at the coast, often occurring on relatively unweathered lava flows like those encountered at Kaunolū.

In contrast, *Aleurites, Artocarpus, Syzygium,* and to a lesser extent *Acacia koa* and *Styphelia* are more reflective of mesic and/or upland environments. It would be particularly difficult to argue that the former three grew at Kaunolū, given their water requirements; most likely they were initially brought to the site as tools or timbers, or possibly collected from the beach as driftwood. It is notable that none of these taxa is represented in large amounts, although *Syzygium* is found in all four levels of site A6-78.

More unexpected are the eight native species that today typically occur in dry forests at higher elevations: *Bobea*, *Diospyros*, *Myrsine*, *Nothocestrum*, *Santalum*, *Sophora*, *Acacia koaia*, and *Nototrichium*. The first six occur in the Kānepu'u Reserve, and the latter two have been observed in relict vegetation elsewhere on the island (Spence and Montgomery 1976, Harris et al. 1991). All conceivably could have been introduced to the fire features as discarded artifacts, but we argue otherwise below.

Another notable aspect of these assemblages is that only one of the 22 archaeological taxa grows at Kaunolū today. The area's current vegetation is dominated by dry shrubs and herbs, many of which are exotic. The only arborescent species is the historically introduced *kiawe* (*Prosopis pallida*). Not only are the archaeologically recovered dryland forest taxa absent from Kaunolū, but they are generally uncommon elsewhere on the island, including the Kānepu'u Preserve. In the latter, *Nestegis* composes 85 to 90% of the canopy, followed by *Diospyros*, which makes up the other 15% (Warshauer 1976 *in* Ziegler 1989). *Bobea* is represented in the reserve by a few plants with a small but obvious cover (Spence and Montgomery 1976:78). The other six archaeological dry forest taxa are rare even in this reserve, which is not only fenced but also experiences an appreciably higher rainfall than Kaunolū.

It is interesting that no historically introduced species are found in the archaeological assemblages. The most conspicuous absences are *Prosopis pallida* (*kiawe*), introduced by at least 1828 (Nagata 1985), and *koa haole* (*Leucaena leucocephala*). Based on his palynological work, J. S. Athens (pers. comm., 1997) suggests that the former did not become common until after 1870. The lack of important postcontact firewood species at A6-78 suggests that Euro-American plants may have been introduced into the area after the settlement was abandoned.

Patterns of Vegetation Change

Two questions flow from the archaeological finds. First, what was the nature of the vegetation along this southern coast during the late prehistoric period? Did the dryland forest found today at Kānepu'u grow considerably closer to the coast than proposed by Hobdy (1993)? Second, when was the woody vegetation lost and to what degree were Native Hawaiians versus exotic animals responsible? Olson and James (1984) and Athens (1997) suggested that the process of deforestation was nearly complete by the time of Euro-American contact. Hobdy (1993: 205) in contrast, suggested that the local forests were largely intact when the first Westerners arrived. Ziegler (1989:22) concluded that land use within the last 125 yr has had a greater impact than did Native Hawaiians before 1778. As we discussed above, secure answers to these questions will require a number of archaeological samples from more varied contexts than is currently available. However, the most *parsimonious* explanation is that the woods present in a hearth reflect the local vegetation. In this vein, we suggest that the suite of taxa recovered indicates that a different vegetation once existed in the local area. Although the process of deforestation on Lāna'i was undoubtedly initiated in the traditional period, we argue that substantial change also occurred in the postcontact period.

Looking first at the local environment, it seems highly probable that most, if not all, of the taxa represented in these assemblages grew closer to Kaunolū than they do today. Based on other kinds of evidence, Hobdy (1993) previously proposed that the dry coastal forest of Lāna'i once extended to ca. 300 m elevation, essentially the lower edge of the Pālāwai Basin and a distance of 3 km from Kaunolū. This also is the 500-mm rainfall isohyet. Below this, he suggested there was an arid grassland and shrubland community. The archaeologically recovered *Sida* and *Scaevola* wood charcoal are consistent with such a shrubland vegetation. *Chamaesyce*, which persists today at Laehī Beach and elsewhere along the northeastern slopes at lower elevations (Harris et al. 1991:56), also probably grew at Kaunolū in the past. The dominance of *Chamaesyce* in the Kaunolū assemblages might be a reflection of its local abundance, as well as its desirability as a fuel. Other rarer woody taxa, however, still require explanation.

If sufficient local wood resources were available, particularly preferred ones like *Chamaesyce*, it seems unlikely that Native Hawaiians would have traversed the additional 3 to 4 km to the edge of the Pālāwai Basin to secure other fuels. Moreover, modern analogs indicate that many of the dryland species represented archaeologically are rare elements of the vegetation. If this modern analog accurately represents the late prehistoric vegetation, then foraging for fuel in the interior regions probably would have resulted in better representation of *Diospyros* and *Nestegis*, known dominants of the extant dryland forest.

Given the foregoing, we suggest that the eight dryland forest taxa discussed above (*Bobea*, *Diospyros*, *Myrsine*, *Nothocestrum*, *Santalum*, *Sophora*, *Acacia koaia*, and *Nototrichium*) once grew in the Kaunolū region, or relatively nearby, and persisted there into the historic period. These arborescent species may have been sparsely distributed within a grassland and native shrub community; some may have been concentrated in the slightly moister gulches as well. Ellis (in Emory 1969:7), for example, noted in the early 1800s that the island's coastal ravines and glens were filled with thickets of small trees that were exploited for house posts by people from as far away as Maui. This scenario also is consonant with some early botanical opinions regarding the former extent of the Lāna'i dryland forest. Fosberg (1936:123) argued that native forest, similar to that found at Kānepu'u, "must have covered great areas in the lowlands of the older islands" before the arrival of Europeans. Although the period of most dramatic vegetation change may have occurred shortly after Native Hawaiian settlement, as on O'ahu (Athens 1997), this study demonstrates that woody taxa persisted in the Lāna'i lowlands into the early historic period.

Supporting evidence comes from previously analyzed wood-charcoal assemblages from other dryland archaeological contexts (Table 1). The survey revealed that the Kaunolū assemblages are most similar to those from localities with similar rainfall regimes. This pattern supports the argument that the species associations seen in the Kaunolū assemblages are ecologically based and not unduly biased by cultural factors. The most similar assemblages are those from the southwestern coast of Kaho'olawe (Graves and Murakami 1993), an area like Kaunolū where the annual rainfall is less than 250 mm. The two localities share 11 arborescent taxa, including *Santalum*, *Reynoldsia*, *Sida*, and *Chamaesyce*. As Graves and Murakami (1993) observed, all of these taxa are adapted, or have varieties that are adaptable, to arid conditions—again supporting the idea that these species could have grown at Kaunolū. More generally, the assemblages of Table 1 provide multiple independent cases of support for the hypothesis that elements of Hawaiian dryland forests once extended into coastal regions and in late prehistory were still sufficiently plentiful to make their way into the archaeological record.

Timing of Forest Demise

The second issue of relevance here is the timing of vegetation change. The stratigraphic sequence of A6-78 appears to extend from ca. the sixteenth century into the early contact period (after A.D. 1778). Despite the probable early historic age of the upper A6-78 samples, there are no dramatic shifts in taxonomic composition and, as noted earlier, historic introductions are absent. The slight decrease in sample richness at A6-78 through time could reflect a process of gradual biodiversity loss. However, the early diverse samples are also the largest (both by weight and counts), raising the possibility that this is an artifact of sample size (see Grayson 1984). Here additional samples would be particularly instructive. Nevertheless, the continued availability of native dryland taxa throughout the period of Native Hawaiian settlement at Kaunolū seems unquestionable. The persistent representation of high-quality native timbers in the fire features suggests to us that these woody taxa were sufficiently proximate to Kaunolū in the late prehistoric to early historic period to make their use as fuel feasible.

Broadly supportive evidence comes from the avifaunal records of the island. According to Ziegler (1989; see also Munro 1960), many native bird species were still common in late 1800s, suggesting that native habitat also remained. In contrast, five endemic species have become extinct in this century. She suggested that two causes were removal of forest from higher elevations, and extensive soil erosion from overgrazing by free-ranging livestock (Ziegler 1989:22). Both processes were said to have been initiated in the 1800s.

From the historic records, we know that two highly destructive herbivores were introduced to Lāna'i in the early to mid-1800s. Goats were brought early in the nineteenth century and quickly destroyed the *Chamaesyce* forest of the Pālāwai Basin (Hobdy 1993). Then in the mid-1800s, sheep were introduced and added to continued forest loss, particularly in drier areas. By 1854, turkeys, pigs, and cattle were being raised at the Morman settlement in the Pālāwai Basin, and goats, sheep, and horses were present by the 1860s (Beck 1972:42). By 1867, the Morman settlement in the Pālāwai Basin was reporting 18,000 goats and 12,000 sheep (in Kaschko and Athens 1987:11). Accelerated loss of woody species coincident with the establishment of these herbivores also is implied by the early land records. In 1852, the *konohiki* of Pālāwai Ahupua'a placed a restriction on the taking of *'Ahakea* (*Bobea*) wood, and a similar *kapu* was placed on *'Akoko* (*Chamaesyce*) by the *konohiki* of Kamoa Ahupua'a (in Kaschko and Athens 1987:8).

Compared with the impoverished arborescent flora of Kaunolū today, the wood-charcoal assemblages indicate an astonishingly diverse array of species that were used by the Native Hawaiian inhabitants of this late prehistoric settlement. There are some suggestions that Native Hawaiians contributed to a gradual decline in the *diversity* of arborescent taxa, but this remains to be unambiguously demonstrated at Kaunolū. It seems reasonable to assume that they affected the *abundance* of woody taxa as well, although this assumption is based on data from other islands (after Athens 1997, Kirch 1982). As Spriggs (1991 : 108) suggested for Kaho'olawe, Native Hawaiians may have transformed a diverse dry forest into an open savanna of grassland and trees. However, our evidence indicates that native woody plants persisted in the region through the period of settlement abandonment in the mid-1800s. Therefore, we suggest that some other mechanism, most likely introduced herbivores, had an important role in creating the impoverished vegetation witnessed today. With the accumulation of additional wood-charcoal records from other sites along this coast and other areas of Lāna'i, we should be favorably positioned to test and refine the hypotheses outlined here.

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