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INTRODUCTION

WHEN POLYNESIANS discovered the Hawaiian Islands over 1,500 years ago they brought with them the traditions of their ancestors. These traditions included an ability to adapt to new lands. Colonizers brought with them all of their major food crops such as taro (*Colocasia esculenta*), sweet potato (*Ipomoea batatas*), breadfruit (*Artocarpus altilis*), yam (*Dioscorea alata*), banana (*Musa*), and sugarcane (*Saccharum officinarum*). These crops were critical in sustaining human populations on the islands.

The Hawaiian people sustained their society, in part, by altering their landscape to support their subsistence systems. When we think about landscape alteration we are primarily referring to the agricultural field systems in the windward valleys and on the leeward slopes. From the earliest written accounts of Hawai'i, Europeans remarked with admiration on the cultivated landscape. They described the agricultural fields as "(of) amazing ingenuity and industry" (Portlock 1789:191-192), "in a high state of cultivation" (Menzies 1920:75), and "surpassing all the neighboring islanders" (Handy and Handy 1972:406).

Archaeologists believe that as the crops increased over time they were able to support growing populations until they (the crops) reached their "maximum extent, nearly reaching the edge of productive lands" (Ladefoged et al. 1996). There is evidence that the need to clear forest land to plant crops resulted in widespread habitat alteration which had a ripple effect on the native fauna and flora (Athens 1997). Researchers believe that as the size and number of crops increased across the landscape, the habitat of many native species, in particular birds, decreased (James and Olson 1991; Olson and James 1982, 1984, 1991). Steadman and Dye (1990) report that in the earliest Hawaiian sites (Halawa, Moloka'i; Kuliou'ou, O'ahu; Wai'ahukini, Hawai'i; and South Point, Hawai'i) shellfish, birds, and fish dominate the assemblages. Over time, however, these taxa declined (Steadman and Dye 1990). Large-bodied birds, in particular, declined rapidly (Steadman and Dye 1990:211).

The decline of large-bodied land birds and seabirds, may have had a significant effect on the population. The Hawaiian people depended on both land birds and seabirds for food, feathers, and tools. Seabirds were an especially important part of the Hawaiian subsistence system. In the Kuliou'ou, South Point and Wai'ahukini assemblages, a majority of the avifauna are seabirds (Moniz 1997). Hunters probably favored catching seabirds over land birds because they provided a lot of meat, and they were easy to catch; a large and predictable resource (Moniz 1997). Today, many of the bird taxa identified in these early sites are either extinct, extirpated from the Islands, or in such small numbers that they are near extinction (Moniz 1997).

Faunal material is particularly useful for understanding the impact of humans on the native taxa. Artifacts such as snares, bird catching sticks and nets are all related to bird catching, but are less useful for this purpose of identifying subsistence change. Hu et al. (in press), suggest that modified pits identified in the lowlands as possibly related to agricultural production are, in the uplands of Mauna Loa, related to the procurement of birds. If these features are related to bird catching they could possibly represent another "artifact" for understanding the impact of humans on avifauna.

In this paper we test the hypothesis put forth by Hu et al. (in press) with pit features identified at Pōhakuloa on the Island of Hawai'i (Figure 1). We suggest that if the upland pits were being used to exploit birds as a resource, then the impact of humans should be patterned and identifiable in the archaeological record. We go further to question whether it is possible to identify, archaeologically, the remnants of a kind of intensification of bird catching over time. Is it possible that the upland pits represent a means to intensify seabird capture as a response to their decline? Applying the patch choice model from Optimal Foraging Theory, we consider whether a technological adaptation that may have improved the ability of hunters to cull avifauna existed in the past.

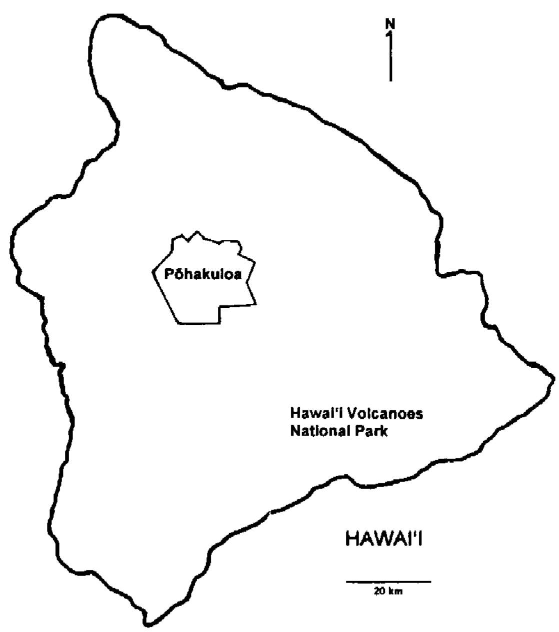

Figure 1. Map of Hawai'i showing the location of upland excavated pit sites at Pōhakuloa.

PREHISTORIC PITS

Hawaiian farmers knew their plants well. They understood the growing conditions needed for hundreds of taro and sweet potato varieties (Kirch 1985:216). Taro, for example, was a good crop for the wet windward sides of the Islands. Most of the leeward sides of the Islands were less suitable for irrigated crops because surface water run off was limited to streams. However, Hawaiians intensively cultivated even these arid areas. After it was introduced to Hawai'i, the sweet potato became the dominant food crop in the dry leeward field systems.

The sweet potato can withstand much drier conditions than taro and farmers can easily propagate new plants from tubers or cuttings.

Archaeologists still find remnants of dryland field cultivation across the Islands. Many of the sites are composed of stone mounds or long walls that run in a grid-like pattern across the landscape. The walls served both as boundary markers (those which ran perpendicular to the slope) as well as soil and water retainers (those which ran parallel to the slope) (Kirch 1985:228).

Archaeologists also find other more amorphous features used primarily for planting sweet potatoes in the coastal regions. These features consist of excavated pits or holes where humans broke into the flat *pāhoehoe* lava flow and removed the boulders and cobbles (Figure 2). Removal of the rocks from the surface exposed the spaces between the surface and the underlying flow. The excavators either tossed the rocks out of the pit in a haphazard fashion, or stacked them along one or more of the edges. The rocks which are removed from the pit are much less weathered than the surrounding untouched lava. Hawaiians called sweet-potato patches in stony places *makaili* (Handy and Handy 1972:129).

Figure 2. Excavated pit feature from Pōhakuloa. (Photo by J. Moniz Nakamura)

Lowland Makaili

The first reference for these features is found in the historic literature. In 1846, Chester A. Lyman visited Kamoamoa in the Puna district, and took note of the features Hawaiians grew sweet potatoes in:

> We passed a potato patch in the broken lava which exceeded anything I had seen. Not a particle of soil was anywhere to be seen, and the holes dug among the stones to receive the potatoes were some of them 6 feet in depth – thus securing a degree of moisture and shelter from the sun – though no more soil than at the surface (Lyman 1924:101 as cited in Ladefoged et al. 1987).

Since then, archaeologists have recorded excavated pits in several areas across Hawai'i Island. They are found in the lowlands at Ka'ūpūlehu, 'Anaeho'omalu, Waikoloa, in both lowland and upland areas in Puna (at the Hawai'i Volcanoes National Park) and in the uplands of Pōhakuloa. The pits may be more abundant on Hawai'i island than the other islands in the Hawaiian chain because of the relatively "recent" volcanic activity here. On the older islands like O'ahu and Kauai weathering and soil development is extensive. The surface of Hawai'i island, however, is more "youthful" and thus many areas of the island are composed of bare lava surface with little to no vegetation (Macdonald et al. 1970:181). Thus, the development and occurrence of pit features, for whatever use, would be expected to be greater on the island of Hawai'i.

William Barrera first identified these features in 1971 at 'Anaeho'omalu. After looking at some of the features there, a geologist confirmed that the pits were not naturally formed but were anthropogenic in origin (Barrera 1971:60). Barrera initially believed that the features he found at 'Anaeho'omalu were functionally equivalent to those Chester Lyman described in 1846. The holes (or pit) protected sweet potato plants from the sun and helped to retain moisture. Barrera later questioned his interpretation after talking to Dr. Douglas Yen, a Bishop Museum ethnobotanist. Yen believed that if this had been the function of the pits some vegetal material would be preserved, yet none was found (Barrera 1971:60). Yen did not, however, dismiss the idea that the pits had some agricultural function and Barrera recommended further work be done on the issue (Barrera 1971:60).

In 1972 Moore and Bavacqua identified approximately 230 pits in Waikoloa. In light of Dr. Yen's questions they proposed that the pits served two functions, neither of which was agricultural. They concluded that the "upper *pāhoehoe* layer was used for abraders and the lower *pāhoehoe* was used for construction material" (for the construction of shelters and the curbstone Kiholo-Puako Trail) (Moore and Bevaqua 1972:18-20).

More than ten years later, in 1986, archaeologists were still debating the function of these features. Laura Carter (1986) identified over 2,100 pits in the *pāhoehoe* flows at Ka'ūpūlehu. Like Moore and Bavacqua (1972), she thought the pits had multiple uses. Carter (1986:17-21) believed they functioned as abrader quarries and sweet potato planters. Although she did not find any abrader grinding surfaces or soil in or around the pit surfaces, she argued that "the possibility still exists that they are agricultural features or abrader quarry locations" (Carter 1986:21). Carter (1986:21) also suggested a possible relationship between the pits and shelter caves but did not explore the topic further.

In 1987 Ladefoged et al. (1987) identified over 2,630 pit features on *'a'ā* lava flows in the Hawai'i Volcanoes National Park. Citing previous research in other areas as well as the ethnohistoric evidence, Ladefoged et al. (1987) concluded that the pits were indeed used for planting sweet potatoes. The fact that the National Park features are located in *'a'ā* flows as opposed to the *pāhoehoe* in other areas on the Island is, according to the authors, "a reflection of local environmental conditions" (Ladefoged et al. 1987:68).

Archaeological and ethnohistoric evidence indicate that Hawaiians planted sweet potatoes in excavated pits well into the historic period. In Ka'ūpūlehu some of the cleared rocks excavated from the pits were found lying on a 1801 lava flow (Ladefoged et al. 1987). Hillebrand wrote in the 1880s that "the natives of Puna, Hawaii raise good crops of sweet-potatoes in the hollows and cracks of bare lava by simply covering the budding sprigs with decayed leaves and herbs" (cited in Ladefoged et al. 1987).

Upland Makaili?

In the Pōhakuloa flats and on the slopes of Mauna Loa, within the Hawai'i Volcanoes National Park, researchers recently identified numerous excavated pit features in the *pāhoehoe* flows (Glidden et al 1997 unpub. ms.; Moniz Nakamura 1998 unpub. ms.; Hu et al. 1998). These Pōhakuloa and Mauna Loa pits were located at elevations of 1,280 - 2,700 m (4,200 - 8880 ft) and 2,743 m (9,000 ft) respectively (see Figure 1).

The distribution of these features in such remote, upland locations was unexpected. There is some question as to the use of the pits in these upland sites. Were the upland sites used for the same purpose as the coastal *makaili*? Both Pōhakuloa and the slopes of Mauna Loa are marginal island locations for farming. Both areas are arid (between 10.2-40.6 cm of rain per year at Pōhakuloa) and the temperature gradients in a day can vary widely (average of 15.6 degrees C). These extreme conditions make the hypothesis of agricultural use less likely.

BIRD CATCHING PITS?

Pit features at the Hawai'i Volcanoes National Park are not uncommon. As stated above, Ladefoged et al. (1987) recorded over 2,630 pits. These pits, however, were identified in the lowlands. Biologists and archaeologists working for the Hawai'i Volcanoes National Park first identified pits in the uplands elevation while surveying the area for the Dark-rumped petrel (*Pterodroma phaeopygia sandvicensis*) or *'Ua'u* (Glidden et al unpub. ms.; Hu et al. in press). Although once abundant on all Hawaiian islands, this seabird is now considered endangered (US Fish and Wildlife Service and Telfer 1983). Archaeological evidence, however, suggests the *'Ua'u* were once abundant on Hawai'i Island and ranged from the lowlands to the uplands (Moniz 1997; Moniz Nakamura unpub. ms.). Today, breeding locations are only found on the upper slopes of Mauna Loa (Hu et al. in press).

Mauna Loa

The active nesting of *'Ua'u* in human modified pits prompted Hu et al. to suggest that unlike the coastal sites, the upland pits may have been "modified for catching seabirds." They discounted the use of these sites as quarry features because no habitation sites were found nearby (Hu et al. in press:9). Use of the rock for abrader blanks was also discounted because the *pāhoehoe* in the area was determined to be too "large and blocky and unsuitable for manufacturing abraders" (ibid.). The use of these features for planting sweet potatoes was dismissed on several grounds. First, they state that "Hawaiian varieties of sweet potato, the most likely crop, cannot tolerate the combination of cold, aridity and lack of soil" at that elevation (ibid.). Second, they claim that the lack of soil on the Mauna Loa slopes would require a time-consuming effort for obtaining mulch and the lack of soil "severely restricts the growing potential of all plants" (ibid.).

Hu et al. (in press) support their functional interpretation with evidence of active *'Ua'u* nesting in the excavated pits. They report that of the 40 *'Ua'u* burrows recorded, 19 (47.5%) were in human modified pit features. The remaining 21 (52.5%) were found in "naturally occurring features including lava tubes, cracks in tumulus mounds and spaces created by the uplift of *pāhoehoe* slabs" (Hu et al. in press:6). Because many seabirds nest in burrows, biologists believe that the lava features provide them with habitat that could afford some protection from the cold and predators (Hu et al. in press). The ethnohistoric literature appears to support their hypothesis as Henshaw (1903:130-131) wrote that the *'Ua'u* nested "in the lava."

Humans may also have found the pits to be favorable for catching these birds. In their study, Hu et al. (in press) report that cats predated on the *'Ua'u* more frequently in the human modified pits. Thus, the opening of the pits may make the birds more accessible to both the *'Ua'u* and to its predators.

Many questions regarding the function of the upland pits are still unanswered. At Pōhakuloa, faced with a large distribution of these features across the landscape, we were left wondering whether or not it would be possible to grow sweet potatoes at higher altitudes with little to no soil? And, why would Native Hawaiians put such effort into creating these features when there are so many natural areas in the *pāhoehoe* flows where nesting sites would be available? Finally, unlike Mauna Loa, the Pōhakuloa pits are located near both habitation sites and religious features. Could Pōhakuloa shed more light on the possible function(s) of these pits? In this paper we begin to address some of these questions. The work we have begun is by no means complete, but we suggest that it serves as a model for future investigation into the issue of functional differences.

PŌHAKULOA

Pōhakuloa is located in the "saddle" region between the three primary mountains that form the Island of Hawai'i—Mauna Kea, Mauna Loa and Hualalai. In ancient times it was part of *Kaohe ahupua'a* (ancient land division). The area is quite arid and marginal in terms of rainfall, vegetation and native fauna. There are no natural surface water flows in the flats. However, water can be found dripping from the ceilings of the many lava tubes that run through the area.

In 1956 the United States Army established the Pōhakuloa Training Area (PTA) on approximately 109,000 acres. PTA serves as a training facility for US Army Pacific Command (USARPAC) and other Pacific Command (PACOM) units.

Over 900 years ago Pōhakuloa was used for other purposes. Prehistoric trail systems through the area indicate Pōhakuloa lay along the route of several cross-island paths. Travelers and hunters used many of the tube systems for shelter and water. Artifacts and midden found in the caves, and testimony given by natives to the Land Boundary Commission who were living in adjacent *ahupua'a* strongly suggest the area was also used by bird catchers hunting *'Ua'u* and other seabirds and forest birds for their meat and feathers (Athens et al. 1991; Moniz Nakamura unpubl. ms.). In one of the few direct references to *Kaohe*, Lyons, stated "Kaohe, whose owners belonged the sole privilege of capturing the *'u'au,* a mountain-inhabiting but sea-fishing bird" (Lyons 1875:111).

Some of the earliest radiocarbon dates indicate that use of the area began some time around the turn of the millenium circa

A.D. 1000 (PTA unpublished data). A peak in activity occurred around A.D. 1400, although consistent use continued through the nineteenth century (Streck 1992).

TECHNOLOGICAL ADAPTATION

A 1997 survey of 1,500 acres in the eastern training lands at Pōhakuloa conducted by OGDEN Environmental and Energy Services, through a contract with the US Army Corps of Engineers Honolulu Division, resulted in the discovery of nearly 1,000 excavated pits (Williams in prep). The pits are found primarily on a single *pāhoehoe* flow type (Figure 3). Geographers classified this flow as a Holocene lava flow of the Ka'u Basalt type. This particular flow, designated as k1o, originated from the southwest rift zone of Mauna Loa formed between 5000 and 10,000 years before present. The Ka'u basalt flows are generally brown, orange brown and red brown in color. The original surfaces of the flows are deeply weathered (Wolf and Morris 1997).

To understand this issue from a theoretical perspective we applied the patch choice model from Optimal Foraging Theories to the Pōhakuloa data set. The model predicts that as humans continue to hunt (forage) in a particular area (patch) the

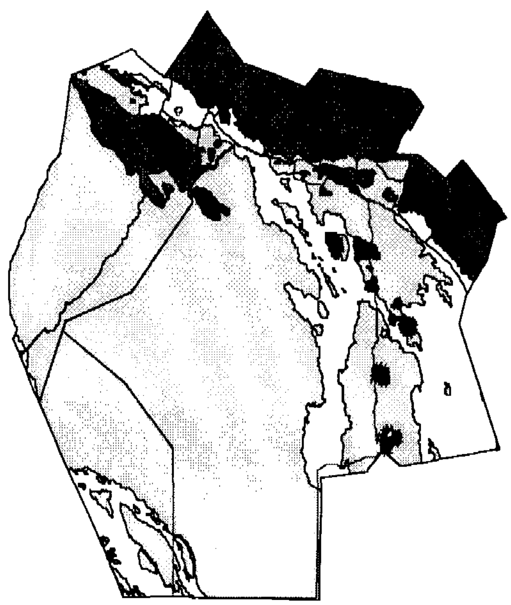

Figure 3. Distribution of Excavated Pits and Associated Habitation Sites and Activity Areas On the Pōhakuloa Training Area.

number and kinds of taxa (energy) in the patch declines. When this point is reached, the model states that the hunter is faced with the following choices: 1) move on to a more distant and profitable patch; or 2) modify his/her procurement strategy. The uplands of Mauna Loa and Pōhakuloa are two of the most marginal and distant areas on the Island of Hawai'i. It may be that it is in these most distant patches that technological change becomes an outcome because the hunter has few other patches to go to.

In most cases, technological adaptations generally involve the improvement of culling ability. For example, foragers may adopt the use of snares, traps, projectile points or bows and arrows. However, there are also technological changes that involve habitat alteration. Habitat alteration would improve on the taxa's ability to reproduce, expand nesting habitat, or make the taxa more predictable for foragers. The development of pens and herding of cattle is one example. Other examples in the Pacific include the creation of fishponds. Fish are, in a sense, "herded" into a relatively enclosed area where they remain captive to breed, reproduce and grow. Once a sufficient size, individuals within the stock are harvested.

Creating artificial habitat is likened to the development of agricultural crops. Although the initial input of energy to create the field, or pen or fishpond is relatively large, these techniques eventually decrease search costs as resources become more "predictable" and they are used again and again. We would suggest that this type of change in technology occurred in the uplands on Hawai'i Island with the creation of nesting "pits," aimed, in particular, at enhancing seabird habitat.

The goal of our study was to test the hypothesis that hunters were exploiting known nesting sites in natural features (as suggested by Hu et al. in press). If hunters were creating pits while exploiting known nesting sites they would be looking for natural cleavages in the *pāhoehoe* surface where the birds would be nesting. The opening in the flow would thus have to be large enough for the birds to get in and out. In the process of exploiting these natural habitats, the hunter would break into the lava surface and peel back the adjacent rock to expose the nest site. Theoretically, it would be "easier" to gather the birds if the hole were bigger. Using the patch choice model, patterns in pit construction would indicate changes in procurement strategies for petrels.

FIELD TESTING

Between the summer of 1997 and the spring of 1998 we conducted two field projects at Pōhakuloa. The first project was to test whether or not sweet potato would grow at this high altitude. The second project was a systematic survey of seven acres to identify and classify the excavated pits. The goal of the second project was to identify any pattern in pit construction which may inform on its functional use.

Sweet Potato

To answer our first question, would it be possible to grow sweet potatoes at high altitudes on Hawai'i Island, we carried out a trial test. Five pits were randomly selected to plant both sweet potato cuttings and rooted plants. A single cutting and rooted plant was placed in each pit on August 4, 1997. Unlike the Mauna Loa pits, many of the Pōhakuloa pits have some soil in them. We mounded the soil around the plants and gathered mulch from the surrounding vegetation. Although vegetation is sparse in the area we collected enough mulch to cover the surface of the mound. We then constructed wire "cages" to keep the goats and sheep from eating the shoots and leaves.

For the first week we gave each plant 1 cup of water every day. From the second week until the September 30 we gave each plant 1 cup of water once a week. From the beginning of October until the end of December 1997 we watered the plants in pits 1, 3 and 4 once every two weeks while the plants in pits 2 and 5 got no water.

Plant growth was measured by counting the number of leaves on each visit to the site. Figures 4 and 5 indicate the growth of the sweet potatoes over time. The dashed lines represent the point at which the plant was no longer watered. As these figures indicate, the rooted plants grew much better than the cuttings (more leaf growth). All of the test plots were doing fairly well until the end of November when they began to die. The plants probably failed because of the onset of winter.

Although the sweet potato plants eventually died, our tests indicate that with very little human intervention it is possible for sweet potato to grow at this altitude. Whether or not the plants would have produced tubers is still questionable. We suggest that sweet potato be planted during the warmer Spring season and a full year of testing occur before we can accept or reject the hypothesis that the pits were not multi-functional—used for planting as well as bird habitat.

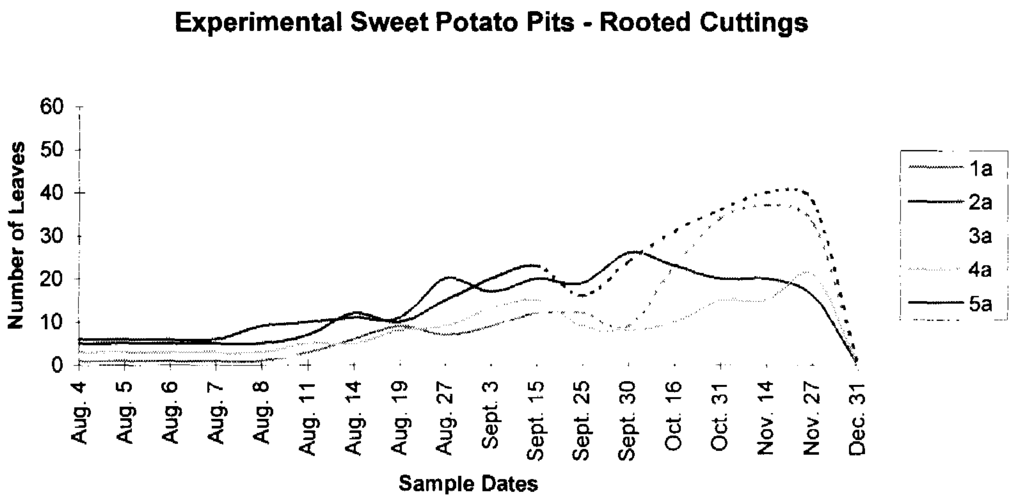

Figure 4. Growth pattern of Sweet Potato plant rooted cuttings.

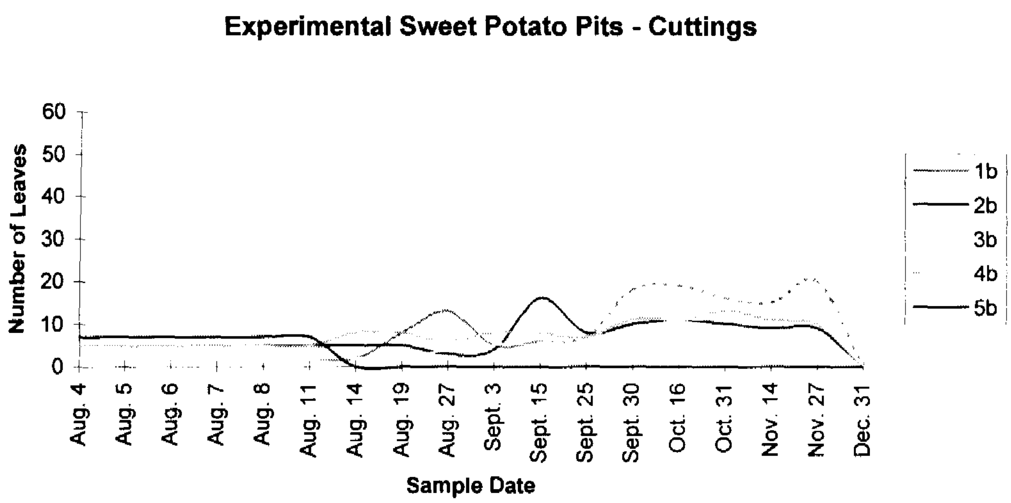

Figure 5. Growth pattern of Sweet Potato plant cuttings.

Excavated Pit Survey

To answer our second question, why would Native Hawaiians create pit features when there are so many natural areas in the *pāhoehoe* flows where nesting sites would be available, we systematically surveyed seven acres of the k lo flow. During our survey we identified and classified a total of 164 pits. The pits at both upland locations appear to be similar to the coastal features and Mauna Loa features (Figures 2 and 6). Although individual pits may vary in terms of size and placement of excavated rocks, the overall construction is the same.

At Pōhakuloa, the flat *pāhoehoe* surface is broken using what would be expected to be a very strong stick or hammerstone (Figure 7). Scar fractures are still evident on the edge of pits and on the excavated rocks. The broken surface rocks are taken out of the hole and either stacked neatly around one or several sides of the pit or at times strewn haphazardly both inside and outside of the pit.

The features that we classified during our survey relate to the construction of the pits. These features included descriptions of size as well as interior and exterior modifications. The features include number, location, and size of the pits, presence or absence of an overhang, aspect, flow surface, and location of excavated rock.

The results of the survey suggest that the pits may be multifunctional. They may not only represent an end-point of a procurement effort as Hu et al. suggest, but they also likely served to enhance the nesting sites as a kind of artificial habitat.

Number and Size of Pits

Each pit was classified in the field as either a single feature or a complex of features. A set of pits was classified as a "complex" when they were less than a meter apart, or if the pit boundaries overlapped (ie. one pit expanded or built into another). We took a geographic position using a Trimble Geoexplorer II GPS for each pit or complex of pits. Of the 164 pits, 129 are single features, nine are complex features composed of two pits each (18 features total), and four are complex features composed of three pits each (12 features total). Thus, over seven acres there is an average of 23.4 pits per acre. Assuming the average frequency of pits remains constant, if we extrapolate our results across the approxi-

Figure 6. Excavated pit feature from Hawai'i Volcanoes National Park. (Photo by K. Sherry)

mately 3,904 acres of k1o lava flow which lie in the boundaries of the Pōhakuloa Training Area, we could expect to find 91,353.6 pits. This number may be greatly exaggerated, however, as the frequency of pits may depend on the presence of habitation sites or nearness to frequently used trail systems. It is also likely that the pits are not limited only to the k1o flow. Future research should focus on addressing questions of distribution.

Calculations on the average amount of rock excavated from these pits indicate that of the 164 pits in the 7 acre survey area, humans removed approximately 42 cubic meters of rock. The amount of labor expended on the creation of these pits is incredible. Considering labor alone, a multi-use hypothesis may be more reasonable.

Figure 7. Possible hammerstone used to create pit features. (Photo by J. Moniz Nakamura)

Overhang

A second feature we recorded was the presence or absence of an overhang. The overhang refers to the space beneath the flow surface that is created by uplift of the *pāhoehoe* as the molten lava flows through the area. If there was no overhang we recorded it as "none" on our data sheet. If there was an overhang we recorded its aspect. Of the 164 pits we identified, we recorded the presence or absence of an overhang for 139 features. Eighty-six of the pits had no overhang, while 53 did. Because a majority (62%) of the pits did not have an overhang, we suggest nesting seabirds were not difficult to catch because they could not escape from the hunter under the lava flow surface.

Aspect

For 88 pits we recorded the aspect, or direction the overhang was facing. No significant pattern was found. Twenty-seven (38%) of the overhangs faced north, 14 (16%) faced east, 17 (19%) faced south, and 30 (34%) faced west. If Hawaiians used the upland pits to plant sweet potatoes, we would expect a significant percentage of the pits to have an aspect that provided favorable shade and moisture. However, it appears that aspect is likely a reflection of natural flow formation.

Flow Surface

Of the 164 pits identified, we classified 136 according to the breaks in the flow surface. If the pits were constructed in cracks in tumulus mounds or spaces created by the uplift of *pāhoehoe* slabs we classified them as "natural cleavage" features. If, however, the pits were formed on the flat *pāhoehoe* and no surface fissures were visible we classified them as "modified surface" features. If hunters were solely exploiting known nesting habitat and in the process, enlarging the nesting site (thus forming a pit), we would expect a higher percentage of pits to be classified as "natural cleavage" features. The results showed that only 26 (19%) pits were formed from flow surfaces that were associated with natural cleavages. A majority of the pits (110 or 81%) were formed on the flat *pāhoehoe* surfaces that have no natural cleavage. Thus, our results appear to indicate that natural cleavages are not the favored location to find excavated pits. This finding supports the hypothesis that the pits were perhaps intentionally built to enhance nesting habitat, thus making the seabirds more predictable for procuring.

Location of Excavated Rocks

We recorded two features related to the excavated rocks: location and placement. Of the 164 pits we identified, we recorded the location of the excavated rocks for 108 of them. Seventy-seven (72%) of the excavated rocks were found outside of the pits. Twenty-eight (26%) were both inside and outside of the pits and only two (2%) of the pits had rocks that were placed back into the pit. As expected, the majority of the excavated rocks were removed from the cavity of the pit thus allowing for the utilization of the pit interior.

Of the pits with rocks removed from the pit cavity, 94 percent of the excavated rocks were stacked along either one or more edges of the pit. The excavated rocks were stacked as low as one course to as much as four courses high. The stacking of the rocks appears to suggest they were systematically removed.

Habitation and Activity Areas

Unlike the Mauna Loa location, habitation caves and activity areas are found in and around the pits at Pōhakuloa (Figure 3). The habitation caves contain evidence of butchered *'Ua'u* bones, likely gathered just outside the cave entrance. In addition, two volcanic glass and basalt lithic scatters suggest multiple use of the area. Five cairns, or stacked rock piles are found around the perimeter of the habitation caves. Cairns are often found along trails or near cave systems at Pōhakuloa. They were likely used as site or trail markers. Their presence around the caves suggest there was repeated use of the area and in turn repeated use of the excavated pits.

It is not unreasonable to expect habitation sites to be near petrel nesting sites. Seabirds are known to be loud and appear to be undisturbed by human presence. Biologists often camp next to their nesting sites on Mauna Loa as they study the birds (Hu personal communication). On Laysan, seabirds are known to burrow under the tents of the scientists camping there (L. Laniawe, personal communication).

Conclusion

The evidence from this survey suggests the upland pits were used for more than one purpose: bird catchers were breaking into known burrows to catch nesting birds and were also expanding habitat for suitable nesting sites—a form of intensification. Use of the pits for planting sweet potato is still possible, although less likely. Use of the pits, however, for birds as artificial habitat is plausible. We propose the following hypothesis for the petrels and shearwaters found on Hawai'i Island: after the introduction of predators (including humans), petrel and shearwater colonies declined in the lowlands. Subsequently, these taxa were restricted to the uplands. As overall population numbers of seabirds decreased and demand by humans for food increased, a technological solution may have been reached to compensate for a decline in species abundance.

The behavior and breeding ecology of seabirds supports the multi-functional hypothesis we propose. Seabirds are a large and predictable resource for humans because they breed in large colonies during the spring and summer seasons (Harrison 1990:68; Moniz 1997). While on land, seabirds nest on the ground or in burrows. The result is a large population of birds in a relatively small fixed area. Thus, seabirds are vulnerable to attack by predators, especially humans. Hunters learn the seasonal patterns of the birds, and thus know when the adults return to the islands to nest and when the young fledglings will leave the nest. Because seabirds nest on the ground they are also more accessible to predators. Today, the *'Ua'u* is known to nest "in deep burrows or cavities beneath rocks" (Harrison 1990:72). It is probable, however, that this characteristic is a reflection of increased predation pressure on the taxa, especially by cats. In the past when there were no cats, this taxa may not have burrowed so deeply in the rock cavities. Thus, it is plausible that the pits could have served as artificial habitat.

Another characteristic that makes seabirds vulnerable in the presence of humans and also a high ranking food item for hunters is high site fidelity—the tendency to nest in familiar physical surroundings (Harrison 1990; Moniz 1997). Adult birds will breed in, or very near to, their old nesting sites year after year. When they are of mating age, offspring will also return to their hatch site to breed. Taxa nesting in large numbers, in a prescribed area that can consistently be found from season to season, would be highly vulnerable to predation. We suggest that the creation of artificial habitat would not only make the birds more accessible to the hunters, but by expanding habitat it would help sustain large numbers of the population from year to year, until such time when demand outweighed the supply.

If we view the ethnographic accounts as a reflection of the late prehistoric-early protohistoric period, a time when Pōhakuloa was still being used, we can begin to understand the process of resource intensification. The ethnographic evidence suggests that the young *'Ua'u* were highly prized, and were "tabooed for the exclusive use of the chiefs" (Henshaw 1920:120). Preference towards young birds is likely due, in part, to their high fat content. Athens et al. (1991:80), referring to the recovery of few juvenile bones in their assemblages from Pōhakuloa, suggest that perhaps the young birds were transported to the coast, while the adult birds were consumed in the nearby habitation caves. We suggest that much of the bird bone found in the caves are not adults, and are, in fact, young fledglings.

A brief examination of the bones from a fledgling which died at Hawai'i Volcanoes National Park indicates that the bone structure is very similar to that of an adult in both size and density. One of the key visual characteristics in identifying juvenile bones from adult is their porous bone structure. The bones of the fledgling appeared to be the same as those found in the archaeological assemblages. Physiologically, this would make sense, as the fledgling period is described as "the interval between hatching and flight" (Skutch 1976), and thus the skeletal structure of the bird would likely resemble very closely that of an adult. Visually, however, the birds may still be distinguishable from the adults by the persistence of down. These observations are supported by Munro (1960:26) who stated that "the young chicks were taken when almost completely grown, but they still had down."

If a primary activity at Pōhakuloa was to hunt the young birds, a favored food, the adults would presumably be avoided, in part because their "flavor was so strong" (Munro 1944:26). Thus, the adults would be able to return to the nesting site the following season to lay another egg.

The construction of the Pōhakuloa pits is datable. Our survey showed that while creating pits on the k1o flow, hunters chipped into a nearby later flow. This later flow (k4) dates to 200 to 750 B. P. indicating that hunters created the Pōhakuloa pits some time between A. D. 1200 and 1750. The construction of the pits would place the technological change in procurement strategy to the late prehistoric period when species numbers were likely declining in the lowlands and people were moving into the Pōhakuloa region (Streck 1992; Moniz 1997).

Because seabirds return to the same place year after year to breed in large numbers on a seasonal basis, they were a favored food source for Hawaiians during the pre-contact period (Moniz 1997). If their "natural" nesting habitat is enhanced, the birds would have more areas in which to nest. If a bird catcher "creates" or "expands" the seabird habitat, the birds become an even more predictable resource. This would be advantageous in a marginal area. If travelers are moving through the area to access the adze quarry on Mauna Kea on one of the cross-island trails, or if hunters were using the saddle region as a base to collect birds and sandalwood, knowing where your "crop" is would save both time and energy.

While creating habitat would require a large expenditure of energy in the initial phase, once the bird catchers established the nesting sites they would only have to return to the artificial "patch" to gather the prey. By establishing a known patch, the taxa would be more predictable for the forager. Due to the color of the k1o flow in the Pōhakuloa flats, it is easily identifiable from the adjacent flows. Thus, once in the area, hunters would probably not have difficulty in finding the patch and subsequently the pits within them.

Creation of these pits may be a direct response to the decline in taxa abundance, specifically seabird taxa. Construction of pit features in upland areas improved species habitat and availability, thus enhancing the subsistence regime of Native Hawaiians.

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Correction

In our last issue of Rapa Nui Journal (Vol. 12, No. 3) for September, the item about the first human settlement dates in Fiji was stated to be 3,000 B.C. That should have read "B.P." The Lapita peoples did not arrive in Remote Oceania until about 3500-3200 years ago (B.P.) We regret the error, and thank Dr Steven Fischer for his sharp eye!