Appendix H

Survey of Terrestrial Invertebrate Resources at Kaloko Makai

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November 2008

Survey of Terrestrial Invertebrate Resources at Kaloko Makai, Kaloko and Kohanaiki, North Kona, Hawai'i Island

DRAFT

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SCD Kaloko Makai, LLC

November 15, 2008

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SUMMARY

The Kaloko Makai project site sampled in this biological survey yielded native and adventive arthropods. No invertebrate currently listed as endangered or threatened under either federal or state statutes was located within the survey area.

INTRODUCTION

This report summarizes the findings of an invertebrate[1] survey conducted in support of an environmental impact statement as part of a proposal to construct residential units, areas for retail and commercial use, and supporting infrastructure in North Kona, Hawai'i. SCD Kaloko Makai, LLC, proposes to build on 1,142 acres / 462.2 hectares (h.) of land, within portions of Tax Map Keys: (3) 7-3-009: 017, 025, 026, and 028. This survey was conducted by Steven L. Montgomery, Ph. D., for SCD Kaloko Makai, LLC, as part of a team effort directed by Wilson Okamoto Corporation and Stanford Carr Development, LLC

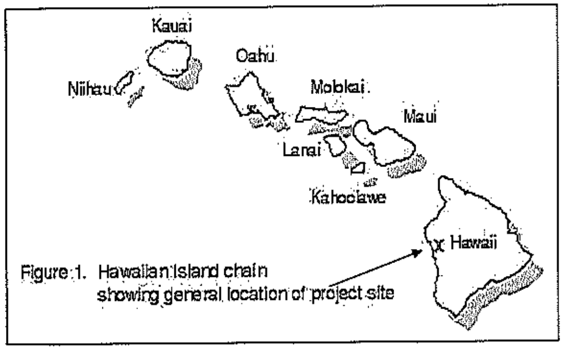


Figure 1. Hawaiian Island chain showing general location of project site

Invertebrates are often the dominant fauna in natural Hawaiian environments. The primary emphasis of this survey was on terrestrial arthropods, particularly those that are endemic or indigenous species, especially those having legal status under either, or both federal and state endangered - threatened species statutes (DLNR 1996, 1997, USFWS 2005a, 2007, 2008).

[1] Animals without backbones: insects, shrimp, snails, spiders, etc.

Native Hawaiian plant, vertebrate, and invertebrate populations are interdependent. Certain insects are obligatorily attached to host plants and use only that plant as their food. The health of native Hawaiian invertebrate populations depends on habitat quality and absence or low levels of continental predators. Sufficient food sources, host plant availability, and the absence or low levels of introduced, continental predators and parasites comprise a classic native, healthy ecosystem. Consequently, where appropriate in the survey discussion, host plants and some introduced arthropods are also noted.

GENERAL SITE DESCRIPTION

The project area is on the leeward coast of the Island of Hawai'i (Figure 1) in the Kaloko and Kohanaiki ahupua'a, North Kona district. The property is approximately one mile mauka of the coastline, between 100 +/- feet (ft.) above sea level (ASL) / 30.5 meters (m.) at the western end to 740 ft. ASL / 213.4 m. at the eastern end. It is bounded by Queen Kaahumanu Highway to the northwest. The makai portion of the property is framed by Kaloko Light Industrial Park, Kohanaiki Industrial Park, and Queen Kaahumanu Highway. The largest part of the property is bisected by Hina Lani Street. (Figure 4).

Figure 2. Typical area of koa haole (*Leucaena leucocephala*) and fountain grass (*Pennisetum setaceum*)

Geologically, the site is mostly pāhoehoe and ʻaʻā lavas with lava tubes present throughout the area. Much of the surface is uneven and irregular. The site incorporates several vegetation communities, from a nearly intact lowland dry forest to scrub dominated by koa haole (*Leucaena leucocephala*) or by Christmas berry (*Schinus terebinthifolius*) (Figure 2). Biologically the most interesting area is the "open to closed native forest occurring on the relatively recent lava flow comprising most of the central portion of the southern half of the study area" (Figure 3) (Whistler 2006). The area was recognized as Management Unit 10 in the US Fish & Wildlife Service's *Recovery Plan for the Big Island Plant Cluster* (1998). This dry forest area has supported several native Hawaiian plants of interest as hosts or shelter for native invertebrates.

Figure 3. Typical native dry forest area on ʻaʻā lava flow.

The larger site has been through a variety of changes as first Polynesians then Europeans adapted the area to their own needs. Early Hawaiian cultivation of crops, water collection in lava tubes, and establishment of housing began the process of change. Historic grazing of domesticated and feral animals, and more recent bulldozing (Bell et al. 2008a, b, c; Esh 2008) all combined to replace large portions of the native vegetation - and native invertebrate population - with a succession of introduced plants and animals (Whistler 2006; David 2006). The bird and mammal survey found evidence of 20^{th} century host plant damaging goats, sheep, and pigs in the area (David 2006).

There are no natural year-round surface sources of fresh water that would support specialized invertebrates. Some of the lava tubes were used into the historic period for collection of dripping fresh water (Bell et al. 2008a, b, c; Esh 2008).

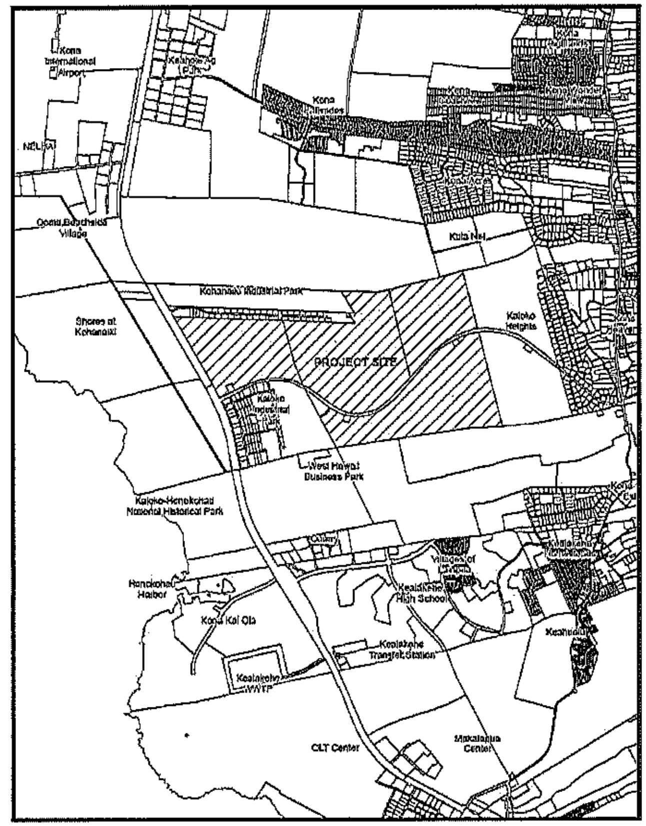


Figure 4. Map showing North Kona, Hawaiʻi, location of project site [hatched box].

[from Wilson Okamoto 2007, Figure 1-4]

INVERTEBRATE SURVEY METHODS

Since 1970, I have taken part in field projects at other locations in the Kailua-Kona area and in other dryland locations throughout the island chain. Surveys of other dryland areas have created a sizeable body of information on native invertebrate and related botanical resources found in areas similar to Kaloko Makai (Bridwell 1920, Swezey 1935). Those experiences and the results of those surveys provided the basis for my study design and my analysis of results.

Previous Surveys and Literature Search

Botanical surveys of the project area have been conducted since at least 1983 (Nagata 1983). A previous Environmental Impact Statement associated with this site (Kimura 1996) was reviewed. Recent avian, mammalian (David 2006), and botanical surveys (Whistler 2006) also were very helpful in preparing for this study. None of the previous studies referenced terrestrial invertebrate surveys or surveys of lava tubes for cave-adapted invertebrate species.

Recent archaeological studies (Bell et al. 2008a, b, c; Esh et al. 2008) showed evidence of extensive lava tubes in the project area, but no mention of cave-adapted invertebrate species.

Searches were made in the Bishop Museum Library, University of Hawai'i Hamilton Library, and State's Office of Environmental Quality Control web site (2008). Surveys done for other projects in the general area were reviewed (Char 1986, 1990, Geometrician 2003; Heiber et al. 1986, 1991a, 1991b; PBR 1991, 2007, 2008; Towill 1976, 1988; Wilson Okamoto 2000). Only the planning for Kula Nei, a nearby mauka project, included a survey of lava tube invertebrates (Howarth 2006, SWCA 2006-7).

A search was made for independent studies of invertebrates associated with this site or with nearby sites. Online proprietary data bases of such as AGRIS, Biological Abstracts, Ingenta Connect, and Zoological Record also were searched. Searches were made for publicly available articles mounted on the web (Goggle Scholar) and in regional and national databases which provide geographic access, such as the Pacific Basin Information Node and Hawaii Natural Heritage Program. Data base searches were made in Bishop Museum's Arthropod Checklist, and the University of Hawaii, Hamilton Library's Hawaii-Pacific Journal Index. Access to the project area was limited prior to construction of Queen Ka'ahumanu Highway. The bulldozing of a jeep road by Huehue Ranch in 1955 gave access to part of the property, but travel was mostly through the subject area to reach ocean resources (Bell et al. 2008a). The area lacked

the commercial agriculture which generated much of Hawaii's formal entomological surveys since the 1900s. The combination of these factors makes it unremarkable that this review showed no previous independent invertebrate surveys of the area.

The US Fish & Wildlife Service has demonstrated an interest in the native dry forest area of the property for many years. Since 1995 USFWS personnel have surveyed the property at least once (USFWS 1997). As a part of our literature search a Freedom of Information Act Request (FOIA) was initiated with USFWS regarding those surveys and records were obtained. Unfortunately, detailed cave by cave records were not found. The information resulting from the FOIA request is incorporated in several places in this report.

Fieldwork

Field surveys were conducted in September and October 2008. I conducted a general assessment of terrain and habitats at the start of the survey. Surveying efforts were conducted at various times of day and night, a technique which is vital for a thorough survey. Native botanical resources identified by Nagata (1983), Whistler (2006), and US Fish & Wildlife Service records (see "Previous Surveys and Literature Search" above) were an important focus of my searches, as were lava tubes located by the archaeological survey (Bell et al. 2008a, b, c; Esh et al. 2008).

Fieldwork schedule:

September 12-15, 2008	Site examination, orientation, collecting; light survey
September 28-30, 2008	
October 1-4, 2008	General collecting; light survey; lava tubes surveys
October 7, 2008	Lava tube orientation; general collecting; light survey
October 8-10, 2008	General collecting; light survey; lava tubes surveys

Daylight surveying was concentrated during the cooler early morning and late afternoon hours when temperatures are lower and invertebrates would be more active.

See Figure 7 for light surveying locations within the survey area.

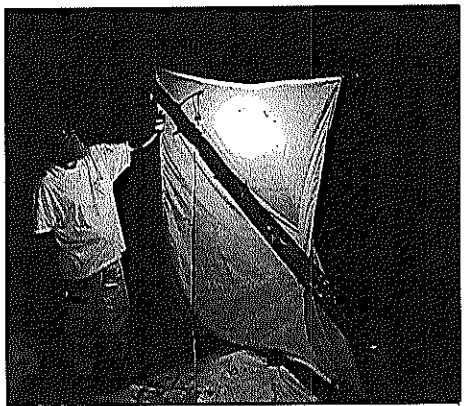
Collecting Methods

The following collecting methods for terrestrial invertebrates were used as appropriate to the terrain, botanical resources, and target species.

Baiting: Baits are used to attract insect species to specific tastes or smells. For example, some flies come to dead or dying plants with a specific odor. Baits can mimic that smell and taste and so attract those insects. Insects are enticed by the bait's 'advertisement.' Baits are placed at likely locations or inserted in bottle traps and checked periodically. Any insects at the bait are then observed and collected if appropriate. This is much more efficient than roaming the research area seeking cryptic insects. Baiting is a recognized method of censusing lava tubes for cave adapted fauna.

Lava tubes were chosen for baiting from among tubes located in my own work and in the previous archaeological surveys. In choosing lava tubes for baiting I excluded from my survey all lava tubes which archaeological surveying had shown contained human remains and those chosen for preservation. Also excluded were tubes with multiple skylights or a short dark zone. Tubes were chosen for baiting based on the size of the dark zone, presence and amount of intruding roots, and dampness which experience shows create a lava tube environment suitable for cave fauna. Traps used shrimp paste and blue cheese baits, both proven and durable attractants in other lava tube surveys. Baited traps were placed in 3 lava tubes October 10 and retrieved on October 13, 2008.

Host plant searches: Potential host plants, both native and introduced, were searched for arthropods that feed or rest on plants. Wandering transects were followed throughout the inland area with emphasis on reaching native host plants.



© Figure 5. A light census is important to understand the invertebrate fauna.

Light sampling: A survey of insects active at night is vital to a complete record of the fauna. Many insects are only active at night to evade birds, avoid desiccation

and high temperatures, or to use night food sources, such as night opening flowers. Light sampling uses a bright light source in front of a white cloth sheet (Figure 5). Night active insects seem to mistake the collecting light for the light of the moon, which they use to orient themselves. In attempting to navigate by the collecting light, confused insects are drawn toward the light and land on the cloth in confusion. This type of collecting is most successful during the dark phase of the moon or under clouds blocking starlight. Most moths and other night fliers are not capable of very distant flight. Consequently, light sampling does not call in many insects from outside the survey area.

Sampling was conducted for approximately 11 hours on each night of surveying. The light source was a mercury vapor (MV) bulb. An additional, UV light source was used at all sites. Every effort was made to diminish competing light from

Figure 6. Monitoring locations [blue light] were located away from competing light sources [background] to the extent possible.

housing, street lights and other artificial sources (Figure 6), but these were a factor in response success at some locations.

Locations were chosen based on experience, host plant proximity, and terrain. The botanical survey placed most of the native plants in the dry land forest area. As the interconnection of arthropods and host plants would predict, light sampling in that area yielded the most native arthropods. All light sample locations are marked on Figure 7.

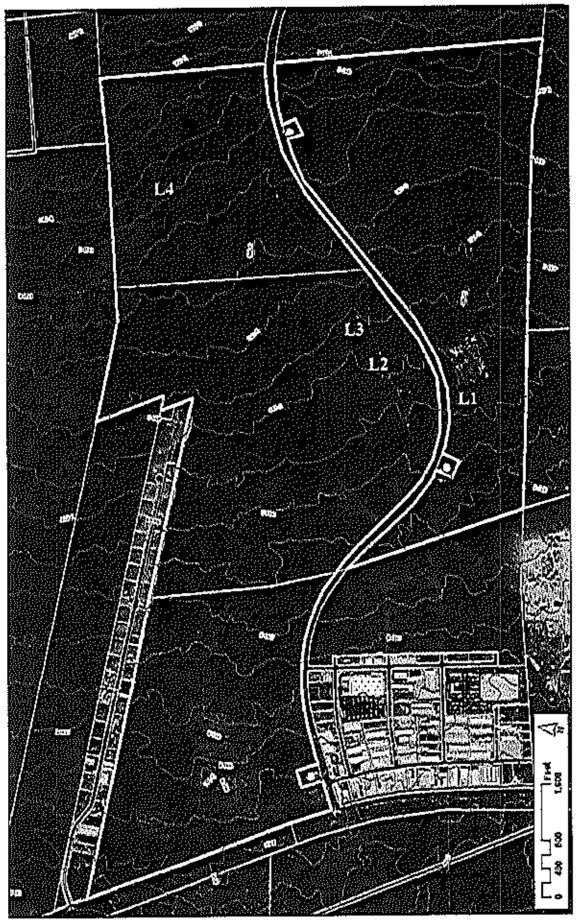


Figure 7. Map of Kaloko Makai project area showing light monitoring sites, lava tube.

L = light monitoring   = lava tube

Sweep nets: This is a most common and general method of collecting most flying and perching insects. A fine mesh net was swept across plants, leaf litter, rocks, etc. to collect any flying, perching, or crawling insects. Transfer from the net was either by aspiration, or by placing the net contents into a holding container.

Visual observation: At all times, I was vigilant for any visual evidence of arthropod presence or activity. Visual observations provide valuable evidence and are a cross check that extends the reach of sampling techniques. Visual observation also included turning over rocks, examining dead wood, and other debris.

Survey Limitations / Conditions

My ability to form advisory opinions is influenced in the following ways:

Collecting conditions:

Weather: Weather was favorable for surveying during each field day. The atmospheric vog did not appear to alter the behavior of invertebrates.

Seasons: Monitoring at a different time of the year might produce a longer or different arthropod list. Weather and seasonal vegetation play an especially important role in any survey of invertebrates. Many arthropods time their emergence and breeding to overlap or follow seasonal weather or to coincide with growth spurts of an important plant food. Host plant presence/absence, and seasonal changes, especially plant growth after heavy rains, affect the species collected.

Although there were some small rains in the weeks prior to this survey, true winter rains and vegetation revitalization had not taken place. If vegetation had developed after winter rains, a different insect list might have resulted. Nevertheless, the low level of native plants outside the dry forest zone was a stronger factor in determining the invertebrates encountered than the season or condition of vegetation.

Moon: The moon presented competition to the collecting light on the evenings of September 12-13-14, 2008. The moon rose between 4 and 5 p.m. each night[2] and set between 3 and 4 a.m. the following morning. The moon was described as "waning gibbous" with 85-90% of the Moon illuminated. (USNO) The relative lack of artificial light sources at the chosen sites compensated to a degree for the competition.

The moon did not present any competition to light collecting efforts September 28-October 2, and relatively little on October 3 and 4. At the start of fieldwork, the moon rose during daylight hours and then set before dark. At the end of fieldwork the moon was setting in the early evening 8:00-830 p.m., continuing to provide many moon-free hours for light surveying (USNO) During the short period the moon was 'up,' it presented small competition to my bright light in the largely unlit parcels under study.

Limited duration: Surveying for a longer period of time might enlarge the list of species; however, I believe the survey provides a fair review of the invertebrates present.

Selectivity: My survey was focused on finding any endemic and indigenous Hawaiian land invertebrates species. No attempt was made to collect or completely document the many common alien arthropod species present.

The exclusion of lava tubes based on cultural content and human remains did limit the choice of tubes. A thorough review of color photographs of lava tube interiors and faunal remain listings provided in the archaeological reports (Bell et al. 2008a, b, c; Esh et al. 2008) allowed a useful review of some aspects of the lava tube setting in the excluded tubes (see Lava Tube Species page 20).

RESULTS:
Incidental records:
In addition to the invertebrate results noted below, rats were present as shown by their destruction of kukui seeds (*Aleurites moluccana)*. The small Indian mongoose (*Herpestes auropunctatus*) was seen at various locations on the property.

[2] Times given are for Kailua-Kona as closest city tracked by U. S. Naval Observatory

DISCUSSION
Native species of note are discussed. Also, information is provided on adventive species often misidentified by the public, especially those confused with native species. Non-native species in conflict with native species or human beings are discussed.

INVERTEBRATE RESOURCES
ARTHROPODS
CRUSTACEA
DECAPODA (Shrimps, Lobsters, Crabs, Crayfish)
Undetermined species

Parts of three individual crabs (Figure 8) were seen in one lava tube. The examples observed in the lava tube did not appear to be part of any midden. Photographs of the specimens are under review by specialists to determine the species. Further information will be provided as it becomes available.

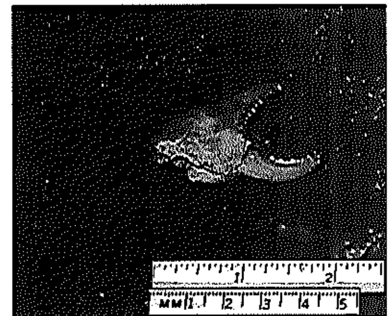


Figure 8. Crab remains seen in several tubes.

ARANEAE (spiders)
Dysderidae: *Dysdera crocota* C L Koch, 1838
This small spider (10-14 mm), known to bite humans, was seen on the floor of a lava tube.

Salticidae: Unidentified species
One immature jumping spider was noted under stones on the inland lava flow. Identification of immatures from one sample is extremely difficult. There are 9 spiders of the family Salticidae reported from Hawai'i Island, four endemics, all of the genus *Sandalodes*, and 5 adventive or introduced spiders. (HBS 2002a, Nishida 2002)

Scytodidae: *Scytodes* sp. or spitting spider

There are three adventive species known on Hawai'i Island: *S. fusca*, *S. longipes*, and *S. stlatipes*. This genus gets its common name from the hunting method of spitting strands of silk from its fangs to fasten down prey for easy dining. (Mascord 1970)

INSECTA

HETEROPTERA (True bugs)

Lygaeidae: *Nysius* sp.

This native seed bug, commonly found in dryland locations, uses many alien and native host plants. It is known from most islands in the Hawaiian chain.

LEPIDOPTERA (butterflies, moths)

Cosmopterigidae: *Hyposmocoma* sp.

Two species of *Hyposmocoma*, as caterpillars, were found in the rocky habitat (Figure 9) and three species, in adult stage (Figure 11), came to light. Considering the population is likely at a low level due to the dry weather, the diversity is noteworthy. In the wet season it could be expected that a higher number of individuals and more species would be recovered. *Hyposmocoma* are called "case bearers" because after an early beginning inside a leaf curl or similar hiding place, the caterpillars create protection in an intricately constructed portable "cave" woven of their own silk. For camouflage, they add bits of their surroundings to the case using silk: snips of dry grass or leaves, flakes of bark, a little dirt (Figure 10). The case is then easily mistaken by a predator as

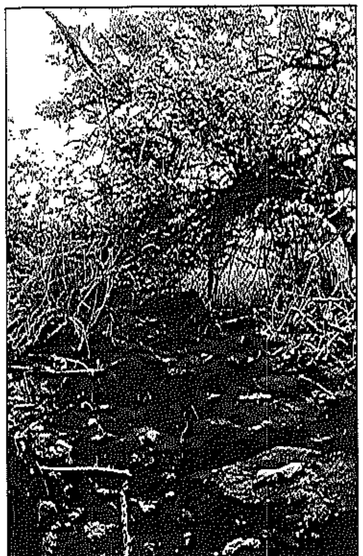


Figure 9. *Hyposmocoma* casebearers were found by lifting up slabs of broken pahoehoe.

another part of the inedible landscape. These bunkers are fitted with a hinged lid (operculum), pulled shut by tiny mandibles to defend them from enemies. Their relationship to the case is similar to that of a hermit crab to his shell. They are dependent on their case, and die if removed – even if protected from predators and given food. They don't move far, but feed while partly emerged from the case, dragging along protective armor by their six true legs. Cases are sometimes attached to rocks or tree trunks and foliage. (Manning/Montgomery in Liittschwager & Middleton 2001)

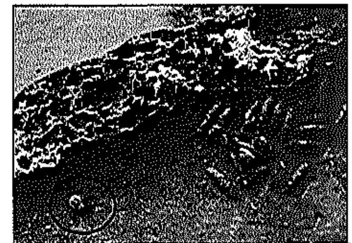
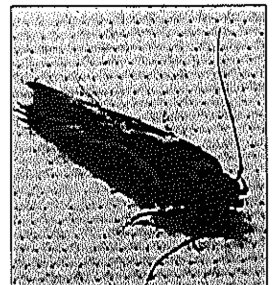


Figure 10. *Hyposmocoma* caterpillars sheltered under rocks. Far left, a pseudoscorpion shared the habitat.



© Figure 11. *Hyposmocoma* sp.
Photo# starr-030724-0089
credit: "Forest & Kim Starr" (HEAR)

With over 500 kinds, *Hyposmocoma* micromoths are the greatest assemblage of Hawaiian Island moths, showing astonishing diversity. After writing 630 pages on them, Dr. Elwood Zimmerman lamented the inadequacy of his study. He noted an enormous cluster of species with explosive speciation and diverging radiation (Zimmerman 1978). Much remains to be learned about the life ways of this interesting group of insects now under study by University of Hawaii's Dr. Daniel Rubinoff and his students (Rubinoff & Haines 2006).

Crambidae (grass moths)

Tamsica hyacinthina (Meyrick 1899)

This was the most common native species found during the survey. The caterpillars feed on a wide variety of grasses, allowing them to adapt to the changing flora at Kaloko. The genus was described by E. C. Zimmerman as "a cluster of poorly understood, obscure, difficult little species." (1958) Pioneering biologist R. C. L. Perkins noted "They are able to flourish in the driest localities near the coast...." (Perkins 1913).

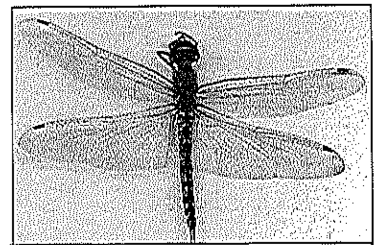
Gracillariidae:
Caloptilia mabaella (Swezey), 1910 or *Caloptilia azaleella* (Brants), 1913

Figure 12. Lama (*Diospyros sandwicensis*) or Hawaiian persimmon at Kaloko dry forest showing damage by leaf miner *Caloptilia* sp.

The young and terminal leaves of lama trees (*Diospyros sandwicensis* or Hawaiian persimmon) in the dry forest area at Kaloko Makai show distinctive feeding damage associated with leaf miner caterpillars (Figure 12). Leaf miners burrow or "mine" inside a leaf, creating scars or bumps on the leaf surface where they have eaten out the inner flesh of the leaf. The most likely adventive pest is *Caloptilia* sp. *C. mabaella*, which has been known in the Islands since 1910 (Swezey 1910, 1954), is previously recorded only from O'ahu. *Caloptilia azaleella* is known from O'ahu and Hawai'i Island, but not previously associated with *Diospyros sandwicensis*. (HBS 2002a; HOSTS 2008; Nishida 2002)

Noctuidae: *Schrankia* sp.
This small moth was previously noted in the lava tubes of Kaloko by US Fish & Wildlife Service personnel (USFWS 1997) and was found by this survey as well. The genus is very complex. As noted by Dr. F. G. Howarth (2006): "There are often 2 or 3 morphs in each cave that show different degrees of cave adaptation…"

ODONATA (Dragonflies and Damselflies)
Libellulidae: *Pantala flavescens* Globe skimmer



© Figure 13. Globe skimmers often use human created water sources

This indigenous dragonfly (Figure 13) was observed on the property. Among the most easily observed native insects, they are large, easily approached by people, and graceful in flight. Any small amount of fresh water will attract them and they often colonized human maintained water sources such as golf-course water hazards and stock tanks. Globe skimmers are widely distributed throughout the Hawaiian Islands, from Kure to Hawai'i Island (HBS 2002a, Nishida 2002) and have even been found flying at sea (Howarth & Mull 1992).

ORTHOPTERA (Praying Mantis, Grasshoppers, Crickets)
Gryllidae
Gryllodes sigillatus (Walker), 1869 Flightless field cricket
This world-wide traveler was first recorded in the Hawaiian Islands in 1895 (Zimmerman 1948). In the years since, it spread up and down the island chain.

Although superficially similar in appearance, *Gryllodes sigillatus* males can 'sing' by rubbing vestigial wings together, while the native species, *C. anahulu* (see page 25), is mute.

Table 1: List of Invertebrates:[3] Kaloko Makai, North Kona, Hawai'i

Species	Common Name	Status	Abundance	Notes
ARTHROPODA				
ARACHNIDA				
ARANEAE	spiders			
Dysderidae				
Dysdera crocota C L Koch, 1838		Adv	U	in lava tube
Heteropodidae				
Heteropoda venatoria	large brown spider cane spider	Adv	U	leaf litter
Salticidae	jumping spider			
unidentified immature		?	U	under stones
Scytodidae				
Scytodes sp.	spitting spider	Adv		in lava tube
PSEUDOSCROPIONIDA	pseudoscropions			
unidentified species 1		?		sheltering with casebearers
SCORPIONES	scorpions			
Buthidae				
Isometrus maculatus (De Geer)	lesser brown scorpion	Adv	U	in lava tube
CRUSTACEA				
DECAPODA	Shrimps, Lobsters, Crabs, Crayfish			
Coenobitidae:	Crab			
Coenobita sp.				
INSECTA				
BLATTODEA				
Blattidae	cockroaches			
Periplaneta americana(Linnaeus), 1758:	American cockroach	Adv	C	in lava tubes
COLLEMBOLA	springtails			
Entomobryidae				
undetermined sp. 1		?	R	under stones
HETEROPTERA	true bugs			
Lygaeidae	seed bugs			
Nysius sp.		End	O	at light
HOMOPTERA	planthoppers			
Cixiidae				
Oliarus sp.		End	R	*Reynoldsia* bark

[3] Names authority: Hawaii Biological Survey 2002a; Nishida 2002; Zimmerman 1948-80; Zimmerman 2001

Table 1: continued

Species	Common name	Status	Abundance	Notes
HYMENOPTERA	wasps, bees, ants			
Apidae				
Ceratina smaragdula (Fabricius)	small carpenter bee	Adv	U	at *Sophora*
Formicidae	ants			
Camponotus variegatus	carpenter ant	Adv	C	to light
Pheidole megacephala (Fabricius, 1793)	big-headed ant	Adv	C	on soil
Anoplolepis gracilipes (F. Smith, 1857)	longlegged ant	Adv	C	on soil
Vespidae	wasps			
Polistes exclamans Viereck, 1906	common paper wasp	Adv	C	at flowers
LEPIDOPTERA				
Cosmopterigidae	case bearers			
Hyposmocoma sp. 1	slender wedge case	End	R	under stones
Hyposmocoma sp. 2	broad case	End	U	under stones
Hyposmocoma sp. 3	black, pointed adult	End	A	at light
Crambidae (Pyralidae)	micro-moths			
Mestolobes sp.		End		at light
Orthomecyna sp.		End		at light
Tamsica hyacinthina (Meyrick 1899)		End	A	at light
Noctuidae				
Schrankia		End	O	in lava tube
Olethreutidae				
Cydia latifemoris (Walsingham, 1907)		End	O	reared from *Sophora* seeds
Plutellidae				
Plutella noholio Robinson & Sattler, 2001		End	R	at light
Plutella xylostella (Linnaeus, 1758)		Adv	C	at light
Xyloryctidae				
Thyrocopa abusa Walsingham, 1907		End	R	in leaf litter, twigs uhiuhi
ODONATA	dragonflies; damselflies			
Libellulidae	skimmers			
Pantala flavescens (Fabricius, 1798)	globe skimmer	Ind	C	in flight

Table 1: continued

Species	Common name	Status	Abundance	Notes
ORTHOPTERA	praying mantis, grasshoppers, crickets			
Gryllidae	crickets			
Gryllodes sigillatus (Walker)1869	flightless field cricket	Adv	A	on lava
CHILOPODA				
SCOLOPENDROMORPHA				
Scolopendridae	centipedes			
Scolopendra subspinipes Leach, 1815	large centipede	Adv	U	on soil

Status:
End endemic to Hawaiian Islands
Ind indigenous to Hawaiian Islands
Adv adventive
Pur purposefully introduced
? unknown

ABUNDANCE = occurrence ratings:

R	Rare	seen in only one or perhaps two locations.
U	Uncommon-	seen at most in several locations
O	Occasional	seen with some regularity
C	Common	observed numerous times during the survey
A	Abundant	found in large numbers
AA	Very abundant	abundant and dominant

Lava Tube Species

The lava tube survey yielded a few native invertebrates, with *Schrankia* sp. a moth, being the most common native species encountered. The most common arthropod encountered in the small sample of lava tubes surveyed was the adventive *Periplaneta americana* (American cockroach). These results are not surprising given that many of the lava tubes have skylights creating a short dark zone, or none at all (Figure 14). Some tubes lack covering vegetation. In many tubes there is no root system reaching into the lava tubes, and insufficient moisture to support a richer ecosystem. Other tubes have only a few grass roots (Figure 16). The major food source, long roots, (Figure 15) supporting most lava tube arthropod communities, is mostly absent.

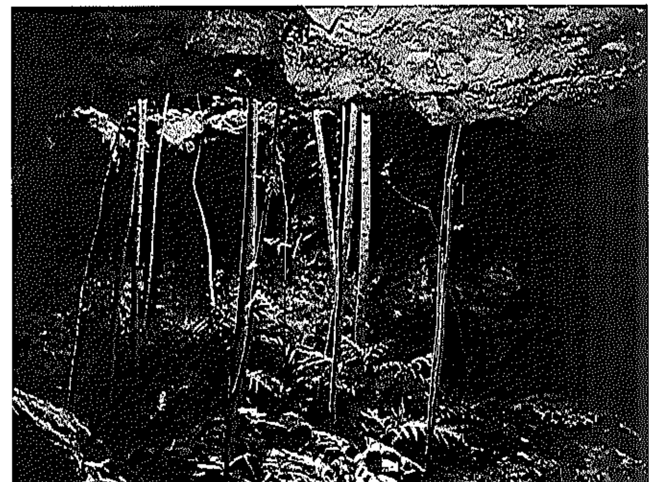


Figure 14. Skylights or openings to the outside, common in the Kaloko tube system, make many of the tubes too dry and too bright for a healthy dark-adapted cave ecosystem.

My examination of a small sample of lava tubes was augmented by a thorough review of color photographs taken inside numerous tubes and of faunal remains listings provided in the archaeological reports (Bell et al. 2008a, b, c; Esh et al. 2008). The images in those reports with very few exceptions show the lava tubes surveyed by archaeologists displaying no descending roots, or short roots.

In wetter lava tubes at other locations, large portions of the wall surface may be covered with a slime, on which the larvae of crane flies (*Limonia* sp.) leave characteristic trails. My review of the small patches in my sample caves (Figure 17) and of the color photographs in the archaeological reports (Bell et al. 2008a, b, c; Esh et al. 2008) shows no evidence of the baseball-stitch pattern (Figure 18) left by the feeding of the larvae of crane flies (*Limonia* sp.). Factors affecting the suitability of a habitat for *Limonia* include low humidity and apparent reduced nutritional content in the coating (Howarth 1973). Kaloko Makai tubes present both low moisture and few overhead plants with descending roots.

My findings seem to parallel those from a 1995 US Fish & Wildlife Service visit to some of the tubes. Fish & Wildlife representatives entered 25-30 caves as part of a survey of the property's dry forest area. US Fish & Wildlife Service reported most caves lacked aspects recognized as necessary to support cave-adapted ecosystems. Moisture levels were low and root penetration into the lava tube system was lacking. Although 6 caves looked more promising, only one species of *Shrankia* moth was seen in those caves. (USFW1997)

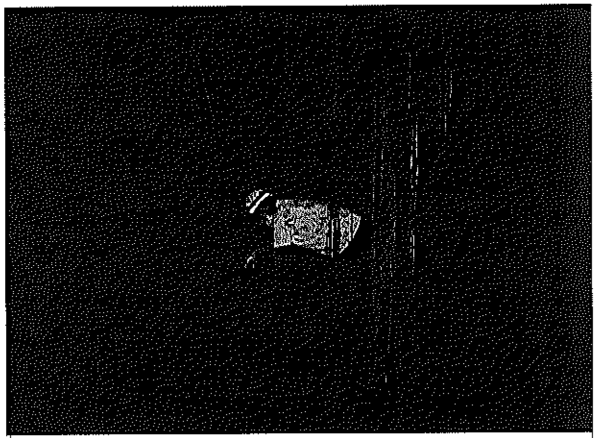


Figure 15. To support a thriving lava tube ecosystem a typical cavern (above) needs a large number of long and healthy roots penetrating from overhead vegetation.

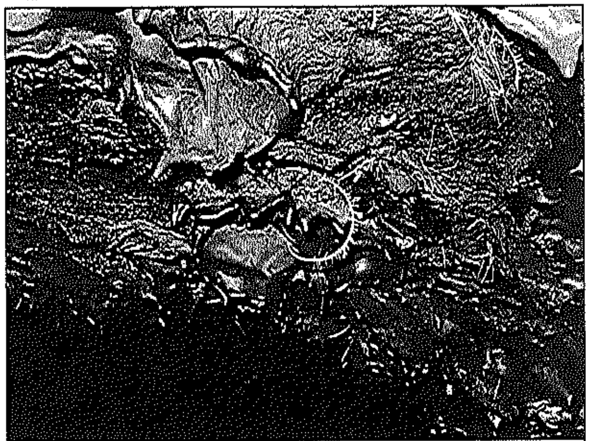


Figure 16. Typical view of short roots penetrating Kaloko Makai lava tubes.

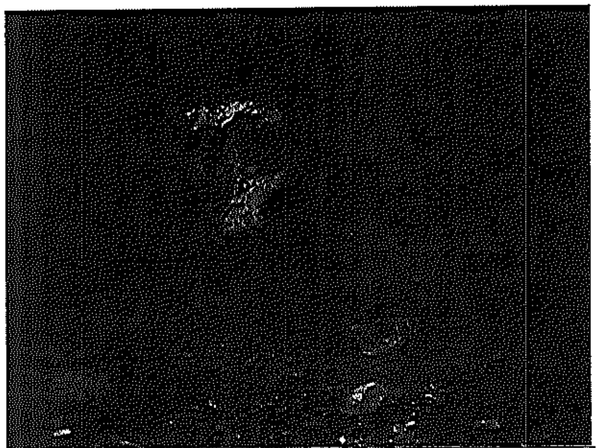


Figure 17. Typical view inside Kaloko lava tube. Slime coverings (white patches) were sporadic and showed none of the patterns created by feeding endemic crane fly larvae (example below).

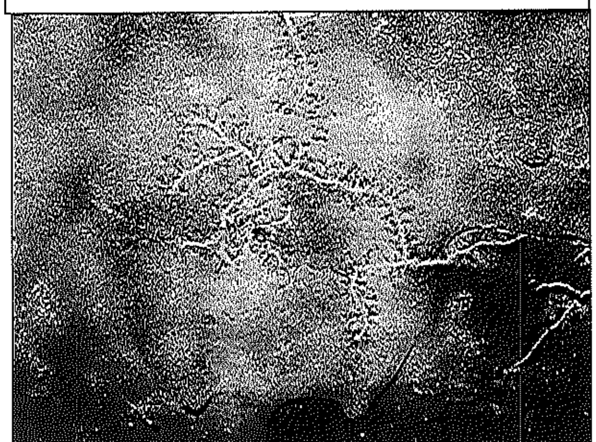


Figure 18. In wetter lava tubes large portions of the surface may be covered with a slime, on which the larvae of crane flies (*Limonia* sp.) leave characteristic trails. © near volcano Feb 2008

Invertebrates Not Present

Alien predatory ants are a major cause of low numbers of native arthropods. The big-headed ant (*Pheidole megacephala*), longlegged ant (*Anoplolepis gracilipes*), and carpenter ant (*Camponotus variegatus*), which prey on other insects (Zimmerman 1948-80), are present on the property. Ants are well documented as a primary cause of low levels of native arthropods at elevations up to 2000 ft. (Perkins 1913). On all nights, during light censusing, ants quickly appeared and began attacking the resting moths and smaller insects at my light. Ant populations often do not overlap. Rather they have separate territories, effectively apportioning the hunting grounds between themselves, offering few ant-free zones to native arthropods.

MOLLUSCA

Gastropoda (Snails) Pulmonata

No native snails were observed on the project property.

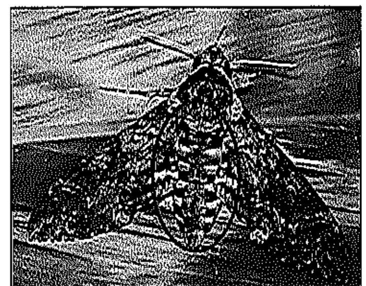
ARTHROPODA

Diptera: Drosophilidae: *Drosophila*

No native *Drosophila* (picture-winged flies) were observed on the property. The location does not provide appropriate habitat for any of the 12 native *Drosophila* species recently listed as endangered or threatened. (USFWS 2006a, b).

Lepidoptera: Sphingidae:

Agrius cingulata Sweet potato hornworm



© Figure 19. Sweetpotato hornworm showing pink markings.

The sweet potato hornworms feed on all sweet potato, morning glory, and related plants. Although it did not respond to my light survey, it is very likely to be seen on the property as it is widely distributed around the Hawaiian Islands and appropriate host plants are present. (HBS 2002a, Nishida 2002) This large and easily seen moth is most easily confused by the public with the Blackburn's sphinx moth (*Manduca blackburni*) described below. The adult *A. cingulata* having PINK markings (Figure 19) along both sides where *Manduca* has orange (Figure 20). When the moth is at rest with wings folded, these color markings are hidden, leading to possible misidentifications.

Manduca blackburni
Blackburn's sphinx moth (*Manduca blackburni*), (Figure 20) an endangered species (Fed Reg 1999-2000) which favors leeward slopes, was not found in this survey. Neither the moth's solanaceous native host plant, 'aiea (*Nothocestrum* sp.), nor the best alien host, tree tobacco (*Nicotiana glauca*), were observed on the property in my own survey or the most recent botanical survey (Whistler 2006). *Capparis sandwichiana*, reported to be adult nectar plants is known on the property. Whenever the plants were encountered in my surveying, I was alert for adults feeding on blooming flowers. *Manduca* was not observed.

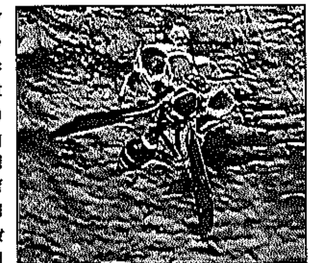

© Figure 20. Blackburn's sphinx moth is distinguished from other hawk moths by orange markings.

Although the original *Recovery Plan* (USFWS 2005b) for this large sphinx moth proposed two small management areas in North Kona, Hawai'i, the *Final Rule* (USFWS 2003) designated habitat only at the more inland location, Pu'uwa'awa'a.

Orthoptera: (Praying Mantis, Grasshoppers, Crickets)
Gryllidae
Caconemobius anahulu Otte, 1994 Lava cricket
This species was first discovered by Dr. D. Otte on barren lava 1 km from 'Anaeho'omalu Bay, Hawai'i Island. In his major revision of Hawaiian crickets Otte writes this species "may be widespread along the western slopes of Hawaii Island." (Otte 1994) It is much less common than *Gryllodes sigillatus* (see page 16) in these extremely barren lavas at Kaloko Makai. Although not found in this survey, it is likely a longer search at another time of year would have recovered this species.

Medically important species

The Kaloko Makai project area includes classic habitat for centipedes, scorpions, and widow spiders, so these medically important species may be present in the area. *Dysdera crocota* , a 10-14 mm spider known to bite humans (page 12), and scorpions were seen inside the lava tubes and in the rocky areas. Common paper wasps (*Polistes exclamans*) (Figure 21) were seen repeatedly on the property. Employees should be alert for these species when working in the area. These species may pose a serious risk to some individuals, and supervisors should be aware of any special allergy of employees. Some individuals can experience anaphylactic reactions to venom. Also note that the ant species reported present (see page 24) are known to bite people. When moving stones or piled brush, use of gloves and long sleeves will greatly reduce the risk of accidental contact and bites with all species noted here. Please see *What Bit Me?* (Nishida & Tenorio 1993) and *What's Bugging Me?* (Tenorio & Nishida 1995).


© Figure 21. Paper wasp

POTENTIAL IMPACTS
Potential Impacts on Native, Rare, Federally or State Listed Species
No federally or state listed endangered or threatened species were noted in this survey (USFWS 2008). No anticipated actions related to the proposed project activity in the surveyed locations are expected to threaten an entire species.

RECOMMENDATIONS
Data retrieval
Decapoda
As the presence of the crab remains I observed in my survey had been marked by the archaeological surveyors, they were not collected. A consultation with B. P. Bishop Museum specialists shows that no specimens of this sort have been closely examined by scientists knowledgeable in this group. As the examples in these caves are in relatively good condition, they should be retrieved for specific identification by invertebrate specialists as part of the archaeological data recovery and mitigation process. During data retrieval, a search should be made for additional parts of the crab to aid in identification (i.e., lifting rocks, looking for smaller parts of the crab). Proper and specific identification will provide valuable information to increase both biological and cultural knowledge.

Prevent habitat degradation:
Fulfillment of the plan to preserve some archaeological sites and parts of the dry forest habitat should assist native invertebrate species, including cave adapted species. Selective removal of alien plants in these areas can assist native plants in filling the available niches. Additionally, it is important to prevent establishment of new competitive or predatory alien invertebrate species.

A **Best Practices Management Plan** for construction should be written and implemented specifying methods and controls for the entire construction zone to prevent or minimize runoff, spills, and impact on the makai coastal habitats (Kaloko-Honokōhau National Historical Park) as well as fragile archaeological and biological zones within the property. Establish construction staging areas and storage of materials well away from the fragile areas.

Two factors influence establishment of alien species: access and regular food sources.

Inspect construction materials for hitchhiking seeds or animals.

Clean tools, boots, and equipment used at other sites to minimize the chance of transporting new pest plants or animals to the area. Soil packed in tires, on helicopter runners, or workers' boots can transport seeds, and insect or snail eggs. Ants, snails and slugs, and many other invertebrates can hide in boxes or equipment resting at one location and later be carried to Kaloko Makai.

When establishing plantings after construction, care should be taken to prevent alien plant or animal species from being introduced on the plantings or associated soil.

Remove trash regularly. Predatory species such as ants easily establish in areas where food trash is consistently available. Food trash during construction can increase mongoose (*Herpestes auropunctatus*) populations as well. Construction workers are socialized to simply drop food remains and food wrappers, bottles and containers. Change expectations: Provide trash cans, establish a culture of using them, and empty the cans frequently.

Shield external lighting:
We concur with the advice of David (2006) to shield outdoor lighting. Light is attractive to all arthropods (see *Methods* page 7). The potential presence of *Manduca blackburni* in the greater area makes shielded lighting an important protection for this endangered invertebrate.

Landscape with native dryland plants for lower cost maintenance:

We concur with the advice of Whistler (2006) to revegetate public and common areas with native dryland adapted plants. Given the Kona climate of the project area, it would be both practical and appropriate. Native plants would provide habitat for native arthropods, while creating interesting areas for walking, cultural learning, nature study, and bird watching. Importantly, using dryland plants to landscape can lower long-term watering costs and water draws, following an initial establishment period. Native plants will remain green and thus more fire resistant throughout the summer. Most native plantings will have lower human maintenance costs as well (less hedge trimming, weed whacking). Planted in a mix of ground cover, shrub, and tree heights native plants also help slow run off and retain moisture when rains do come. Native plants usually grow well without the use of fertilizers, reducing the potential for runoff into Kaloko-Honokōhau National Historical Park (David 2006). Native insects will find this refuge over time. The plantings will provide educational, visual, and aesthetic benefits to residents while conserving water at very low on-going cost.

Home buyers should be given guidance on xeriscaping with restrictions being considered as part of covenants or homeowner association rules. Plants that are adapted to dryland areas also will not require doses of fertilizer and pesticides and so reduce non-point pollution. Several southwestern U. S. continental cities have long enforced water / yard planting restrictions due to water concerns. Their experiences may prove helpful in planning.

Resources helpful in understanding Hawaiian plants in an urban setting include *Native Hawaiian Plants For Landscaping, Conservation, and Reforestation* (Bornhorst & Rauch 1994) and *Growing Native Hawaiian Plants* (Bornhorst 2005). By prior arrangement with growers, native Hawaiian plants can be as convenient to mass plant as the introduced plants commonly used to re-vegetate after new construction. Some suppliers of native plants are listed at

http://hbs.bishopmuseum.org/botany/riparian/pdf/propagators.pdf

Some plants have demonstrated their adaptation to the area by growing at the Kaloko Makai site naturally [marked with asterisk (*) in the list below]. Dryland adapted plants suitable for landscaping, many with beautiful foliage or flowers, are listed below. Comments on some of the plants follow.

Ground cover:

ʻilima	*Sida* sp. (prone) (*)
malapilo	*Capparis sandwichiana* (*)
nehe	*Melanthera integrifolia, Melanthera subcordata*
ʻohai	*Sesbania tomentosa*
pāʻūohiʻiaka	*Jacquemontia ovalifolia*
pili grass	*Heteropogon contortus* (*)
ʻulei	*Osteomeles anthyllidifolia*

Shrub:

ʻaʻaliʻi	*Dodonaea* sp. (*)
ʻākia	*Wikstroemia* sp.
ʻilieʻe	*Plumbago zeylanica*
ʻilima	*Sida* sp. (upright) (*)
naio	*Myoporum sandwicense* (*)
pōhinahina	*Vitex rotundifolia*

Tree:

kou	*Cordia subcordata*
milo	*Thespesia pupulnea*
ʻohe makai	*Reynoldsia sanwicensis* (*)
ʻōhiʻa lehua	*Metrosideros polymorpha* (*)
wiliwili	*Erythrina sandwicensis*

ʻAʻaliʻi / *Dodonaea* sp.

ʻAʻaliʻi (Figure 22) grows at roughly shrub height without hedge triming. It produces flowers and foliage useful in lei making and is host to several invertebrates. It stays green year round without watering.

© Figure 22. ʻAʻaliʻi *Dodonaea* sp. foliage and blossoms

ʻIlima / *Sida* sp.

Figure 23. ʻIlima *Sida* sp.

ʻIlima (Figure 23) is host to a large number of native invertebrates, maintains color and foliage during the dry months and needs little maintenance. It grows in a prone, ground cover form and an upright, shrub form. The plant will grow at seaside or inland locations.

Malapilo / *Capparis sandwichiana*)

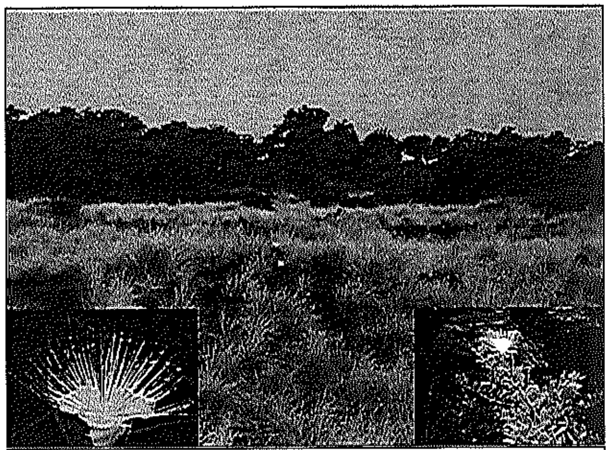
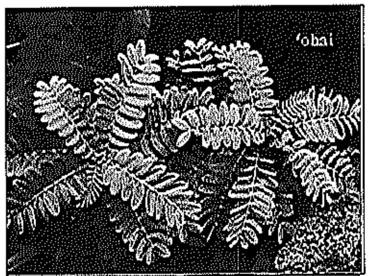


Figure 24. Malapilo (*Capparis sandwichiana*) [center] blooming amidst native pili and alien fountain grasses.

Malapilo (Figure 24), host to several native arthropods, is well adapted to the Kaloko Makai site. The plant bears numerous white flowers, which wilt to a beautiful pink as the day progresses. Already growing on site, malapilo, planted as a ground cover, provides nectar, pollen, and keeps down weeds. Morning walkers and joggers would find them a special attraction.

'Ohai / *Sesbania tomentosa*

Once known from all major islands, 'Ohai (Figure 25) now is rare outside planted areas. It has beautiful, moisture retaining, silvery leaves and dark orange, curved blossoms. It is a short shrub and stays 'green' all summer.



© Figure 25. 'Ohai *Sesbania tomentosa*

'Ōhi'a lehua (*Metrosideros polymorpha*)

'Ōhi'a lehua (Figure 26) can be a bush or tree and is well known for its attractive flowers much desired for lei making. It is now used more frequently in home landscaping on all islands. It could be planted in common areas at Kaloko Makai. In addition to the red flower, there are also other colors.

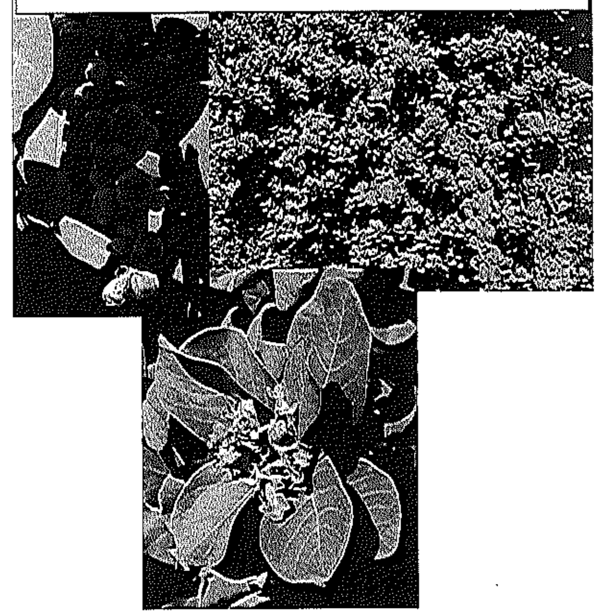
Figure 26. The species name of 'ōhi'a lehua, *polymorpha*, refers to the many physical and color varieties encompassed by the species.

'Ōhi'a is host to many native insects. As it provides a dependable nectar source for birds, the trees would make a reliable location for bird watching when in bloom.

Pōhinahina / beach vitex / *Vitex rotundifolia*

Now considered a beach plant (Figure 27), this hardy, flowering creeper likes to cascade over rocky areas or down small slopes but will form hedges. It will easily grow in upland locations. It tolerates abuse associated with human co-habitation, and even responds to pruning. It would form a natural hedge along pathways, thus keeping people on pathways with grace, beauty, and low upkeep. Spicy smelling leaves, small blue flowers, and brown seed capsules create visual interest. No watering required after establishment. Foliage, flowers, and seed capsules are all good lei making materials.

© Figure 27. Pōhinahina seed capsules, foliage, and flower



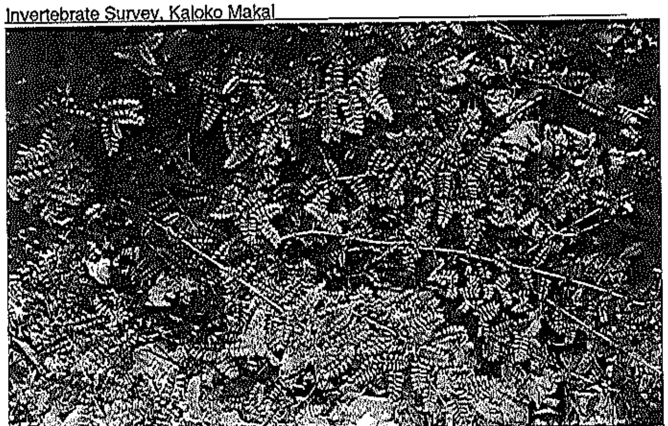
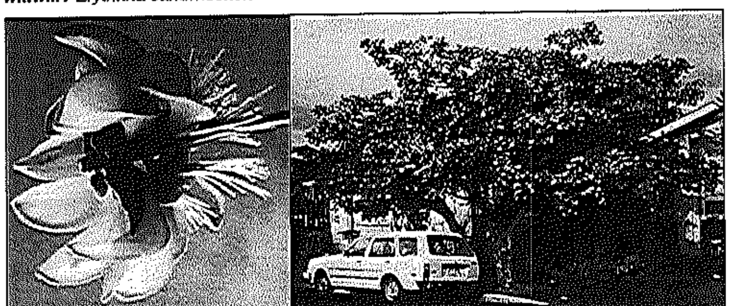


Figure 28. 'Ulei (*Osteomeles anthyllidifolia*)

'Ulei *(Osteomeles anthyllidifolia)*
'Ulei is a low growing plant (Figure 28) making a good ground cover, sometimes combined with other plants. It will grow in open areas or semi-shade. It is slower growing than some plants.

wiliwili / *Erythrina sandwicensis*



© Figure 29. Wiliwili is dryland adapted and needs no watering

Wiliwili (Figure 29) has a proven track record as a dryland decorative, low maintenance planting, co-habiting with homes and parks. Seasonal flushes of flowers provide remarkable beauty. The seeds make beautiful lei.

© Figure 30. Wiliwili receives solar energy through green bark when leaves are dropped.

Although currently wiliwili is under attack from a recently introduced alien gall wasp, a control agent of that pest is expected soon. Wiliwili is summer deciduous - dropping its leaves in summer and relying on minimal photosynthesis through green bark (Figure 30). Native wiliwili have suffered less from the wasp's attacks than the alien *Erythrina* trees, in part because their green bark provides some nutrition during periods when leaves are reduced by the wasp's effect.

Community Education:
The best defense the fragile dry forest ecosystems can have is an informed public. Providing signage and partnering with community environmental groups to provide information and guidance about enjoying the preserved dry forest, archaeological, and natural features, would make preservation more effective. Providing defined pathways would reduce trampling of plants and disturbance of wildlife.

ACKNOWLEDGMENTS
Thanks are extended to Stanford Carr Development, Wilson Okamoto Corporation, and Jim Medlin for assistance in site access. Dr. Francis Howarth provided access to identifications of the Kula Nei survey results. Karen Marlowe, U. S. Fish & Wildlife Service, assisted with a Freedom of Information Act request for USFWS files related to the dry forest portion of the property. Mindy Simonson, of Rechtman Consulting, provided on-site guidance to locate lava tubes. Thanks are extended to the personnel of the Dept of Land and Natural Resources for permits to conduct this work.

Steven Lee Montgomery conducted all collecting and is responsible for all conclusions. Anita Manning contributed to preparation of this report. Some images used in this report were not taken in the course of this project. These photos, marked by © symbol were made by Anita Manning and/or S. L. Montgomery prior to this contract and were chosen because they best illustrate the subject.

STANDARD NOMENCLATURE

Bird names follow *Hawaii's Birds* (Hawaii Audubon Society 2005).
Invertebrate names follow
Freshwater & Terrestrial Mollusk Checklist (HBS 2002b)
Common Names of Insects & Related Organisms (HES 1990)
Hawaiian Terrestrial Arthropod Checklist (HBS2002a; Nishida 2002)
Mammal names follow *Mammals in Hawaii* (Tomich 1986).
Place name spelling follows *Place Names of Hawaii* (Pukui et al. 1976).
Plant names follow
Manual of the Flowering Plants of Hawaii (Wagner et al. 1999)
A Tropical Garden Flora (Staples and Herbst 2005)

ABBREVIATIONS

ASL	above mean sea level
DLNR	Department of Land and Natural Resources, State of Hawai'i
DOFAW	Division of Forestry and Wildlife, State of Hawai'i
FOIA	Freedom of Information Act Request
ft	feet
HBS	Hawai'i Biological Survey
m	meter
MV	Mercury Vapor
n.	new
sp.	species
spp.	more than one species
TMK	Tax Map Key
UH	University of Hawai'i
USFWS	United States Fish and Wildlife Service
UV	Ultraviolet

GLOSSARY[4]

Adventive: organisms introduced to an area but not purposefully.

Alien: occurring in the locality it occupies ONLY with human assistance, accidental or purposeful; not native. Both Polynesian introductions (e.g., coconut) and post-1778 introductions (e.g., guava, goats, and sheep) are aliens.

Arthropod: insects and related invertebrates (e.g., spiders) having an external skeleton and jointed legs.

Aspiration: invertebrates are transferred from the original location (leaf, net, etc.) into a large vial. Two tubes are lodged in one stopper in the vial. Air drawn in on one tube, creates suction at the end of the second tube; the target insect is drawn into the vial by the pulling air.

Endemic: naturally occurring, without human transport, ONLY in the locality occupied. Hawaii has a high percentage of endemic plants and animals, some in very small microenvironments.

Gibbous: describes the Moon or a planet before and after it is full, when it has more than half its disk illuminated; swollen on one side.

Indigenous: naturally occurring without human assistance in the locality it occupies; may also occur elsewhere, including outside the Hawaiian Islands. (e.g., Naupaka kahakai (*Scaevola sericea*) is the same plant in Hawai'i and throughout the Pacific).

Insects: arthropods with six legs, and bodies in 3 sections

Invertebrates: animals without backbones (insects, spiders, snails / slugs, shrimp)

Larva/larval: an immature stage of development in offspring of many types of animals.

Makai: toward the ocean

Mauka: toward the mountains

Midden: food refuse in an archaeological setting, often in a heap or pile

Mollusk: invertebrates in the phylum Mollusca. Common representatives are snails, slugs, mussels, clams, oysters, squids, and octopuses.

Morph: one form of a polymorphic (or many formed) population which despite their physical differences are part of the same genus or species.

Native: organism that originated in area where it lives without human assistance. May be indigenous or endemic.

Naturalized: an alien organism that, with time, yet without further human assisted releases or plantings, has become established in an area to which it is not native.

4 Glossary based largely on definitions in *Biological Science: An Ecological Approach*, 7th ed., Kendall/Hunt Publishing Co., Dubuque, a high school text; on the glossary in *Manual of Flowering Plants of Hawai'i*, Vol.2, Wagner, et al., 1999, Bishop Museum Press, and other sources.

Glossary: cont.

Nocturnal: active or most apparent at night.

Pupa: the stage between larva and adult in insects with complete metamorphosis, a non-feeding and inactive stage often inside a case

Purposefully introduced: an organism brought into an area for a specific purpose, for example, as a biological control agent.

Rare: threatened by extinction and low numbers.

Species: all individuals and populations of a particular type of organism, maintained by biological mechanisms that result in their breeding mostly with their kind.

Waning: describes a gradual decrease in the amount of the moon's disk that is visible; shrinking

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