Kaho'olawe Island Conveyance Commission
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The Identification of Charcoal from Archaeological Assemblages on Kaho'olawe Implications for Reconstructing Prehistoric Vegetation.

A Report Prepared for
The Kaho'olawe Island Conveyance Commission

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Executive Summary

This study reports on the re-analysis of a series of wood charcoal assemblages excavated from nine archaeological sites on Kaho'olawe. A total of 30 different taxa are identified, all but three of which are native to Hawai'i or which were introduced by Polynesians who first settled the archipelago. These taxa include a number of trees and shrubs whose presence had not been previously documented for the island, by botanical survey or records, the ethnohistoric record, or through pollen or macrobotanical analyses. Most of these taxa may have once grown or have been cultivated on the island. More generally, we believe that this study should help Native Hawaiians realize the potential of wood charcoal analyses as a means to identify the locations where native plants of Hawai'i were once found.

Because the sites included in this study were located in uplands and coastal settings on Kaho'olawe, we are also able to characterize the woody vegetation of the whole island as well as geographic portions of it. In particular, the uplands which now consist of eroded hardpan and depauperate areas of vegetation may have once supported a rather diverse set of small trees and shrubs, of which one form, 'akoko (Chamaesyce spp.) was the most abundant. Other aspects of the woody vegetation of the uplands might have included lama (Dispyros sandwicensis), naio (Myoporum sandwicense), 'a'ali'i (Dodonaea viscosa), kulu'ī (Nototrichium sp), 'ohe (Reynoldsia sandwicensis), 'aiea (Nothocestrum sp), 'iliahi (Santalum sp.), kōpiko (Psychotria sp), and alahe'e (Canthium odoratum). Two vegetation zones were identified along the coast: a western area and northeastern area. Differences in vegetation match patterns of rainfall with the western area having more taxa adapted to dry conditions or which occur as shrubs. Most of the taxa which are likely to have grown on the island occur in a variety of forms and tolerate a range of ecological conditions, including periodic drought. These are desireable qualities for any plants that are introduced to Kaho'olawe during its restoration.

The woody vegetation of Kaho'olawe as represented by the charcoal from these archaeological sites shows no marked change during the prehistoric period. Thus, our findings are in keeping with recent geoarchaeological and ethnohistorical research which suggest that massive erosion and vegetation depletion on the island occurred after European contact. Interestingly, the charcoal data do not confirm a shift--proposed by some archaeologists--towards savannah or grasslands during the prehistoric period (represented by our assemblages) on Kaho'olawe. Although these vegetation communities may have already existed by the late prehistoric period, there is no evidence from the charcoal assemblages to indicate that they became more extensive prior to European contact.

Not only has this research identified a number of taxa which formerly grew on Kaho'olawe, we also suggest our findings be used to help identify plants which may be successfully re-established in different locations on the island during its restoration.

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Introduction

This project has two related objectives, the first is to identify wood charcoal taxa recovered from excavated assemblages at archaeological sites on Kaho'olawe. The purpose of identifying the wood taxa is to then use information about the taxa as a means to reconstruct vegetation patterns on the island which predate its modern condition. Such reconstructions should be helpful to the Kaho'olawe Island Conveyance Commission as it plans for the rehabilitation of the island, because this work will help to identify the taxa of native and Polynesian introduced woody vegetation most suited for establishment in different environmental zones of the island. The second aim of this project is archaeological, and that is to use the information from the identification of the wood charcoal (along with other data) to assess opposing hypotheses regarding the timing and source of environmental change on Kaho'olawe.

By virtually any measure, the island of Kaho'olawe has been substantially altered in terms of its natural vegetation and landscape. The uplands are severely eroded and erosion continues at the present. Substantial areas, especially in the northern and eastern portions of the uplands lack any appreciable vegetation or ground cover whatsoever. In a number of places erosion has removed not only the topsoil but also portions of the weathered geological substrate. Along the northeastern edge of the uplands erosion has removed sediments down to an exposed hardpan. Farther down slope from the uplands, the land is being rapidly and dramatically eroded, especially where it consists of exposed unconsolidated sediments. The coastal areas of the island have not been immune to these processes. There has been considerable progradation of the coastline, particularly around the mouth of gullies where eroded sediments are deposited. Introduced plants have altered the water table and displaced native plants. Locations where native vegetation occur are limited on the island, due to erosion, the effects of grazing by goats, the alteration of ground water availability, an increase in wind speeds, and competition from introduced taxa. This latter includes grasses, and the ubiquitous kiawe.

Several projects have been started or are underway to restore or rehabilitate the vegetation of the island, especially in the eroded upland portion of Kaho'olawe (Ahlo 1981; Holmes and Reeve 1991; U.S.D.A. Soil Conservation Service 1979; Some of these have been somewhat successful; others less so (see Graves and Abad 1992). Among the issues still to be resolved is the matter of what kinds of plants might be best suited to sustain growth and establish new colonies on Kaho'olawe.

Archaeological research (Barrera 1984; Hommon 1980a, 1980b; 1983; Rosendahl et al. 1992) on Kaho'olawe over the past decade has successfully located a number of sites, many of them threatened by erosion or disturbance. To help preserve information on some of these sites, selected features and deposits were excavated. One component of the archaeological material recovered during excavations has been wood charcoal. This material represents burned remnants, usually of firewood but possibly also of food remains or artifacts. Identification of these pieces of wood charcoal from archaeological sites provides a potentially valuable source of information about past wood use and its availability on the island. Where it is possible to document not only the occurrence of woods in archaeological deposits, but also that the woods were likely obtained from local stocks, such information may prove invaluable in guiding future efforts to restore the woody portion of the island's vegetation. Because these would be taxa which had adjusted to the islands climatic and physical conditions previously, they may well be suited to the conditions which obtain on the island today.

The investigation of wood charcoal from archaeological sites can also contribute to the resolution of a major research topic in Hawaiian archaeology, namely, the study of prehistoric environmental variability. Here, the objective is to reconstruct patterned variation in the geographic occurrence of wood taxa and then to identify change in reconstructed environments. In Hawai'i, the emphasis is placed, not so much on naturally induced environmental change (although there is some evidence for such change before human colonization [Athens and Ward 1993]), but rather on the role humans and animals played in the modification of natural environments (Kirch 1982, 1983, 1985). This is especially the case for indigenous plants and animals in Hawai'i (such as birds and land snails) whose abundance is thought to have been affected significantly by humans (Athens and Ward 1993; Christensen and Kirch 1986; James et al. 1987; Olson and James 1984; Steadman 1989).

Archaeological research on Kaho'olawe has played an important part in the development and acceptance of such ideas. This can, in part, be attributed to the current condition of the island, in which considerable portions of its interior uplands have been devegetated and subjected to soil and sediment erosion. The evidence is unequivocal that the environment of Kaho'olawe has been and is currently changing. Given the scale and intensity of environmental change on Kaho'olawe, it is not surprising that humans might have been implicated in it.

Yet, any resolution of the problem of environmental change on Kaho'olawe must involve a historical dimension to it, because the condition of the island today is the result of past processes. Thus, questions have included: how far into the past were such changes initiated; what was the extent of environmental change at any point or interval in the past; and what or who were the agents responsible for the changes in the environment of Kaho'olawe.

One hypothesis, developed during the early 1980s (see Hommon 1980a, 1980b; Barrera 1984; also Kirch 1982, 1983, 1985), placed much of the environmental change in the late prehistoric period (i.e., before European contact with Hawai'i), and attributed the loss of vegetation and the onset of erosion to the effects of converting woodland and grassland areas of the uplands of Kaho'olawe to agricultural uses or for pili grasslands. The immediate agent would have been the use of fire by Hawaiians in a manner comparable to contemporary swidden or slash and burn agriculture, in which areas are cleared for fields by burning the vegetation. Burning can also enhance agricultural productivity by the incorporation of nutrients into the soil in the form of ash and charcoal. However, it has also been suggested that swidden systems can sometimes lead to considerable soil erosion when fields are established on moderate slopes and the length of time between clearing an area is reduced or if the vegetation has insufficient time to recover (Spencer 1966). This reconstruction seemed to match the sequence of agricultural development and landscape change discovered by archaeologists on other islands of the Pacific (Kirch 1977; Kirch and Yen 1982; Spriggs 1985), although in these cases erosion appeared to enhance the agricultural potential of coastal lands. These examples, however, represented relatively humid tropical or subtropical localities. Consequently, given the generally arid conditions on Kaho'olawe, even at the higher elevations of its uplands, the use of the uplands for agricultural pursuits for a relatively short period of time (e.g., 200-300 years), might lead to vegetation reduction, then loss, and finally substantial soil erosion, and landscape degradation.

The island wide survey of Kaho'olawe (Hommon 1980b), done under compliance with federal historic preservation and environmental protection laws, generated data which were considered to be consistent with this hypothesis. In particular, a characteristic sedimentary deposit (the Ahupu formation) was identified at many sites. This deposit contained charcoal flecking and sometimes had thin layers of burned material within it as well. This was taken to represent eroded sediments within which remnants of charred vegetation occurred. In short, this deposit was inferred to be evidence of environmental change, and was thought to be stratigraphically associated with in situ late prehistoric deposits. Thus, the timing was placed prior to European contact. Volcanic glass dating was used extensively during this first survey and the dates suggested an interval between A.D. 1500 and 1600 as the most likely period when extensive erosion and devegetation took place. These characteristic deposits occurred in both upland and coastal contexts, and given the nature of sediment deposition--that is, it must always move downhill--the archaeologists inferred that the bulk of the environmental change occurred in the uplands (but they also suggest considerable fouling of the marine environment as a result of soil erosion). Some evidence for this massive erosion remained in the form of uneroded deposits containing burned material, but much of it was redeposited down slope where it was found in deposits of some depth along the margins of ephemeral streams.

That this highly characteristic deposit contained evidence of burned material and was dated to prehistoric times, and was originally derived from uplands areas which currently exhibit extensive erosion, has led archaeologists to conclude the bulk of this process was the result of efforts by Hawaiians to convert formerly wooded or grassy areas of the uplands of Kaho'olawe to agricultural purposes. The conversion was carried too far and both the vegetation and the topsoil as well as other sediments were removed, and once removed, erosion (in addition to reduced rainfall and increased surface winds) maintained the denuded and degraded aspect of this portion of the island.

A second hypothesis has been advanced, most recently by M. Spriggs (1991) but also by an earlier generation of archaeologists (McAllister 1935). They propose that the devegetation and destruction erosion of the uplands on Kaho'olawe were a historic era processes, the result of repeated fires set on the island and the introduction of cloven-hoofed animals, particularly, goats, but also including cattle and horses. These large scale changes were initiated, not by Hawaiians, but by visitors and haole ranchers and land owners. Spriggs (1991) notes the relatively fragile nature of environmental stability in Hawai'i and other distant and isolated islands of the Pacific. The introduction of new species, which had generally evolved in more continental settings, set in motion destructive changes to Hawai'i's terrestrial environment. Additionally, the physical and climatic characteristics of Kaho'olawe made it especially vulnerable to newly introduced species and practices. The island could not recover from the repeated fires set, nor from the continuous grazing practices of cattle and goats, the latter which were abundant on the island until an eradication program was instituted in the 1970s.

The evidence used to support this second hypothesis included a reexamination of the charcoal flecked deposits which had previously been associated with prehistoric contexts. Spriggs (1991) demonstrated that most of these deposits post-date archaeological materials (either artifacts or features) associated with the late prehistoric period in Hawai'i. Additionally, Spriggs (1991) cites a number of historic sources which describe the island, the repeated fires set on the island during the historic era, and the introduction and increase of goats and cattle on the island. These historic sources also describe the appearance of eroded areas and the erosion of the reddish colored soil and sediments from the uplands of Kaho'olawe.

Currently, the hypothesis of a historic era onset for massive environmental change on Kaho'olawe enjoys the most support. However, this is not to suggest that archaeologists believe the environment was unchanged during the prehistoric Hawaiian period. Some of the burn layers and charcoal flecked deposits are thought to date to a period predating European contact. Thus, at a smaller scale and in less dramatic fashion, the environment on Kaho'olawe may have been altered. Additionally, there is wide agreement among archaeologists that the uplands of the island were occupied prehistorically, that this area contained resources of considerable utility (e.g., timber and high quality basalt), and that the uplands were probably the used for agricultural purposes. The problem then remains, what was the nature of the environment on Kaho'olawe and how might it have been modified prior to the historic period. Spriggs (1991:108) hypothesizes that:

> "...accelerated erosion is an inevitable result of forest clearance and agricultural practices. The major environmental effects of prehistoric human occupation appears to have been vegetation clearance for firewood and agriculture. It seems likely that where a diverse dry forest once existed, it had in large part been changed by the time of European contact to an open savannah of grassland and trees, probably maintained by regular burning."

This, then, represents a third hypothesis. It extends the onset of environmental change to prehistoric times, but at the same time considers such change to have involved a change in the type of vegetation community represented in the uplands of Kaho'olawe. It borrows aspects of the first hypothesis, that prehistoric Hawaiians occupied upland zones on Kaho'olawe, and this was most likely the major focus for their attempts to cultivate on the island, given its higher elevation, cooler temperatures, greater and more reliable precipitation. It also assumes (as did Hommon's hypothesis) that Kaho'olawe represents an environment which would be susceptible to cultural impact, especially given its low and unpredictable rainfall, small geographic size, and low elevation.

This re-analysis of the wood charcoal assemblages from archaeological sites on Kaho'olawe should add to our understanding of the timing and extent of changes in the island's vegetation, and thus provide additional evidence with respect to the hypotheses outlined above.

The Archaeological Sites and Assemblages

Upon the completion of the island wide survey (Hommon 1980b) and recognition that a number of the sites located contained archaeological features which were in some danger due to exposure and erosion (Ahlo 1980; Carson 1980; Morgenstein 1980; Neller 1980, 1981), a series of data recovery projects were undertaken. The first of these in 1981 involved considerable mapping and limited excavation but only for sites located in the uplands (see Hommon 1983). Excavations focused on eroding features, often of firepits, earth ovens, or other combustible features which contained charcoal. Charcoal, of course, can be used for radiocarbon dating. However, G. Murakami had just completed a pilot study of wood charcoal from archaeological sites on the island of Hawai'i (Murakami 1983a). The Kaho'olawe excavations recovered several pieces of wood charcoal from firepits and selected pieces were given to Murakami for identification. Murakami (1983b) was able to identify some of the wood provided her, but the results were suggestive at best, since the charcoal had not been recovered or selected for analysis by any systematic means. Only large pieces, which might not be representative of the feature assemblage, were identified in this first project. Nonetheless, several taxa were found in the firepit wood charcoal.

Subsequently, a second data recovery project was undertaken on Kaho'olawe in 1982. This involved an extensive program of mapping, surface collection, and excavation of a number of features at 21 different sites. Sites were located in both uplands and coastal zones. Of these sites, nine provided charcoal material for identification (see Figure 1). A brief description of each site follows.

Site Descriptions

Site 142: This site is located along the southwest coast of Kaho'olawe, and included 19 features representing a habitation complex, with an associated religious feature. The charcoal came from two firepits excavated on the southern edge of the site which were being eroded by surge activity from the surf. This was part of a complex of at least six firepits. The two firepits from which the charcoal was obtained were numbered 8 and 15. The base of Firepit 8 was stone-lined, contained fire-cracked rock, and was cut into sterile white beach sand. The south half of the pit was excavated and the contents of the cooking feature, including charcoal, were removed. Firepit 15 was a rectangular stone-lined firepit. Charcoal was concentrated at the base of the firepit, and the feature was completely excavated.

Site 378: This is a large site complex located along the west coast of Kaho'olawe at Honokoa gulch. Many features representing a major habitation complex exist at this site. The charcoal was excavated from Feature B, a terrace complex on the south side of the gulch. The excavations sampled a deep (to more than one m in depth) and complex set of cultural deposits, including what may have been a pit (Layer IV) dug into the original surface of the ground. Charcoal was recovered and analyzed from Layers II, III, and IV of Feature B. The only concentration of charcoal noted was in Layer III; elsewhere the charcoal was recovered along with other midden materials, including fishbone, shell, lithic debitage, coral tools, lithic tools, fishhooks, and historic materials.

Site 569: This site is located on the northeast coast of Kaho'olawe, at a small gulch north of Hakiowa (and which has sometimes been called Hakiowa Iki). The site includes a possible heiau, several shrines, and a number of habitation features and deposits. Feature C is a terrace, thought to be a shrine given the presence of coral pieces as part of the terrace construction and at least two uprights at the front of the terrace. The excavations revealed cultural deposits within the terrace fill, containing shell, fishbones, dog and pig bone, volcanic glass, lithic debitage, adze pieces, and a bone fishhook. Charcoal came from several of the excavated layers (II, III, IV), as well as from preliminary facing of the exposed sample column of the terrace. This latter probably combined charcoal from the lowest layers.

Site 636: Also located on the northeast coast of Kaho'olawe, Site 636 is situated a short distance north of Site 569. The site represents a small habitation complex, and includes a possible shrine. Feature A, a midden deposit, was the location from which the charcoal assemblage was recovered. The materials within this deposit included shell, coral fragments, fish bone, bird bone, lithic debitage, a fishhook, and a coral tool. At least two charcoal concentrations were noted in the excavations, and these appear to be small scoop firepits, lacking any stone lining.

Site 474: This upland site is located along the southeast margins of this zone on Kaho'olawe. This site was not described in the report, but information contained on the bags of charcoal submitted for analysis indicated that a firepit at this site was excavated. Presumably, this represented an eroding feature. Charcoal was recovered from two different layers within the feature.

Site 512: This site is located on the northeastern margin of the uplands, above the head of Hakioawa Gulch. As was the case with most of the excavated upland sites, in situ features were located on remnant hummocks of soil, held in place by grass, shrubs, and occasionally, trees. Buried and partially intact features are typically visible along the eroding sides of the hummocks. The hummocks sit on the more resistant saprolitic hardpan. Eroded cultural material from such sites can be found as a surface scatter on this hardpan, although only the heaviest material remains. The rest has either been washed or blown away. Feature C, a shallow basin firepit, was discovered about 25 cm below the hummock surface. It was from the interior fill of this feature that the charcoal assemblage was recovered. In addition to charcoal, lithic debitage and fire-cracked rock were found in the firepit or immediately adjacent to it.

Site 620: Located on the southeastern margin of the uplands, this site is not far from Site 474. This complex included a number of eroded scatters of material, in addition to firepits contained within uneroded hummocks. Feature A includes both an eroded section and four hummocks, one of which contained a firepit that was excavated. This large firepit contained evidence of multiple uses, and contained a large amount of charcoal, numerous fire-cracked rocks, and both shell and fish bone. The base of the pit was identified by a well-defined baked soil, indicative of repeated use and relatively high temperature.

Site 680: This site was not located on either the map or in the text, nor is there any record of this site in the SHPD site files. The report from the data recovery project (Rosendahl et al. 1992) indicates this is an upland site, and this seems likely given its charcoal assemblage and its number (most of the 600 series sites are located in the uplands). The bag which contained the charcoal had writing on it indicating the material was recovered from a firepit.

The five upland sites and four coastal sites, sampled a total of 10 different features (two firepits are represented from Site 142). The context of the deposits from upland and coastal locations, however, is markedly different. All of the upland sites sampled firepits; the coastal sites sampled both firepits, cultural deposits within structural features, and cultural deposits not contained within features. At one or two of the coastal sites there were concentrations of charcoal in some stratigraphic units, suggesting casually cooking or heating features were sometimes constructed. The coastal excavations also apparently sampled stratigraphically distinct deposits, suggesting that some time may have elapsed during different depositional episodes. Only Site 620 in the uplands contained a firepit in which multiple burning episodes were identifiable in stratigraphic context.

Site Dating

Ironically, despite over 100 radiocarbon dates and an even larger number of volcanic glass dates, the prehistoric chronology of Kaho'olawe remains uncertain. Although volcanic glass dating was vigorously pursued in Hawai'i since the early 1970s, the reliability of the dates generated by this method is now suspect (Graves and Ladefoged 1991; Olson 1983; Welch 1989). A recent attempt (Adams 1992) to match radiocarbon dates to volcanic glass dates from sites on Kaho'olawe has proved inconclusive. Although radiocarbon dating does not suffer from the same reliability problems as does volcanic glass dating, there is little consistency among the radiocarbon dates except to suggest that the bulk of the occupation of the island occurred within the past 300 to 400 years. With that caveat in mind, we have examined the published radiocarbon dates from the nine sites which produced the wood charcoal assemblages and have attempted to infer the most likely interval of occupation consistent with the dates.

Firepits and earth ovens (imu) were the most common recovery contexts from which charcoal was collected at these sites (see Table 1). Stratigraphic units within features or cultural deposits were the next most common recovery contexts. All of the sites, even those (Sites 474 and 680) whose materials were not reported or apparently recovered by the PHRI excavations, have associated radiocarbon dates (Table 2). Unfortunately, the temporal resolution provided by these dates is uneven, at best. Of the 27 samples submitted for dating, 14 returned "modern" dates. These are samples in which the proportion of ^{14}C is insufficiently different from the modern standard to be distinguished from it. Although such "modern" dates can occur on samples whose true age is as much as 300 to 400 B.P., their abundance in this collection (and from the larger assemblage dated) from Kaho'olawe suggests some form of systematic contamination or error. This is also supported by the general lack of Western artifacts or materials associated with the excavations, and which likely indicates that most of the settlements on Kaho'olawe were abandoned by the early historic period (i.e., between 1820 and 1850).

The method employed here to estimate the age of the archaeological features or deposits from which charcoal was recovered was as follows. Where it was possible to provide calibrated age intervals for the dated samples, we have done so (using the Stuiver and Becker [1986] procedure). Though lacking precision, it was possible to estimate calibrated age intervals for those "modern" dates whose conventional ^{14}C age was given as a percentage less than 100 in the original report (Rosendahl et al. 1992). Only dates whose conventional ^{14}C age was estimated as a percentage greater than 100 could not be assigned a calibrated age interval. These were placed into the A.D. 1650-1820 (or the late prehistoric through the protohistoric periods) interval.

All of the Kaho'olawe sites had multiple radiocarbon dates, often from the same feature or stratigraphic layer. We first attempted to isolate stratigraphically consistent age differences. Only one of the sites included in this study shows consistent stratigraphic patterning in the radiocarbon dates. The lowest stratum at Site 378, Feature B is associated with dates we estimate to most likely span the 14th through late 17th centuries. This was also the deepest cultural deposit represented among the nine sites. The upper stratum of this site dates to the late prehistoric through historic periods (probably 17th to early 19th century). At Site 569, Feature C, there was no stratigraphic patterning to the radiocarbon dates leading us to infer relatively late prehistoric to protohistoric occupation for the cultural deposits within this feature. Similarly, the two radiocarbon dates from Site 636 Feature A that are from two different test pits also suggest a late occupation interval.

The radiocarbon dates within individual firepits or imu tend to overlap, suggesting relatively short intervals of use and reuse. This is true even for the two firepits from upland sites which produced stratigraphic evidence of more than a single use of the feature. However, the two firepits excavated at Site 142, Feature A produce markedly different date intervals: Firepit 8 was used during the late prehistoric to protohistoric periods, and Firepit 15 dates to the 15th and early 17th centuries. Again, this is consistent with the stratigraphic information; Firepit 15 was cut into sterile beach sands.

Figure 2 shows our interpretation of the dated intervals most likely represented for six features (or separate strata within features) at the four coastal sites and at the five cooking features represented from the inland sites. Although we remain cautious about extrapolating from these limited sample locations to other localities on Kaho'olawe, we offer a few observations that may bear further examination. First, as expected there may be somewhat earlier occupation of the coastal area than the uplands. This should come as no surprise, yet previously, it has not been documented based on radiocarbon dates. Furthermore, the coastal occupation may have extended over a longer period of time within features (and presumably residential complexes), than concluded by Rosendahl et al. (1992:V-31). Second, there is intriguing evidence that inland sites located along the southern margin have somewhat earlier dates than those along the northeastern section. If dates from cooking features tend to date the last use of the feature, this would suggest that the more southerly inland sites dropped out of use earlier than northern sites. Third, the bulk of the Hawaiian occupation represented in these sites from Kaho'olawe was concentrated in the late prehistoric period. We find it unlikely that there was an extensive 19th century historic occupation of

Kaho'olawe by Hawaiians as suggested by Rosendahl et al. (1992:VII-2).

The nine sites included in this study sampled an array of features and deposits from both upland and coastal locations, as well as, both northeastern and western coastal localities. Although the temporal resolution is not as strong as we might have hoped given the resources put into dating these sites, the estimates we have generated suggest most of the sites were occupied within the last 500 years. However, it is possible to separate an earlier, pre-A.D. 1600, interval of occupation in a few upland and coastal sites, followed by the bulk of the prehistoric occupation in the following two centuries. We return to these chronological divisions of the sites represented in a later section when we examine changes in the vegetation of Kaho'olawe.

Analytical Technique and Identified Taxa

The history of wood charcoal identification in Hawai'i is relatively short, and its most recent development can be traced to several contract archaeology projects initiated during the late 1970s and early 1980s (Clark and Kirch 1983; Hommon 1983). Both studies included a report by Murakami (1983a, 1983b) listing the taxa which could be identified in the archaeological samples from Hawai'i Island and Kaho'olawe. These first studies demonstrated that wood charcoal recovered from archaeological contexts could be matched with modern reference materials. To accomplish this, Murakami developed a procedure for first sorting the charcoal samples under low power magnification into different groups, and then embedding representative pieces of charcoal from the sorted groups with an epoxy resin (Smith and Gannon 1973; Spurr 1969). When the resin had completely infiltrated the charcoal it was hardened, and then microscope sides of thin section of the three facets of each charcoal piece were prepared. These slides were compared to thin section reference material from the Department of Botany, University of Hawai'i for identification.

Although these earliest studies were hampered by low identification rates for the archaeological materials due to small reference collections and the unrepresentative nature of the wood charcoal submitted for identification, they clearly showed the potential of this archaeobotanical approach. For instance, Murakami (1983b) identified six different woody taxa across five upland sites on Kaho'olawe despite the limited charcoal samples made available to her. These included several which had not been previously recorded for Kaho'olawe at that time: Bidens (ko'oko'olau), Nototrichium (kulu'ī), Canthium ('alahe'e), and Nothocestrum ('aiea).

In 1982, after the completion of the second data recovery project on Kaho'olawe, Murakami analyzed the wood charcoal from a number of sites. Her report, completed in 1983, was not formally accepted until nearly ten years later (Murakami 1992). In this report, a total of 18 taxa were identified, only three of which had been found during the previous study. Three of the newly described taxa represented exotic woods which have never been reported to grow in Hawai'i, and include Quercus (oak), Sequoia (redwood), and Pinus (pine). They are presumed to have drifted here from the west coast of North America, where they were then scavenged for subsequent use. The modern occurrence of driftwood from North America has been previously documented (Strong and Skolmen 1963). Emory and Sinoto (1969:4) identified both Douglas fir and cedar among the modern driftwood on a beach along the south coast of Hawai'i Island. Vancouver (1798) had observed driftwood derived pine logs being used by Hawaiians for the construction of canoes during his historic period visits to the Islands.

Of the endemic, indigenous, or Polynesian introduced taxa identified by Murakami during this second project, nine had not been previously reported for Kaho'olawe. Three of these taxa could not be confirmed in the present study (and have been dropped from the list of identified taxa), and one (Aleurites moluccana or kukui) of the remaining five taxa might also have occurred as driftwood. Nonetheless, two (Sophora chrysophylla or māmane, and Myoporum sandwicense or naio) of these newly identified taxa may have once grown on the island according to Murakami (1992).

Murakami's identification of wood charcoal from Kaho'olawe more than doubled the number of taxa identified from archaeological contexts on the island over the earlier study. More sites were represented, and they were distributed across both coastal and upland locations. Yet, at the time this study was completed a number of wood charcoal groups could still not be identified to a known taxon at many of the sites. In some cases, these unidentified groups represented as much as 50 to 75 per cent of the charcoal by weight recovered from a site.

Thus, the primary analytic goal of the present study was to re-examine all the previously identified material from Kaho'olawe, from both Hommon's 1981 project, as well as the second set of excavations in 1982. This was possible, because Murakami had retained the charcoal from the second excavation project, plus thin section slides of the charcoal identified from both projects. This material, including the unidentified groups, was systematically compared to the reference collection--now expanded to include more than 100 taxa--with much greater success than had been achieved previously. A preliminary account of our research was presented in 1993 (Graves and Murakami 1993).

A total of 30 taxa are now known from the Kaho'olawe archaeological collections, making this one of the most diverse assemblages known from the Hawaiian Islands. The number of unidentified charcoal groups was reduced from 31 in the second study, to only nine in the present study. And at no site do these unidentified groups constitute more than 20 per cent of the assemblage. Of the identified taxa, 10 represent newly reported occurrences on Kaho'olawe. Two additional cultivated taxa (Ipomoea batatas or 'uala, and Lagenaria siceraria or ipu) had been previously reported from a macrobotanical analysis (Allen 1992), but were identified here among what were thought to be exclusively wood charcoals. Most of these newly identified taxa may also have once grown on the island.

Review of Identified Taxa

Acacia koa Gray (koa)

This tree, which sometimes grows to more than 20 m. in height, is an endemic species that was used traditionally by Hawaiians for storage (i.e., calabashes), canoe hulls, paddles, weaponry (e.g., spears) (Abbott 1992). Koa has not ever been reported to grow on Kaho'olawe; it tends to occur today at higher elevations, over 200 m (Rock 1913; Wagner et al. 1990) but may have grown at somewhat lower elevations in the past.

Koa occurred at only two sites in low quantities, and may have been introduced to and deposited on the island in the form of tools, containers, or canoes and paddles that had worn out or broken. The two samples identified as koa were not A. koaia, a now rare form of koa which grows in open dryland environments on some of the islands.

Aleurites moluccana (L.) Willd. (kukui)

Kukui or candlenut tree is a Polynesian introduction to Hawai'i. It was widely used for a variety of purposes, including a dye made from the bark, lighting from burning the oily kernel, and net floats made from the wood. The nut was used medicinally, as were the gums and resins of the tree. The trunk of kukui was sometimes used for canoe construction. (Wagner et al. 1990:598; Malo 1951).

The tree may once have been cultivated in Hawai'i, but has since escaped into the native forest where the large trees most often occur in moist gulches and valleys. Kukui has been reported to grow on all the islands except Kaho'olawe to elevations of 700 m. Kukui nuts were recovered from a number of sites during excavations by PHRI (Allen 1992), including those located in the uplands and along the coast. A piece of driftwood kukui was noted in an earlier botanical survey (EISC 1979). Only one coastal site produced kukui wood, and this may reflect scavenging of driftwood. Allen (1992) suggests kukui may have grown in a few of the moister gulches at higher elevations, or it may have been cultivated at lower elevations.

Artocarpus altilis (S. Parkinson ex Z) ('ulu) (breadfruit)

Another tree introduced to Hawai'i by Polynesians, 'ulu has been recorded from all the islands except Kaho'olawe. Breadfruit was cultivated, growing to a height of 10 to 20 m. The variety of 'ulu grown in Hawai'i prior to European contact was seedless, and consequently was propagated by root shoots. The foliage is dark green and dense. Trees begin to bear fruit by their 7th year, and continue for as many as 30 to 40 years (Abbott 1992). In Hawai'i the fruit ripens during the summer, with a smaller second crop in the winter (Neal 1965). Preparation of 'ulu involved baking, pounded as for poi, and occasionally mixed with coconut cream and baked. The wood of the tree was used in canoe construction, the bark could be used for tapa, and the milky sap as a resin or gum (Neal 1965). 'Ulu was also used in making surf boards and musical instruments (Abbott 1992)

'Ulu was recovered from a single coastal site on Kaho'olawe, and this is the first recorded identification of this taxon from the island. The tree probably could not survive on the island without cultivation (i.e., watering) or by being placed in a well-watered location. Its low occurrence may indicate transport of the wood to Kaho'olawe through exchange or as an artifact.

Bidens spp. L. (ko'oko'olau) (Spanish needle)

An endemic herb or shrub, this taxon includes 19 species (Wagner et al 1990). Ko'oko'olau grows widely in Hawai'i in dryland and mesic environments. Some species prefer disturbed habitats. Bidens has been previously recorded on Kaho'olawe including the botanical survey (EISC 1979). Some species were used medicinally, as well as for a herbal tea.

Although the genus has been previously reported for Kaho'olawe during the botanical survey, this is the only documented occurrence from an archaeological site on the island. It was identified at an upland site (Murakami 1983b), where it may have formerly grown. Pollen recovered from both upland and coastal localities (Athens et al. 1992) of Kaho'olawe includes substantial quantities of the family Asteraceae, which includes the genus Bidens.

Canthium ororatum (G. Forster) Seem. ('alahe'e)

A native tree of Hawai'i, 'alahe'e has not been previously reported from Kaho'olawe (Wagner et al. 1990). In Hawai'i it occurs in mesic environments or dry shrublands, as well as in wet forest. It occurs as a shrub or small tree, usually not more than a few m. in height. Because of its hard and dense wood 'alahe'e was used to make wood working and cultivation tools.

'Alahe'e was recovered from a single coastal site during the 1982 excavations. It was also identified at an upland site from material excavated during the first data recovery project (Murakami 1983b) It may have once been present on the island given its occurrence at two both coastal and upland sites, or it may have been transported to the island as a tool and later burned.

Chamaesyce spp. ('akoko)

The endemic 'akoko consists of a number of species and several varieties, and is one of the most variable plants in Hawai'i. This taxon was formerly designated Euphorbia (St. John 1973), but was recently reclassified into a separate genus, Chamaesyce by Wagner et al. (1990). This genus may be found in coastal to wet forests and as a low shrub to a small tree a few m. in height. Three native species have been reported for Kaho'olawe. Only one of these, C. celastroides, occurs as a small tree. C. multiformis is found as a shrub, and can be sometimes confused with C. celastroides. C. skottsbergii is a subshrub growing close to the ground. All three of these species develop woody characteristics, although the size of woody sections increases from C. skottsbergii to C. celastroides. Today, the most common form of this genus is a recently introduced species C. hirta. This taxon is a decumbent annual herb. The native species of 'akoko occur much less frequently, although C. celastroides was noted in the botanical survey (EISC 1979).

'Akoko was the most common wood taxa identified in the archaeological samples from Kaho'olawe, it occurred at all coastal and inland sites. The recent pollen study of Kaho'olawe (Athens et al. 1992) identified Euphorbia in all of the cores analyzed. Although not specifically attributed to 'akoko, it is possible that this group of plants may have contributed much of the pollen recovered from the cores. 'Akoko was valued as a source of firewood by Hawaiians (Hillebrand 1888). The size of some of the pieces of 'akoko firewood recovered from the excavations at upland sites on Kaho'olawe suggests that tree-sized varieties occurred in some sections of the island.

Chenopodium oahuense (Meyen) Aellen ('āheahea, 'āweoweo)

This endemic species occurs as a low shrub near the coast and a somewhat larger shrub to small tree in the dry lowlands. It is relatively common in many xeric habitats of Hawai'i, but had not been previously reported for Kaho'olawe. As Allen (1992) observes, Chenopodium is noted as a colonizer in disturbed habitats (e.g., roadways and agricultural fields), and has been documented in such contexts in Hawai'i. The leaves of the native Chenopodium were eaten as a green (Buck 1964; Malo 1951; Handy and Handy 1972). The juice of the plant was also consumed; the buds and bark were given medicinally. A tapa dye was produced from the shrub as well.

Seeds of _Chenopodium_ occurred abundantly in the archaeobotanical samples analyzed by Allen (1992), and wood charcoal from this taxon was found at both coastal and upland sites, making its occurrence relatively ubiquitous in the prehistoric assemblages. Similarly, Cheno-ams were a large component of the pollen samples analyzed by Athens et al. (1992). Its current absence from the island may be the result of grazing pressure from goats and cattle.

Diospyros _sandwicensis_ (A.DC) Fosb. (_lama_)

This endemic species has not been reported previously for Kaho'olawe. _Lama_ grows into a tree as much as 10 m. in height. It tolerates a range of habitat conditions, although it generally prefers moist conditions, and is found to as much as 1000 m. in elevation (Wagner et al. 1990). The wood was used for house construction, to fence sacred areas, and figured importantly in _hula_ where a block of wood was used as an altar within a _halau_ or structure (Abbott 1992).

Lama was recovered from four sites in both midden material and as firewood. A specimen of _lama_ was also recovered among materials from an upland site excavated during an earlier data recovery project (but was not identified until the present study). Its presence in these contexts on Kaho'olawe suggests it grew there previously, perhaps in the cooler and wetter portions of the uplands.

Dodonea _viscosa_ Jacq. (_'a'ali'i_)

This indigenous taxa occurs throughout Polynesia and Oceania. It is extremely polymorphic and a number of varieties and forms exist. It grows as both a shrub and small tree to as much as 5 m. in height. In Hawai'i, botanists have been unable to sort specimens within this taxon into varieties, although there is considerable variation in leaf size, shape, and form (Wagner et al. 1990). _'A'ali'i_ grows commonly throughout Hawai'i, often in open areas where there is little soil development (e.g., lava fields). It can be found from the coast to over 2000 m. in elevation, and from dry to wet conditions. It has not previously been reported for Kaho'olawe. Uses for _'a'ali'i_ include framing for house construction, and its fruit and leaves were employed in _lei_ making (Abbott 1992; Wagner et al. 1990).

Although recovered primarily from two coastal sites in midden contexts, _'a'ali'i_ was also found in an upland fire pit. This plant was discovered during this study among the charcoal materials from another upland firepit excavated in 1981. _Dodonea_ was also a ubiquitous taxon identified in the pollen extracted from several localities on Kaho'olawe (Athens et al. 1992). Its polymorphic qualities and tolerance for a wide range of environmental conditions suggest it may have once grown on Kaho'olawe.

Erythrina sandwicensis Deg. (wiliwili)

This endemic tree occurs on all the major islands, including Kaho'olawe, in dryland localities, to an elevation of 700 m. (Neal 1965). The tree which can grow to as much as 10 m. in height, has been previously recorded for the island, and specimens of it occur in the uplands today. The wood was used to make surfboards (Abbott 192), as well as floats for nets and outriggers for canoes. The seeds were strung onto lei.

When burned, wiliwili forms a very fragile charcoal which is easily broken apart. Charcoal from this taxon was part of the firewood assemblage of two firepits from a coastal site on Kaho'olawe. It was also a minor component of the upland pollen from Kaho'olawe (Athens et al. 1992).

Ipomoea batatas ('uala) (sweet potato)

'Uala was one of the traditional staple foods of Hawai'i and was introduced by Polynesians. Unlike taro, 'uala could be grown in relatively arid locations. The hardiest varieties can grow in almost any kind of soil and where the annual rainfall approaches 15 inches per year. Sweet potatoes are grown primarily for their tubers, and can be planted in rotation so that two or three harvests may be made in a single year (Abbott 1992). The tubers were baked, and mashed and eaten as poi. In many areas of Hawai'i, especially where taro could not be grown, 'uala replaced taro as the staple carbohydrate food. The leaves of this cultigen are also edible.

Although the uplands of Kaho'olawe have been identified as a likely area for the cultivation of 'uala (Hommon 1980a, 1980b; Spriggs 1991), no physical evidence had been recovered prior to the 1982 excavations. Allen (1992) identified sweet potato seeds from a coastal site, and had tentatively identified part of a charred tuber from a firepit in an upland site. This study has now confirmed the identification of a charred fragment of 'uala tuber from a coastal site. The presence of two different parts of sweet potato at two different coastal sites, and the possible identification of it at an upland site provide direct evidence for the cultivation of this crop on Kaho'olawe.

Lagenaria siceraria (Molina) Standl. (ipu) (bottle gourd)

This taxon is a Polynesian introduction, but occurred in at least three very different forms or sizes, all of which are assignable to the same species (Abbott 1992). Their differentiation is indicative of artificial selection under Hawaiian cultivation. Ipu was an important cultigen, despite the fact that only one of the forms was ever eaten. The plant was valued, instead, for its fruit which were made into containers, both large and small. Ipu was also made into percussion instruments which were employed as part of chanting and hula. This plant grows best in dry sunny conditions, and may have been cultivated at both upland and coastal locations on Kaho'olawe.

Allen (1992) previously identified ipu carbonized seeds and fruit rinds from four inland sites and a single coastal site. The present study identified carbonized rind fragments from the same coastal site from which Allen's identification was made. It seems likely given the environmental conditions on Kaho'olawe that ipu was cultivated there.

Metrosideros polymorpha Gaud. ('ōhi'a lehua)

A plant endemic to Hawai'i 'ōhi'a lehua shows considerable morphological and ecological variability (Wagner et al. 1990). Several varieties are recognized which appear to be associated with different ecological requirements. None of these varieties of 'ōhi'a lehua has been reported for Kaho'olawe. Among the forms in which 'ōhi'a lehua occurs are prostrate shrubs, erect shrubs, to tall trees. They can be found up to 2000 m. elevation in a variety of habitats, including wet forests and dry shrublands. 'Ōhi'a lehua was used in a variety of ways, including house and canoe building, for containers, for sacred images, as part of lei making, and as an offering for hula (Abbott 1992).

'Ōhi'a lehua was identified from a single coastal site on Kaho'olawe, but in more than one stratigraphic layer of midden deposit. Its ecological range and tolerance makes it likely that this plant formerly grew on the island.

Myoporum sandwicense Gray (naio)

An endemic shrub to small tree which has been previously reported from all the main Hawaiian Islands except Kaho'olawe. It is found to an elevation of 3300 m, and is both ecologically and morphologically quite variable (Wagner et al. 1992). It can survive in xeric or wet environments, and in good and poor soils. The wood has an odor similar to sandalwood, and was substituted for it when sandalwood became scarce during the Historic Period. Naio was used for house construction by Hawaiians.

This identification of naio is the first for Kaho'olawe. It was found in two different coastal sites, in midden contexts.

Although this wood may have been introduced to the island, its ecological tolerance makes it likely that it could have grown there naturally.

Myrsine sp. (kōlea)

A number of species of this genus occur in Hawai'i; most of them are found in upper elevations and relatively moist ecological conditions (Wagner et al. 1990). Only M. lanaiensis occurs in upland dry forest on all the main islands, except Kaho'olawe. The sap and charcoal of kōlea was used for dye, and the wood for house construction or for beating tapa (Neal 1965).

This is the first identification of kōlea from Kaho'olawe, where it was found in moderate quantity at a single coastal site. If it formerly grew on the island, this is likely a representative of M. lanaiensis.

Nestigis sandwicensis (A. Gray) (olopua)

An endemic species, olopua, has been previously recorded for all the islands except Kaho'olawe and Ni'ihau (Wagner et al. 1990). This is a moderately sized tree up to 20 m in height. It occurs in dry and mesic environments, from about 30 m. to as much as 1300 m in elevation. A hard and durable wood, olopua, was used to make adze handles, digging sticks, and as a tool for finishing fish hooks. The wood was also prized for firewood.

This is the second identification of this taxon on Kaho'olawe; Murakami (1992) previously identified it at another site (but its taxonomy at that time was Osmanthus). In this study, olopua was found at one coastal site, and although it is possible that it once grew on the island, this cannot yet be confirmed by a single occurrence.

Nothocestrum spp. ('aiea)

There are four endemic species of this genus found in Hawai'i (Wagner et al. 1990). Of these four, N. latifolium, would be the most likely to grow on Kaho'olawe. It grows as a small tree up to 10 m. in height. This species of 'aiea grows in dry to mesic forest, between 450 and 1500 m. elevation, but has not previously been found on Kaho'olawe. The wood of 'aiea is soft and was used for thatching sticks, making fire, and as canoe timber (Malo 1951).

Nothocestrum was identified at a single coastal site during the 1982 excavations, but Murakami (1983) previously identified it from an upland firepit. Pollen identified to the family Solanaceae was recovered from an upland context on the island (Athens et al. 1992), and Nothocestrum is a member of this family. Its presence in both localities suggests the tree formerly grew on Kaho'olawe, most likely in the uplands.

Nototrichium spp. (A Gray ex Hillebr.) (kulu'ī)

Two species of this endemic genus are recognized (Wagner et al. 1990), but the most likely species represented here is N. sandwicense. Wagner et al. (1990:194) state that it has been found on all the main islands, which would include Kaho'olawe. We have been unable to verify this; nor do the recent botanical (EISC 1979; Corn et al. 1980) surveys confirm its presence on the island. Kulu'ī occurs as a shrub or small tree, growing at low elevations to 750 m. It favors dry open forests, and on ridges and lava fields.

Kulu'ī was identified at four sites excavated in 1982, three coastal and one in the uplands. It also occurred at another upland site studied by Murakami (1983). The ubiquity of this taxon indicates that is very likely grew on Kaho'olawe.

Osteomeles anthyllidifolia (Sm.) Lindl. ('ūlei)

A native species of Hawai'i, 'ūlei is a shrub which has been found all the islands with the exception of Kaho'olawe and Ni'ihau (Wagner et al. 1990). It grows in a wide variety of habitats along the coast, in lava fields, and dry to mesic shrublands and forests. A variety of uses are listed for 'ūlei including as a medicine, for digging sticks, fish spears, fish net hoops, making lei, and musical instruments (Abbott 1992).

This taxon was present at a single coastal site on Kaho'olawe, and although its abundance at the site was low, 'ūlei may have once grown on the island.

Perrottetia sandwicensis A. Gray (olomea)

This is a small endemic tree, 3 to 6 m in height. It has been found on all the main Hawaiian islands, except for Ni'ihau and Kaho'olawe (Wagner et al. 1990). It is an understory tree, common in wet forests above 300 m. elevation to 1250 m. Olomea was used with hau to make fire by rotating it against the softer wood of hau.

The only reported presence of olomea from Kaho'olawe occurred in very low quantity at a coastal site. Given its habitat preference for moist conditions, it may have been transported to the site. It is not yet clear if suitable habitat for its growth would have existed in the upper elevations of Kaho'olawe.

Pinus sp. (pine)

Pine does not grow in Hawai'i, but is found in the continental United States. A small quantity of pine charcoal was identified from a coastal site on Kaho'olawe. It most likely represents driftwood which was subsequently used by Hawaiians.

Psychotria spp. (kōpiko)

A Polynesian introduced shrub or tree, there are several species of kōpiko identified for Hawai'i (Wagner et al. 1990). It is found in mesic to wet environments at elevations over 200 to 300 m. throughout the islands. None of the species have ever been reported for Kaho'olawe, and only P. mauiensis occurs on Lāna'i.

This taxon was recovered at two different coastal sites, one of which contained somewhat abundant quantities. It is unlikely that it grew at the coast, but must have been transported from a higher elevation. It was also identified (but previously unreported) during the present study from an upland site on the island, and thus may have once grown in the more moist conditions provided by higher elevations on Kaho'olawe.

Quercus sp. (oak)

Oak is not a native wood of Hawai'i, but is found in the western United States. It was identified at a coastal site on Kaho'olawe, and as was the case with the presence of pine, oak probably represents the use of driftwood.

Rauvolfia sandwicensis A. DC (hao)

This taxon was formerly included a number of species, but has recently been collapsed into a single highly polymorphic species (Wagner et al. 1990). Hao is a shrub or tree to 10 m in height, and occurs on all the main Hawaiian islands, except Kaho'olawe. It grows in dry or mesic environments, on exposed ridges, lava flows, in shrublands, and in some forests at elevations between 100 and 500 m. No traditional uses are reported for hao, although other species within this genus are used medicinally.

This is the first reported recovery of hao on Kaho'olawe. Hao was found at two coastal sites, but in relatively low quantities. It could have grown at higher elevations on Kaho'olawe, and been subsequently transported to the coast.

Reynoldsia sandwicensis A. Gray ('ohe)

This taxon was also formerly described as constituting several different species. They have now been grouped together in a single species (Wagner et al. 1990). Other species of this genus are found in Polynesia. It may have been a Polynesian introduction or it could have been indigenous to Hawai'i. Reynoldsia grows as a tree up to 20 or 30 m. in height, and occurs in dry or mesic forest up to 800 m. elevation. It has been reported from most of the Hawaiian islands, except Kaho'olawe and Kaua'i. Its resin was used by Hawaiians, and it may have medicinal uses. The Hawaiian term 'ohe (Abbott 1992:139) is also used to refer to bamboo (Schizostachyum glaucifolium), not to be mistaken with Reynoldsia.

This is also the first reported occurrence of this taxon for Kaho'olawe, where it was recovered from three coastal sites. Pollen of the family Araliaceae was identified from a core taken in the uplands of Kaho'olawe (Athens et al. 1992). Reynoldsia is a member of this family. 'Ohe may have grown at higher elevations on the island.

Saccharum spp. L. (kō) (sugar cane)

This cultigen was first introduced to Hawai'i by Polynesian settlers. At the time of European contact, Hawaiians grew at least 40 varieties of sugar cane. Other species of sugar cane have been introduced during the historic era. Very likely, S. officinarum, the species cultivated by Hawaiians is the form represented here. Sugar cane was used as a source of sweeteners, fiber, and thatching. Sugar cane was grown on all the main Hawaiian islands (Wagner et al. 1990), although we are unaware of any previous record of it for Kaho'olawe.

Kō was identified from a single coastal site on Kaho'olawe. This is the first record we have found for its occurrence on this island. It may have been brought over through exchange, or it might have been grown along the sides of gullies, or in the moist uplands of the island.

Santalum spp. L. ('iliahi) (sandalwood)

There are four species of this genus currently recognized as endemic to Hawai'i (Wagner et al. 1990). Of these four, only one,

S. ellipticum, appears to have been found on Kaho'olawe at one time. A second species, S. freycinetianum, could have occurred on Kaho'olawe given its ecological requirements, and presence in comparable dry woodland areas of Lāna'i. Sandalwood is a small tree, occasionally a shrub (S. ellipticum), whose wood was valued for its scent.

'Iliahi was recovered at two coastal sites on Kaho'olawe in relatively abundant quantities. It was previously found at two upland sites (Murakami 1983b). The occurrence of sandalwood in both kinds of environmental settings suggests it once grew on the island.

Sequoia sp. (redwood)

Sequoia does not grow in Hawai'i, but is found along portions of the west coast of North America. This durable timber probably floated as driftwood to the coast of Kaho'olawe.

Sida fallax Walp. ('ilima)

'Ilima is an indigenous shrub to Hawai'i and other Pacific islands. S. fallax is the most morphologically variable of the taxa which occur in Hawai'i (Wagner et al. 1990). It typically grows no more than about 1 m. in height, especially at coastal locations, but can grow to a small shrub within mesic woodlands. It tolerates a fairly wide range of ecological conditions, although it is most abundant along sandy or rocky coastlines. The flowers of 'Ilima are used for making lei; its roots and flowers were used medicinally. Stems from larger plants were used for slats in houses (Neal 1965). 'Ilima still grows today on Kaho'olawe, and was likely a very common shrub throughout the island in the past.

The charred wood of 'ilima was found at a single coastal archaeological site. Charred seeds of Sida were also identified from two inland sites and a second coastal sites during the macrobotanical analysis (Allen 1992). 'Ilima was also found among the burned materials recovered from one of the burn layers excavated at an upland site. Sida is a common taxon identified in all the pollen samples taken from Kaho'olawe (Athens et al. 1992).

Sophora chrysophylla (Salisb.) Seem. (māmane)

This is an endemic tree to Hawai'i, with a dense and hard wood (Wagner et al. 1990). Māmane occurs in a variety of elevational settings to as much as 3300 m. above sea level. Trees of māmane can grow to as much as 10 m. tall. A number of different tools and construction uses were made of mãmane, including adze handles, digging sticks, and posts and beams for houses (Abbott 1992). Sophora has not previously been recorded for Kaho'olawe.

A small quantity of mãmane was identified from a firepit at a coastal site. If from Kaho'olawe, this taxon most likely grew at higher elevations on the island.

Results

Table 3 shows the distribution by percentage of the total weight (in grams) of the taxa identified in the present study across the nine archaeological sites excavated during 1982. It also shows the nine unidentified charcoal groups; these may or may not be taxonomically comparable to the identified materials. The weights were summed across sites (and their respective provenience units), so that the weights represent the percentage of each taxa within provenience units at a particular site. The charcoal assemblages from each of the upland sites was derived of a single well defined feature: a firepit. At two sites, the firepit materials could be separated into upper and lower units. However, there is no discernable difference in the taxa from the different levels represented, and for the purposes of this presentation their percentage weights were combined. Charcoal from coastal sites was derived from a greater variety of contexts, although most appear to have been midden associated with habitation sites. Only at Site 142 was the charcoal from two firepits. The taxa identified from these two firepits and their relative abundance in each firepit are remarkably similar.

Before we can begin to reconstruct environmental patterns on Kaho'olawe using the wood charcoal data, it is necessary to consider the effects of different sized samples on taxa diversity or variability. This follows from the often observed relation in zooarchaeological analyses that as the size of the sample increases, so do both the number and abundance of taxa which are identified (Grayson 1984). Typically, there is a point at which an increase in sample size no longer is correlated with taxa diversity, but as Nagaoka (in press) observes, this must be empirically determined for each study. Allen (1989) has recently shown that sample size effects also occur in archaeobotanical assemblages from elsewhere in Hawai'i. Thus, we begin with an assessment of taxa richness by total sample weight for the five upland firepits, the two coastal firepits from Site 142, and seven stratigraphic units at the remaining three coastal sites.

There is no indication that there is any relation between total charcoal weight and the number of taxa identified at the upland sites. In general, relatively few taxa were identified within these firepits, despite the recovery of very large amounts of charcoal from two of the firepits. The largest sample by weight, in fact, is associated in a single identified taxa, <u>'akoko</u> from Site 620.

With only two coastal firepits it is difficult to generalize, but they do seem to contain a greater number of taxa on average than the upland firepits. At the same time, the coastal firepits contain considerably fewer taxa than the coastal midden assemblages, especially when the total weight of the charcoal is taken into account. Comparable midden assemblages contained three to four times as many taxa as did the firepits from Site 142.

This suggests that the recovery of wood charcoal from firepits, whether upland or coastal, is sampling a different depositional context than that for midden samples. This may reflect a shorter duration of use and a more homogeneous pattern of use for the firepits than for the midden areas of sites, or some combination of the two.

There is a correlation between the total weight of charcoal from the seven coastal stratigraphic units and the number of taxa identified (see Table 4). As the total weight of charcoal represented in a sample increases, so does the number of taxa identified. This is important, because some of the smallest charcoal samples (as measured by total weight) were obtained from the upper levels of midden deposits at Sites 569 and 636. These small samples also contain the fewest number of wood charcoal taxa. In this case sample weight is a confounding variable in our efforts to isolate changes in the woody vegetation of Kaho'olawe.

Two factors, then, appear to structure the number of taxa identified at these archaeological sites on Kaho'olawe. The first has to do with the type of deposit or feature represented. Firepits contain fewer taxa than do midden deposits. There is also a geographic aspect to this, since only firepits have thus far been sampled from upland geographic contexts on the island. Second, among midden derived charcoal assemblages, there is an increase in the number of identified taxa with larger total weights of charcoal samples. Variation in total sample weights is at least partly a function of stratigraphic position at some sites, with smaller samples recovered from later deposits.

These factors make the analysis of geographic and temporal variation in the charcoal assemblages from archaeological sites on Kaho'olawe more difficult or less precise and reliable. However, it is possible to estimate some aspects of the former vegetation on the island if we remember the tentative nature of these inferences.

Geographic Patterning

We have prepared tables of the taxa identified by geographically grouped sites: coastal and uplands (Tables 5 and 6). These show the distribution of taxa across sites, but now grouped into four frequency categories: abundant, moderately abundant, trace, and absent. On Kaho'olawe both the coastal and uplands woody vegetation was dominated by 'akoko (Chamaesyce spp.). It was the only taxon to occur at all sites and within all the major stratigraphic units at these sites. Out of the fourteen provenience contexts represented at all nine sites, 'akoko was abundant (as defined by more than 50 per cent of the assemblage by weight) at all but four units in two sites. It occurred in moderate amounts in these remaining units. Thus, this taxon was both ubiquitous across sites and comprised the primary wood used for cooking and heating purposes.

Chamaesyce is represented in Hawai'i by several native species. During the re-identification of the samples previously analyzed by Murakami, we discovered at least three anatomically different forms of Chamaesyce, only one of which appears to match the reference material for C. celastroides. However, Wagner et al. (1990) note that this taxon shows considerable morphological variability and this is confirmed by both large and small limb or stem pieces of 'akoko in the charcoal samples. We conclude that a variety of native 'akoko once grew on Kaho'olawe, that these included both large and small forms, and very likely represented several varieties of C. celastroides, and possibly other species of Chamaesyce as well. We cannot yet match the anatomical variation with geographic or ecological factors, but the occurrence of large stem and limb charcoal fragments in upland fire pits suggests that 'akoko grew to tree size at higher elevations where precipitation was more abundant and reliable. It is possible, then, that at lower elevations and near the coast 'akoko would have taken smaller forms.

In addition to 'akoko, other taxa which occur in four or more provienence contexts include, Chenopodium oahuense ('āheahea or 'āweoweo), Dispyros sandwicensis (lama), Dodonaea viscosa ('a'ali'i), Nototrichium (kulu'ī), and Reynoldsia sandwicensis ('ohe). All of these taxa occur in moderate to trace amounts at sites, and with the exception of Reynoldsia all have been recovered from both upland and coastal locations (although pollen of the same family as Reynoldsia has been identified from upland contexts). These species are also characterized by the ability to tolerate a variety of ecological conditions (including aridity), and often to take different forms or sizes under these different ecological conditions. Again, with the exception of Reynoldsia, all these taxa probably grew at different elevations and in different forms on Kaho'olawe.

There is some evidence of geographic differentiation of the wood charcoal taxa recovered from the nine Kaho'olawe sites. At the five upland sites, the charcoal assemblages were dominated by 'akoko, with this taxon constituting 100 per cent of the assemblage at three sites, and more than 75 per cent of the assemblage at the other two sites. Chenopodium oahuense was the next most ubiquitous and abundant taxon at upland sites. Chenopodium was the dominant taxon among the archaeobotanical remains (i.e., seeds) recovered from upland sites (Allen 1992) and may be an indicator of vegetation disturbance, since this genus is elsewhere known to colonize cleared areas (e.g., fields in fallow). The geographic distribution of Chenopodium wood charcoal and seeds is congruent across the four upland sites whose location is known. This pattern matches Allen's (1992) observation that Chenopodium is more prevalent in the northern upland sites, and its occurrence diminishes to the south. Radiocarbon dates from the upland features show a similar trend, with later dates from firepits at sites on the north end of the uplands. We infer that the dates from these features are dating the last use of the firepits, and may indicate a retraction over time of agricultural clearance from the south to the north of the uplands.

A similar pattern is apparent in the density of archaeological sites in the uplands of Kaho'olawe, with more sites clustered around the northeastern portion of this zone. Similarly, contemporary vegetation patterns show a comparable pattern, very likely the result of the distribution of rainfall and wind direction and speed. Thus, Chenopodium appears to be a proxy paleoenvironmental indicator of human disturbance and prehistoric dryland agricultural development.

Yet, Chenopodium was not the dominant source of firewood at any of the upland sites on Kaho'olawe, suggesting that it may have had some economic importance, perhaps as a supplementary food source. Along with gourd and sweet potato, both of which have now been identified in coastal midden charcoal assemblages, Chenopodium may have been cultivated in the cooler and more moist uplands of Kaho'olawe.

Other woody taxa identified among the five upland sites and from the earlier archaeological excavations in this locality, included Diospyros sandwicensis (lama), Dodonea viscosa ('a'ali'i), Santalum sp. ('iliahi), Nothocestrum spp. ('aiea), Canthium odoratum (alahe'e), and Psychotria spp. (kōpiko). These taxa plus 'akoko suggest a dry vegetation community of mixed shrubs and grassland with occasional woodlands. This community may have been similar to the alahe'e/'akoko/pili (Canthium/Chamaesyce/Heteropogon) association described by Wagner et al. (1990:70), although it is possible that the community represented by these assemblages has no modern counterparts, especially if we consider the presence of Chenopodium to indicate an anthropogenic character. Interestingly, this upland association is somewhat different from that described for Lāna'i, the Nestegis/Diospyros lowland dry forest near Kānepu'u and which has been suggested (Rosendahl 1992) as an analog vegetation community for the late prehistoric period on Kaho'olawe. The difference may be the result of the prehistoric agricultural use of this zone on Kaho'olawe which promoted the establishment of Chenopodium over time. Alternatively, lacking suitable higher and wetter elevations in which certain species may have maintained their populations, the uplands of Kaho'olawe may have been characterized by forest elements in which only those best suited for periodic droughts could survive over time.

The coastal site charcoal assemblages from Kaho'olawe were also dominated by 'akoko; it occurs at all sites and within all provenience units. However, moderate abundances of this taxon were reported for about one-half the proveniences, a contrast to the pattern from the uplands. These differences in the relative abundance of 'akoko are difficult to interpret given the disparity in recovery contexts between the two zones. Nonetheless, even the two firepits from Site 142 report smaller percentage weights of 'akoko than all but one of the upland sites. The charcoal pieces are smaller from these two firepits as well, possibly indicating smaller forms of 'akoko were available near the coast. At least ten woody taxa occur at coastal sites on Kaho'olawe whose ecological requirements suggest they may have once grown in this zone. Additionally, a few taxa may have been cultivated in certain coastal settings, including breadfruit (Artocarpus altilis), sugar cane (Saccharum), and gourd (Lagenaria siceraria).

We are also able to tentatively distinguish two coastal vegetation communities on Kaho'olawe: western and northeastern. The two western sites include relatively large proportions of 'akoko, and moderate to trace amounts of wiliwili (Erythrina sandwicensis), naio (Myoporum sandwicense), 'ohe (Reynoldsia sandwicensis), 'ilima (Sida fallax), and 'iliahi (Santalum). Notably, these are all taxa which are adapted to or have varieties or species which are adaptable to arid conditions. Several of them may also occur as shrubs. Thus, this listing of the most common native woody taxa from the western side of Kaho'olawe suggests shrubs were more common than tree forms and in combination with Allen's (1992) macrobotanical study indicate shrub and grassland as the dominant vegetation.

Despite this evidence for a more xeric or dry environment on the western coast of Kaho'olawe, the charcoal assemblages recovered from Sites 142 and 378 do contain a variety of woody taxa which occur only as trees. Some of these are exotic (e.g., Pinus), or must have been transported from the uplands or from other islands (e.g., koa, māmane). Also, most of the cultivated taxa recovered on Kaho'olawe were found at these two sites. These include sweet potato, gourd, breadfruit, and sugar cane. With the exception of gourd, these cultigens would have been relatively difficult to maintain on the dry west coast of island. Either they were intermittently cultivated when conditions permitted or they were transported to these sites from the uplands or other islands. Drier environmental conditions on the western coast of Kaho'olawe may also have enhanced the preservation of charred cultigens.

The two sites (569 and 636) located on the northeast coast are also dominated by 'akoko, but generally produced the lowest proportions of this taxon of all the charcoal assemblages. Other taxa which occur more often on the northeast than the western coastal sites, include 'āheahea (Chenopodium), lama (Diospyros), 'a'ali'i (Dodonea), 'ohi'a (Metrosideros), kōpiko (Psychotria), and hao (Rauvolfia). These taxa are generally rare to absent at western coast sites, but most have been identified from upland sites. Despite the differences in recovery contexts which affect the overall diversity of taxa, the northeast coastal sites generally share more taxa in common with upland sites than with coastal sites to the west. This may indicate that similar vegetation associations occurred in both these zones although with markedly different proportions of taxa represented.

In our view, the coastal woody vegetation on Kaho'olawe as represented in these archaeological sites was characterized by relatively few taxa, none of which grew to large size, and whose distribution would have been patchy. Grasses, vines, herbaceous plants, and shrubs probably dominated most areas. Some of the taxa which take the form of trees may have grown in the bottoms and sides of gullies which drained the uplands. Possibly some of these taxa extended beyond their known range today, either the result of greater water availability, deliberate cultivation practices by Hawaiians, or they represent varieties with somewhat different water ecological requirements than those present today. The uplands vegetation included a variety of woods which grew to tree size and which also occur as shrubs. Again, their distributions is likely to have been patchy with locations of wooded areas where conditions were unfavorable for agriculture or grasslands.

Changes in the Paleoenvironment

Relative to the archaeological wood charcoal assemblages, all coastal localities on Kaho'olawe are dominated today by kiawe (Prosopis pallida) and other introduced grasses or shrubs. We note that there is a marked reduction in the overall diversity of the coastal wood communities on the island, and the geographic differentiation of woody taxa from the western and northeastern coasts is no longer as marked. Very little 'akoko occurs in the uplands of Kaho'olawe today and none of this taxon to our knowledge can now be found in its larger form. Many of the woody species we suggested once grew in the uplands are not found there today. This poses the final questions, when and how did this change in the vegetation of Kaho'olawe occur?

Given the possible effects of recovery context, sample size differences, and geographic variability, the identification of changes in the paleoenvironment offered here should be regarded as extremely tentative. However, there are charcoal assemblages associated with different inferred periods of deposition in the uplands and at two coastal sites. The earliest upland sites, Site 474 and 680, contain relatively less diverse sets of woody taxa than the later sites in the uplands. At sites 142 and 378 on the western coast of Kaho'olawe, there is no discernable change across the provenience units in terms of taxa diversity or abundance. Only one of the northeastern sites (Site 569), whose occupation appears to date relatively late, shows any appreciable difference in taxa diversity across stratigraphically related provenience units. Again, there is a substantial decrease in the abundance of 'akoko through time. At Site 636, the abundance of 'akoko increases through across the stratigraphic levels, but the differences are not sufficiently great to be statistically significant (and as expected the total weight of charcoal varies in a similar manner across the strata). Rather, the most common taxa represented at the site are relatively stable through the units. Thus, there is currently only slight evidence for any change through time in the wood taxa availability at coastal sites on Kaho'olawe, and what evidence there is supports the upland pattern of greater not less diversity.

The data from the wood charcoal assemblages does not currently support a hypothesis that there was substantial change in the composition and abundance of woody taxa during the prehistoric period on Kaho'olawe from a more to less diverse community or one increasingly constituted by shrubs and grasses. This finding is not congruent with either Sprigg's (1991) view of the geoarchaeological evidence and ethnohistorical record or Athens et al. (1992) recent assessment of the pollen record from the island. Possibly, we have over-estimated the number of woody taxa which may have once grown on Kaho'olawe. We also note that it is not possible, solely with wood charcoal to reconstruct all aspects of the vegetation. In particular, grasses and some shrubs are poorly represented among the wood charcoal. This caution, however, is also true for the macrobotanical analysis, which contains mostly the remains of herbaceous and annual plants and few woody taxa. At the same time, we are struck by the relatively impoverished nature of woody taxa in the pollen record from Kaho'olawe (Athens et al. 1992). Could it be that there is some form of bias operating on the production, spread, or preservation of pollen among different taxa?

Given the relatively few locations sampled by any of the paleoenvironmental analyses and the lack of congruence between assemblages (with the possible exception of the upland occurrence of Chenopodium), it is difficult to choose among the reconstructions offered. At this point, we prefer a reconstruction which makes the fewest assumptions about the island's vegetation based on historic period observations. We regard this as problematic, since they first occur well after European contact and the introduction of new practices and organisms to Hawai'i. Thus, we suspect the island harbored scattered trees and shrubs throughout the prehistoric era, and in places there may have been small areas of woodland vegetation. Finally, given that Chenopodium is associated with agricultural areas in the uplands of Kaho'olawe, and that it was allowed to grow to sufficient size for use as firewood, perhaps other woody taxa were afforded the same kind of protection by Hawaiians living on the island. If so, the late prehistoric increase in charcoal taxa diversity in the uplands may reflect the increasing use of secondary woods and would suggest that 'akoko might have become less abundant through time.

Finally, 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. We conclude along with Spriggs (1991) that this is most likely to have occurred during the nineteenth century after European contact and the introduction to Hawai'i of large scale fires and new grazing animals.

Conclusions and Recommendations

As we hope to have demonstrated the identification of wood charcoal from archaeological sites has considerable potential for Hawaiian history and prehistory. Kaho'olawe is an excellent case study in which to show that modern botanical surveys (even those which employ the best ethnohistorical research) may only begin to hint at the diversity and range of woody taxa which were once present on the island, but which can be documented in the archaeological assemblages by the present wood charcoal analyses. Wood charcoal identification has also proved more productive than either pollen analysis or macrobotanical analysis as a means to specify the kinds of trees and perennial shrubs which might have grown on Kaho'olawe in the past.

Over the past 10 years, the identification of wood charcoal from archaeological sites on the island has added substantial numbers of new taxa to the list of plants which once were found on Kaho'olawe. Currently, there are at least 30 woody taxa identified for the island. Of these at least half were likely once found growing on Kaho'olawe, and all but four or five were possibly found or cultivated there. We note that there are still portions of the wood charcoal assemblages from the 1982 excavations which have not yet been analyzed and which probably contain additional taxa. Once studied, this assemblage would provide greater geographical scope and temporal resolution than was achieved in the present investigation. Furthermore, as the historical sites of Kaho'olawe are stabilized and in some cases, restored over the next few years, there may be opportunities to recover additional samples of wood charcoal from these properties. It is our view that these samples should receive high priority for recovery, dating, and wood identification.

This re-analysis of the wood charcoal material from the excavations on Kaho'olawe helped to characterize the overall nature of the woody environment of the island, as well as to specify some of the geographical variation in that vegetation. Many of the woody plants that we think grew on Kaho'olawe are adapted to a range of conditions and occur with considerable morphological variability. Although the uplands were dominated by a single taxon, <u>'akoko</u>, this may be due to the kind of the features excavated there (i.e., firepits) and the relatively temporary nature of occupation. Several taxa were recovered from upland sites which would have grown there, and other taxa were found at coastal sites which could only have survived at higher elevations. We infer a relatively diverse set of woody taxa, although their distribution is likely to have been restricted to areas surrounding agricultural lands, perhpas on slopes, rocky ground, and the edges of ridges and hills.

Perhaps the most unanticipated aspect of the geographic patterning in wood charcoal occurrence was the separation of western and northeastern coastal assemblages. The western sites contained more introduced woody taxa, and several taxa which probably occurred as shrubs. The northeastern sites shared a greater number of taxa with the uplands than with the western coastal sites. This side of the island receives somewhat greater rainfall and may have supported a greater number and diversity of small trees and shrubs.

The geographical patterning of the wood charcoal assemblages has implications for future attempts to rehabilitate or restore portions of the island's vegetation. Efforts to introduce new trees and shrubs to the island should take note of the taxa listed in this report and their geographical distribution as a means to match taxa with the environmental conditions in which they are most likely to prosper.

The changes which have occurred to the vegetation of Kaho'olawe may be difficult to undo or to correct. It may be that the loss of soil and ground cover from the uplands and the invasion of kiawe along the coast have changed the environmental conditions of the island so that successful reintroduction of native or endemic plants will take much more time and effort. Yet, the wood charcoal identifications presented here demonstrate that a variety of native trees and shrubs once grew on Kaho'olawe. There is no evidence for substantial change in the diversity of plants which were represented in the charcoal assemblages. Our analyses also suggest these trees and shrubs survived throughout the prehistoric occupation of the island, only to be lost with the introduction of new grazing animals and the widespread (and perhaps, uncontrolled) use of fire after European contact.

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Table 1. Sites on Kaho'olawe from which Charcoal Assemblages Were Obtained for Identification.

Site No.	Feature	Recovery Context	Location
142	A8,A15	Firepit	West Coast
378	B	Terrace, Pit?	West Coast
569	C	Terrace	Northeast Coast
636	A	Midden	Northeast Coast
474	A	Earth oven	South Upland
512	C	Firepit	Northeast Upland
549	A	Earth oven	Northeast Upland
620	A	Firepit	South Upland
680		Firepit	Upland

Table 2. Radiocarbon Dates and Estimated Occupation Range for Sites with Charcoal Assemblages.

Coastal Site No.	^{14}C Age	$^{13}C/^{12}C$ Ratio	Adjusted ^{13}C B.P.	Calibrated A.D.	Inferred Age Range
142A, FP 8	100.9 +/-1.3% modern	-24.87			A.D. 1650-1820
FP 15	130 +/-70	-11.60	360 +/-70	1449-1629	A.D. 1450-1625
	150 +/-70	-11.87	370 +/-70	1443-1627	
378B, L III	98.2+/-1.4%(modern)	-21.49	150 +/-120	1665-1885	A.D. 1660-1880
	103.1+/-5.5%(modern)				
L IV	<120	-15.56	130 +/-50	1667-1886	A.D. 1300-1425
	430 +/-50	-15.88	580 +/-50	1314-1410	
569C, L II	140 +/-50	-20.42	210 +/-50	1645-1805	A.D. 1650-1800
L IV	100.4 +/-0.8%(modern)				
636A, TP 2	107.7 +/-3.6%(modern)				A.D. 1650-1800
TP 3	<130				
Inland					
474A, Imu	100 +/-80	-11.34	320 +/-80	1480-1646	A.D. 1500-1650
	90 +/-60	-12.47	290 +/-60	1508-1655	
	110 +/-60	-11.79	330 +/-60	1490-1637	
	96.9 +/-1.5%(modern)	-12.81	260 +/-130	1480-1807	
	95.9 +/-3.7%(modern)	-13.28	340 +/-320	1280-1850	
512C, FP	101.4 +/-1.2%(modern)				A.D. 1650-1820
	101.2 +/-1.1%(modern)				
549A, Imu	100.9 +/-0.6%(modern)				A.D. 1635-1810
	<150	-16.57	110 +/-70	1683-1901	
	<130	-10.37	210 +-60	1636-1810	
	100.0 +/-0.7%(modern)				

Site No.	^{14}C Age	$^{13}C/^{12}C$ Ratio	Adjusted ^{13}C B.P.	Calibrated A.D.	Inferred Age Range
620A, FP	100.3 +/-0.7%(modern) 100.1 +/-0.9%(modern)				A.D. 1650-1820
680, FP	280 +/-170 101.2 +/-0.6%(modern)	-25.39	270 +/-170	1450-1808	A.D. 1450-1810

*Notes: ^{13}C Adjusted dates calibrated following Stuiver and Becker (1986), Method B, 1σ.

Table 3. DISTRIBUTION OF IDENTIFIED TAXA FROM ARCHAEOLOGICAL SITES ON KAHO'OLAWE IN PERCENT SAMPLE WEIGHT.

	142A		378B		569C			636A		474A	512C	549A	620A	680
	FP-8	FP-15	II/III	IV	II	III/IV/PF	I(3/5)	I(6-7)	I(8)	I/II			UP/LOW	
Acacia koa	-	-	-	6	-	4	-	-	-	-	-	-	-	-
Aleurites moluccana	-	-	-	-	-	3	-	-	-	-	-	-	-	-
Artocarpus altilis	-	-	-	2	-	-	-	-	-	-	-	-	-	-
Canthium odoratum	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Chamaesyce spp.	72	67	51	64	43	81	48	36	23	100	56	93	100	93
Chenopodium oahuense	-	-	-	-	-	3	-	4	-	-	16	1	-	7
Diospyros sandwicensis	-	-	1	*	-	1	8	8	8	-	-	6	-	-
Dodonaea viscosa	-	-	-	-	5	-	24	24	31	-	26	-	-	-
Erythrina sandwicensis	8	*	-	-	-	-	-	-	-	-	-	-	-	-
Ipomoea batatas	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Lagenaria siceraria	-	-	1	*	-	-	-	-	-	-	-	-	-	-
Metrosideros polymorpha	-	-	-	-	-	-	4	2	7	-	-	-	-	-
Myoporum sandwicense	-	-	1	10	-	1	-	-	-	-	-	-	-	-
Myrsine sp.	-	-	6	-	-	-	-	-	-	-	-	-	-	-
Nestegis sandwicensis	-	-	-	-	-	-	-	4	-	-	-	-	-	-
Nothocestrum spp.	-	-	2	-	-	-	-	-	-	-	-	-	-	-
Nototrichium spp.	-	-	3	-	5	2	-	-	-	-	2	-	-	-
Osteomeles anthyllidifolia	-	-	-	-	5	1	-	-	-	-	-	-	-	-
Perrottetia sandwicensis	-	-	-	*	-	-	-	-	-	-	-	-	-	-
Pinus sp.	-	-	-	*	-	-	-	-	-	-	-	-	-	-
Psychotria spp.	-	-	-	3	-	-	4	11	-	-	-	-	-	-
Quercus sp.	-	-	-	-	9	-	-	-	-	-	-	-	-	-
Rauvolfia sandwicensis	-	-	-	-	-	1	4	-	-	-	-	-	-	-
Reynoldsia sandwicensis	19	14	15	-	-	1	-	-	-	-	-	-	-	-
Saccharum officinarum	-	-	-	2	-	-	-	-	-	-	-	-	-	-
Santalum spp.	-	-	10	-	-	-	-	-	31	-	-	-	-	-
Sequoia sp.	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Sida fallax	-	-	-	5	-	-	-	-	-	-	-	-	-	-
Sophora chrysophylla	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Unknown 1	-	-	9	-	-	-	-	-	-	-	-	-	-	-
Unknown 2	-	-	-	3	-	-	-	-	-	-	-	-	-	-
Unknown 3	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Unknown 4	-	-	-	3	-	-	-	-	-	-	-	-	-	-
Unknown 5	-	-	-	-	-	-	8	-	-	-	-	-	-	-
Unknown 6	-	-	-	-	-	-	-	11	-	-	-	-	-	-
Unknown 7	-	-	-	-	33	-	-	-	-	-	-	-	-	-
Unknown 8	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Unknown 9	-	19	-	-	-	-	-	-	-	-	-	-	-	-
Total Weight (g)	40.2	16.1	14.7	24.1	2.1	15.6	2.5	5.3	1.3	16.3	13.0	207.5	425.1	9.9

* Less than 0.5%.

Table 4. Number of Wood Charcoal Taxa in Relation to Total Charcoal Weight (in g.) from Coastal and Upland Sites on Kahoʻolawe.

Upland		Coastal	
No. Taxa	Weight	No. Taxa	Weight
1	9.9	3	16.1*
1	16.3	4	1.1
1	425.1	4	40.2*
3	207.5	5	2.1
4	13.0	7	3.9
		7	4.1
		11	14.1
		11	14.7
		11	15.6

* firepit contexts

Table 5. The Occurrence of Wood Charcoal at Coastal Sites on Kaho'olawe

Taxon	142A		378B		569C		636A		
	FP-8	FP-15	II/III	IV	II	III/IV/PF	I(3, 5)	I(6-7)	I(8)
Acacia koa	-	-	-	T	-	T	-	-	-
Aleurites moluccana	-	-	-	-	-	T	-	-	-
Artocarpus altilis	-	-	-	T	-	-	-	-	-
Canthium odoratum	-	-	-	T	-	-	-	-	-
Chamaesyce spp.	A	A	A	A	M	A	M	M	M
Chenopodium oahuense	-	-	-	-	-	T	-	T	-
Diospyra sandwicensis	-	-	T	T	-	T	T	T	T
Dodonaea viscosa	-	-	-	-	T	-	M	M	M
Erythrina sandwicensis	T	T	-	-	-	-	-	-	-
Ipomoea batatas	-	-	T	-	-	-	-	-	-
Lagenaria siceraria	-	-	T	T	-	-	-	-	-
Metrosideros polymorpha	-	-	-	-	-	-	T	T	T
Myoporum sandwicense	-	-	T	M	-	T	-	-	-
Myrsine sp.	-	-	T	-	-	-	-	-	-
Nestegis sandwicensis	-	-	-	-	-	-	-	T	-
Nothocestrum spp.	-	-	T	-	-	-	-	-	-
Nototrichium spp.	-	-	T	-	T	T	-	-	-
Osteomeles anthyllidifolia	-	-	-	-	T	T	-	-	-
Perrottetia sandwicensis	-	-	-	T	-	-	-	-	-
Pinus sp.	-	-	-	T	-	-	-	-	-
Psychotria spp.	-	-	-	T	-	-	T	M	-
Quercus sp.	-	-	-	-	T	-	-	-	-
Rauvolfia sandwicensis	-	-	-	-	-	T	T	-	-
Reynoldsia sandwicensis	M	M	M	-	-	T	-	-	-
Saccharum officinarum	-	-	-	T	-	-	-	-	-
Santulum spp.	-	-	M	-	-	-	-	-	M
Sequoia sp.	-	-	-	-	-	T	-	-	-
Sida fallax	-	-	-	T	-	-	-	-	-
Sophora chrysophylla	T	-	-	-	-	-	-	-	-

A= abundant >50%, M= moderate ≥10% and <50%; T= trace <10%; "-"= absent

Table 6. The Occurrence of Wood Charcoal at Upland Sites on Kaho'olawe.

Taxon	474A	512C	549A	620A	680	
	I/II			UP/LOW		
Acacia koa	-	-	-	-	-	
Aleurites moluccana	-	-	-	-	-	
Artocarpus altilis	-	-	-	-	-	
Canthium odoratum	-	-	-	-	-	
Chamaescyce spp.	A	A	A	A	A	*
Chenopodium oahuense	-	M	T	-	T	*
Diospyros sandwicensis	-	-	T	-	-	*
Dodonaea viscosa	-	M	-	-	-	*
Erythrina sandwicensis	-	-	-	-	-	
Ipomoea batatas	-	-	-	-	-	
Lagenaria siceraria	-	-	-	-	-	
Metrosideros polymorpha	-	-	-	-	-	
Myoporum sandwicense	-	-	-	-	-	
Myrsine sp.	-	-	-	-	-	
Nestegis sandwicensis	-	-	-	-	-	
Nothocestrum spp.	-	-	-	-	-	*
Nototrichium spp.	-	T	-	-	-	*
Osteomeles anthyllidifolia	-	-	-	-	-	
Perrottetia sandwicensis	-	-	-	-	-	
Pinus sp.	-	-	-	-	-	
Psychotria spp.	-	-	-	-	-	*
Quercus sp.	-	-	-	-	-	
Rauvolfia sandwicensis	-	-	-	-	-	
Reynoldsia sandwicensis	-	-	-	-	-	
Saccharum officinarum	-	-	-	-	-	
Santalum spp.	-	-	-	-	-	*
Sequoia sp.	-	-	-	-	-	
Sida fallax	-	-	-	-	-	
Sophora chrysophylla	-	-	-	-	-	

A= abundant >50%; M= moderate ≥10% and <50%; T= trace <10%; "-"= absent;
"*"= present at other upland sites

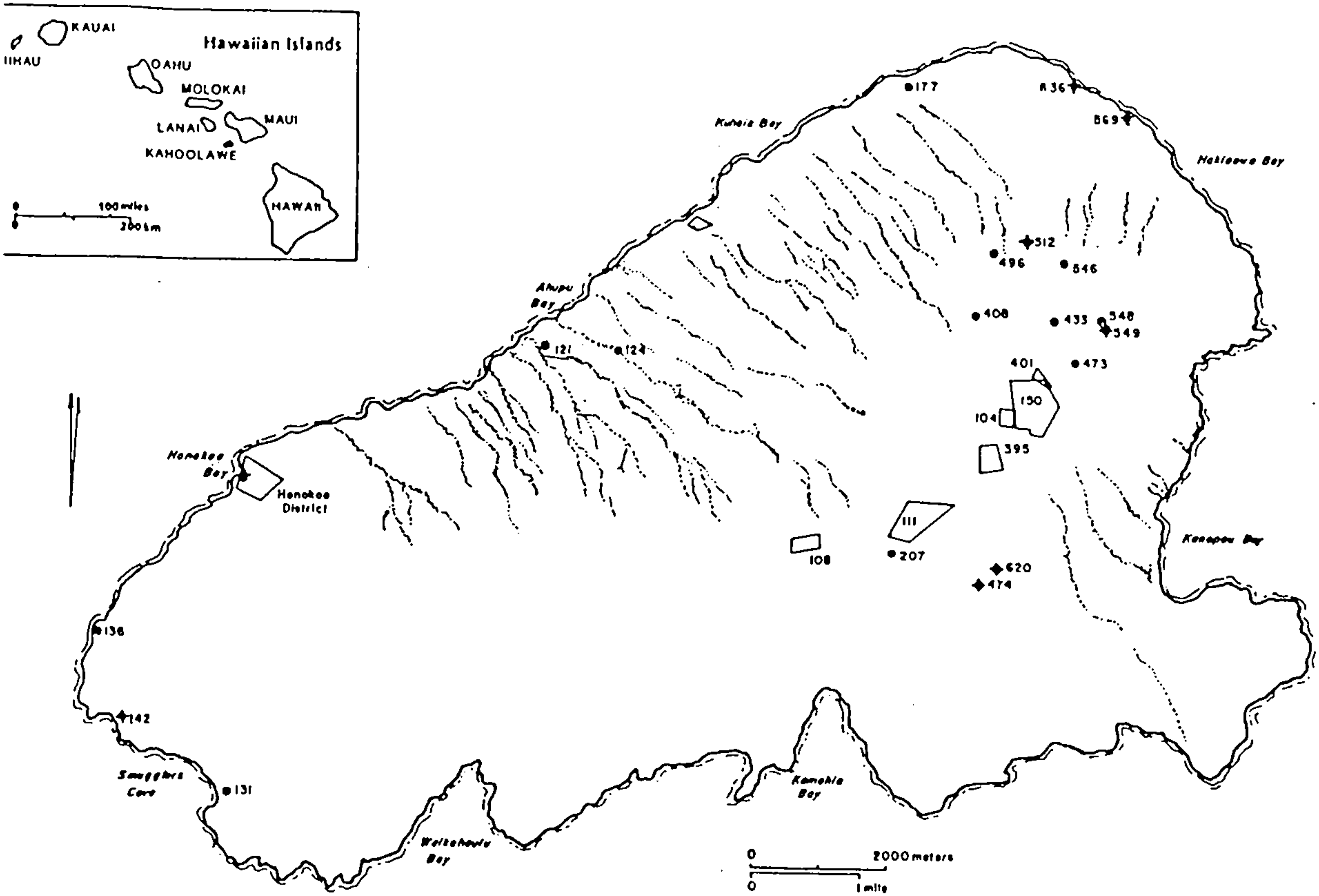

Figure 1. Map of Kaho'olawe showing sites mapped or excavated in 1982.
◆ are sites included in wood charcoal analysis.

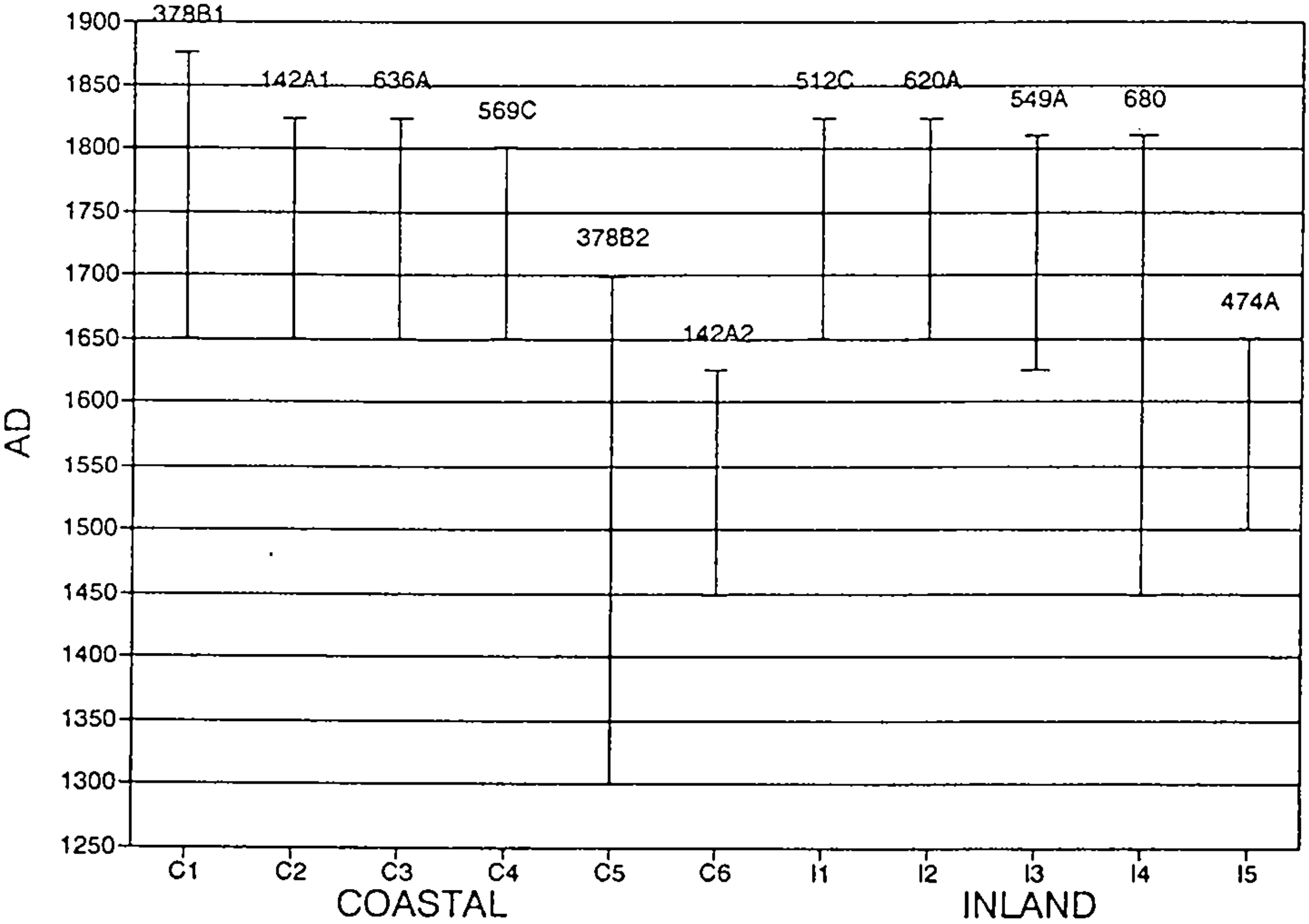

Figure 2. Diagram showing inferred age range of deposition or occupation indicated for sites and features from Kaho'olawe included in the wood charcoal analysis.