PETITION TO LIST
ONE SPECIES OF HAWAIIAN YELLOW-FACED BEE
(*Hylaeus hilaris*)
AS AN ENDANGERED SPECIES
UNDER THE U.S. ENDANGERED SPECIES ACT

Hylaeus hilaris

Prepared by

Lisa Schonberg, The Xerces Society
Sarina Jepsen, The Xerces Society
Scott Hoffman Black, The Xerces Society

Submitted by

The Xerces Society for Invertebrate Conservation
March 23, 2009

Ken Salazar
Secretary of the Interior
Office of the Secretary
Department of the Interior
1849 C Street N.W.
Washington D.C., 20240

Dear Mr. Salazar:

Due to the threat of extinction and because of its small population size, restricted distribution, isolation, and the numerous factors threatening the species and its remaining habitat, the Xerces Society hereby formally petitions to list the Hawaiian Yellow-faced bee *Hylaeus hilaris* as endangered pursuant to the Endangered Species Act, 16 U.S.C. §§ 1531 *et seq.* This petition is filed under 5 U.S.C. § 553(e) and 50 C.F.R. § 424.14 (1990), which grants interested parties the right to petition for issue of a rule from the Secretary of the Interior.

Petitioners also request that critical habitat be designated concurrent with the listing, as required by 16 U.S.C. § 1533(b)(6)(C) and 50 C.F.R. § 424.12, and pursuant to the Administrative Procedure Act (5 U.S.C. § 553).

Multiple threats including habitat loss, the rarity of these species, and the natural instability of small populations of island endemics lead us to conclude, unequivocally, that *Hylaeus hilaris* is threatened with extinction and must be given protection under the Endangered Species Act.

We are aware that this petition sets in motion a specific process placing definite response requirements on the U.S. Fish and Wildlife Service and very specific time constraints upon those responses. 16 U.S.C. § 1533(b).

Sincerely,

Scott Hoffman Black, Executive Director
Xerces Society
4828 SE Hawthorne Blvd.
Portland, OR 97215
503-232-6639

The Xerces Society is an international, nonprofit organization that protects wildlife through the conservation of invertebrates and their habitat. For over three decades, the Society has been at the forefront of invertebrate conservation, harnessing the knowledge of scientists and the enthusiasm of citizens to implement conservation programs.

TABLE OF CONTENTS

I. EXECUTIVE SUMMARY

Hylaeus hilaris is a rare bee endemic to the Hawaiian Islands of Maui, Lanai, and Molokai that is in imminent danger of going extinct. There is strong evidence of significant decline of *H. hilaris*, and it is the most highly endangered native Hawaiian *Hylaeus* species that is known to be extant (Magnacca 2007). It is of global evolutionary significance, as one of only five cleptoparasitic species in the family Colletidae. It is restricted to extremely rare native coastal strand habitat (Daly & Magnacca 2003, Magnacca 2005, Magnacca 2007). Species numbers have declined precipitously with the concurrent loss of these habitats; as a cleptoparasite whose hosts are also rare, it is at especially high risk of extinction. It was absent from all of its historical localities when revisited by Karl Magnacca between 1998 and 2005, and from many sites with suitable habitat where its host species have been recently collected (Daly & Magnacca 2003).

Because the remnant population of *H. hilaris* is small and isolated, it is especially vulnerable to habitat loss, predation, stochastic events, and other changes to their habitat. *Hylaeus hilaris* depends on coastal strand habitat, which is increasingly rare and patchily distributed (Cuddihy and Stone 1990, Magnacca 2005). The only remnant population is at Moomomi Preserve on Molokai (Appendix 1c) (Daly and Magnacca 2003, Magnacca 2005). However, even in habitats protected from development, *Hylaeus* populations are still vulnerable to decline because their habitat is not actively managed to protect them from threats such as fire, invasive invertebrates, and the replacement of native vegetation by invasive plants (Magnacca 2007).

Conservation of *H. hilaris* will require the active protection and management of natural areas where populations are known to exist and active searching for other remnant populations before they disappear. The continued impact of development, fire, feral ungulates, invasive ants, and the loss of native vegetation to invasive plant species will undoubtedly have a negative impact on the remaining populations of *H. hilaris* and may cause its extinction if habitat is not managed for conservation of this species (Magnacca 2007).

The threats, the rarity of this species, and the natural instability of small populations of island endemics lead us to conclude, unequivocally, that *Hylaeus hilaris* is threatened with extinction and must be given protection under the Endangered Species Act.

II. CANDIDATE BACKGROUND, STATUS, AND LISTING HISTORY

Hylaeus hilaris is not listed as a Species of Concern in the State of Hawaii (Magnacca 2005). It has a Global Heritage Status Rank of GNR, meaning that its rank has not yet been assessed. It is listed as Critically Imperiled on the Xerces Society for Invertebrate Conservation's Red List of Pollinator Insects (Magnacca 2005).

Magnacca (2007) assigned conservation status ranks to *Hylaeus* species on a scale of 1 to 6, with relatively safe and abundant species ranked “1,” and increasingly threatened species given higher ranks, with those species that are endangered or likely extinct ranked “6.” *Hylaeus hilaris* was given a rank of 5, which indicates that it is “very rare” and “potentially endangered.”

Hylaeus hilaris was listed by the United States federal government as a “Category 3A” Candidate Species in 1984, indicating the belief that it was “probably extinct” (USFWS 1984).

III. TAXONOMY

The taxonomy of *H. hilaris* is uncontested. *Hylaeus hilaris* is a small bee in the family Colletidae. The genus *Hylaeus* is widespread and very diverse in the Hawaiian Islands, with 60 native species, including 38 that are endemic to a single island (Magnacca 2007). They are in the subgenus *Nesoprosopis,* which includes all 60 *Hylaeus* species native to the Hawaiian Islands (Michener 2000, Magnacca and Danforth 2006). *Hylaeus* species are commonly known as yellow-faced bees, for the yellow to white markings on their face. Hawaiian *Hylaeus* species form a diverse and large lineage that evolved in an unusually short amount of time relatively recently (Magnacca and Danforth 2006, Magnacca and Danforth 2007).

Hylaeus hilaris was described as *Prosopis hilaris* by F. Smith (1879). It was transferred along with the other Hawaiian species to the newly-erected genus *Nesoprosopis* by Perkins (1899). *Nesoprosopis* was reduced to a subgenus of *Hylaeus* by Meade-Waldo (1923), so the species is now called *Hylaeus hilaris* (Daly and Magnacca 2003). The most recent taxonomic treatment for *H. hilaris* is Daly and Magnacca (2003).

IV. SPECIES DESCRIPTION

A. Adult

Hylaeus species have a wasp-like appearance; they appear hairless but actually have plumose (branched) hairs on the body that are longest on the sides of the thorax. They can be distinguished from wasps by these plumose hairs (Michener 2000).

Hylaeus hilaris was described by Daly and Magnacca (2003). It is distinguished by its large size relative to other coastal *Hylaeus* species. *Hylaeus hilaris* has slightly smoky to smoky wings. The space from the base of the mandible and the bottom margin of the compound eye (malar space) is short. It is the most colorful of the Hawaiian bees: the face of the male is almost entirely yellow, with yellow markings on the legs and thorax, and the metasoma usually largely red. Females are drab, with brownish markings; like other cleptoparasitic species, they lack the specialized pollen-sweeping hairs of the front legs (Daly and Magnacca 2003). It is also one of only two Hawaiian species to possess apical bands of fine white hairs on the segments of the metasoma.

B. Immature

The egg, larva, and pupa of *H. hilaris* are unknown (Magnacca 2005). The species is a cleptoparasite, laying its eggs in the nests of *H. anthracinus*, *H. assimulans*, and *H. longiceps* (Perkins, 1913).

V. POPULATION DISTRIBUTION AND STATUS

A. Historic Distribution

Historic records for Hawaiian *Hylaeus* species are based largely on collections made by R.C.L. Perkins between 1892 and 1906 (Daly and Magnacca 2003). Perkins collected on all of the higher islands with the exception of Kahoolawe (Hawaii, Oahu, Kauai, Maui, Lanai and Molokai) (Liebherr and Polhemus 1997). Perkins called Hawaiian *Hylaeus* species "almost the most ubiquitous of any Hawaiian insects" (Perkins 1913), but more recent surveys (Daly and Magnacca 2003) indicate that most *Hylaeus* species are in decline, many are extremely rare, and several are possibly extinct (Daly and Magnacca 2003, Shepherd *et al.* 2005, Magnacca 2007). *Hylaeus hilaris* is among the most endangered of Hawaiian *Hylaeus* species, and has not been found in recent searches of its historic collection localities, as

detailed below under "current distribution" (see Figure 1 for a table of historic and recent collection sites).

Hylaeus hilaris is historically known from coastal strand locations on the Hawaiian Islands of Maui, Lanai, and Molokai (Figure 1, Appendix 1a-c). *Hylaeus hilaris* probably occurred historically along much of the coast of Maui Nui, since its primary hosts, *H. anthracinus*, *H. assimulans*, and *H. longiceps*, also likely extended throughout this range. Nearly the entire habitat in this area has been either developed or degraded and is no longer suitable for *H. hilaris* (Liebherr and Polhemus 1997). Perkins (1899) noted that while another cleptoparasitic species, *H. volatilis*, occurred in company with *H. hilaris* at the coast but also extended up into the mountains, and the coastal host species of both range into lowland dry forest up to approximately 1500 feet elevation, *H. hilaris* appeared to be restricted to sandy coastal sites.

On Maui, Perkins collected *H. hilaris* from coastal habitat at the Wailuku Sand Hills, the "sandy isthmus" (presumably the area south of Wailuku, now urbanized or sugarcane fields) and from an unknown site labeled "Maui;" the type collection, made by Rev. Thomas Blackburn, was also from an unspecified location on Maui (Daly and Magnacca 2003). On Lanai, he found *H. hilaris* in coastal habitat at Manele (Perkins 1899). It was later recorded from Molokai by Fullaway (1918). See Appendix 1 a-c for maps of historic collection sites for *H. hilaris*.

B. Current Distribution

There was a gap of about 70 years between major collecting efforts of Hawaiian *Hylaeus* species. Information on current distribution is largely based on collecting efforts by K. Magnacca between 1998 and 2005. Additional recent collections were made by other researchers between 1975 and 1997 (Daly and Magnacca 2003). Magnacca attempted to search for *Hylaeus* species in all habitats where they were likely to occur, but could not access some sites because of restricted access, weather, or time (Magnacca 2007).

There is strong evidence of significant decline of *H. hilaris*. *Hylaeus hilaris* was once widely distributed, but degradation and loss of its habitat has decreased its range significantly and it is now restricted to a single population, as seen in the maps in Appendix 1 (Daly and Magnacca 2003, Magnacca 2005). *H. hilaris* was absent from all of its historical localities that were revisited by K. Magnacca between 1998 and 2006. It was also absent from additional sites with suitable habitat, many from which other native *Hylaeus* species have been recently collected (Figure 1; Daly and Magnacca 2003, K. Magnacca pers. comm., Jan. 2008, July 2008). The species has been collected only twice in the last 70 years, in 1989 and 1999.

Thirteen sites on Maui, Molokai, and Lanai were recently searched for *H. hilaris*. Three of these were historic collection sites; at all of these, native habitat has been largely or entirely lost to development or other land conversion (Liebherr and Polhemus 1997, K. Magnacca, pers. comm., July 2008).

The only known population of *H. hilaris* is on protected land in the Moomomi Preserve, Molokai, which is managed by the Nature Conservancy (Magnacca 2005).

Collection sites and habitats searched are outlined below in Figure 1. The location of these sites is indicated in the maps in Appendix 1a-c.

1. Maui (see Figure 1 and Appendix 1a)

There have been no recent collections of *H. hilaris* on Maui, and it may have been extirpated from the

island (Magnacca 2005, Magnacca 2007). Four potential sites, including two with historic collection records, were recently searched for *Hylaeus* species, and *H. hilaris* was not found at any of these sites despite the presence of two of its recorded host species (Daly and Magnacca 2003).

2. Lanai (see Figure 1 and Appendix 1b)
There have been no recent collections of *H. hilaris* on Lanai, and it may have been extirpated from the island (Magnacca 2005, Magnacca 2007). Four sites with suitable habitat for *H. hilaris*, including one historic collection site, were recently searched for *Hylaeus* species, and *H. hilaris* was not found at any of these sites despite the presence of two of its recorded host species (Daly and Magnacca 2003).

3. Molokai (see Figure 1 and Appendix 1c)
The only known population of *H. hilaris* is on Molokai. Recent search efforts have been made at 5 sites on Molokai, including two areas of sandy dune habitat, but *H. hilaris* was only collected at Moomomi, where a single male was collected in 1989 and another in 1999. Other rare *Hylaeus* species, including two hosts of *H. hilaris*, were recently collected at Moomomi and the three Kalaupapa sites (Daly and Magnacca 2003). However, the latter are rocky and may not be suitable for *H. hilaris*; the fifth site (northwest dunes) has been developed and invaded by alien plants.

Table 1. Historic and recent collections, and recent search effort for *Hylaeus hilaris.*
Historic collection sites with unspecified locations are in quotation marks and associated boxes are shaded. o = absent; x = present; empty box = not searched. The Wailuku sandhills site and Waiehu dune are both considered to be historic collections because they were previously a contiguous system and it is unknown exactly where Perkins collected. NAR =State Natural Area Reserve.

	SITE	ELEVATION	Historic collections of *H. hilaris* (1879-1918)	Recent searches and collections of *H. hilaris* (1993-2006)	Host *Hylaeus* species recently collected from same site?
Maui	"Maui"		x		
	Wailuku Sand Hills/Waiehu Dune	30 m/100 ft	x	o	x
	Waiehu Sang Hills – Kahului Section	30 m/100 ft	x	o	o
	sandy isthmus between East and West Maui	30 m/100 ft	x	o	o
	Manawainui gulch	coast		o	x
Lanai	Manele	coast	x	o	o
	Manele Road	180 m/600 ft		o	x
	Polihua Beach	coast		o	o
	Shipwreck Beach	coast		o	x
Molokai	"Molokai"	coast	x		
	Moomomi	coast		x	x
	northwest dunes	coast		o	o
	Hoolehua beach	coast		o	x
	Kaupikiawa	coast		o	x
	Kuololimu Point	coast		o	x

VI. HABITAT REQUIREMENTS

A. Overview

Hylaeus hilaris is endemic to the Hawaiian Islands of Maui, Lanai, and Molokai, and has narrow habitat requirements. It depends largely or entirely on coastal strand habitat, which is increasingly rare and patchily distributed (Cuddihy and Stone 1990, Liebherr 2005, Magnacca 2005, Magnacca 2007, Sakai *et al.* 2002). Unlike most other species associated with coastal habitats, including its hosts (*H. anthracinus*, *H. assimulans*, and *H. longiceps*), *H. hilaris* has never been collected away from sandy dune sites.

1. Habitat description

In the Hawaiian Islands, coastal strand habitat occurs in a relatively narrow belt around each island. Coastal strand community composition is strongly influenced by the ocean, and vegetation must withstand salinity in the root zone, salt spray, and geologic shoreline processes (Richmond and Mueller-Dombois 1972, Cuddihy and Stone 1990, Alpha *et al.* 1996). Undisturbed coastal strand communities support a unique assemblage of native shrubs and sedges. The dominant native vegetation in coastal strand habitats is the shrub *Scaevola sericea* (naupaka kahakai) (Alpha *et al.* 1996). Other common native plant species are *Ipomoea pes-caprae* (beach morning-glory), *Sporobolus virginicus* (beach dropseed), *Jaquemontia ovata* (pau o Hiiaka), and *Sesuvium portulacastrum* (akulikuli or sea purslane) (Cuddihy and Stone 1990).

2. Relationships with other species

All Hawaiian *Hylaeus* species strongly depend on an intact community of native vegetation (Magnacca 2007). They are very rarely found visiting non-native plants for nectar and pollen, and are almost completely absent from habitats dominated by exotic plant species (Daly and Magnacca 2003, Magnacca 2007). They require a habitat with a diversity of plants that flower throughout the year so that a consistent forage source is available (Magnacca 2007). Hawaiian *Hylaeus* species are highly dependent on relatively few species of native Hawaiian plants, and probably require a mix of native species (Daly and Magnacca 2003). In coastal sites, the most important pollen sources for *Hylaeus* species are *Scaevola* spp., *Chamaesyce* spp., *Myoporum sandwicense*, *Tournefortia argentea* (non-native, tree heliotrope), *Jacquemontia ovata*, and *Sida fallax* (K. Magnacca, unpub. data).

As a cleptoparasite, *H. hilaris* does not collect large quantities of pollen from flowers for larval provisions (although adults still rely on pollen and nectar as a food source). However, they depend on a sizeable population of hosts, since the parasite population is inherently much smaller. This is probably why *H. hilaris* has not survived in the small fragment of dune habitat at Waiehu while a host species, *H. longiceps*, persists there. This makes cleptoparasites especially vulnerable to extinction. The most endangered bee in North America, *Epeoloides pilosula*, is also a cleptoparasite, and its situation is very similar to that of *H. hilaris* (Ascher, 2005). It was formerly found throughout North America east of the Rocky Mountains, but has virtually disappeared in the last 50 years; its host species, *Macropis nuda*, is still widespread and locally abundant but mostly occurs in small, widely separated populations throughout its range. The decline of *M. nuda*, in turn, is primarily the result of displacement of its host plant by wetland alteration and invasive plants (Ascher, 2005), much like the loss of coastal habitats in Hawaii.

3. Nesting requirements

Hylaeus hilaris uses the ground nests made by its host species (Perkins, 1913). Nest site availability is an important habitat requirement for *Hylaeus* populations; ground-nesters need relatively dry conditions (Zimmerman 1972, Daly and Magnacca 2003). Many bees are more restricted in their

distribution by nest site requirements than floral host requirements, and it is likely that *H. hilaris*' strict association with sandy dune habitat is related to nesting specialization.

B. Diet

1. Larvae

Larvae of *H. hilaris* are unknown. Some cleptoparasitic species in other bee families are highly modified in the first instar, while others are differ little from industrious species (Michener 2000). The Hawaiian species, including *H. hilaris*, are the only cleptoparasites in the family Colletidae.

2. Adult

Adult *Hylaeus* consume nectar for energy; however, *H. hilaris* has never been observed at flowers.

C. Life Cycle

Hylaeus hilaris and the four species related to it (*H. hostilis*, *H. inquilina*, *H. sphecodoides*, and *H. volatilis*) are cleptoparasites or cuckoo bees. The mated female does not construct a nest or collect pollen, but instead enters the nest of another species and lays an egg in a partially-provisioned cell. Upon emerging, the larva kills the host egg and consumes the provisions, pupates, and eventually emerges as an adult. As a result of this lifestyle shift, they have lost the pollen-collecting hairs that the other species possess on the front legs. This habit is common in bees; it has evolved many times, and approximately 1/4 of all bee species are cleptoparasites. However, none are known from the family Colletidae aside from the Hawaiian group (Michener 2000).

D. Habitat Status

The only known population of *H. hilaris* is on protected land at the Nature Conservancy's Moomomi Preserve on the north coast of Molokai (Magnacca 2005, Appendix 1c). However, there are no other currently protected sites where *H. hilaris* might potentially occur based on its habitat requirements.

Hylaeus hilaris depends on coastal strand habitat, which is increasingly rare and patchily distributed (Magnacca 2005; Cuddihy and Stone 1990). Even more so than other lowland habitats, coastal sites – and the sandy dunes required by *H. hilaris* in particular – are favored for recreation and development, and highly vulnerable to invasion by alien vegetation. Dunes are also easily eroded by off-road vehicle use, which facilitates substrate disturbance and subsequent colonization by alien plants. Almost all of the coastal and lowland collection sites where Perkins collected *Hylaeus* species between 1892 and 1906 have changed drastically (Liebherr and Polhemus 1997).

The habitat status of all historic and recent collection sites for *Hylaeus hilaris* are discussed in detail below, with the exception of unknown sites labeled "Molokai" and "Maui."

1. Maui

Habitat in most of Perkins' collection sites on Maui has been lost to development (Liebherr and Polhemus 1997). Although all three of its recorded hosts have been collected there, two are currently known only from rocky and/or dry forest sites that unsuitable for *H. hilaris*, and the third occurs as a small population in a tiny area. As a result, it is likely that *H. hilaris* has been extirpated from the island. See Figure 1 for a table of collection sites, and Appendix 1a for a map of collection sites.

a. Waiehu Dune/Wailuku Sand Hills/sandy isthmus

These three sites were formerly part of a contiguous ecosystem that has now almost completely disappeared. Most of the once-extensive system of sand dunes near Wailuku has now been developed, while the Maui isthmus region has been converted to sugarcane cultivation.

Waiehu (30 m/100 ft) is a very small (less than 1 ha) remnant of native sand dune coastal habitat on state-owned land near a golf course. Undeveloped sand dunes nearby are overgrown with the invasive tree *Prosopis pallida* (kiawe) (Magnacca 2007). One of the major threats to the habitat at Waiehu is the activity of off-road vehicles. Perkins (1899) collected specimens of many *Hylaeus* species from this location, including *H. hilaris*, referring to it as the Wailuku sand hills. *Hylaeus hilaris* was not found in recent search efforts there by K. Magnacca in 1999 and 2001. *Hylaeus longiceps* was the only species collected here recently, but the population appears to be small and restricted to the dune itself. As such, it is likely to be too small to support a viable population of *H. hilaris*. Other remnant undeveloped dunes in Wailuku and Kahului, dominated by alien vegetation, were searched but no bees were found.

2. Lanai

Hylaeus hilaris has not been recently collected on Lanai. Native habitats are severely degraded across the entire island, and it may be extirpated. Large areas of remote sandy beach on the north and east coasts have not been thoroughly searched; however, those that have been checked possess few native plants. Its host species are known to exist on the island, although recent collections of them have primarily come from lowland dry forest and shrubland where *H. hilaris* has never been collected. All of Lanai is privately owned. A map of collection sites on Lanai is in Appendix 1b.

a. Manele

Perkins (1899) collected *H. hilaris* in coastal habitat at Manele, on the southern coast of Lanai. It is now the site of the ferry landing from Lahaina and a small boat harbor, and is close to a major resort development. The area was searched in 1999 but little native vegetation is present aside from *Scaevola sericea* (naupaka kahakai), and no *Hylaeus* were collected. However, the alien bee *Lasioglossum impavidum* was present at the site.

3. Molokai

Although it was never collected there by Perkins, Molokai currently has the only known population of *H. hilaris*. Fullaway (1918) first collected *H. hilaris* on Molokai at an unspecified site. As on all of the islands, most of the coastal habitat is dominated by alien vegetation. A map of collection sites on Molokai is in Appendix 1c.

a. Moomomi

This site is part of a large area of calcified dunes, some of which are dominated by native plants and others by aliens. A moderately large population of *H. anthracinus* and *H. longiceps*, both hosts of *H. hilaris*, is present here. Only two collections have been made since 1930, each of a single male: one by J. Rosenheim in 1989, and one by K. Magnacca in 1999. The site is protected and actively managed by the Nature Conservancy. Other unprotected dunes to the west are completely dominated by non-native vegetation, and no *Hylaeus* have been collected from them.

E. Current Conservation Efforts

The federal and state governments have not developed any conservation plans for *Hylaeus hilaris*, nor have they made any targeted efforts to preserve or restore habitat for this species.

VII. CURRENT AND POTENTIAL THREATS – SUMMARY OF FACTORS FOR CONSIDERATION

A. The present or threatened destruction, modification, or curtailment of its habitat or range

The primary threats to *H. hilaris* are the loss of its habitat and the encroachment into this habitat of invasive plant species that are displacing native plant communities (Cuddihy and Stone 1990, Daly and Magnacca 2003, Magnacca 2005). Although not specific to native plants itself, it requires a healthy population of its host bees which are closely tied to native plant species (Magnacca, 2007). Coastal and lowland habitats have been most heavily impacted by human occupation. More than 75% of the recognized coastal and lowland habitat types in Hawaii are rare, and as of 1987, a third of these coastal and lowland sites were not protected from development (Nature Conservancy of Hawaii 1987). Almost all of the coastal and lowland collection sites where Perkins collected *Hylaeus* species between 1892 and 1906 would be unrecognizable to him now (Liebherr and Polhemus 1997).

1. Habitat loss

Coastal strand habitat is one of the most endangered habitats on the Hawaiian Islands (Wagner *et al.* 1985, Cuddihy and Stone 1990). The coastal strand habitat that remains is in small remnant patches, and most of these remnants have been overtaken by invasive plant species and have relatively low diversity (Cuddihy and Stone 1990). Most of the coast of the Hawaiian Islands lacks significant amounts of native foraging plants besides *Scaevola sericea* (naupaka kahakai), which cannot support *Hylaeus* populations on its own (Magnacca 2007). The restricted and isolated nature of coastal strand habitat makes species that depend on these areas even more at risk (Sakai *et al.* 2002).

Most of the former coastal strand and dune habitat has been converted for urban development, tourist resorts, military use, lost to fire, or overcome with invasive vegetation (Wagner *et al.* 1985). Increased access to coastal areas, and resulting habitat disturbance, has been facilitated by coastal development and road-building (Cuddihy and Stone 1990).

Hylaeus hilaris was once widespread, and the decline in its population has paralleled the loss of coastal habitat and the decline in its associated host species (Magnacca 2005). It is now restricted to a single locality, and is extremely rare even there (Daly and Magnacca 2003). *Hylaeus hilaris* is now absent from its historical collection localities, which have largely been developed or taken over by invasive plant species.

Magnacca (2007) outlined the reasons that this habitat and the *Hylaeus* species that inhabit it are so susceptible to extinction:

> Coastal strand habitat is the most endangered in Hawaii for a number of reasons: it is highly valued for development, popular for recreation, typically dry and therefore vulnerable to fire, susceptible to invasion by exotic plants, and it covers a small area by definition. On most of the Islands, only one coastal site with diverse native vegetation is protected, making the [*Hylaeus*] bees that inhabit them vulnerable to single catastrophes.

2. The replacement of native vegetation with invasive plant species

The majority of lowland habitats on the Hawaiian Islands below 600 m (1969 ft) are dominated by invasive plant species (Wagner *et al.* 1985). Aggressive non-native species are increasingly replacing native flora in coastal strand and dry lowland habitats (Cuddihy and Stone 1990, Mascaro *et al.* 2008). Native coastal vegetation in many sites is threatened by *Prosopis pallida* (kiawe), an invasive

deciduous thorny tree. Other invasive plant species abundant in coastal habitats include *Melinus minutiflora* (molasses grass), *Leucaena leucephala* (koa haole), and *Cenchrus ciliaris* (buffelgrass). Many native plant species that are being replaced are foraging resources for numerous *Hylaeus* species (Daly and Magnacca 2003, USFWS 2008). The spread of invasive plant species is a threat to populations of *H. hilaris* because *Hylaeus* species depend closely on native vegetation for nectar and pollen and are almost entirely absent from habitats dominated by invasive vegetation (Daly and Magnacca 2003). *Hylaeus hilaris* is limited to dry coastal sites (Daly and Magnacca 2003), and the greatest proportion of endangered or at risk Hawaiian plant taxa are limited to these same habitats; 25% of listed plant species are from dry forest and shrubland alone (Sakai *et al.* 2002). Is it suspected that dry lowland areas once supported a more diverse *Hylaeus* community than they now do, because many *Hylaeus* foraging plants are now extirpated (Magnacca 2007). The loss of native plant species from dry lowland habitats is one of the main causes of decline of *Hylaeus* species (Sakai *et al.* 2002, Liebherr 2005).

Many taxa of native plants that serve as hosts to numerous *Hylaeus* species are in decline (Daly and Magnacca 2003, USFWS 2008), and many exist in only very small populations (Cox and Elmqvist 2000). Four native Hawaiian plant taxa from coastal strand habitats and seventeen taxa from lowland dry or mesic forests are federally listed as endangered species and included in the USFWS recovery plan for Hawaiian plants that occur on multiple islands (USFWS 1999). Three of these species are known to be visited by *Hylaeus* species (USFWS 2008). *Hylaeus* host species that are listed as endangered under the Endangered Species Act include *Chamesyce* spp. (akoko), *Scaevola coriacea* (naupaka), and *Sesbania tomentosa* (ohai).

As a cleptoparasite, *H. hilaris* relies on large, vigorous populations of its hosts. Because the population of a cleptoparasite is inherently much smaller than that of its host, it is particularly vulnerable: loss of native plant communities causes a decline and fragmentation of its host bee species, which in turn can result in extinction of the cleptoparasite even while the host species remains in moderate abundance.

3. Habitat disturbance by feral ungulates

Feral ungulates have contributed to the decline of native Hawaiian plant communities, which likely has had a negative impact on *Hylaeus* species. A number of coastal and lowland plant species listed as endangered by the federal government are threatened by the presence of feral ungulates (USFWS 1999). Some of these are confirmed foraging sources for *Hylaeus* species and are likely foraging sources for *H. hilaris* (Daly and Magnacca 2003). Several species of feral ungulates have been introduced to the Hawaiian Islands by humans, and their populations have spread into many natural areas (Cuddihy and Stone 1990). Feral ungulates present in or around coastal and lowland scrub areas on the Hawaiian Islands include feral cattle (*Bos taurus*), goats (*Capra hircus*), and axis deer (*Axis axis*) (USFWS 2006).

The native Hawaiian flora evolved in the absence of browsing mammals such as ungulates (Wagner *et al.* 1985, Blackmore and Vitousek 2000). Hawaiian native plants largely lack defensive structures such as thorns, spines, stinging hairs, and unpalatable or poisonous chemicals that deter herbivory. Feral ungulates damage native plants by browsing, trampling and digging vegetation (Stone 1985, Cuddihy and Stone 1990). Some feral ungulates carry seeds in their hair, facilitating the colonization of new habitat by invasive plant species. Feral ungulates' excrement increases the nutrient content of soils, benefiting invasive plants that are better adapted to richer soils than are native species (Cuddihy and Stone 1990).

Research on other endemic Hawaiian invertebrates that also depend closely on native vegetation has shown that ungulate-inflicted damage to native vegetation can negatively impact invertebrate populations. Several species of rare and endemic Hawaiian *Drosophila* (pomace flies) are federally listed as endangered species under the Endangered Species Act (USFWS 2006). Foote and Carson (1995) showed that excluding pigs from *Drosophila* habitat increased populations of these rare *Drosophila* species. Active management to control feral ungulates typically involves building exclusionary fences and hunting (Cuddihy and Stone 1990).

4. Fire

Fires were uncommon in the Hawaiian Islands until the arrival of humans about 2000 years ago (Smith and Tunison 1992). Native habitat in the Hawaiian Islands has been increasingly colonized by fire-adapted invasive plant species that take the place of native plant species (Smith and Tunison 1992, D'Antonio *et al.* 2000). Many invasive plant species are able to proliferate after fire comes through a habitat whereas most native species' populations do not recover (Cuddihy and Stone 1990). Fire can dramatically alter the species composition of the plant community in coastal and lowland habitats, thus impacting *Hylaeus* populations. This process has been facilitated by feral ungulates, which alter the floral composition of native habitats, making conditions more conducive to fire. They remove or damage native vegetation, allowing seeds of invasive plant species to establish. These invasive species are much better adapted to fire than native Hawaiian species, as the invasive species will burn more easily and recolonize more rapidly than natives (Cuddihy and Stone 1990). Ordnance-induced fires on Army land have increased the frequency and intensity of fires in some areas (USFWS 2006).

B. Overutilization for commercial, recreational, scientific, or educational purposes

1. Collection

Insect collecting is a valuable component of research including taxonomic work, and is often necessary for documenting the existence of populations and population trends. In general, because of the high fecundity of individual insects, the collection of insects does not pose a threat to their populations. However, in the case of *H. hilaris*, which is rare and has small populations, the collecting of a small number of individuals could significantly reduce the production of offspring.

C. Disease or predation

1. Invasive ants

Humans have facilitated the introduction of 40 species of ants to the Hawaiian Islands (Reimer 1994), mostly within the past one hundred years (Reimer 1990). The native Hawaiian invertebrate fauna evolved in the absence of all social insects (Zimmerman 1948, Wilson and Taylor 1967, Howarth 1985), and the native species are not adapted to defend themselves against highly aggressive social species such as ants (Stone and Anderson 1988). Several ant species have had a deleterious impact on the native Hawaiian invertebrate fauna (Perkins 1913, Gagne 1979, Krushelnycky *et al.* 2005), including *Hylaeus* species (Cole *et al.* 1992, Daly and Magnacca 2003), and likely caused the extinction of some native invertebrate species (Perkins 1913, Zimmerman 1948).

Of all invasive ant species in Hawaii, *Pheidole megacephala* (the big-headed ant) and *Anoplolepis gracilipes* (syn. *longipes*) (the crazy or long-legged ant) pose the biggest threat to remaining populations of *H. hilaris*. *Pheidole megacephala* is primarily restricted to dry lowland habitats below 1000 m (3289 ft) and is almost always the dominant ant in its habitat. *Anoplolepis gracilipes* occurs from sea level to 800 m and has been found up to 1200 m (Medeiros *et al.* 1986). These two species are the most ubiquitous invasive ant species in lowland areas, and are known to colonize both undisturbed native areas and areas dominated by invasive vegetation (Reimer 1994). *Pheidole*

megacephala and *A. gracilipes* are generalist predators and are very abundant and aggressive (Holway *et al.* 2002).

Hylaeus populations are drastically reduced in ant-infested areas (Medeiros *et al.* 1986, Stone and Loope 1987, Cole *et al.* 1992, Reimer 1994). Aggressive ant species' primary impact on the native invertebrate fauna is via predation (Reimer 1994), and they also compete for nectar (Howarth 1985, Holway *et al.* 2002, Daly and Magnacca 2003, Lach 2008) and nest sites (Krushelnycky *et al.* 2005). Some ant species may impact *Hylaeus* species indirectly by predating on seeds of native plants (Bond and Slingsby 1994). Invasive ants' largest ecosystem-level effect has been to negatively affect pollination, partially due to direct predation on the larvae of *Hylaeus* species (Reimer 1994).

Invasive ants have severely impacted ground-nesting *Hylaeus* species (Cole *et al.* 1992, Medeiros *et al.* 1986); *Hylaeus* brood are more vulnerable to attack by aggressive ants than adult *Hylaeus* (Daly and Magnacca 2003) because they are immobile and their nests are easily accessible and in or near the ground. *Hylaeus hilaris* only attacks species that nest in the ground (Perkins 1913), and thus its brood would be especially susceptible to ant predation.

2. Non-native bee species

There are 15 species of non-native bees in Hawaii besides the native *Hylaeus* species (Snelling 2003), including two non-native *Hylaeus* species. Most non-native bees inhabit areas dominated by invasive vegetation and thus are not competing with *Hylaeus* species (Daly and Magnacca 2003). *Apis mellifera* (the European honeybee) is a major exception; this social species is often very abundant in areas with native vegetation, and aggressively competes with *Hylaeus* species for nectar and pollen (Daly and Magnacca 2003, Snelling 2003). *Apis mellifera* was first introduced to the Hawaiian Islands in 1875, and it currently inhabits areas from sea level to tree line (Howarth 1985). The major parasites that have decimated populations of *A. mellifera* in the continental United States are largely absent from the Hawaiian Islands, although the varroa mite (*Varroa destructor*) was recently discovered on Oahu and Hawaii (Ramadan 2007). They have been observed foraging on *Hylaeus* host plants such as *Scaevola* (Magnacca 2007). Populations of *A. mellifera* are not as vulnerable to predation by invasive ant species as are *Hylaeus*. Lach (2008) found that *Hylaeus* species that regularly collect pollen from ohia trees (*Metrosideros polymorpha*) were entirely absent from flowers visited by *P. megacephala*, but visits by *A. mellifera* were not affected.

Other non-native bee species present in areas of native vegetation include *Ceratina* spp., *Hylaeus albonitens*, and *Lasioglossum impavidum* (Magnacca 2007). These may have a significant impact on the hosts of *H. hilaris* through competition for pollen, because they are more similar in size and probably visit similar flowers. The impact of these species on *Hylaeus* species has not been studied (Magnacca 2007).

3. *Vespula pensylvanica* (the western yellow jacket wasp)

Vespula pensylvanica (the western yellow jacket wasp) is a social wasp native to North America. It was first reported from Oahu in the 1930s (Sherley 2000), and an aggressive race had become established by 1977 (Gambino *et al.* 1987). In temperate climates, *V. pensylvanica* has an annual life cycle, but in Hawaii's tropical climate, colonies often persist through a second year, allowing them to have larger numbers of individuals per colony (Gambino *et al.* 1987) and thus a greater impact on prey populations. Most colonies are found between 600 and 1050 m elevation (1969 to 3445 ft), but they can be found down to sea level (Gambino *et al.* 1990). *Vespula pensylvanica* is an aggressive opportunist generalist predator, and predates on *Hylaeus* species, although *Hylaeus* is not its primary prey source (Gambino *et al.* 1987). Because of the rarity of *H. hilaris*, the presence of any *V.*

pensylvanica colonies within their range might easily extirpate populations. *Vespula pensylvanica* might also compete for nectar with *Hylaeus* species.

D. The inadequacy of existing regulatory mechanisms

Currently no Federal, State, or local laws, treaties, or regulations specifically apply to *Hylaeus hilaris.* Only a single population of *H. hilaris* is known, on protected land at Moomomi Preserve on Molokai (Magnacca 2005).

It is important to note that even in areas protected from development, *Hylaeus* populations are still vulnerable to decline if their habitat is not actively managed to protect them from threats such as fire, feral ungulates, invasive invertebrates and the replacement of native vegetation by invasive plants (Magnacca 2007). Conservation of *H. hilaris* will likely require active management of protected areas, which can include exclusion and removal of feral ungulates, control and removal of invasive plant and insect species, and the restoration of native vegetation. Existing regulatory mechanisms are inadequate to provide the necessary active management to protect *Hylaeus hilaris.*

E. Other natural or manmade factors affecting its continued existence

1. Small population size and stochastic events

Small populations are generally at greater risk of extirpation from normal population fluctuations due to predation, disease, and changing food supply, as well as from natural disasters such as floods or droughts. They may also experience a loss of genetic variability and subsequent reduced fitness due to the unavoidable inbreeding that occurs in such small populations (Cox and Elmqvist 2000). *Hylaeus hilaris* is rare and has only one, very small population, and is likely more vulnerable to habitat change and stochastic events due to its low genetic variability.

2. Global climate change

Global climate change may threaten *H. hilaris*. A changing climate may cause shifts in the range of host plant species and can be especially detrimental to dependent pollinators when combined with habitat loss (NRC 2007). Most native bees have difficulty crossing geographical barriers and tend to fly only during good weather (Michener 2000), and successive generations of solitary species tend to nest in the same area year after year. *Hylaeus hilaris* is restricted to habitat patches where host species are present, and is not likely to disperse far to find new habitat. Thus, the ecology of this species, combined with the patchy distribution of its remaining habitat, might hinder dispersal made necessary by climate change (Michener 1974, Daly and Magnacca 2003) and cause the extirpation of remaining populations.

Climate change may also have a deleterious effect on *H. hilaris* if it results in altered rainfall patterns. The dry coastal habitat already incurs cyclical droughts, and an increase in rainfall variability would result in longer periods between vegetation flushes and concomitant high host bee populations. Again, the inherently smaller population of a cleptoparasite makes it more likely to die out during a time of poor weather, while its host may survive in small numbers and increase once conditions improve.

3. The vulnerability of island endemics

Hylaeus hilaris is endemic to the Hawaiian Islands of Molokai, Lanai, and Maui. Species that are endemic to islands are particularly vulnerable to population decline and extinction because they evolved in isolation from many aggressive species that have been introduced to the Hawaiian Islands (Stone and Scott 1985). Furthermore, many Hawaiian species, such as *H. hilaris,* have small populations that are patchily distributed and highly localized, making them especially vulnerable to habitat disturbance and stochastic events (Daly and Magnacca 2003, Magnacca 2007).

Hawaiian *Hylaeus* species form a diverse and large lineage that evolved in an unusually short amount of time relatively recently (Magnacca and Danforth 2006, Magnacca and Danforth 2007). Lineages of island endemics with high proportions of recently evolved taxa are at higher risk of extinction if associated with narrow habitat specificity (Sakai *et al.* 2002). *Hylaeus hilaris*, being both a cleptoparasite and restricted to sandy coastal sites, is the most habitat-specific of all Hawaiian bees (Daly and Magnacca 2003). Furthermore, the close interdependence of Hawaiian endemic flora and their endemic pollinators (Sakai *et al.* 1995) makes them vulnerable to reciprocal decline and extinction (Cox and Elmqvist 2000).

VIII. CONCLUSION

There is strong evidence of significant decline of *H. hilaris*, and it is the most highly endangered native Hawaiian *Hylaeus* species that is known to be extant (Magnacca 2007). Perkins, whose 1892-1906 survey of the *Hylaeus* is the basis for most of the historic records of the genus in Hawaii, called *Hylaeus* species "almost the most ubiquitous of any Hawaiian insects" (Perkins 1913). *Hylaeus hilaris* was widespread in Perkins' time, but not abundant in its habitat (Magnacca 2005). Recent surveys indicate that most *Hylaeus* species are in decline, many are extremely rare, and several are possibly extinct (Daly and Magnacca 2003, Shepherd *et al.* 2005, Magnacca 2007). Thirteen sites on Maui, Molokai, and Lanai, including three historical collection sites, were recently searched for *H. hilaris*.

The primary threats to *H. hilaris* are:

1. Habitat loss due to development or land conversion (Cuddihy and Stone 1990, Magnacca 2007)
2. The displacement of native flora that it depends upon by invasive plant species, fire, and feral ungulates (Cuddihy and Stone 1990, Daly and Magnacca 2003)
3. Predation by:
    a. Adventive ants such as *Anoplolepis gracilipes* (the long-legged ant) and *Pheidole megacephala* (the big-headed ant) (Cole *et al.* 1992, Daly and Magnacca 2003)
    b. *Vespula pensylvanica* (the western yellow-jacket wasp) (Gambino *et al.* 1987)
4. Stochastic effects (e.g. storms, drought) due to extremely small population size and limited range

The above threats, the rarity of this species, and the natural instability of small populations of island endemics lead us to conclude, unequivocally, that *Hylaeus hilaris* is threatened with extinction and must be given protection under the Endangered Species Act.

IX. REFERENCES

Alpha, C. G., D. R. Drake, and G. Goldstein. 1996. Morphological and physical responses of *Scaevola sericea* (Goodeniaceae) seedlings to salt spray and substrate salinity. American Journal of Botany 83(1): 86-92.

Ascher, J. S. 2005. Species Profile: *Epeoloides pilosula*. *In* Shepherd, M. D., D. M. Vaughan, and S. H. Black (Eds). Red List of Pollinator Insects of North America. CD-ROM Version 1 (May 2005). Portland, OR: The Xerces Society for Invertebrate Conservation.

Blackmore, M. and P. M. Vitousek 2000. Cattle grazing, forest loss and fuel loading in a dry forest ecosystem at Pu'u Wa'aWa'a Ranch, Hawai'i. Biotropica 32(4a): 625-632.

Bond, W. and P. Slingsby. 1984. Collapse of an ant-plant mutualism: the Argentine Ant (*Iridomyrmex humilis*) and myrmecochorous Proteaceae. Ecology 65:1031-1037.

Cole , F.R., A. C. Medeiros, L. L. Loope, and W. W. Zuehlke. 1992. Effects of the Argentine ant on arthropod fauna of Hawaiian high-elevation shrubland. Ecology 73:1313 – 1322 .

Cox, P. A. and T. Elmqvist. 2000. Pollinator extinction in the Pacific Islands. Conservation Biology 14(5): 1237-1239.

Cuddihy, L. W. and C. P. Stone. 1990. *Alteration of Native Hawaiian Vegetation: Effects of Humans, Their Activities and Introductions*. Honolulu: University of Hawaii Cooperative National Park Resources Studies Unit.

Daly, H. V. and K. N. Magnacca. 2003. *Insects of Hawaii: Volume 17: Hawaiian Hylaeus (Nesoprosopis) Bees (Hymenoptera: Apoidea).* Honolulu: University of Hawaii Press.

D'Antonio, C. M., J. T. Tunison, and R. Loh. 2000. Variation in impact of exotic grass fueled fires on species composition across an elevation gradient in Hawaii. Austral Ecology 25: 507-522.

Foote, D. and H. L. Carson. 1995. Drosophila as monitors of change in Hawaiian ecosystems. *In* E.T. LaRoe, G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac (Eds.) *Our Living Resources: A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems*. Washington D.C.: U.S. Department of Interior, National Biological Service.

Fullaway, D. T. 1918. Notes on Hawaiian Prosopidae. Proceedings of the Hawaiian Entomological Society 3:393-398.

Gagne, W. C. 1979. Canopy-associated arthropods in *Acacia koa* and *Metrosideros* tree communities along an altitudinal transect on Hawaii Island. Pacific Insects 21:56-82.

Gambino, P., A. C. Medeiros and L. L. Loope. 1987. Introduced vespids *Paravespula pensylvanica* prey on Maui's endemic arthropod fauna. Journal of Tropical Ecology 3(2): 169-170.

Gambino, P., A. C. Medeiros and L.L. Loope. 1990. Invasion and colonization of upper elevations on East Maui (Hawaii) by *Paravespula pennsylvanica* (Hymenoptera: Vespidae). Annals of the Entomological Society of America 83: 1088-1095.

Holway, D.A., L. Lach, A. V. Suarez, N. D. Tsutsui, and T. J. Case. 2002. The causes and consequences of ant invasions. Ann. Rev. Syst. 33: 181-233.

Howarth, F. G. 1985. Impacts of alien land arthropods and mollusks on native plants and animals in Hawaii, pp. 149-179 *In* Stone, C. P. and J. M. Scott (Eds.) *Hawaii's Terrestrial Ecosystems: Preservation and Management.* Honolulu: University of Hawaii Press.

Krushelnycky, P. D., L. L. Loope and N. J. Reimer. 2005. The ecology, policy and management of ants in Hawaii. Proc. Hawaiian Entomol. Soc. 37.

Lach, L. 2008. Floral visitation patterns of two invasive ant species and their effects on other Hymenopteran visitors. Ecological Entomology 33(1): 155-160.

Liebherr, J. K. and D. A. Polhemus. 1997. R. C. L. Perkins: 100 Years of Hawaiian Entomology. Pacific Science 51(4): 343-355.

Liebherr, J. K. 2005. Patterns of endangerment or pathways to enlightenment? Reconstructing the *Fauna Hawaiiensis*. Systematics and Biodiversity 2(2): 175-189.

Magnacca, K. N. 2005. Species Profile: *Hylaeus hilaris. In* Shepherd, M. D., D. M. Vaughan, and S. H. Black (Eds.). *Red List of Pollinator Insects of North America.* CD-ROM Version 1 (May 2005). Portland, OR: The Xerces Society for Invertebrate Conservation.

Magnacca, K. N.. and B. C. Danforth. 2006. Evolution and biogeography of native Hawaiian Hylaeus bees (Hymenoptera: Colletidae). Cladistics 22 (5):393–411.

Magnacca, K. N. and B. C. Danforth. 2007. Low nuclear DNA variation supports a recent origin of Hawaiian *Hylaeus* bees (Hymenoptera: Colletidae). Molecular Phylogenetics and Evolution 43(3): 908-915.

Magnacca, K. M. 2007. Conservation status of the endemic bees of Hawaii, *Hylaeus* (*Nesoprosopis*) (Hymenoptera: Colletidae). Pacific Science 61(2): 173-190.

Mascaro, J., K. K. Becklund, R. F. Hughes, and S. A. Schnitzer. 2008. Limited native plant regeneration in novel, exotic-dominated forests on Hawaii. Forest Ecology and Management 256(4): 593-606.

Meade-Waldo, G. 1923. Hymenoptera, fam. Apidae, subfam. Prosopidae, fasc. 181. pp.1-45 *In* P. Wystman (Ed.), *Genera Insectorum.* Brussels: L. Desmet-Verteneuil.

Medeiros, A. C., L. L. Loope, F. R. Cole. 1986. Distribution of ants and their effects on endemic biota of Haleakala and Hawaii Volcanoes National Park: a preliminary assessment. pp. 39-52. Proc. 6thConf. Nat. Sci., Hawaii Volcanoes National Park.

Michener, C. D. 1974. The Social Behavior of Bees. Cambridge: Harvard University Press.

Michener, C. D. 2000. *The Bees of the World*. The Johns Hopkins University Press: Baltimore and London.

National Research Council. 2007. *Status of Pollinators in North America*. Washington D.C.: National Academies Press.

Nature Conservancy of Hawaii. 1987. *Biological overview of Hawaii's Natural Area Reserves System.* Hawaii Heritage Program. Prepared for Hawaii State Department of Land and Natural Resources. Honolulu.

Perkins, R. C. L. 1899. Hymenoptera, Aculeata, pp. 1-115, Pls. 1-2. *In* D. Sharp (Ed.), *Fauna Hawaiiensis.* Vol. 1. Cambridge University Press, Cambridge, United Kingdom.

Perkins, R. C. L. 1913. Introduction. Pages i–ccxxvii *In* D. Sharp (Ed.) *Fauna Hawaiiensis*. Vol. 1. Cambridge University Press, London.

Ramadan, M. M. 2007. Trouble in paradise - First varroa mites found in Hawaii. American Bee Journal 147:465-465.

Reimer, N. J., J. W. Beardsley, and G. Jahn. 1990. Pest ants in the Hawaiian Islands. Pp. 40-50 *In* R. K. Vander Meer, K. Jaffe, and A. Cedeno (Eds.) *Applied Myrmecology: A world perspective*. Westview Press, Boulder, CO.

Reimer, N. J. 1994. Distribution of invasive ants in vulnerable Hawaiian ecosystems. *In* David F. Williams (Ed.) *Exotic Ants: Biology, Impact and Control of Introduced Species.* Boulder, Colorado: Westview Press.

Richmond, T. de A. and D. Mueller-Dombois. 1972. Coastline ecosystems on Oahu, Hawaii. Vegetation 25: 367-400.

Sakai, A.K., W. L. Wagner, D. M. Ferguson. 1995. Origins of dioecy in the Hawaiian flora. Ecology 76:2517-2529.

Sakai, A. K., W. L. Wagner and L. A. Mehrhoff. 2002. Patterns of endangerment in the Hawaiian flora. Systematic Biology 51:276–302.

Shepherd, M.D., D.M. Vaughan, and S. H. Black (Eds.). *Red List of Pollinator Insects of North America.* CD-ROM Version 1 (May 2005). Portland, OR: The Xerces Society for Invertebrate Conservation.

Sherley, G. (Ed.). 2000. Invasive species in the Pacific: A technical review and draft regional strategy. Apia, Samoa: South Pacific Regional Environment Programme.

Smith, F. 1879. Descriptions of new species of Aculeate Hymenoptera collected by the Rev. Thos. Blackburn in the Sandwich Islands. Journal of the Linnaean Society 14:674-685.

Smith, C. W. and J. T. Tunison. 1992. Fire and invasive plants in Hawai'i: research and management implications for native ecosystems. *In* C. P. Stone and J. M. Scott (Eds.). *Hawai'i's terrestrial ecosystems: preservation and management*. Pp. 394-408. Cooperative National Park Resources Study Unit, University of Hawai'i. Honolulu. Hawaii.

Snelling, R.R. 2003. Bees of the Hawaiian Islands, exclusive of *Hylaeus* (*Nesoprosopis*) (Hymenoptera: Apoidea). Journal of the Kansas Entomological Society 76**:**342 – 356.

Stone, C. P. and S. J. Anderson. 1988. Introduced animals in Hawaii's natural areas. Vertebrate Pest Conference Proceedings Collection: Proceedings of the 13th Vertebrate Pest Conference. University of Nebraska, Lincoln.

Stone, C. P. 1985. Invasive animals in Hawaii's native ecosystems: toward controlling the adverse effects of introduced vertebrates. pp. 251-288 *In* C.P. Stone and J. M. Scott (Eds.) *Hawaii's Terrestrial Ecosystems: Preservation and Management.* Cooperative National Park Resources Study Unit. Honolulu: University of Hawaii.

Stone, C. P. and L. L. Loope. 1987. Reducing negative effects of introduced animals on native biotas in Hawaii: What is being done, what needs doing, and the role of national parks. Environmental Conservation 14:245-258.

Stone, C. P. and J. M. Scott (Eds.). 1985. *Hawaii's Terrestrial Ecosystems: Preservation and Management*. Proceedings of a Symposium held June 5-6, 1984 at Hawaii Volcanoes National Park. Cooperative National Park Resources Studies Unit: University of Hawaii, Honolulu.

USFWS. 1984. Endangered and threatened wildlife and plants: Review of invertebrate wildlife for listing as endangered or threatened species. Fed. Regist. 49:21664-21673.

USFWS. 1999. Recovery Plan for the Multi-Island Plants. U.S. Fish and Wildlife Service: Portland, Oregon.

USFWS. 2006. Endangered and threatened wildlife and plants: Determination of status for 12 species of Picture-Wing Flies from the Hawaiian Islands. Federal Register. Vol. 71 No. 89. Tuesday, May 9, 2006. Rules and Regulations. Accessed 5 August 2008. http://www.fws.gov/pacificislands/CHRules/picturewings.pdf

USFWS. 2008. Hawaiian Islands Plants: Listed species, as designated under the U.S. Endangered Species Act. Accessed 23 June 2008. http://www.fws.gov/pacificislands/wesa/HIlistingplants.pdf

Wagner, W. L., D. R. Herbst and R. S. N. Yee. 1985. Status of the native flowering plants of the Hawaiian Islands. *In* C. P. Stone and J. M. Scott (Eds.) *Hawaii's Terrestrial Ecosystems: Preservation and Management.* Cooperative National Park Resources Study Unit. Honolulu: University of Hawaii.

Wilson, E. O. and R. W. Taylor. 1967. The ants of Polynesia. Pacific Insects Monograph 14.

Zimmerman, E. C. 1948. *Insects of Hawaii*. Vol. 1. Introduction. xv. Univ. of Hawaii Press, Honolulu.

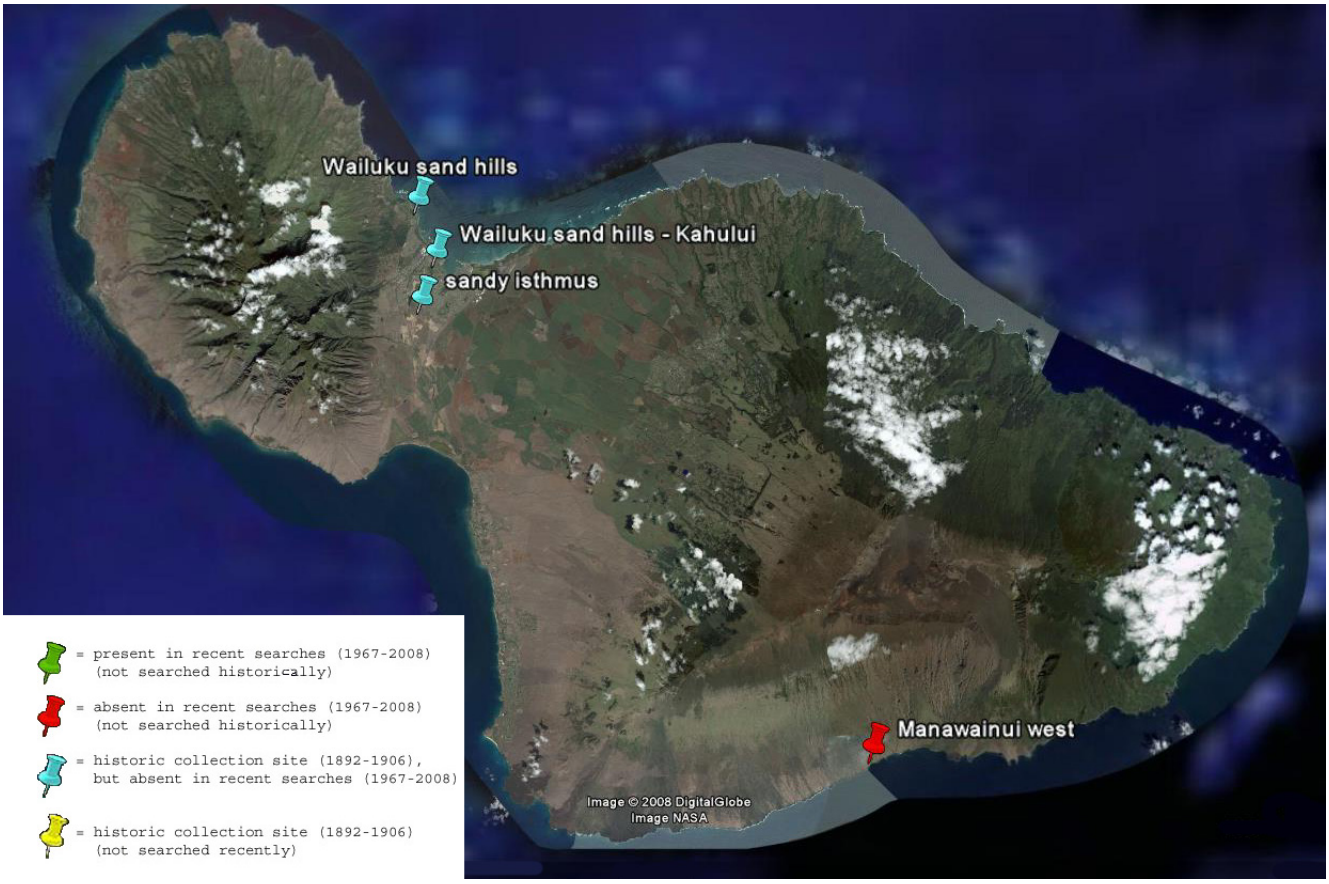
Zimmerman, E. C. 1972. Adaptive radiation in Hawaii with special reference to insects. pp.528-534 *In* A. Key (Ed.) *A Natural History of The Hawaiian Islands.* Honolulu: University Press of Hawaii.

Personal communication
K. Magnacca, Jan. and July 2008

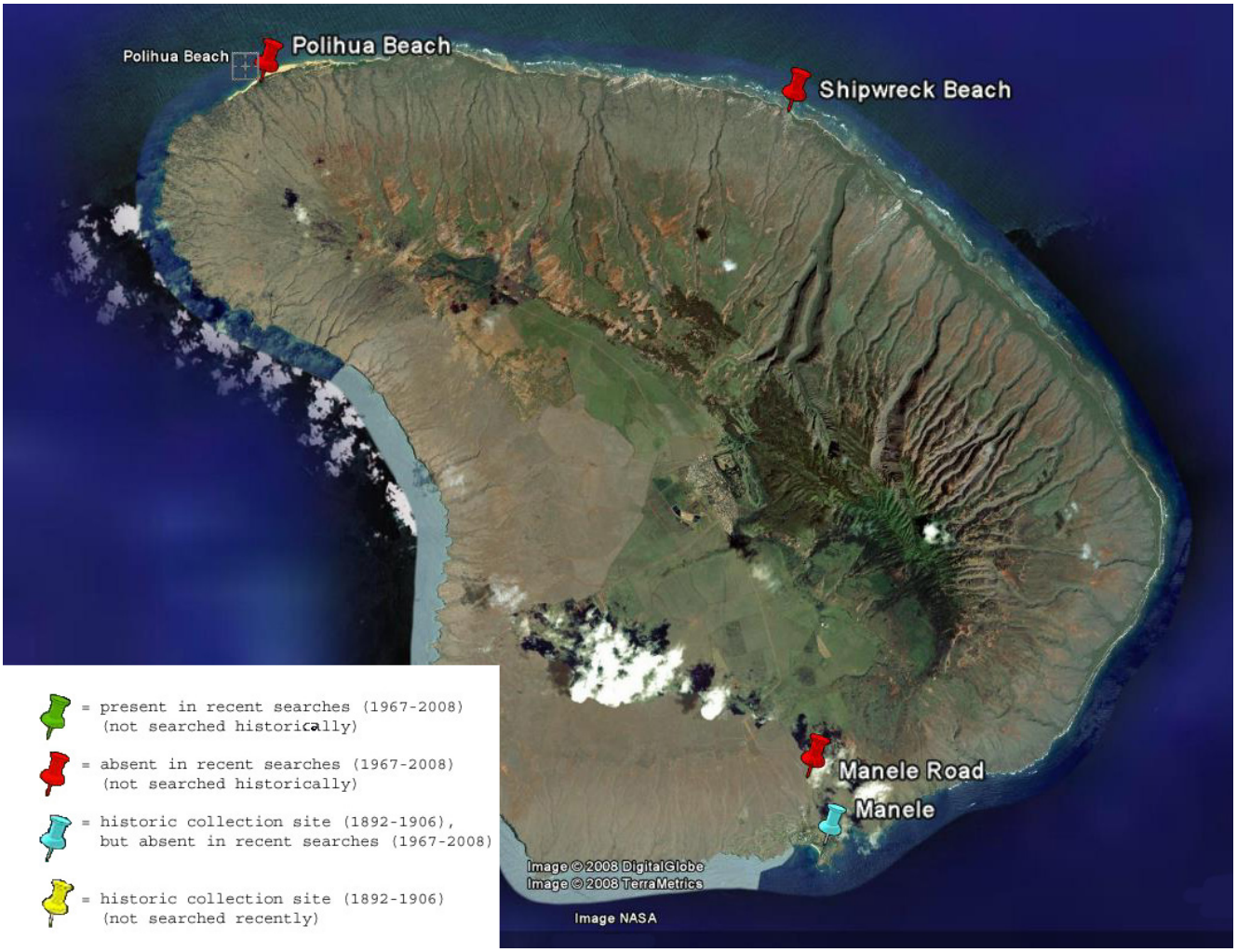
Unpublished data
K. Magnacca

APPENDIX 1A-C. Locations of recorded specimens of *Hylaeus hilaris.*

Appendix 1A. Map of Maui showing recent and historic collection sites for *Hylaeus hilaris* (map ©2008 Digital Globe).



Appendix 1B. Map of Lanai with historic and recent collection sites for *Hylaeus hilaris* (map ©2008 Digital Globe)



Appendix 1C. Map of Molokai showing recent and historic collection sites for *Hylaeus hilaris* (map ©2008 Digital Globe).