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Technical Report 185

**Assessing the presence and distribution of 23
Hawaiian yellow-faced bee species on lands adjacent to military
installations on O'ahu and Hawai'i Island**

September 2013

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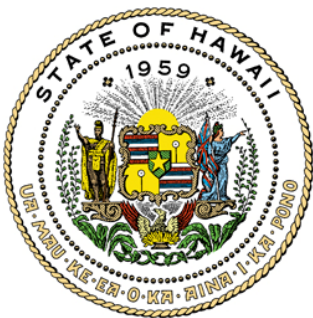
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Hylaeus anthracinus on flower of *Heliotropium foertherianum*



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Abstract

The endemic *Hylaeus* bees are critical pollinators in native ecosystems in Hawai‘i. Seven species are proposed for listing as endangered, and many more are rare and potentially endangered. We surveyed 40 localities on O‘ahu, 56 on Hawai‘i, and approximately 70 km of the coastline of Hawai‘i for 23 species of native *Hylaeus*, including four added during the course of the project. All of the native *Hylaeus* were much rarer than they were during previous surveys in 1999–2002, including many previously considered common. The only target species found in significant numbers was *H. anthracinus*, which is restricted to narrow strips of seashore vegetation on both islands but can occur in high density where present. However, the largest O‘ahu population, at Ka‘ena Point, appears to have completely disappeared since it was last observed in 2002. Significant populations exist on Hawai‘i, but only two sites are currently known on O‘ahu. Six of the other species on O‘ahu were not seen at all, and the remaining six (*H. anomalus*, *H. laetus*, *H. makaha*, *H. mamo*, *H. mana*, and *H. mimicus*) were collected once or twice and/or with a total of 1–5 individuals each. On Hawai‘i, only *H. flavipes*, *H. kona*, *H. laetus*, *H. ombrias*, and *H. rugulosus* were collected, mainly from in or around Pōhakuloa Training Area during a brief period of July and August. Most non-target species have been found at least once, but nearly all in low numbers; some of the less common ones, including *H. setosifrons* on Hawai‘i, were extremely rare or absent. The past several years have been extremely dry on the leeward sides of the islands, where most of the rare species occur, and drought may be a factor in the low numbers of bees. Serious damage and mortality among *Myoporum sandwicense*, an important floral resource, as a result of thrips infestation may also be important in reducing numbers and diversity of bees in montane areas of Hawai‘i. These results indicate that management of *Hylaeus* for recovery will be difficult, particularly at montane sites, but that the conservation need is also increasingly urgent as invasive species and climate change are having a greater and more rapid impact than anticipated. In coastal sites, the alien tree *Heliotropium foertherianum* (= *Tournefortia argentea*, tree heliotrope) is a critical floral resource for *Hylaeus* and should be managed with careful regard for impacts on bee populations.

Background

The Hawaiian Islands

Hawai‘i is frequently referred to as the “endangered species capital of the world,” and it is unquestionably the center of endangered species in the United States. Of the 1406 species currently listed as threatened or endangered, 375 are endemic to the Hawaiian Islands – 27% of the total listed species, on 0.29% of the nation’s land area. This dubious distinction results from a combination of long biological isolation, producing a diverse biota of endemic species derived from relatively few original colonists, and severe ecological disturbance following the arrival of humans and introduction of alien species including ungulates, plants, and insects. Subsequent changes in the fire regime and hydrology as a result of direct and indirect human impacts have made many of these effects irreversible.

Positioned in the middle of the Pacific Ocean, Hawai‘i has also long been an important strategic location. U.S. military bases and training areas, including Kawaihoa and Kahuku Training Areas, Schofield Army Barracks, Mākua Military Reservation, and Naval Magazine Lualualei, utilize about 20% of the land area of O‘ahu, and significant facilities are present on

Kaua‘i (Pacific Missile Range Facility) and Hawai‘i island (Pōhakuloa Training Area). Large parts of these sites are undeveloped, and longtime restrictions on human access have resulted in reduced impacts compared to other areas. As a result, Hawai‘i military lands contain a high number of endangered species: 12 plants and 4 animals at Pōhakuloa (Center for the Environmental Management of Military Lands 2006), and 58 plants and 13 animals on the various O‘ahu training areas (Pacific Cooperative Studies Unit 2005). With a legal mandate to protect endangered species found on military lands and mitigate any impacts caused by training, the Army has undertaken vigorous conservation programs on O‘ahu and Hawai‘i, including conducting management on nearby state forest reserve lands.

Hawaiian *Hylaeus* (*Nesoprosopis*)

The Hawaiian Islands are globally unique for their combination of being high islands capable of generating rainfall, and their extreme isolation from any other similar land masses. Located approximately 3700 km from the nearest continent and 3400 km from the nearest oceanic high islands, relatively few colonists have managed to survive such a long overwater dispersal and reach the islands themselves. As a result, the biota is depauperate at the higher levels of order and family – and many dominant continental groups, such as ants, social wasps, and most aquatic orders (aside from Odonata), are lacking entirely – but many of those that do survive have evolved into large radiations of diverse species (Zimmerman 1948).

While bees are highly diverse in most continental systems, they are poorly represented on oceanic islands. Only one group, the yellow-faced bees (*Hylaeus*, family Colletidae), has colonized Hawai‘i. The Hawaiian species belong to the subgenus *Nesoprosopis*, which are found primarily in East Asia (Hirashima 1977) and presumably arrived from there. At present, 63 species are known, all derived from a single ancestor (Daly and Magnacca 2003, Magnacca 2011). In keeping with the trend among Hawaiian taxa, while this number is low relative to a continental region of similar size, it represents 10% of the world’s *Hylaeus* species, and more than are found in all of North America (49). They have adapted to virtually all habitats in the islands, ranging from coastal strand to montane wet forests to subalpine shrubland above 10,000 feet, and early naturalist R.C.L. Perkins described them as “almost the most ubiquitous of any Hawaiian insects” (Perkins 1913). They are solitary and almost exclusively visit native plants, for which they are important pollinators.

However, like much of the native biota, *Hylaeus* have experienced dramatic range reductions, population declines and possibly extinctions over the last 100 years. Ten species have not been collected in at least 80 years, and another five appear to have been extirpated from one or more islands where they were historically known (Magnacca 2007a). As a result, thirty-three yellow-faced bee species were placed on the U.S. Fish and Wildlife Service Category 2 candidate list, and were later reclassified as “Species of Concern” (SOC) in 1996 (U.S. Fish and Wildlife Service 1996). In March 2009 an international invertebrate conservation organization, The Xerces Society, petitioned for the federal listing of seven species of yellow-faced bees (*Hylaeus anthracinus*, *H. assimulans*, *H. facilis*, *H. hilaris*, *H. kuakea*, *H. longiceps*, and *H. mana*), citing that there are sufficient data which show them to be at imminent risk of extinction. In June 2010, the U.S. Fish and Wildlife Service responded by publishing a 90-day finding for the seven species, and in September 2011 the agency’s 12-month finding determined that listing the species as endangered was warranted but precluded by higher-priority actions, and placed them on the candidate endangered species list.

Despite attracting interest from the beginnings of entomological studies in Hawaii, there is still relatively little known about the natural history of the native *Hylaeus*, including their precise habitat preferences, nesting habits, and patterns of floral usage. There was a gap between 1930 and 1990 during which they were virtually ignored, and most of the recent distribution data comes from surveys conducted from 1999–2002 as part of the lead author’s graduate study (Daly and Magnacca 2003). The goal of this project was to expand knowledge of the distribution of rare species in preparation for management on military lands in the event that they are federally listed under the Endangered Species Act.

Geographic Setting

Below we describe the vegetative characteristics of the main target sites of this survey, with particular reference to plants favored by bees and previous collections.

Pōhakuloa Training Area and adjacent sites

Pōhakuloa is a sprawling military training site located in the broad plateau between Mauna Loa, Mauna Kea, and Hualalai (Figure 1). Since it primarily sits on Mauna Loa, the entire area of PTA consists of a mosaic of substrates of varying age and consequently differing vegetation. The flat central region is an impact area for live fire exercises and is completely off-limits; it is also only sparsely vegetated. Two sections, Area 22 (including Kīpuka Kalawamauna) in the northwest and Area 23 (Kīpuka ‘Alalā) in the southwest, receive little training activity and are intensively managed for rare plants. Area 4, in the northeast, includes a section of the old Saddle Road and is also largely unused for training; it is adjacent and similar to Mauna Kea State Park. Area 21 (Redleg Trail), in the east, includes most of the ground live-fire ranges. To the south, it adjoins the Mauna Loa Forest Reserve, and several small kīpuka (“islands” of denser vegetation surrounded by bare lava) in the vicinity of Pu‘u Kōlī are vegetatively similar to those found inside Area 21.

Kīpuka Kalawamauna is largely shrubland with scattered trees, with stands of *Euphorbia (Chamaesyce) olowaluana* dense in some areas. Floral resources are dominated by *Euphorbia*, *Bidens menziesii*, *Dubautia linearis*, and *Dodonaea*, with some *Sida*. On the western side of the Kīpuka Kalawamauna fence, *Euphorbia* is regenerating strongly after suffering from intense grazing pressure; those outside the fence continue to die, especially during droughts when feral sheep and goats are driven to strip bark from the trees. Most of the remainder of Area 22 consists of open *Metrosideros* forest, with or without a shrub understory. There are some kīpuka that contain almost entirely *Myoporum*, but the entire west side of PTA has been extremely heavily impacted by the myoporum thrips (*Klambothrips myopori*). This has caused heavy mortality in combination with recent droughts and greatly reduced flowering in the survivors, and consequently it is not a major foraging source for bees there anymore (pers. obs.). Four species of *Hylaeus* were collected here in 1999: *H. difficilis*, *H. laetus*, *H. ombrias*, and *H. pele*.

Area 23 consists of mixed short-stature *Myoporum-Sophora* forest with significant stands of *Euphorbia olowaluana* and a dense shrub component including *Dodonaea* and *Bidens menziesii*. Taller trees, including *Santalum paniculatum* and *Metrosideros*, are present in the southern portion. In 1999, eight species were collected here: *H. difficilis*, *H. dimidiatus*, *H. inquilina*, *H. kona*, *H. laetus*, *H. paradoxicus*, *H. pele*, and *H. sphecodoides*, primarily on *Euphorbia*.

Area 21 is largely sparsely vegetated lava, with scattered shrubs on younger flows and a few small kīpuka of *Myoporum* or *Metrosideros* on older substrates accessible along the Redleg Trail. Along the old Hilo-Kona Road to the south are another group of *Myoporum-Sophora*

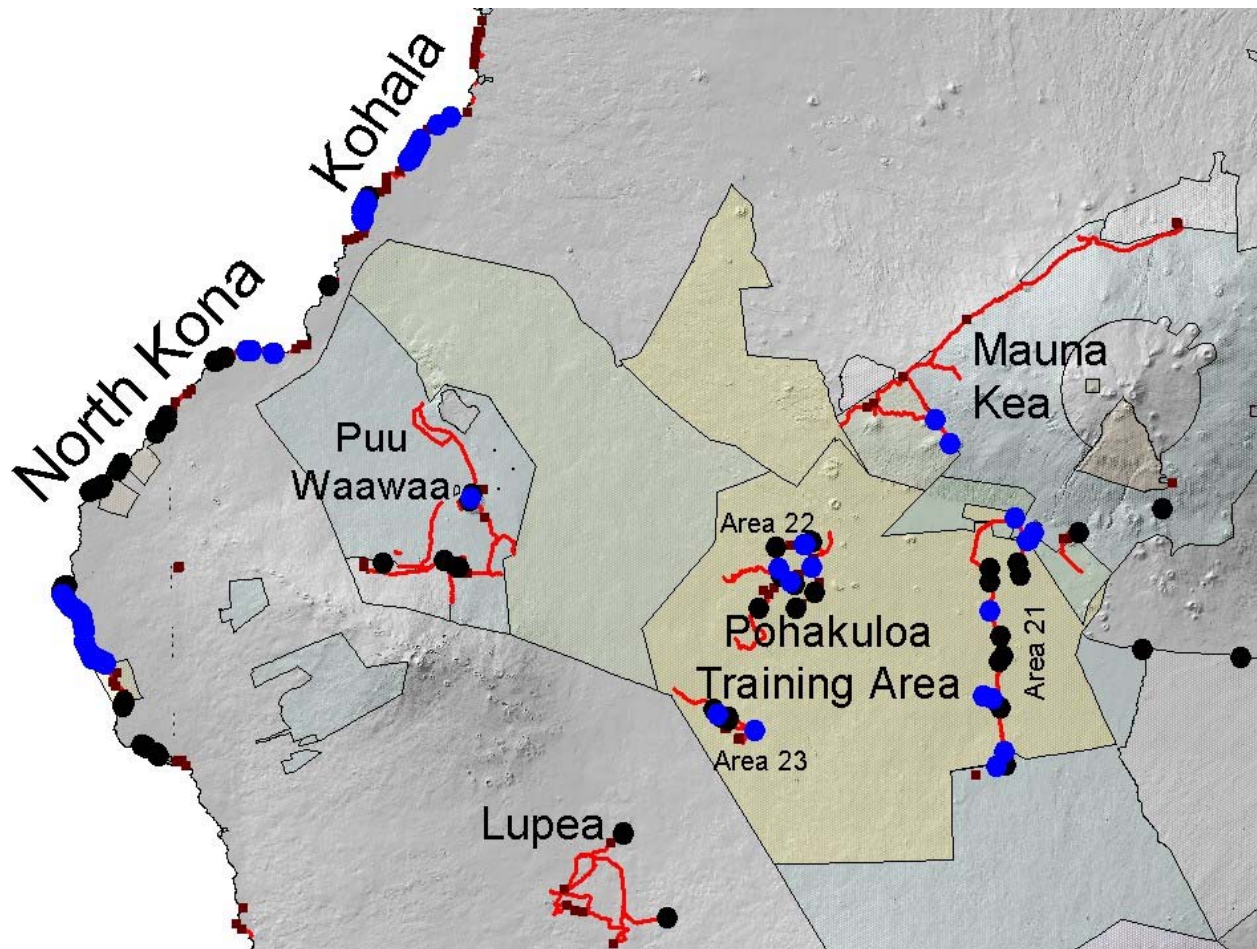


Figure 1. Northwest coast and montane areas of Hawai'i island, showing survey sites. Red lines indicate roads and trails where surveying was conducted. Blue dots are sites where at least one target *Hylaeus* species was found, black dots are sites where other (non-target) *Hylaeus* species were found, and small brown squares are specific sites with suitable vegetation that were surveyed but where no *Hylaeus* were found, including sites where only alien bees were present.

kīpuka on state land in the Mauna Loa Forest Reserve, near Pu'u Kōlī. To the north, Area 4 contains a patch of open *Myoporum-Sophora* forest on Mauna Kea substrate along the old Saddle Road, which is continuous with Mauna Kea State Park across the new Saddle Road alignment. The myoporum thrips is present throughout the area but currently causes much less damage than on the west side of PTA, and many *Myoporum* trees were flowering abundantly. None of these sites have been searched for *Hylaeus* previously.

Lupea

Lupea is located on the western slope of Mauna Loa in North Kona at an elevation of 1580–1800 m, at the contact boundary with Hualalai lava flows (Figure 1). It is about eight km west of Pōhakuloa, on the other side of the Mauna Loa-Hualalai saddle. The land is part of a large tract of land owned by Kamehameha Schools (Keauhou-Kona) and was formerly leased for ranching, when it was known as the Pulehua Ranch and later W.H. Greenwell Ranch. While working on the Fauna Hawaiiensis project, R.C.L. Perkins stayed at Pulehua and collected widely in the area; he reported koa finches and the Kona grosbeak to be abundant here in 1892 and 1894, but they had declined significantly by 1896 and become extinct by 1902. Perkins collected 11 species of

Hylaemus here: *H. connectens*, *H. difficilis*, *H. dimidiatus*, *H. kona*, *H. ombrias*, *H. paradoxicus*, *H. pubescens*, *H. setosifrons*, *H. simplex*, *H. sphecodoides*, and *H. volcanicus*. However, most came from 1200 m elevation or below, where the forest is now largely destroyed.

The flora consists of dry forest with a generally open tree canopy of *Santalum paniculatum*, *Myoporum*, *Sophora*, and *Acacia*, with grass below. In some areas *Santalum* is the dominant tree; some of the largest specimens in the state can be found here, as they were spared the ravages of the sandalwood harvesting during 1790–1830. A few pockets of *Metrosideros* occur, but overall this widespread tree is unusually rare here. There is little reproduction of shrubs in the understory due to the continued presence of sheep, but the area is currently in the process of being fenced off. Above this forest band, there is a large expanse of relatively intact dry shrubland on pahoehoe flows, consisting of *Dodonaea*, *Leptecophylla*, and scattered *Metrosideros* trees.

Mauna Kea

The upper area of Mauna Kea is encircled by a jeep road, which runs for most of its length between 2100–2600 m elevation (Figure 1). On the west side it begins at Ka'ohē Game Management Area, northwest of PTA, and proceeds clockwise around the mountain for 60 km close to the lower boundary of Mauna Kea Forest Reserve, until reaching Hale Pohaku on the summit access road. Below the road on all sides the land has been ranched for over 100 years and little native vegetation remains, with the exception of the Puu Mali restoration area on the north side. The eastern slopes mostly contain shrubland and previous visits have found few bee species; it was therefore ignored during this survey. Collecting efforts focused on the remnant dry forest areas of Ka'ohē GMA in the west and Puu Mali in the north; in between is largely shrubland. Both contain open *Myoporum-Sophora* treeland, with a grassy understory as a result of grazing by sheep (Puu Mali is now fenced). Some *Euphorbia olowaluana* and *Santalum paniculatum* are also present at both sites. *Hylaemus flavipes*, *H. laetus*, and *H. ombrias* were collected here in 1995–99.

East of Mauna Kea State Park is another section of similar forest in Mauna Kea Forest Reserve. Much of the better-quality forest that had existed at this site burned in August 2010, killing all trees in the affected area, but a small remnant persists on and above Puu Ko'ohi. *Euphorbia* is especially abundant here. An area of high-elevation shrubland occurs at Hale Pōhaku near the treeline, dominated by *Dodonaea* and *Leptecophylla* with scattered *Sophora*, and a few outplanted *Argyroxiphium sandwicense sandwicense*.

Pu'u Wa'awa'a

The 'ahupua'a (land section) of Pu'u Wa'awa'a (Figure 1) was leased as a ranch between 1898 and 2000. During that time, the formerly rich forests became severely degraded, and now much of the lower, drier forest is either gone or is relatively undiverse, with an open to semi-closed canopy of *Metrosideros*, scattered *Myrsine lanaiensis*, and little else. A significant number of rare plants still occur, but mostly as single or widely separated individuals. The most intact and wettest forest, in the southwest portion, was set aside in 1984 as a wildlife sanctuary. Like Pōhakuloa, the vegetation may vary depending on the substrate, but since the entire area is relatively old, the history of fires and grazing has a greater impact. The best locations for bees are along the eastern and northern boundaries of the wildlife sanctuary, where the mesic forest rapidly transitions to dry forest. In the latter, *Metrosideros*, *Myoporum*, *Santalum paniculatum*, and *Sophora* occur abundantly, along with rare stands or individuals of *Euphorbia olowaluana*.

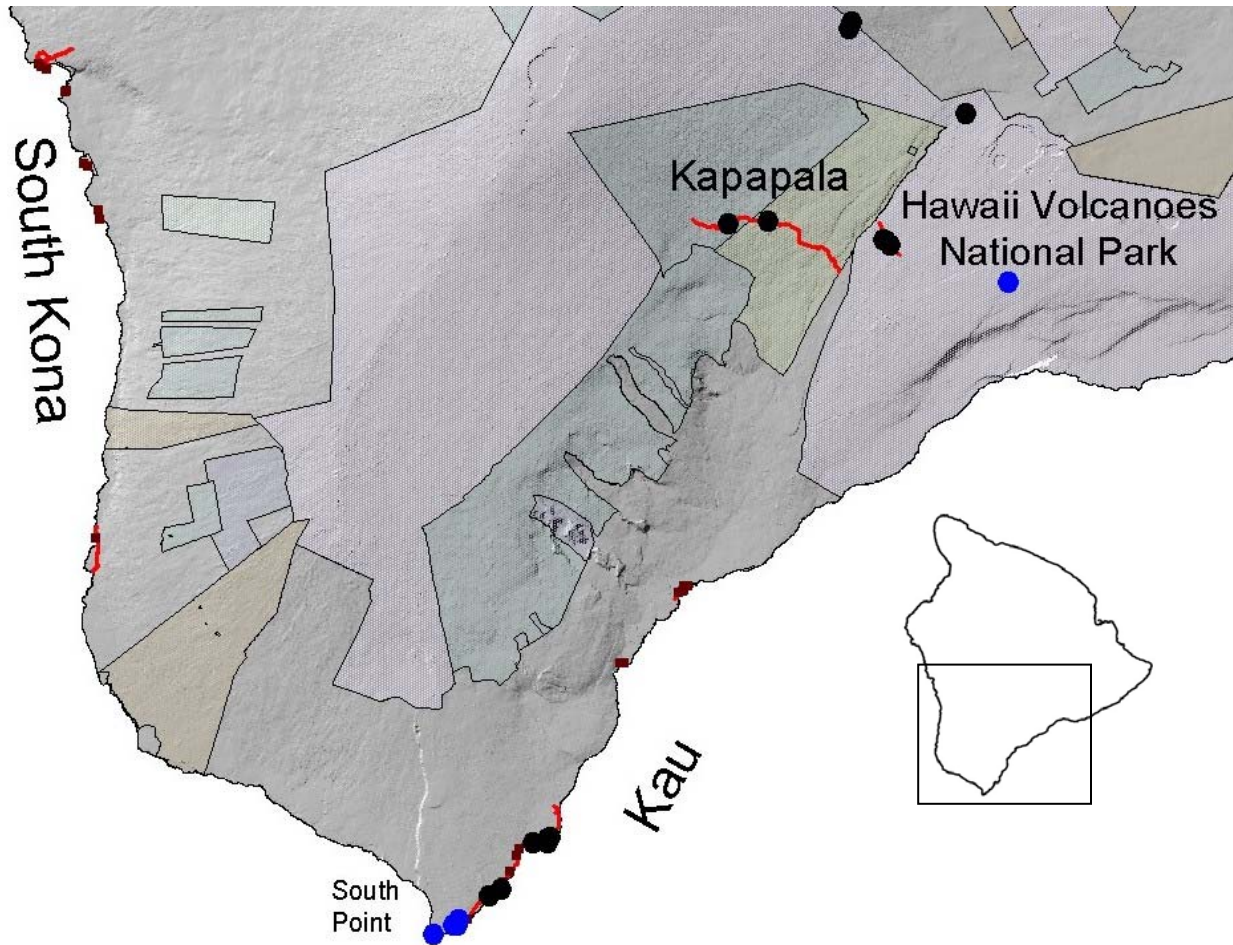


Figure 2. Southern portion of Hawai'i island, showing survey sites. Marks as in Figure 1.

Inside the sanctuary fence, where sheep are excluded, regeneration of *Sophora* has been significant in some areas. In 2002, nine species of *Hylaes* were collected here, all on a single *Euphorbia* tree – *H. akoko*, *H. coniceps*, *H. difficilis*, *H. dimidiatus*, *H. filicum*, *H. hula*, *H. laetus*, *H. paradoxicus*, and *H. pele*. The cinder cone for which the area is named also has a diverse flora, but naturally-occurring plants are relatively few; it is currently undergoing restoration.

Ka'ū mauka

The mauka (upland) regions of the Ka'ū district in the southwest of Hawai'i includes Hawai'i Volcanoes National Park and Kapāpala and Ka'ū Forest Reserves (Figure 2). The last is largely wet forest and was not sampled. Northwest of Kīlauea caldera between 1200 and 2000 m elevation, the slopes of Mauna Loa are covered in a mosaic of mesic to dry forest and shrubland of varying composition. Major plants include *Acacia*, *Dodonaea*, *Leptecophylla*, *Metrosideros*, *Myoporum*, *Santalum paniculatum*, *Sophora*, and in a few places *Sapindus saponaria*. This area was severely degraded by cattle in the past, but has recovered significantly under national park management. Perkins collected most non-coastal Hawai'i island species from various locations around Kīlauea. The area was still moderately diverse during 1999–2002 collecting, but many rarer species were lacking – only *H. coniceps*, *H. difficilis*, *H. dumetorum*, *H. hula*, *H. inquilina*,

H. laetus, *H. pele*, *H. pubescens*, *H. setosifrons*, and *H. volcanicus* were found. Kipuka Nēnē, a diverse mid-elevation dryland site at around 900 m including *Sophora* and upland *Sesbania*, had a number of additional species: *H. connectens*, *H. difficilis*, *H. flavipes*, *H. inquilina*, *H. laetus*, *H. pele*, *H. rugulosus*, *H. sphecodoides*, and *H. volcanicus* were collected there.

Hawai'i leeward coast

The leeward coast of Hawai'i in the Kohala, Kona, and Ka'ū districts is largely devoid of intact, diverse, native coastal vegetation. The area between Kawaihae in the north and Keauhou in the south (Figure 1) is heavily developed for tourism, though the impact of development has not always been entirely negative. Coastal vegetation is dominated by indigenous *Scaevola taccada* and *Ipomoea pes-caprae*, and the introduced *Heliotropium foertherianum* (= *Tournefortia argentea*, tree heliotrope) and *Prosopis pallida* (kiawe). Several large expanses of bare lava, less than 500 years old, occur along the coast, notably at Ka'ūpūlehu; these are almost entirely devoid of vegetation. *Hylaeus* primarily occur on intermediate-aged flows 1,500–5,000 years old, where the rock has weathered somewhat and sand accumulated close to the shore, but little soil developed. At these sites, *Heliotropium* trees may form a scattered to dense line just above the beach or rocky shoreline, while *Prosopis* and other alien plants dominate further mauka. Flows older than 5,000 years, such as from Waialea Bay northwards and along most of the coast between Kailua and Kealakekua, tend to have less *Heliotropium* and *Scaevola*, with *Prosopis* occurring down to the shore. Further south, the coast is slightly wetter and fewer host plants occur; however, there are also fewer access points, limiting the area that can be searched for bees.

This habitat is nearly contiguous from Puakō to Kailua-Kona except where it is interrupted by the 1859 and 1800–1801 lava flows. The Kailua-Keauhou area is heavily developed, and from there south to South Point is mainly younger lava flows with slightly more rainfall, often with non-native vegetation. Several sites of varying age with suitable vegetation can also be found on the Ka'ū coast, including one diverse area at Kamilo (Figure 2).

O'ahu coast

Native coastal vegetation is extremely rare on O'ahu (Figure 3). In contrast to Hawai'i, the leeward (western and southern) shores are almost completely devoid of both *Scaevola* and *Heliotropium*, with only scattered individuals occurring across most of the area. The *Scaevola-Heliotropium* vegetation type is found scattered on the windward side and north shore, but the coastal *Hylaeus* are not generally found in wetter sites such as these. The best sites are on the opposite tips of the island – in the northwest, from Mokolē'ia Beach west to Ka'ena Point, and in the southeast, from Sandy Beach east to Kaloko and at Makapu'u Beach Park. Ka'ena Point and small areas at Kaloko and Makapu'u contain diverse coastal vegetation including *Myoporum sandwicense*, *Santalum ellipticum*, *Sesbania*, *Sida*, and (at Ka'ena) *Euphorbia celastroides*. During 1999–2002, *H. anthracinus* and *H. longiceps* were found abundantly at Ka'ena; no bees were found at Makapu'u and the other sites were not searched.

A small remnant of *Myoporum stellatum* shrubland occurs at Kalaeloa on the 'Ewa plain near the southwest tip of the island. The site is adjacent to Kalaeloa airport (the former Barber's Point Naval Air Station) and most of the surrounding land is or was developed for heavy industry or military use. Nearly all the remaining vegetation is non-native, and this site is the only one for *M. stellatum*.

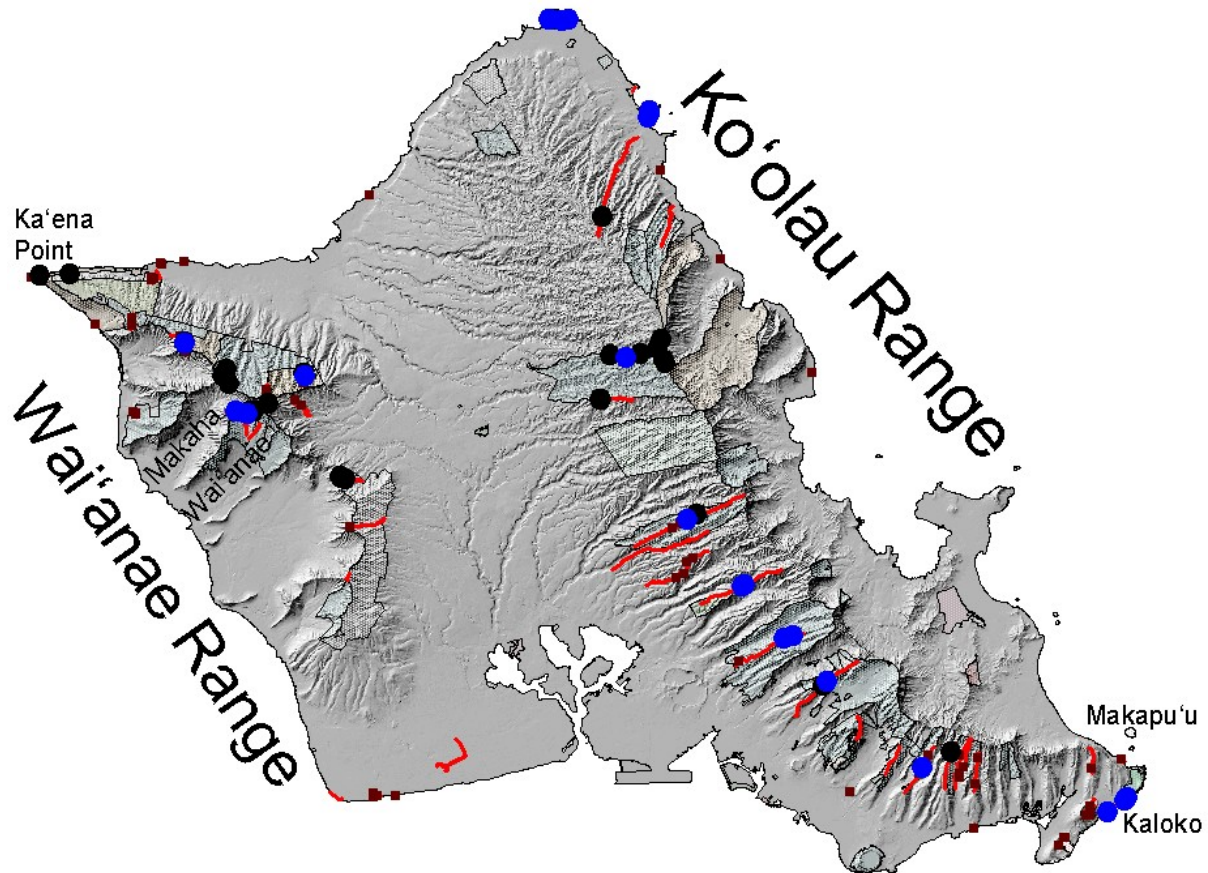


Figure 3. O'ahu collecting sites. Marks as in Figure 1.

Ko'olau range

The Ko'olau range extends along the eastern half of O'ahu, nearly perpendicular to the direction of the trade winds (Figure 3). Due to the relatively low height of the crestline, 700–850 m, there is not a strong rain shadow effect and both the windward and leeward sides of the mountains contain wet forest in the upper reaches, grading into mesic forest on lower portions of both sides. Trails extend up many of the ridges, particularly in the southern and central portions; the northern leeward section and the windward side have much more limited access due to military leases and steep terrain respectively. Most of O'ahu was deforested by the early 1900's as a result of grazing by goats, and what has grown up since their removal has been non-native vegetation (Liebherr and Polhemus 1997). Consequently, on most ridges native vegetation does not begin until reaching an elevation of 400–500 m. In the lower, drier zone, the main flowers visited by *Hylaeus* include *Acacia*, *Metrosideros*, *Santalum freycinetianum*, and *Scaevola gaudichaudiana*; the transition to wet forest proper typically occurs around 600 m, and *Metrosideros* and *Scaevola mollis* are the main floral resources. *Euphorbia multififormis* is sometimes present if native plants extend low enough, but bees have not been found on it here. In 1999–2002, *H. connectens*, *H. mimicus*, and *H. unicus* were collected throughout the elevational range, along with one collection of *H. mana* in the *Santalum* zone and one of *H. specularis* in the wet forest zone. Three species – *H. anomalus*, *H. facilis*, and *H. fuscipennis* – were relatively abundant throughout this area during the early collecting period of 1892–1930, but have not been seen since. This may be due to vegetation changes since that time; *H. facilis* is

mainly found in dry shrubland, which has largely disappeared, and *H. fuscipennis* is associated on Maui Nui with *Cheirodendron*, which is now restricted to the crestline.

Wai‘anae range

Due to its leeward position, the Wai‘anae range receive much less rainfall than the Ko‘olau range and contains primarily dry to mesic forest, with wet forest occurring only at the summit of Ka‘ala (Figure 3). As in the Ko‘olau range, alien plants dominate the lower reaches (often up to 600 m elevation or more). Despite wide differences in aspect, the ridges of this area are remarkably similar in vegetative composition (gulches, in contrast, may differ strongly from one to the next, but they are dominated by plants not attractive to bees, and many are entirely non-native). The dominant trees are *Acacia* and *Metrosideros*, with occasional *Santalum freycinetianum*, and abundant *Bidens torta*, *Dodonaea*, and usually *Euphorbia multififormis* in the shrub layer. Some of the higher summit peaks are wetter and dominated by *Metrosideros*. Ridges ascending from large valleys such as from Wai‘anae or Mākaha may have more diverse vegetation than those coming directly from the plain due to greater moisture, but these are fewer and more difficult to access. Relatively little collecting was done here compared to other areas, but *H. connectens* and *H. unicus* were found at several sites in 1999–2002. In addition, several rare species are known only from sporadic records in the Wai‘anae range: *H. laetus* from Pāhole in the north, *H. kuakea* from a ridge below Pu‘u Hāpapa in the central part, and *H. kuakea*, *H. makaha*, and *H. ulaula* from a patch of rare *Euphorbia rockii* in Mākaha Valley.

Methods

Five of the seven candidate species – *H. anthracinus*, *H. assimulans*, *H. facilis*, *H. kuakea*, and *H. mana* – are known from military sites or immediately adjacent to them on similar habitat (Daly and Magnacca 2003, Magnacca 2007b). In addition to these, 15 rare species that may be the subject of future listing proposals were also included as targets based on their conservation status ranking (Magnacca 2007a) – *H. akoko*, *H. anomalus*, *H. dimidiatus*, *H. filicum*, *H. flavipes*, *H. fuscipennis*, *H. hula*, *H. kona*, *H. laetus*, *H. makaha*, *H. ombrias*, *H. paradoxicus*, *H. specularis*, *H. ulaula*, and *H. volatilis*. During the course of the study, it was decided to drop *H. specularis* as a target species due to the greatly increased collecting effort required for it alone with limited likelihood of success, and four additional species were included. *Hylaeus longiceps* is a candidate species that was not included in the original proposal but occurs in the same habitat as *H. assimulans* on O‘ahu; *H. mimicus* was originally considered to be common enough to be of little concern, but was rarely found during the survey; *H. rugulosus* was expected to be limited to sites outside the target areas but was found at several new localities; and a new species, *Hylaeus mamoo*, was discovered on O‘ahu.

The habits and biology of *Hylaeus*, combined with the environment of Hawai‘i, make these bees impossible to survey quantitatively using methods such as bee plots (LeBuhn et al. 2003). Experience has repeatedly demonstrated that unlike many bees, they are not attracted to bowl or pan traps (LeBuhn et al. in press), even when they can be observed flying over the ground in the immediate vicinity. Even during peak season, flowers that can be reached by a human collector are often few and widely scattered, and capture rates per bee spotted are relatively low. Frequent co-occurrence of common species with rare ones make observational counts unreliable for the purpose of documenting rare species. *Hylaeus* also only visit flowers during sunny periods, and Hawaiian weather is notorious for changing by the minute, particularly in the montane areas

Table 1. Major flowers targeted in this survey.

Species	Common Name	Family	Island
<i>Acacia koa</i>	koa	Fabaceae	
<i>Argyroxiphium kauense</i>	‘āhinahina	Asteraceae	Hawai‘i
<i>Argyroxiphium sandwicense</i>	‘āhinahina	Asteraceae	Hawai‘i
<i>Bidens menziesii</i>	ko‘oko‘olau	Asteraceae	Hawai‘i
<i>Bidens torta</i>	ko‘oko‘olau	Asteraceae	O‘ahu
<i>Dodonaea viscosa</i>	‘a‘ali‘i	Sapindaceae	
<i>Dubautia linearis</i>	na‘ena‘e	Asteraceae	Hawai‘i
<i>Euphorbia celastroides</i>	‘akoko	Euphorbiaceae	O‘ahu
<i>Euphorbia multiformis</i>	‘akoko	Euphorbiaceae	O‘ahu
<i>Euphorbia olowaluana</i>	‘akoko	Euphorbiaceae	Hawai‘i
<i>Euphorbia rockii</i>	‘akoko	Euphorbiaceae	O‘ahu
<i>Heliotropium foertherianum</i>	tree heliotrope	Boraginaceae	
<i>Leptecophylla tameiameia</i>	pūkiawe	Epacridaceae	
<i>Metrosideros polymorpha</i>	‘ōhi‘a lehua	Myrtaceae	
<i>Myoporum sandwicense</i>	naio	Scrophulariaceae	
<i>Sapindus oahuensis</i>	kaulu	Sapindaceae	O‘ahu
<i>Sapindus saponaria</i>	mane	Sapindaceae	Hawai‘i
<i>Scaevola gaudichaudiana</i>	naupaka kuahiwi	Goodeniaceae	O‘ahu
<i>Scaevola mollis</i>	naupaka kuahiwi	Goodeniaceae	O‘ahu
<i>Scaevola taccada</i>	naupaka kahakai	Goodeniaceae	
<i>Sophora chrysophylla</i>	mamane	Fabaceae	Hawai‘i
<i>Santalum ellipticum</i>	‘iliahialo‘e	Santalaceae	O‘ahu
<i>Santalum freycinetianum</i>	‘iliahi	Santalaceae	O‘ahu
<i>Santalum paniculatum</i>	‘iliahi	Santalaceae	Hawai‘i
<i>Sesbania tomentosa</i>	‘ohai	Fabaceae	
<i>Sida fallax</i>	‘ilima	Malvaceae	

where most of the species occur. Therefore, this study is intended to look at presence or absence of bees at sites, not quantify abundance.

Sites were selected based primarily on habitat suitability. Plants with favored flowers, as determined by previous collection records and observations, are listed in Table 1. On O‘ahu, where the terrain is extremely difficult and many areas lack trails, accessibility was also a factor. On Hawai‘i, nearly the entire North Kona-Kohala coastline between Pu‘ukoholā and Kailua, except for barren lava flows, was surveyed on foot along the Ala Kahakai public access trail. Each site was visited multiple times where possible, including at least once during the peak summer flowering period, in order to increase the likelihood of obtaining all potential species. Suitable flowering trees and shrubs were observed for 5–10 minutes; if no bees appeared in that time under favorable conditions, they were considered absent. Bees were netted by hand and identified back in the lab, or in the field if possible. Notes and collections were made of potential competitors and predators, namely ants and alien bees.

Results

One hundred twenty-four field survey days were conducted, 63 on Hawai‘i and 61 on O‘ahu, spread across the various regions (Table 2). Only eleven of the 23 target species were found –

Table 2. Collecting effort across sites.

Hawai'i		O'ahu	
Region	Field Days	Region	Field Days
coast	20	coast	11
Pōhakuloa	15	eastern Ko'olau	11
Mauna Kea	6	central Ko'olau	18
Puu Wa'awa'a	10	northern Wai'anae	10
Lupea	5	southern Wai'anae	3
Ka'ū mauka	3	leeward Wai'anae	8
other	4		

four Hawai'i species, *H. flavipes*, *H. kona*, *H. ombrias*, and *H. rugulosus*; five O'ahu endemics, *H. anomalus*, *H. makaha*, *H. mamō*, *H. mimicus*, and *H. mana*; and two from both islands, *H. anthracinus* and *H. laetus* (Table 3). One new species was discovered on O'ahu, and the record of *H.*

anomalus was the first in over 40 years. The overall decline in abundance and diversity was striking compared to previous years, as even most species earlier considered relatively common were rare. In montane areas, only *H. difficilis* was found at most sites on Hawai'i and *H. unicus* on O'ahu, where previously there had been much more diversity (Daly and Magnacca 2003). Species accounts follow below.

Hylaeus anomalus

This remarkable species was relatively common in early collections from the eastern Ko'olau range, through about 1930 (Daly and Magnacca 2003). Two specimens recently discovered in the University of Hawai'i–Mānoa Insect Museum, one from Tantalus in 1977 and one from 'Aiea in 1978, are the only known collections since then. On the last O'ahu field day of this survey, one male and one female were collected around flowers of *Acacia koa* on Kamaileunu ridge, between Mākaha and Wai'anae valleys (Figure 5). This is the first record of the species from the Wai'anae range, and an indicator of how long these species can persist without being detected. Virtually no *koa* flowering was observed all year on either O'ahu or Hawai'i until this last visit, which may perhaps explain why certain species were in low abundance. Most available collections of *H. anomalus* appear to be from October to February, suggesting that the lack of recent collections may also be related to timing of effort (most collecting has been done in the summer, when other species are more abundant) in addition to their inherent rarity.

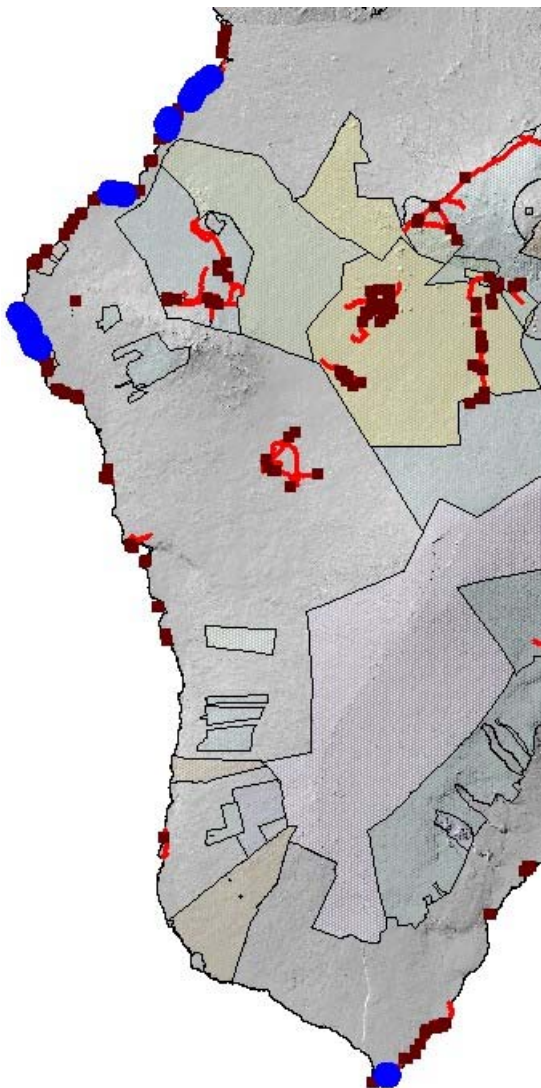


Figure 4. Distribution of *Hylaeus anthracinus* on Hawai'i (blue).

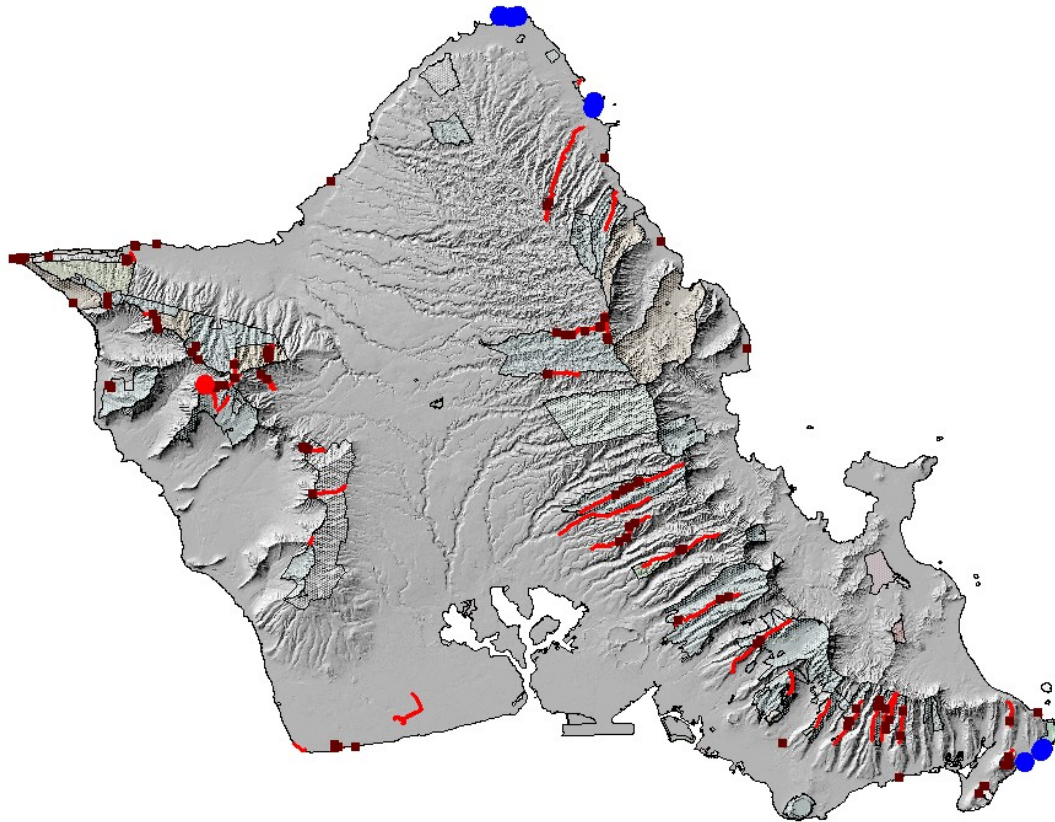


Figure 5. Distribution of *Hylaeus anomalus* (red) and *H. anthracinus* (blue) on O'ahu.

Hylaeus anthracinus

This was the only target species to be found in significant numbers. On Hawai'i, *H. anthracinus* occurs along several stretches of coastline in the North Kona–Kohala area: in Puakō, from Puakō village to the southern end of the Fairmont Orchid hotel property; in Waikōloa, along the frontage of the Hilton Waikoloa Hotel and Kolea condominium property; in Kīholo, at Luahinewai and Manō Point; and the largest, from Keāhole Point to Kōhanaiki, where it co-occurs with *H. difficilis* (Figure 4). Remarkably, this includes two of the large resorts that have been built in this region, indicating that they can survive contact with development. Throughout the inhabited area, they can often be found in extremely high densities, with 20–50 or more bees flying around a single *Heliotropium* tree at any given time – much more than even the most abundant of the “common” montane species.

These sites have several characteristics in common. All are rocky shoreline with *Scaevola* and *Heliotropium*, with either landscaped vegetation, alien kiawe (*Prosopis pallida*), or bare rock inland. The bees are restricted to an extremely narrow corridor between these and the ocean, typically 10–20 m wide, and do not occur on sandy beaches or inland, even on landscaped native plants on hotel grounds. Alien bees, such as *Ceratina arizonensis* and *C. smaragdula*, were sometimes found on cultivated flowers. *Hylaeus* were observed entering holes in coral rubble deposited on shore, and this may be their primary nesting site and a limiting factor on their distribution (*H. difficilis* also occurs in this area, including at sandy beach areas north of Keāhole Point and at Kekaha Kai State Park where *H. anthracinus* was not found). The widespread ant

Table 3. Target species, habitats, and summary of survey results. SOC – Species of Concern; C – Candidate endangered species.

Species	Island	Habitat	Status	Collected?	Sites
<i>Hylaeus akoko</i>	Hawai'i	dry forest			
<i>Hylaeus anomalus</i>	O'ahu	mesic forest	SOC	●	Wai'anae
<i>Hylaeus anthracinus</i>	Hawai'i, O'ahu	coast	C	●	Kona-Kohala coast, South Point, Kahuku, Malaekahana, Kaiwi
<i>Hylaeus assimulans</i>	O'ahu	coast, dry forest	C		
<i>Hylaeus dimidiatus</i>	Hawai'i	dry forest	SOC		
<i>Hylaeus facilis</i>	O'ahu	dry shrubland	C		
<i>Hylaeus filicum</i>	Hawai'i	wet & mesic forest	SOC		
<i>Hylaeus flavipes</i>	Hawai'i	coast, dry forest	SOC	●	Mauna Kea, PTA, South Point
<i>Hylaeus fuscipennis</i>	O'ahu	wet & mesic forest	SOC		
<i>Hylaeus hula</i>	Hawai'i	dry & mesic forest	SOC		
<i>Hylaeus kona</i>	Hawai'i	dry forest	SOC	●	Mauna Kea, PTA
<i>Hylaeus kuakea</i>	O'ahu	mesic forest	C		
<i>Hylaeus laetus</i>	Hawai'i, O'ahu	dry shrubland	SOC	●	Pāhole, PTA
<i>Hylaeus longiceps</i>	O'ahu	coast	C	●	Ka'ena, Kahuku
<i>Hylaeus makaha</i>	O'ahu	mesic forest		●	Manuwai, Wai'anae
<i>Hylaeus mamo</i>	O'ahu	mesic forest		●	Tripler
<i>Hylaeus mana</i>	O'ahu	mesic forest	C	●	'Aiea, Mānana, Tripler, Lanipō
<i>Hylaeus mimicus</i>	O'ahu	wet & mesic forest		●	Poamoho, Lanihuli
<i>Hylaeus ombrias</i>	Hawai'i	coast, dry forest	SOC	●	Pu'u Wa'awa'a
<i>Hylaeus paradoxicus</i>	Hawai'i	dry & mesic forest			
<i>Hylaeus rugulosus</i>	Hawai'i	dry & mesic forest		●	PTA, Saddle Road
<i>Hylaeus ulaula</i>	O'ahu	mesic forest			
<i>Hylaeus volatilis</i>	O'ahu	dry forest & shrubland	SOC		

Anoplolepis gracilipes (long-legged ant or yellow crazy ant) was often found in close proximity, but almost never on plants visited by *Hylaeus*; the ants were often extremely abundant in the slightly denser, moister vegetation just inland of the coastal strand, where bees were not found. The southern end of the *H. anthracinus* population is precisely at the boundary between Kōhanaiki and Kaloko–Honokōhau National Historical Park, at a point where the vegetation becomes denser and *Anoplolepis* ants become evident down to the shoreline, suggesting that they constrain the distribution of *Hylaeus*.

Just to the south, a few more sites appear suitable but had only *H. difficilis*. Beyond Kailua-Kona, there are few sites with good vegetation, and no *Hylaeus*. A very small population of *H. anthracinus* persists at Kaulana Bay just east of South Point, widely disjunct from the remainder in North Kona. However, previous work has shown that the populations are not genetically distinct, despite a high level of difference among the Kaulana individuals (Magnacca and Brown 2010), indicating that *H. anthracinus* probably formerly occurred along the entire Kona coast.

On O'ahu, the situation is more grim. The major population on the island was at Ka'ena Point on the northwestern tip of the island, where both *H. anthracinus* and *H. longiceps* were abundant (Hopper 2002, Daly and Magnacca 2003). Repeated visits during this project found no *H. anthracinus* and only two (male) *H. longiceps*, though anecdotal reports indicate that *Hylaeus*

were easily found there at least through 2010, and *Ceratina* are abundant (S. Plentovich, pers. comm.). However, two previously unknown populations were discovered on the opposite ends of the island: one in the southeast at Sandy Beach Park and Kaloko (Kaiwi Scenic Shoreline), and one in the northeast at Kahuku Point. At the former, the density of bees is high but they occur only in two extremely small patches, about 1.2 km apart (Figure 5). The larger, eastern site has an accumulation of coral rubble on the shore, and the western one is centered on a small rock wall which bees constantly flew around and entered; no such material is found where the bees are absent, though plants are still present. This strongly suggests that nest-site limitation is an important factor in the distribution of *H. anthracinus*. At Kahuku, the density is low but they occur scattered along a roughly 1 km stretch of beach. Another, smaller population was found nearby at Malaekahana, on the shore directly opposite the islet of Mokuauia. Some of the offshore islets may also have populations of *H. anthracinus*; they were documented from at least two, Mokuauia and Moku Iki, as of 2004 (Plentovich 2010). However, Mokuauia was invaded by *Anoplolepis gracilipes* ants in 2006 (Plentovich et al. 2011). The islets were not visited for this study.

The newly-arrived alien *Hylaeus strenuus* was found in company with *H. anthracinus* at Malaekahana, and not far away from the populations at Kaloko and Ka'ena. It is potentially a serious competitor for floral resources, and regularly visits both *Scaevola taccada* and *Heliotropium foertherianum*, the two main food plants of *H. anthracinus*.

Hylaeus flavipes

This species was previously known from several widely scattered localities on Hawai'i: Kīpuka Nēnē and South Point in Ka'ū, and Ka'ohē GMA and Hale Pōhaku on Mauna Kea. In this survey, *H. flavipes* was found at all of these except the last, and in addition was found in Pōhakuloa Training Area at Area 21 and Area 4, and nearby at Mauna Kea State Park (Figure 6). At all the Mauna Kea/PTA sites, it was associated with *Myoporum*. Previously, it was collected at *Sophora* at Kīpuka Nēnē and Hale Pōhaku (Daly and Magnacca 2003), but *Sophora* flowering during the survey period at these areas was brief and occurred in the fall. At Pōhakuloa, *H. flavipes* was found only at a few sites, and in July but not August. However, to the west at Ka'ohē on Mauna Kea they were absent in July after having been found there in May, indicating that they may only be active for short periods but that their seasons differ at different sites.

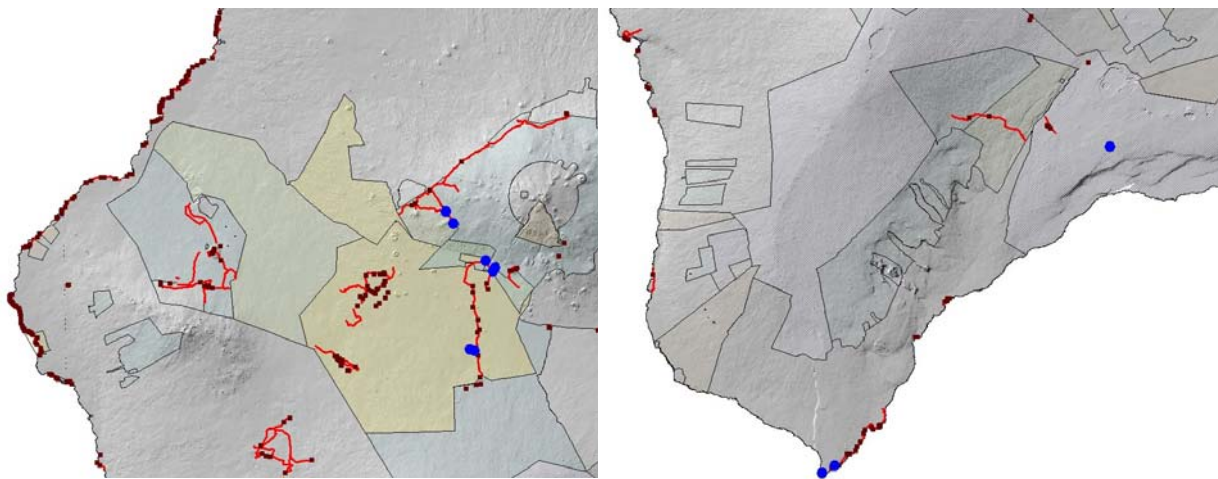


Figure 6. Distribution of *Hylaeus flavipes* in Mauna Kea and Pōhakuloa (left) and Ka'ū (right), indicated by blue marks.

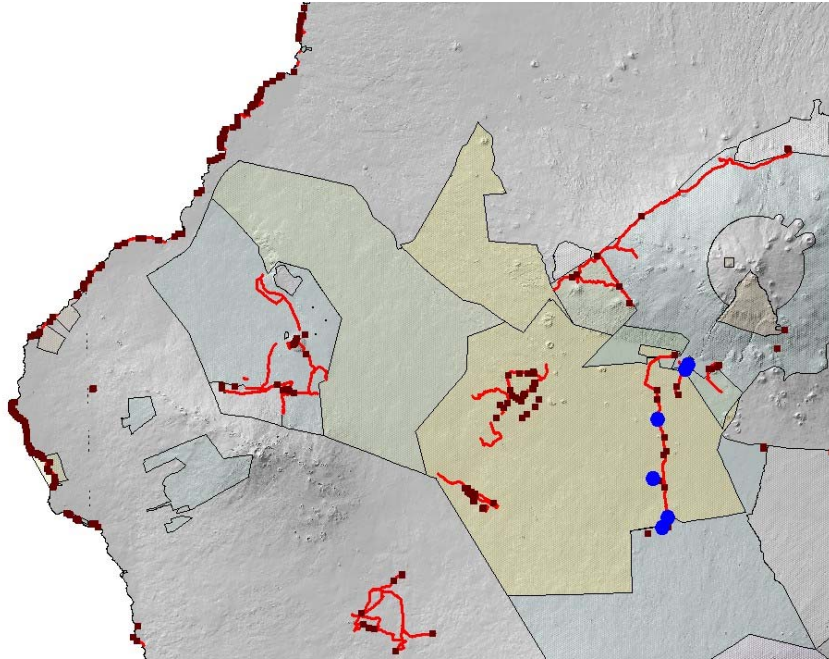


Figure 7. Distribution of *Hylaeus kona* (blue marks).

The population at South Point is extremely tenuous. The bees occur only at a small patch of windswept prostrate vegetation near the point itself, and at one *Heliotropium* patch about 2 km to the east. The area has been hit hard by the ongoing drought and by human impacts, including off-road driving and trampling, and few foraging plants were available. Most of those that were present during the first visit in March were dead or dormant by July. Likewise at Kīpuka Nēnē, the sprawling *Sesbania* runners that had served as the primary flower source for *H. flavipes* there have died back significantly compared to previous years. While *H. flavipes* was still present, the other bee species that were formerly found there in relative abundance were all missing.

Hylaeus kona

This species was found almost exclusively in July, at several sites along the Redleg Trail (Area 21) and Area 4 in Pōhakuloa Training Area, and immediately adjacent at Mauna Kea State Park and Pu‘u Kōlī (Figure 7). It was often found in company with *H. flavipes*, which it closely resembles. Followup searches from August onward failed to find either species at any of the previous sites, with the exception of a single *H. kona* found at Pu‘u Kōlī in October; only *H. difficilis*, the most common Hawai‘i species, was present at most sites. Previously *H. kona* had been found at both Kīpuka Kalawamauna (Area 22) and Kīpuka ‘Alalā (Area 23); it has not been collected elsewhere for several decades.

Hylaeus laetus

Hylaeus laetus is morphologically similar to the common *H. difficilis*, but favors middle to lower elevation dry forest and shrubland, avoiding wet forest and coastal habitats altogether. It was not originally considered a target species on Hawai‘i, since it had previously been quite common, but it was extremely rare throughout the survey (Figure 8). On Hawai‘i it was found only on the west side of PTA, and only after August. On O‘ahu it has always been rare,

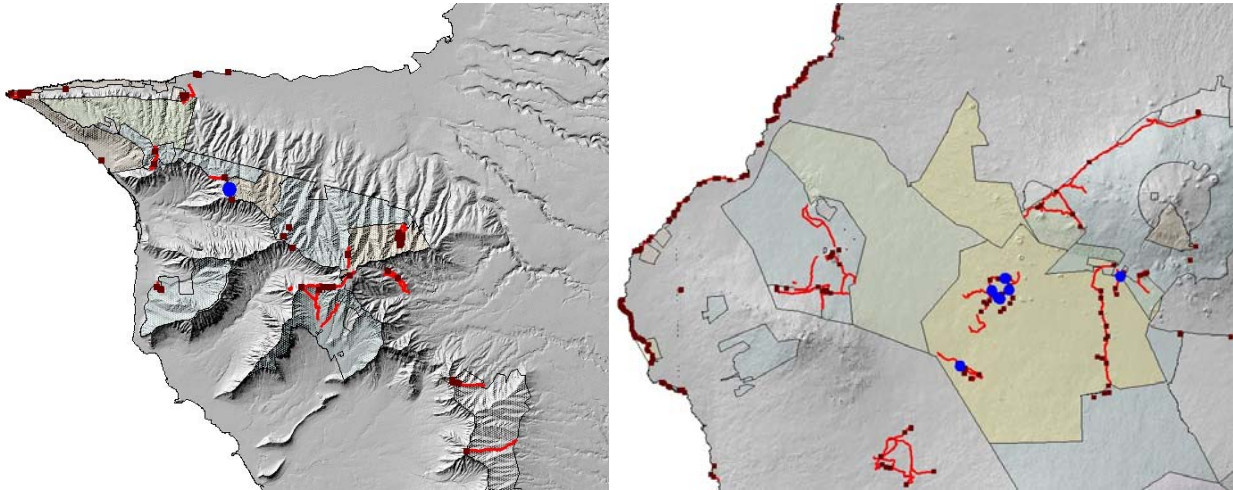


Figure 8. Distribution of *Hylaeus laetus* (blue marks) on O'ahu (left) and Hawai'i (right).

presumably due to the much smaller quantity of habitat available. However, it was still only collected from Pāhole, just 700 m from the sole previous collection in 2001. This was despite the expansion of collecting effort with this survey into much more dry forest and shrubland habitat, identical to that of the collection site, throughout both the northern and southern portions of the Wai'anae range.

Hylaeus longiceps

Found on both O'ahu and the islands of Maui Nui, this species is extremely rare on Maui but was found in moderate numbers on Lāna'i and Moloka'i during 1999–2002, and formerly had a significant population at Ka'ena Point (Daly and Magnacca 2003). However, like *H. anthracinus* there, it has almost completely disappeared in the last few years. Over the course of multiple visits to Ka'ena, only two individuals were observed (both males), despite good flowering of the plants, favorable weather, and few alien bees. This had been the only known population on O'ahu, but late in this survey a second one was discovered at Kahuku Point (Figure 9). Although small in area, they occur at relatively high density on *Sesbania* and *Heliotropium* there. This area is potentially threatened by development – it is directly makai of the Turtle Bay Resort golf course, and although earmarked as “park” land in the Turtle Bay expansion draft supplemental EIS (Sichter 2012), impacts on native invertebrates were not considered, nor were the *Sesbania* noted in botanical surveys for the DSEIS.

Hylaeus makaha

This O'ahu endemic species, related to *H. kona*, was only described in 2011 (Magnacca 2011). The first collection was of a single female from Mākaha Valley on the leeward side of the Wai'anae range in September 2009, and in August 2010 more were found at the same site, along with another new species, *H. ulaula*, and the candidate species *H. kuakea* (itself only discovered in 1997 and described in 2003). Visits to the site during this survey found most of the mature individuals of the endangered plant they were primarily collected on, *Euphorbia rockii*, dead (presumably from drought stress) and no bees at all. However, a single individual was collected in the eastern Ka'ala Natural Area Reserve while sweeping vegetation during poor weather, the first male ever found. A second collection was made in Wai'anae Valley, on

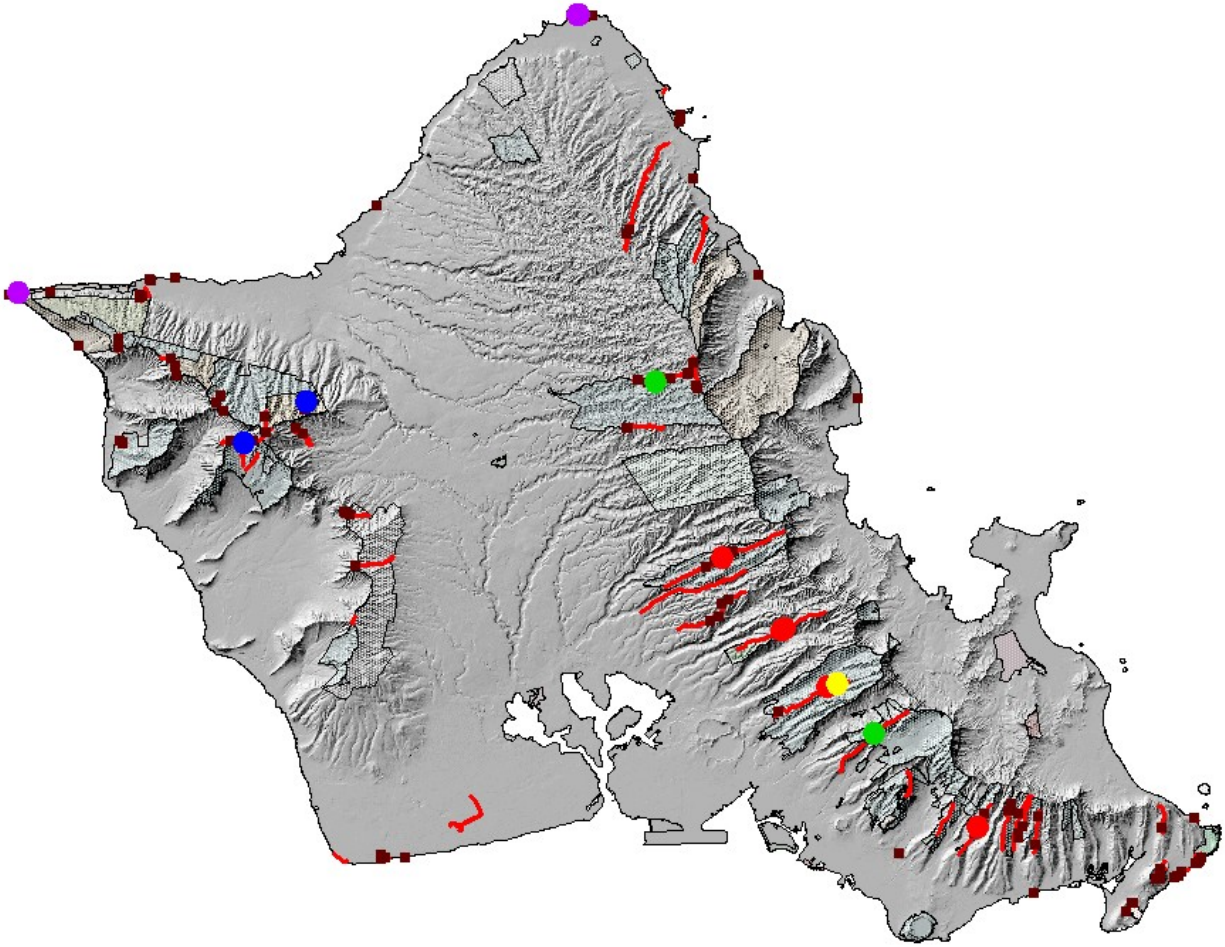


Figure 9. Distribution of *Hylaeus longiceps* (purple), *H. makaha* (blue), *H. mamoo* (yellow), *H. mana* (red), and *H. mimicus* (green) on O‘ahu.

Euphorbia multiformis about 1.2 km from the original Mākaha site, with both males and females together (Figure 9). While *Euphorbia olowaluana* has been a productive species for bee collecting on Hawai‘i, the smaller species on O‘ahu have rarely been found with bees.

Hylaeus mamoo

While searching for *H. mana* on Tripler ridge in the central Ko‘olau range during the last O‘ahu field trip of the survey, a single male was collected which turned out to be yet another new O‘ahu endemic species (Figure 9). It is instantly recognizable, as the only Hawaiian species with a yellow mark on the gena and the only one besides *H. kona* to have the mandibles yellow. It is quite small, like *H. mana*, and given that it has eluded detection for so long, it is probably similarly rare.

Hylaeus mana

Another rare and recently-discovered O‘ahu endemic, this species had been known only from 4 specimens collected in 2002 on the Mānana Trail at flowers of *Santalum freycinetianum*. During this survey, it was found at four ridges across the central and eastern Ko‘olau range (Figure 9). All were from the middle or lower portions of the ridge, and of the five collections

three were from *Santalum* (one was of a resting bee on a cool day in the vicinity of flowering *Santalum*, and the last on *Psychotria*; the latter is probably an incidental record, since *Hylaeus* visit *Psychotria* relatively infrequently). Taken together, these records suggest that *H. mana* is a specialist on *Santalum* and is probably restricted to the relatively narrow zone where it occurs in the Ko‘olau range. While *Santalum* occurs in moderate abundance and *H. mana* is probably more common than previously recognized, the narrowness of its habitat and the presence of abundant *Lasioglossum impavidum* around *Santalum* at some of the sites show that it remains under threat.

Hylaeus mimicus

Like the preceding two species, this is an O‘ahu endemic that appears to be confined to the Ko‘olau range. In 1999–2002 it was collected from ‘Aiea and Wiliwiliui ridges on multiple occasions and from a variety of flowers (Daly and Magnacca 2003). During this survey, only two individuals were found, one each on Poamoho and Lanihuli ridges (Figure 9). One of the plants it was collected on previously, *Scaevola gaudichaudiana*, was flowering abundantly through most of the year but had few visitors; however, there was almost no flowering of *Acacia koa*, another tree that several *H. mimicus* were collected from previously. While not a commonly-used flower in general by *Hylaeus*, if *H. mimicus* is linked to koa then it may explain the reduction in numbers of this species.

Hylaeus ombrias

Like *H. flavipes*, this is a basically coastal/lowland species that also occurs in high elevation montane dry forest habitats on Hawai‘i. Its large size may be an adaptation to feeding on the large pollen grains of *Sida fallax* and other Malvaceae, which are visited by other *Hylaeus* but rarely utilized for pollen (Magnacca, unpublished data). During this survey, only a single individual was found, in a rare plant restoration area on Pu‘u Wa‘awa‘a cone (Figure 10). It was not found at South Point or PTA, where it had been found in moderate numbers previously (Daly and Magnacca 2003), despite abundant flowering of *Sida* and *Bidens* at the latter.

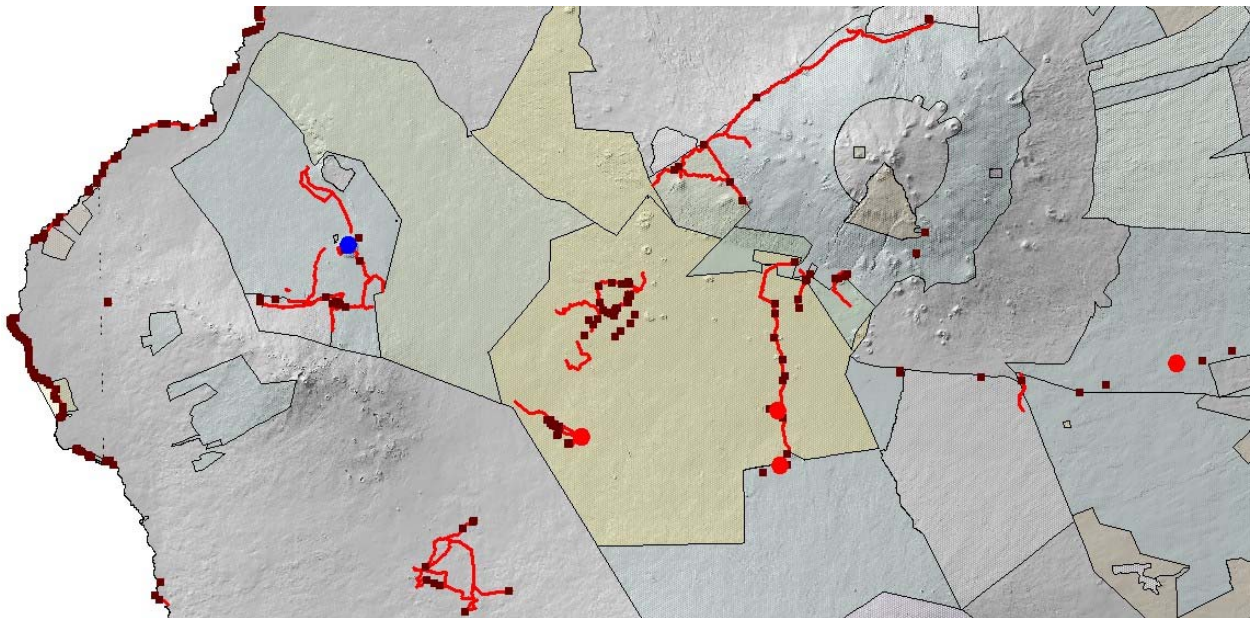


Figure 10. Distribution of *Hylaeus ombrias* (blue) and *H. rugulosus* (red) on central Hawai‘i.

Hylaeus rugulosus

This enigmatic species appears to have no close relatives and had been known from only two recent collections, both in Hawai‘i Volcanoes National Park (Daly and Magnacca 2003). Consequently, although it was known to be rare it was not considered a target species since it was thought to occur only outside the primary survey area. However, during the course of this project it was found across a broad area of the north slope of Mauna Loa in the saddle with Mauna Kea (Figure 10). Collections came from *Metrosideros polymorpha*, *Myoporum sandwicense*, and *Dodonaea viscosa*. Although still uncommon, it was the only species other than the common *H. difficilis* to be found widely in time as well, being found in April, July, and November.

alien *Hylaeus*

At least two non-native species of *Hylaeus* are known to be established in Hawai‘i. *Hylaeus (Gnathoprosopis) albonitens*, a native of Australia, has been present since at least 1995 and is established on at least Kaua‘i, O‘ahu, Moloka‘i, and Hawai‘i (Snelling 2003). However, it appears to have remained confined to relatively few widely separated but small localities. In this survey, it was collected on Hawai‘i at lower Pu‘u Wa‘awa‘a; PTA Area 22 outside Kīpuka Kalawamauna; Palamanui, a remnant dry forest above the Kona airport; and a single individual at Waikōloa near the *H. anthracinus* population. On O‘ahu it was found only twice, at the head of Kaluakauila Valley and on the road to the summit of Mt. Ka‘ala. All of these except Waikōloa are sites with only *Metrosideros* available as a pollen source and no native *Hylaeus*.

In 2007, a new immigrant *Hylaeus* was reported from O‘ahu, and later identified as *Hylaeus (Indialaeus) strenuus* (Dathe 2011, Magnacca et al. 2011). The initial collections were strictly from coastal sites in the east Honolulu area, primarily on *Scaevola taccada*, and it was expected to be a potential serious competitor to the native coastal *Hylaeus*. Since then, it has spread throughout the island. At present, its habitat preferences are difficult to discern (all *Indialaeus* species are virtually unknown in their native range). In this survey, it was found at the coast broadly along Mokulē‘ia beach, east of Ka‘ena, and at Sandy Beach and Kaloko, near the *H. anthracinus* populations. Two collections were made on *Metrosideros polymorpha* flowers on adjacent ridges in the central Ko‘olau range, indicating the potential to invade montane habitats.



Figure 11. *Hylaeus strenuus*, a recent introduction from India. Left: female collecting pollen from the stamens of *Erythrina sandwicensis* (Fabaceae). Right: male holding a droplet of regurgitated nectar.

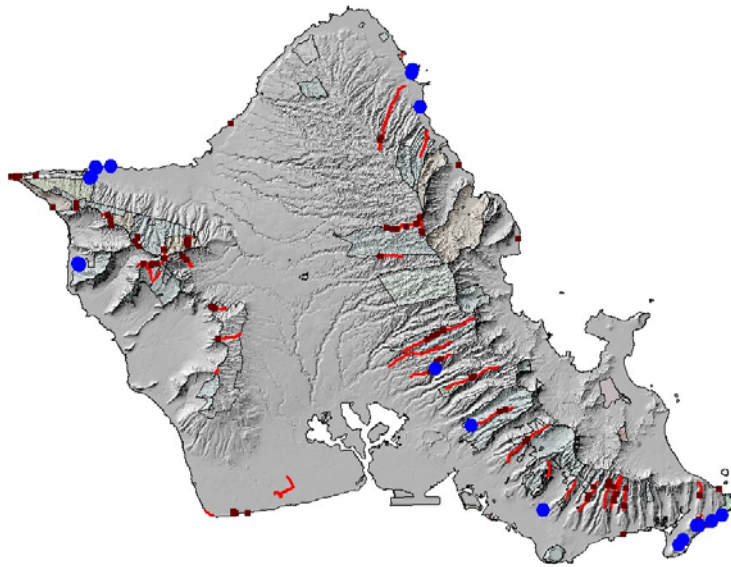


Figure 12. Distribution of *Hylaeus strenuus* (blue) on O‘ahu.

However, it was not recovered from some of the earlier sites where it was found, including Ala Moana Beach Park, suggesting it may not be competitive in these habitats. At the same time, it was consistently found at *Erythrina* flowers, both the native *E. sandwicensis* (wiliwili) and various introduced ornamental or cultivated species. These flowers are clearly evolved to be bird-pollinated – they are large, predominantly red to orange, with a large quantity of relatively dilute nectar concealed beneath overlapping petals – and no bees or other insects were seen visiting them, though honeybees are known to do so occasionally.

Individuals of *H. strenuus* were repeatedly observed both climbing the long stamens to collect pollen, and extruding a droplet of nectar while resting on a branch in order to concentrate it (Figure 11). Members of the subgenus *Indialaeus* are distinctive for their broad, flat mandibles, which may be adapted for the purpose of holding these droplets. The ability of these bees to find remote *Erythrina* populations, the behavioral and morphological characters they exhibit, and their relatively limited distribution in native *Hylaeus* habitat after at least five years suggests that *H. strenuus* may not be a serious competitor to the native species, but it should be monitored.

In addition to the two species discussed above, the European *H. (H.) leptcephalus* was documented from O‘ahu in the 1950’s, but there is only a single specimen recorded since then (in 1994) and it is unknown if it is still present. While this survey was in progress, surveys in lowland disturbed sites by Dr. S. Droege (USGS) discovered a single female of a new adventive species, identified by Dr. H. H. Dathe as *H. (Prosopisteron)* sp. from Australia (Magnacca et al., submitted). Whether this species is established is unknown; searches for it in the vicinity of the original collecting site (in Kalihi Kai near the cargo docks) and elsewhere have failed to turn up additional specimens.

Ceratina

Three species of *Ceratina*, all introduced, occur in the Hawaiian Islands: *C. (Ceratina) arizonensis*, *C. (Neoceratina) cf. dentipes*, and *C. (Pithitis) smaragdula*. All are only found at the coast, except *C. cf. dentipes* which is occasionally found inland. The latter is a parthenogenic species whose exact provenance and identity are unknown (Snelling 2003). *Ceratina arizonensis* is restricted to the North Kona coast of Hawai‘i, where it co-occurs with the other two species (though it is rare for more than two of the three to occur in a single site). *Ceratina cf. dentipes* occurs on all the main islands, and in this survey was also found along the Ka‘ū coast and at Ka‘ena Point. Both of these species were relatively uncommon, and are probably not major competitors with *Hylaeus* despite often inhabiting the same localities.

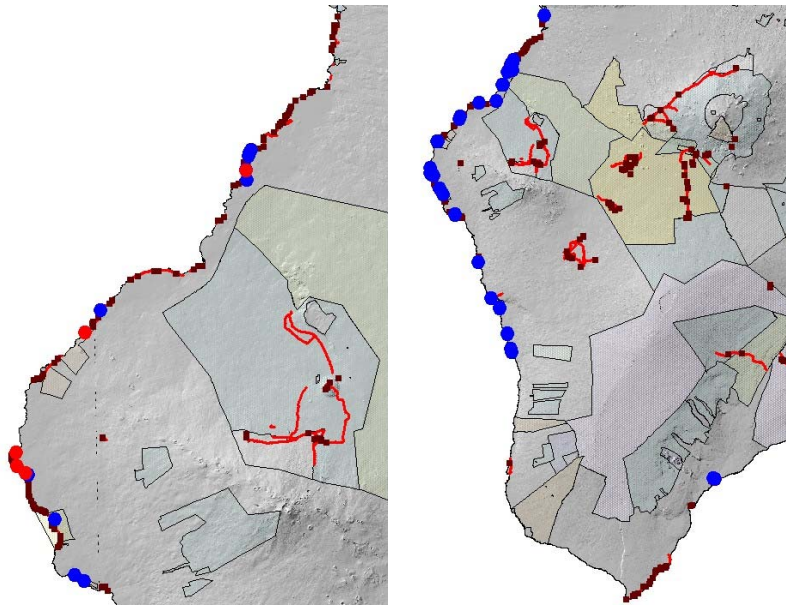


Figure 13. Left: Distribution of *Ceratina arizonensis* (red) and *C. cf. dentipes* (blue) in Kona, Hawai'i. Right: *Ceratina smaragdula* on Hawai'i (blue).

Ceratina smaragdula is the latest arrival, first recorded in 1999, but is already more widespread and abundant than the others (Figure 13). It frequently occurs in large numbers, and may be a factor in the reduction of native *Hylaeus* populations in some areas. On O'ahu, it is found at dry coastal sites at the corners of the island: Ka'ena, Mokulē'ia, Kahuku, Sandy Beach, and Kalaeloa (Barber's Point), as well as in disturbed sites. On Hawai'i, it is found along most of the Kona-Kohala coast and at Punalu'u in Ka'ū, though it is notably absent from both the Puakō and Kōhanaiki-'O'oma areas, where

the largest concentrations of *H. anthracinus* occur. The two species are sympatric at Waikōloa and Keāhole, raising the question of whether *C. smaragdula* is increasing competitive pressure on *H. anthracinus* or if in fact the latter is able to exclude the former under favorable conditions.

Lasioglossum

Only one species of Halictidae had been recorded from Hawai'i, *Lasioglossum impavidum* (Snelling 2003). During the course of this project, collections by Dr. Sam Droege (USGS Patuxent Wildlife Research Center) found two species of *Lasioglossum* (*Dialictus*) widespread in

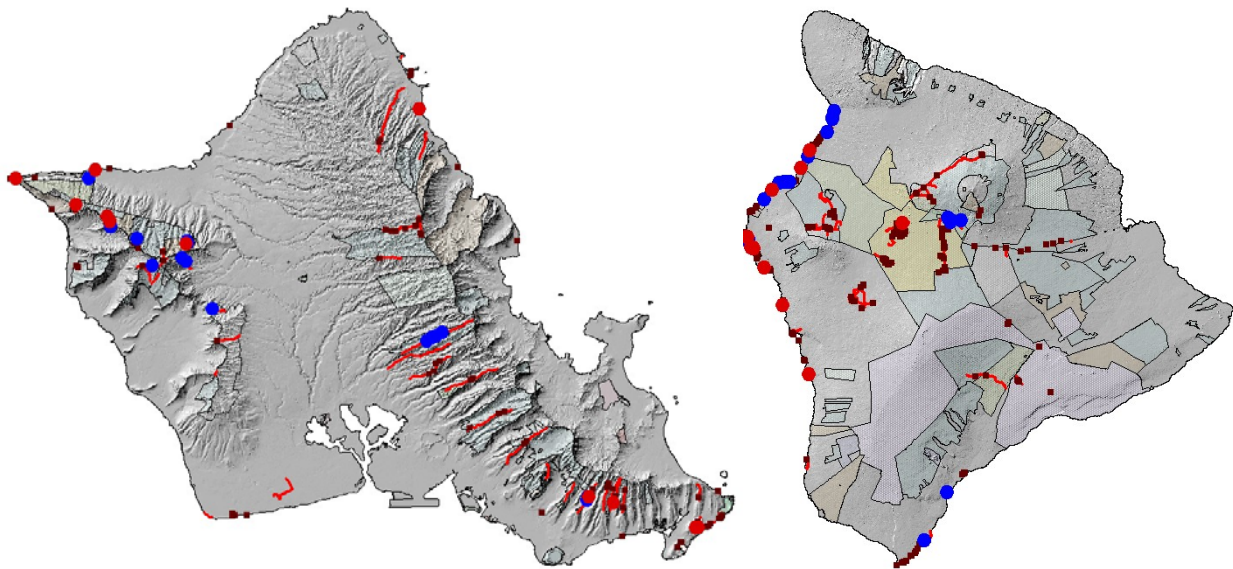


Figure 14. Distribution of *Lasioglossum impavidum* (blue) and *L. imbrex* (red) on O'ahu and Hawai'i.

disturbed coastal and lowland sites on O‘ahu (Magnacca et al., submitted). These were identified by Dr. Jason Gibbs as *L. microlepoides* and *L. imbrex*. On O‘ahu, these two species co-occur frequently. The former is almost entirely restricted to coastal and urban areas and is the more abundant in those habitats; so far only one collection has been made in the mountains, at Kaluakauila, in company with both other *Lasioglossum*. It has not been detected on other islands to date and is likely a recent introduction. Given its rapid dominance in disturbed habitats, it may be a significant pollinator of invasive weeds. *Lasioglossum imbrex* is also primarily found in coastal sites, but was also found on several ridges in the northern Wai‘anae range. *Lasioglossum impavidum*, the longest-established species, is almost exclusively found in the mountains on O‘ahu, but is widespread along the coast of Hawai‘i, suggesting it may have been displaced on O‘ahu by the arrival of *L. microlepoides*. Interestingly, *L. impavidum* and *L. imbrex* seem to occur interdigitated in North Kona but are only rarely sympatric (Figure 14). Both are infrequent in upper montane regions of Hawai‘i and were found there only at Pōhakuloa.

Megachile

Leafcutter bees were uncommon at most sites. *Megachile umbripennis* was widespread and found at numerous locations on the Kona coast from Honokōhau south, and a few in Ka‘ū, but did not overlap with the range of *H. anthracinus*. *Megachile timberlakei* was scattered in a few sites along the Kona and Ka‘ū coasts, co-occurring with both *H. anthracinus* and *H. flavipes* at South Point, but was rare and probably not a major competitor. It was also found on O‘ahu at Ka‘ena and Makapu‘u. A third species, *M. gentilis*, was collected on O‘ahu at Koko Head Botanical Garden. Four other megachilids are recorded from the state (Snelling 2003) but were not found here.

Discussion

The decline in abundance and diversity in Hawaiian *Hylaeus* compared to recent collections is striking and disturbing. Although quantitative measures are highly imperfect for a survey such as this, they are nonetheless illustrative. Effort has been much greater than in 1999, especially on O‘ahu, but the relative number of specimens obtained is well below that of the earlier period (Table 4). Indeed, the two days of collecting at Pōhakuloa Training Area in 1999 alone found 92 individuals of 8 species, 40% of the total for 2012.

A major consideration for future *Hylaeus* surveys is the extreme difficulty in finding many species reliably even in areas where they are present. Day-to-day and even hour-to-hour changes in weather easily affect findings. Several of the species in this survey – notably *H. makaha*, *H. mamo*, and *H. ombrias* – were only found as a result of somewhat arbitrary decisions to look in a certain place at a certain time, often after having visited the same site repeatedly (even on the same day). This element of random chance is frustrating for any attempt to conduct a thorough

Table 4. Comparison of effort and results in 1999 and 2012 surveys.

	Hawai‘i		O‘ahu	
	1999	2012	1999	2012
days	22	63	8	63
species	17	15	5	10
specimens*	160	250	56	96

* - Hawai‘i numbers exclude the abundant *H. difficilis*

and standardized survey, yet it is frequently the only way that some species are detected at all.

The current severe drought in Hawai‘i, which has been ongoing since 2010 and particularly affects the eastern islands, may be partly to blame for the low numbers of bees. In 1998 and 1999, the start of the previous collecting period, there was also a drought, but

it was much less intense and many plants seemed to react to stress by increased flowering during that year. With the current drought now three years old, many plants may be too stressed to produce flowers and particularly nectar. However, this cannot be the explanation for everything. O‘ahu received an average amount of rain this year, including several large storms, and even during the summer it rained twice during visits to Ka‘ena Point; indeed, the plants there looked relatively healthy. Yet the *Hylaeus* that had been abundant there a few years ago are now almost completely gone.

In the upland areas of Hawai‘i, the naio thrips, *Klambothrips myopori* (Thysanoptera: Phlaeothripidae), may be having a severe impact on *Hylaeus* populations by reducing flower production and causing plant mortality. First detected on Hawai‘i in 2008, it has since spread throughout most of the area of high-density *Myoporum sandwicense* forest, between Mauna Kea, Mauna Loa, and Hualalai. The hardest-hit area is in Pōhakuloa, where mortality is extremely high at some sites. Even where infestations are relatively low, flowering is usually much reduced compared to healthy plants. Earlier work on pollen usage by *Hylaeus* (K. Magnacca, unpublished data) found *Myoporum* to be unusual in that it was both heavily used as a pollen source, and a “nectar plant” in the sense that a disproportionate number of bees collected on it were carrying pollen from another type of plant. Thus, it may play an important role both as a food plant during brood rearing and in maintaining adult populations through seasons when other flowers are not available. *Myoporum* flowering and *Hylaeus* abundance and diversity were correlated – Pu‘u Wa‘awa‘a and PTA Areas 22 and 23 (formerly highly diverse sites) were heavily affected by thrips and had little flowering and few bees, while Ka‘ohe GMA and PTA Areas 4 and 21 had only light infestations, moderate flowering, and had *H. flavipes* and *H. kona* present. Despite the extremely dry conditions, there was heavy flowering of *Euphorbia olowaluana* and *Bidens menziesii*, two other plants favored in previous years (Daly and Magnacca 2003), yet bees were largely absent from both in areas where *Myoporum* was severely affected.

It is unknown to what extent *Hylaeus* may be able to survive extended periods of famine. To be sure, this is hardly the first severe drought to strike the islands, and the role of *Myoporum* as a moderating influence is as yet unknown. The question is whether populations such as *H. anthracinus* and *H. flavipes* at South Point, already reduced by habitat loss and direct human impacts, will be able to persist until their food plants resprout or regrow. In many cases, there are no nearby populations that could act as dispersal sources if isolated populations do die out.

The Hawai‘i population of *H. anthracinus* is the only target taxon found in healthy numbers, and even it is limited to an extremely narrow distribution that could easily be threatened by the introduction of a new alien competitor, expansion of ant populations, or even a single stochastic event such as a major tsunami. The disjunct population in Ka‘ū is in an even more perilous situation, inhabiting a short stretch of coastline less than 500 m long with few resources. There is only a single montane record of this otherwise coastal species, from Pōhakuloa Training Area (Magnacca 2007b). The precise locality is not known, but it was found resting in a fruit capsule of *Kadua coriacea*, which typically occurs in open *Metrosideros* treeland, a generally poor habitat for *Hylaeus*. While some other typical coastal species occur in the broader area, namely *H. flavipes* and *H. ombrias*, no additional *H. anthracinus* specimens have been found, and it is questionable whether a permanent breeding population exists there. These factors, combined with the lack of significant genetic divergence between other disjunct populations and relative abundance of *H. anthracinus* along the Kona-Kohala coast, indicate that resources would be best utilized in preserving and expanding coastal populations. Given the high densities found in the

present restricted locations, reintroduction via translocation into suitable restored coastal and lowland habitats may be a viable conservation option, with little impact on the source population.

The extensive reliance on the introduced tree heliotrope, *Heliotropium foertherianum* (= *Tournefortia argentea*), as a floral resource by *H. anthracinus* and *H. longiceps* is a critical discovery of this survey. Along most of the Kona-Kohala coast, this was the dominant flower visited by *H. anthracinus*, which was never found at sites where only *Scaevola taccada* was present. As a non-native tree which is capable of crowding out rare native coastal species, *He. foertherianum* is sometimes targeted for removal by resource managers. In areas where native plant diversity and abundance is high and capable of supporting bees on their own, or where intensive active management is occurring to promote such conditions, removal is warranted. This is particularly the case where *He. foertherianum* is forming dense stands, which appear to provide suitable habitat for invasive ant species such as *Anoplolepis gracilipes* that exclude *Hylaeus*. Total removal of *He. foertherianum* from low-diversity areas where it is relatively non-invasive, solely for the sake of removing alien plants, would be seriously detrimental to the continued existence of *Hylaeus* at such sites; however, thinning dense stands could potentially help in certain conditions, by making an area too dry for ants to persist. Therefore, we urge caution and judgement be used when removal of *He. foertherianum* is considered. Both short and long term outcomes may be difficult to predict.

For montane species, development is not a serious issue since they occur primarily or exclusively in areas remote from direct human impacts and often at sites that are already at least semi-protected, such as forest reserves. However, the coastal species, including *H. anthracinus*, *H. flavipes*, *H. longiceps*, and *H. ombrias* (as well as *H. assimulans*, which was not found in this survey but occurs in similar situations on Maui), frequently live in areas of high human disturbance. Both *H. anthracinus* and *H. longiceps* were found adjacent to major resorts or even on their immediate frontage. While this indicates that native bees are capable of living in proximity to development, their restricted distributions underscore the potential for rapid change. For example, *H. anthracinus* is found at some Kohala resorts but not others, and both *H. anthracinus* and *H. longiceps* are found close to Turtle Bay but not at it, despite the presence of (to human eyes) suitable habitat in all cases. This suggests that other factors may be at play, such as differing groundskeeping methods that may affect the availability of nesting sites.

Ants have had enormous impacts on the native invertebrate fauna of Hawai'i, and the distribution of the tramp ant species that usually have the greatest impact is often closely related to human disturbance. The effect of various species of ants on *Hylaeus* is not fully understood. From their frequent co-occurrence, *Hylaeus* can evidently tolerate the presence of *Ochetellus glaber* in large numbers, and *Pheidole megacephala* in at least moderate abundance. However, the results of this survey indicate that *Anoplolepis gracilipes* (long-legged ant or yellow crazy ant) and *Linepithema humile* (Argentine ant) appear to severely reduce or entirely exclude *Hylaeus* where they occur in noticeable numbers (see Appendix). *Linepithema* has been documented to directly prey on *Hylaeus* larvae (Cole et al. 1992), and both species consume large quantities of nectar (Lach 2005), depriving survivors of a food source. *Anoplolepis* probably plays a major role in limiting the distribution of bees in coastal and lowland habitats, and the expanding range of *Linepithema* has significantly decreased the available montane mesic and dry habitat, particularly at PTA and Hawai'i Volcanoes NP.

An important issue for *Hylaeus* conservation that has not yet been fully explored is the possibility of cryptic species. *Hylaeus anthracinus* almost certainly consists of three cryptic species based on island populations – Hawai'i, Maui + Kaho'olawe, and O'ahu + Moloka'i –

which are highly divergent genetically and non-monophyletic with respect to *H. flavifrons* of Kaua‘i (Magnacca and Brown 2010). Most other species are genetically different between islands as well, including *H. flavipes* and *H. laetus*, but whether these should be considered as a multiple species or one is less clear-cut. Nevertheless, they are clearly distinct evolutionary units that have been isolated for a considerable time. With no clear-cut definition of what may constitute a species where genetic differentiation is moderate to high and morphological differences are absent, this problem may remain unresolved for some time.

In conclusion, the immediate outlook for the candidate and rare *Hylaeus* species is poor. It is difficult to draw conclusions from a single year’s data that can be colored by unusual weather events and other stochastic factors. However, elements of these results – particularly the stark drop in bee diversity in montane dry forest on Hawai‘i despite relatively strong seasonal flowering in several favored host plants – appear to reflect longer term trends of invasive species and climate change that are difficult or impossible to reverse. Preservation of native pollinator diversity in Hawai‘i will require the development of new techniques in response to these challenges, including survey methods for detection of extremely rare species, adaptive management of tree heliotrope, and reintroduction of bees into restored habitat.

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Appendix

Sampling sites and bee records from Hawai'i and O'ahu. Dates indicate the first visit when a GPS point was taken; many were visited multiple times. Sites are numbered by location:

001–299	Hawai'i coastal
300–499	Kona mauka and Mauna Kea
500–599	Ka'ū mauka and windward
600–799	O'ahu

Name	Zone	Easting	Northing	Lat	Long	Elev (m)	Date	Site	Plant	Hylaeus (Nesoprosopis)	Lasio impavidum	Lasio microlepoidea	Lasio sp tegulare grp	Apis	Xylocopa	Ceratina anzonensis	Ceratina dentipes	Ceratina smaragdula	Meg umbripennis	Meg timberlakei	Hylaeus albomittens	Hylaeus strenuus	Anoplolepis	other ants	notes		
063	4Q	813663	2193325	19.81081	-156.00608	coast	1/21/2012	Kua Bay	Heliotropium	difficilis																	
064	4Q	813701	2193366	19.81118	-156.00571	coast	1/21/2012	Kua Bay	Heliotropium	difficilis																	
065	4Q	813646	2193411	19.81159	-156.00623	coast	1/21/2012	Kua Bay	Scaevola	difficilis						y											
066	4Q	808494	2184421	19.73127	-156.05684	coast	1/5/2012	Keahole Point	Heliotropium	difficilis						y	y										
067	4Q	808390	2184390	19.73101	-156.05784	coast	1/5/2012	Keahole Point	Heliotropium	difficilis				y													
068	4Q	808298	2184348	19.73064	-156.05873	coast	1/5/2012	Keahole Point	Heliotropium	difficilis				y													
069	4Q	808266	2184287	19.73010	-156.05904	coast	1/5/2012	Keahole Point	Heliotropium	difficilis				y													
070	4Q	808172	2184219	19.72950	-156.05995	coast	1/5/2012	Keahole Point	Heliotropium	difficilis				y													
071	4Q	808176	2183991	19.72744	-156.05995	coast	1/5/2012	Keahole Point	Heliotropium	difficilis				y													
072	4Q	808365	2183688	19.72467	-156.05819	coast	1/5/2012	Keahole Point	Heliotropium	anthracinus, difficilis				y													
073	4Q	808396	2183642	19.72426	-156.05791	coast	1/5/2012	Keahole Point	Heliotropium	anthracinus, difficilis				y													
074	4Q	808424	2183610	19.72397	-156.05764	coast	1/5/2012	Keahole Point	Heliotropium	anthracinus, difficilis				y													
075	4Q	808502	2183496	19.72292	-156.05693	coast	1/5/2012	Keahole Point	Heliotropium	anthracinus, difficilis				y													
076	4Q	808560	2183406	19.72210	-156.05638	coast	1/5/2012	Keahole Point	Heliotropium	anthracinus, difficilis				y		y	y										
077	4Q	808594	2183356	19.72164	-156.05606	coast	1/6/2012	Keahole Point	Scaevola	anthracinus				y													
078	4Q	808759	2183202	19.72023	-156.05452	coast	1/6/2012	Keahole Point	Heliotropium	anthracinus, difficilis				y													
079	4Q	808861	2183106	19.71935	-156.05356	coast	1/6/2012	Keahole Point	Heliotropium	anthracinus, difficilis				y													
080	4Q	808980	2183028	19.71862	-156.05244	coast	1/6/2012	Keahole Point	Heliotropium	anthracinus, difficilis	y	y	y				y										
081	4Q	809169	2182897	19.71741	-156.05066	coast	1/6/2012	Ooma	Scaevola	anthracinus, difficilis	y	y	y		y	y								Ochetellus glaber			
082	4Q	809308	2182744	19.71601	-156.04936	coast	1/6/2012	Ooma	Scaevola	anthracinus, difficilis				y													
083	4Q	809377	2182649	19.71514	-156.04872	coast	1/6/2012	Ooma	Heliotropium	anthracinus, difficilis				y													
084	4Q	809356	2182747	19.71603	-156.04890	coast	1/6/2012	Ooma	Heliotropium	anthracinus, difficilis				y			y	y									
085	4Q	809352	2182529	19.71406	-156.04898	coast	1/6/2012	Ooma	Heliotropium	anthracinus, difficilis				y													
086	4Q	809357	2182492	19.71373	-156.04894	coast	1/6/2012	Ooma	Scaevola	anthracinus, difficilis	y			y													
087	4Q	809381	2182350	19.71244	-156.04873	coast	1/6/2012	Ooma	Heliotropium	anthracinus, difficilis				y													
088	4Q	809429	2182154	19.71066	-156.04830	coast	1/6/2012	Ooma	Heliotropium	anthracinus, difficilis				y													
089	4Q	809465	2181988	19.70917	-156.04800	coast	1/6/2012	Ooma	Heliotropium	anthracinus, difficilis				y													
090	4Q	809484	2181810	19.70756	-156.04785	coast	1/6/2012	Ooma	Heliotropium	anthracinus, difficilis				y													
091	4Q	809483	2181711	19.70666	-156.04787	coast	1/6/2012	Ooma	Heliotropium	anthracinus, difficilis				y													
092	4Q	809463	2181252	19.70252	-156.04814	coast	1/6/2012	Ooma	Heliotropium	anthracinus, difficilis	y			y													
093	4Q	809485	2181166	19.70174	-156.04794	coast	1/6/2012	Ooma	Heliotropium	anthracinus, difficilis				y													
094	4Q	809630	2180812	19.69852	-156.04662	coast	1/6/2012	Kohanaiki	Heliotropium	anthracinus, difficilis				y													
095	4Q	809760	2180575	19.69636	-156.04541	coast	1/6/2012	Kohanaiki	Heliotropium															y			
096	4Q	809826	2180532	19.69597	-156.04480	coast	1/6/2012	Kohanaiki	Heliotropium	anthracinus, difficilis				y													
097	4Q	809864	2180409	19.69485	-156.04445	coast	1/6/2012	Kohanaiki	Heliotropium	anthracinus, difficilis				y													
098	4Q	809885	2180293	19.69380	-156.04427	coast	1/6/2012	Kohanaiki	Heliotropium	anthracinus				y										y			
099	5Q	193332	2197829	19.85257	-155.92796	coast	1/20/2012	Kiholo Bay	Heliotropium				y	y													
100	5Q	193619	2198080	19.85487	-155.92527	coast	1/20/2012	Kiholo Bay	Heliotropium																		
101	5Q	193957	2198093	19.85504	-155.92205	coast	1/20/2012	Kiholo Bay	Scaevola																		
102	5Q	192020	2197575	19.85006	-155.94044	coast	1/20/2012	Luahinewai	Scaevola	anthracinus, difficilis	y																
103	5Q	191949	2197573	19.85004	-155.94111	coast	1/20/2012	Luahinewai	Heliotropium	anthracinus, difficilis	y		y														
104	5Q	190681	2197816	19.85203	-155.95325	coast	1/20/2012	Kiholo dunes	Heliotropium	anthracinus, difficilis	y		y												Technomyrmex albipes		
105	5Q	190635	2197809	19.85196	-155.95369	coast	1/20/2012	Kiholo dunes	Ipomoea	anthracinus																	
106	5Q	190399	2197820	19.85202	-155.95594	coast	1/20/2012	Kiholo dunes	Heliotropium	anthracinus, difficilis				y													
107	5Q	190349	2197830	19.85211	-155.95642	coast	1/20/2012	Kiholo dunes	Ipomoea									y									
108	5Q	189132	2197502	19.84895	-155.96797	coast	1/20/2012	Kaupulehu dunes	Heliotropium	difficilis	y		y														
109	5Q	188638	2197278	19.84685	-155.97265	coast	1/20/2012	Kaupulehu dunes	Heliotropium	difficilis																	
110	5Q	188556	2197269	19.84676	-155.97342	coast	1/20/2012	Kaupulehu dunes	Heliotropium	difficilis																	
111	4Q	812771	2175197	19.64735	-156.01762	coast	1/13/2012	Old Kona Airport	Heliotropium	difficilis				y	y			y									
112	4Q	812850	2175242	19.64775	-156.01687	coast	1/13/2012	Old Kona Airport	Heliotropium	difficilis				y	y			y	y						Ceratina on Scaevola		
113	4Q	812996	2175135	19.64676	-156.01550	coast	1/13/2012	Old Kona Airport	Heliotropium	difficilis				y	y			y	y								
114	4Q	813108	2175044	19.64592	-156.01444	coast	1/13/2012	Old Kona Airport	Heliotropium	difficilis				y	y			y	y								
115	4Q	813566	2174777	19.64344	-156.01012	coast	1/13/2012	Old Kona Airport	Scaevola								y										
116	4Q	813662	2174747	19.64315	-156.00921	coast	1/13/2012	Old Kona Airport	Heliotropium	difficilis			y														
117	4Q	813704	2174670	19.64245	-156.00883	coast	1/13/2012	Old Kona Airport	Heliotropium	difficilis									y								
118	4Q	813807	2174628	19.64205	-156.00785	coast	1/13/2012	Old Kona Airport	Heliotropium	difficilis								y	y								
119	5Q	185595	2174311	19.63910	-155.99779	coast	1/13/2012	Kailua Harbor	Heliotropium					y													
120	5Q	185662	2174392	19.63984	-155.99717	coast	1/13/2012	Kailua Harbor	Heliotropium					y													
121	5Q	185903	2174390	19.63986	-155.99487	coast	1/13/2012	Kailua Harbor	Heliotropium					y													
122	5Q	186094	2174051	19.63683	-155.99300	coast	1/13/2012	Kailua Harbor	Heliotropium					y													
123	5Q	189138	2165752	19.56242	-155.96263	coast	1/13/2012	Keaouhou marina	Heliotropium																		
124	5Q	189004	2164541	19.55147	-155.96370	coast	1/13/2012	Kuamoo	Heliotropium				y	y	y			y	y						one individual of another Megachile seen		

Name	Zone	Easting	Northing	Lat	Long	Elev (m)	Date	Site	Plant	Hylaeus (Nesoprospolis)	Lasio impavidum	Lasio microlepoidea	Lasio sp legulare grp	Apis	Xylocopa	Ceratma anzonensis	Ceratma dentipes	Ceratma smaragdula	Meg umbripennis	Meg timbertlakei	Hylaeus albomittens	Hylaeus strenuus	Anoplolepis	other ants	notes
186	5Q	194348	2149557	19.41706	-155.91041	coast	6/7/2012	PUHO	Sesbania				y												
187	5Q	194559	2149432	19.41596	-155.90838	coast	6/7/2012	PUHO	diverse				y			y									
188	5Q	194553	2149400	19.41567	-155.90843	coast	6/7/2012	PUHO	Heliotropium				y			y									
189	5Q	217560	2093173	18.91145	-155.68132	coast	7/9/2012	Kalae	Tribulus	flavipes									y						
190	5Q	218989	2093778	18.91711	-155.66786	coast	7/9/2012	Kaulana	Scaevola	anthracinus							y								
191	5Q	219322	2093771	18.91709	-155.66470	coast	7/9/2012	Kaulana	Heliotropium	anthracinus, diffcilis												y			
192	5Q	219426	2094107	18.92014	-155.66376	coast	7/9/2012	Kaulana	Heliotropium	flavipes			y												
193	5Q	220057	2094269	18.92169	-155.65779	coast	7/9/2012	Kaulana	Sida											y					
194	5Q	221249	2095780	18.93549	-155.64670	coast	7/9/2012	Mahana	Heliotropium				y												also Jacquemontia and Scaevola
195	5Q	221651	2095780	18.93555	-155.64289	coast	7/9/2012	Mahana	Heliotropium	diffcilis															ants very abundant
196	5Q	222528	2096283	18.94021	-155.63464	coast	7/10/2012	Mahana	Heliotropium	diffcilis															Pheidole megacephala
197	5Q	222694	2096788	18.94479	-155.63314	coast	7/10/2012	Mahana	Sida																
198	5Q	223261	2097513	18.95141	-155.62785	coast	7/10/2012	Mahana	Sida																
199	5Q	223765	2098679	18.96200	-155.62324	coast	7/10/2012	Kaalualu	Heliotropium			y	y												
200	5Q	223980	2099125	18.96606	-155.62126	coast	7/10/2012	Kaalualu	Heliotropium																
201	5Q	224971	2099510	18.96966	-155.61191	coast	7/10/2012	Kaalualu	Heliotropium	diffcilis	y		y							y					Lasioglossum and Megachile on adjacent Scaevola, not on Heliotropium
202	5Q	225145	2099209	18.96698	-155.61022	coast	7/10/2012	Kaalualu	Heliotropium																
203	4Q	810883	2179743	19.68868	-156.03485	coast	10/16/2012	KAHO																	
301	5Q	202176	2184919	19.73741	-155.84153	1304	1/26/2012	Puu Waawaa	Sophora	pele															Ochetellus glaber
302	5Q	202108	2184940	19.73759	-155.84218	1306	1/27/2012	Puu Waawaa	Sophora	pele															
303	5Q	202899	2188663	19.77131	-155.83524	1183	1/27/2012	Puu Waawaa	Sophora																
304	5Q	228238	2195022	19.83239	-155.59456	2253	3/14/2012	Kaoh	Santalum				y												
305	5Q	232029	2198177	19.86139	-155.55884	2374	3/14/2012	Kaoh	Styphelia																
306	5Q	226452	2193561	19.81895	-155.61138	2000	3/14/2012	Kaoh	Euphorbia																
307	5Q	226094	2193330	19.81681	-155.61476	1978	3/14/2012	Kaoh	Euphorbia																
308	5Q	237158	2185338	19.74618	-155.50808	2070	3/14/2012	Puu Koohi	Euphorbia																
309	5Q	222724	2184704	19.73847	-155.64562	1667	4/1/2012	PTA Area 22	Euphorbia				y												Linepithema humile
310	5Q	222704	2184625	19.73775	-155.64580	1672	4/1/2012	PTA Area 22	Euphorbia				y												Linepithema humile
311	5Q	222610	2184716	19.73856	-155.64670	1666	4/1/2012	PTA Area 22	Euphorbia				y												Linepithema humile
312	5Q	222501	2184302	19.73481	-155.64768	1653	4/1/2012	PTA Area 22	Euphorbia				y												Linepithema humile
313	5Q	222471	2184231	19.73417	-155.64795	1657	4/1/2012	PTA Area 22	Euphorbia				y												Linepithema humile
314	5Q	222526	2184151	19.73345	-155.64743	1662	4/1/2012	PTA Area 22	Euphorbia	laetus			y												laetus collected in August
315	5Q	221738	2183817	19.73032	-155.65489	1634	4/1/2012	PTA Area 22	Euphorbia				y												Linepithema humile
316	5Q	221817	2183791	19.73010	-155.65412	1630	4/1/2012	PTA Area 22	Euphorbia				y												Linepithema humile
317	5Q	217328	2175117	19.65116	-155.69561	1787	4/23/2012	PTA Area 23	Euphorbia																
318	5Q	221539	2183258	19.72525	-155.65670	1640	4/1/2012	PTA Area 22	Euphorbia	pele, laetus, diffcilis			y												Hylaeus collected in August
319	5Q	221325	2183420	19.72668	-155.65876	1630	4/1/2012	PTA Area 22	Euphorbia	laetus, diffcilis			y												wood trap nests set out 23 Apr; two used in August
320	5Q	221047	2183522	19.72756	-155.66143	1622	4/1/2012	PTA Area 22	Euphorbia				y												
321	5Q	220758	2183700	19.72913	-155.66421	1614	4/1/2012	PTA Area 22	Euphorbia	diffcilis			y												wood trap nests set out 23 Apr; diffcilis collected in August
322	5Q	207768	2165220	19.56044	-155.78516	1618	4/17/2012	Lupea	Santalum				y												
323	5Q	208258	2164968	19.55823	-155.78045	1650	4/17/2012	Lupea	Santalum				y												
324	5Q	208659	2164827	19.55702	-155.77661	1681	4/17/2012	Lupea	Metrosideros				y												
325	5Q	210431	2168740	19.59260	-155.76034	1643	4/18/2012	Lupea	Santalum				y												
326	5Q	211132	2169202	19.59687	-155.75374	1700	4/18/2012	Lupea	Styphelia	volcanicus			y												
327	5Q	211180	2169277	19.59755	-155.75329	1705	4/18/2012	Lupea	Metrosideros	volcanicus			y												
328	5Q	213470	2164249	19.55250	-155.73071	2018	4/18/2012	Lupea	Dodonaea	volcanicus			y												
329	5Q	207682	2166200	19.56927	-155.78613	1602	4/17/2012	Lupea	Euphorbia				y												Pheidole megacephala
330	5Q	216608	2176186	19.66071	-155.70263	1684	4/23/2012	PTA Area 23	Euphorbia	diffcilis			y												
331	5Q	217160	2175653	19.65598	-155.69729	1735	4/23/2012	PTA Area 23	Euphorbia	diffcilis			y												wood trap nests set out 23 Apr; also diffcilis collected on Bidens in August & September
332	5Q	217380	2175550	19.65508	-155.69518	1754	4/23/2012	PTA Area 23	Euphorbia	diffcilis			y												
333	5Q	218090	2174522	19.64590	-155.68826	1842	4/23/2012	PTA Area 23	Euphorbia				y												wood trap nests set out 23 Apr
334	5Q	218045	2174487	19.64558	-155.68868	1846	4/23/2012	PTA Area 23	Euphorbia				y												
335	5Q	217980	2174451	19.64524	-155.68930	1842	4/23/2012	PTA Area 23	Santalum				y												
336	5Q	218941	2174859	19.64906	-155.68020	1871	4/25/2012	PTA Area 23	Metrosideros	rugulosus			y												
337	5Q	217157	2175858	19.65783	-155.69735	1726	4/25/2012	PTA Area 23	Euphorbia				y												
338	5Q	230763	2190986	19.79630	-155.56988	2475	5/3/2012	Kaoh	ground	flavipes															
339	5Q	229987	2192393	19.80889	-155.57748	2378	5/3/2012	Kaoh	ground	flavipes															
340	5Q	244313	2203284	19.90914	-155.44234	2051	5/4/2012	Puu Mali	Euphorbia																
341	5Q	244345	2203230	19.90867	-155.44202	2065	5/4/2012	Puu Mali	Euphorbia																
342	5Q	237344	2185321	19.74604	-155.50631	2133	5/8/2012	Puu Koohi	Euphorbia																trap nests set out 8 May

