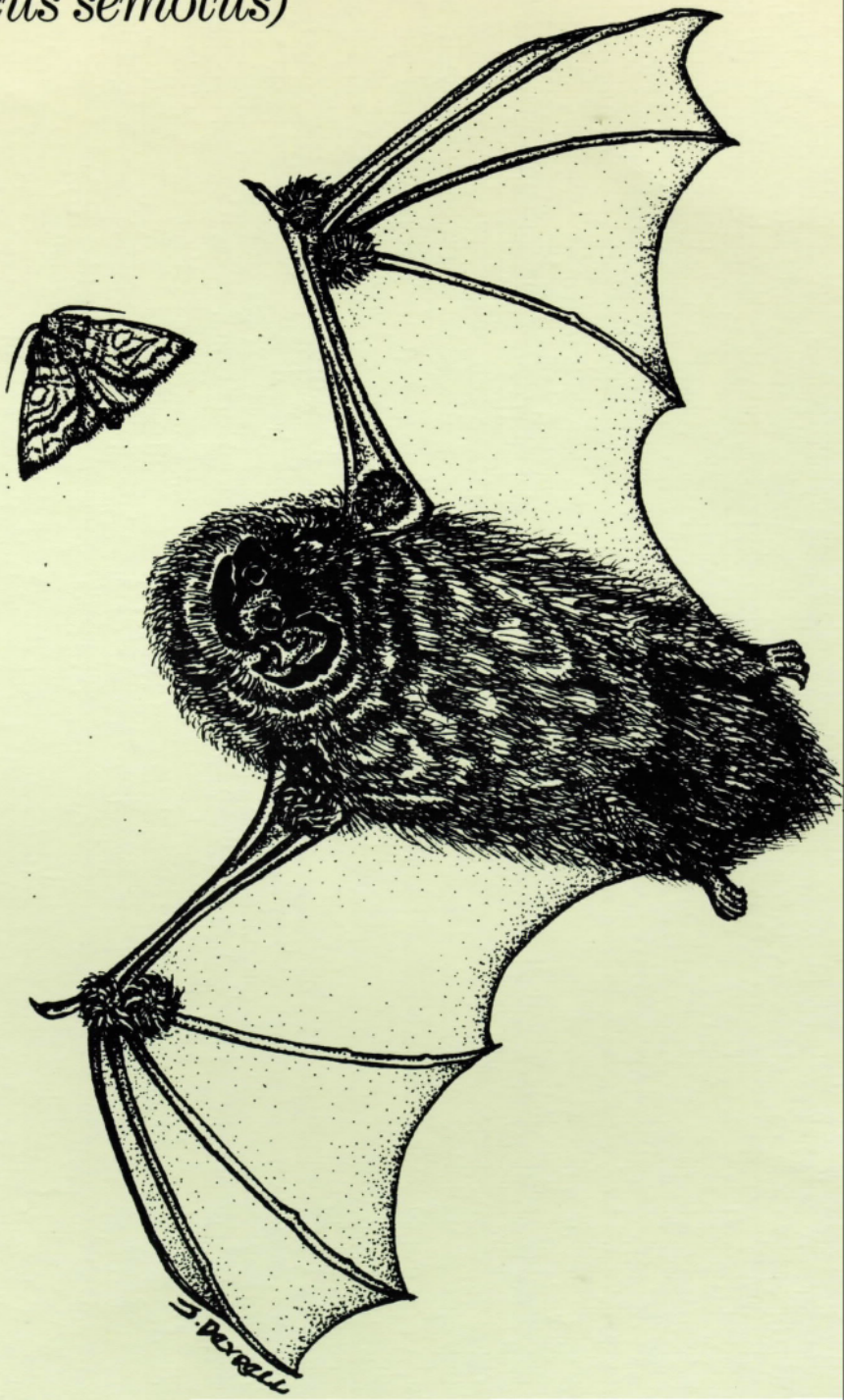
U.S. Fish and Wildlife Service

Recovery Plan for the Hawaiian Hoary Bat

(Lasiurus cinereus semotus)



RECOVERY PLAN

for the

HAWAIIAN HOARY BAT

(*Lasiurus cinereus semotus*)

Published by

Region 1
U.S. Fish and Wildlife Service
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Literature citations should read as follows:

U.S. Fish and Wildlife Service. 1998. Recovery Plan for the Hawaiian Hoary Bat. U.S. Fish and Wildlife Service, Portland, OR. 50 pp.

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EXECUTIVE SUMMARY

Current Species Status: The Hawaiian hoary bat (*Lasiurus cinereus semotus*) is federally listed as endangered. It is known from the islands of Hawaii, Maui, Oahu, Kauai, and Molokai. Population numbers are not known, but Hawaiian hoary bats are observed regularly only on Hawaii, Kauai, and Maui. There is a general lack of historic and current data on this subspecies, and its present status is not well-understood.

Habitat Requirements and Limiting Factors: Habitat requirements for the Hawaiian hoary bat are not well-known. Bats are most often observed foraging in open areas, near the edges of native forests, or over open water, although this may be due to the ease of detection in these habitats. Hawaiian hoary bats roost solitarily in the foliage of trees. Habitat requirements may vary seasonally, but this is not clear. Threats to this subspecies include habitat destruction (elimination of roosting sites), and possibly direct and indirect effects of pesticides, introduced insects, and disease.

Recovery Objectives: Delisting, with interim goals of determining present population status and downlisting to threatened status.

Recovery Criteria: Because the population status and natural history of this subspecies are not well understood, the interim goal of this plan is to determine actual population status and habitat requirements. Determining actual population numbers for this subspecies is not practical, but indices of abundance are obtainable and can be used to identify quantifiable goals. Hence, downlisting can occur when the population on Hawaii is determined to be stable or increasing for at least five consecutive years. For delisting, the criteria outlined for downlisting must be met together with a determination that populations on Kauai and Maui are stable or increasing for at least five consecutive years.

Actions Needed:

1. Conduct research essential to the conservation of the subspecies.
2. Protect and manage current populations and identify and manage threats.
3. Conduct a public education program.
4. Evaluate the progress of recovery and revise recovery criteria as necessary.

Total Estimated Cost of Recovery ($1,000's); some costs are yet to be determined:

Year	Need 1	Need 2	Need 3	Need 4	Total
1999	2,440	0	20	0	2,460
2000	770	0	10	0	780
2001	920	400	2	0	1,322
2002	850	275	2	0	1,127
2003	810	200	2	0	1,012
2004	190	200	2	0	392
2005	190	200	2	0	392
2006	150	0	2	0	152
2007	150	0	2	0	152
2008	150	0	2	0	152
2009	150	0	2	0	152
2010	150	0	2	0	152
2011	150	0	2	0	152
2012	150	0	2	0	152
2013	150	0	2	0	152
Total	**7,370**	**1,275**	**56**	**TBD**	**8,701**

Date of Recovery: Downlisting to threatened may be considered in 2004 and delisting in 2013 if recovery criteria are met.

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I. INTRODUCTION

A. Brief Overview

The Hawaiian Islands are located over 3,200 kilometers (2,000 miles) from the nearest continent, making them the most isolated high islands on earth (Wagner *et al.* 1990) (Figure 1). This isolation has allowed the few plants and animals that arrived there to evolve into many varied and highly endemic (native to a particular area) species. In many cases, these unique species have lost their defenses against threats typical of mainland environments, such as mammalian predation (U.S. Fish and Wildlife Service 1994). Intentional or inadvertent introduction of nonnative plant and animal taxa has contributed to the reduction of native flora and fauna on the Hawaiian Islands (Cuddihy and Stone 1990). This problem has been exacerbated on some islands (e.g., Kauai) by the effects of recent hurricanes, which have blown over large areas of native forest leaving open areas where nonnative plants become established and opening paths for further invasion of nonnative animals. The disturbance to ecosystems caused by nonnative plants and animals, combined with the direct effect of human activities, has resulted in the extinction of more than one half of Hawaii's bird species and land snails and an unknown number of plant species and insects (Cuddihy and Stone 1990). It is possible that the alteration of native ecosystems has contributed to the presumed decline of Hawaii's only bat, the Hawaiian hoary bat (Vespertilionidae: *Lasiurus cinereus semotus* [Allen]), known locally as the ʻōpeʻapeʻa.

The Hawaiian hoary bat is the only existing native terrestrial mammal known from the Hawaiian archipelago; another unidentified insectivorous bat species is known only from subfossil remains (A.L. Zeigler and F.G. Howarth, Bishop Museum unpubl. data). Relatively little research has been conducted on this subspecies, and the data regarding its habitat affinities and population status are often conflicting. The hoary bat has been documented on the islands of Hawaii, Maui, Oahu, Kauai, and Molokai (Figures 2–6) with one unconfirmed observation on Kahoolawe (Hawaii Natural Heritage Program 1992); the distributions of

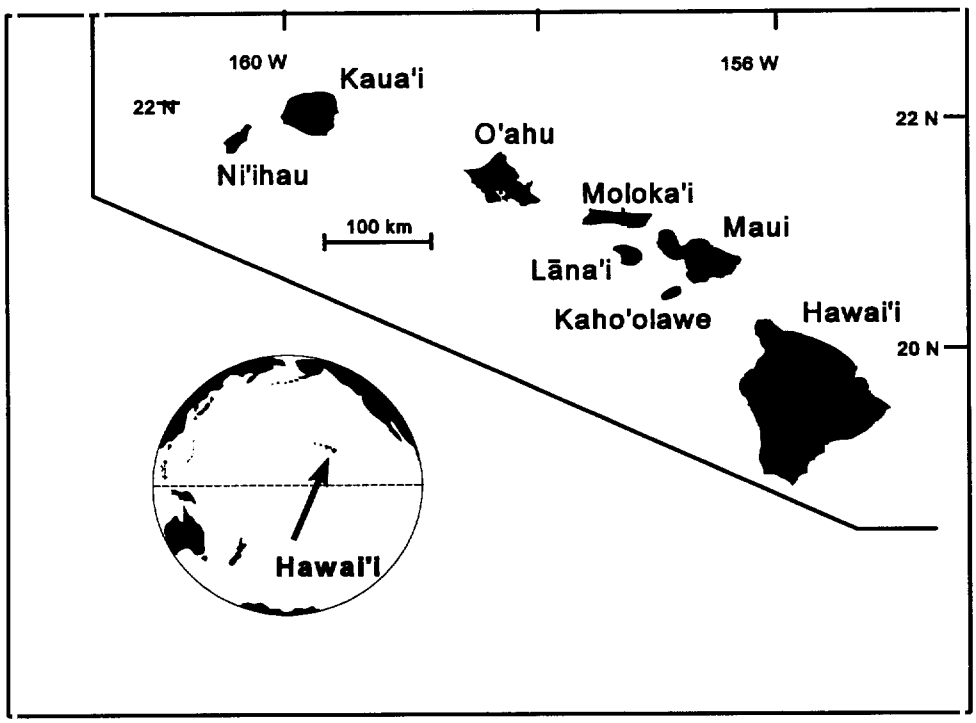

Figure 1. The Main Hawaiian Islands.

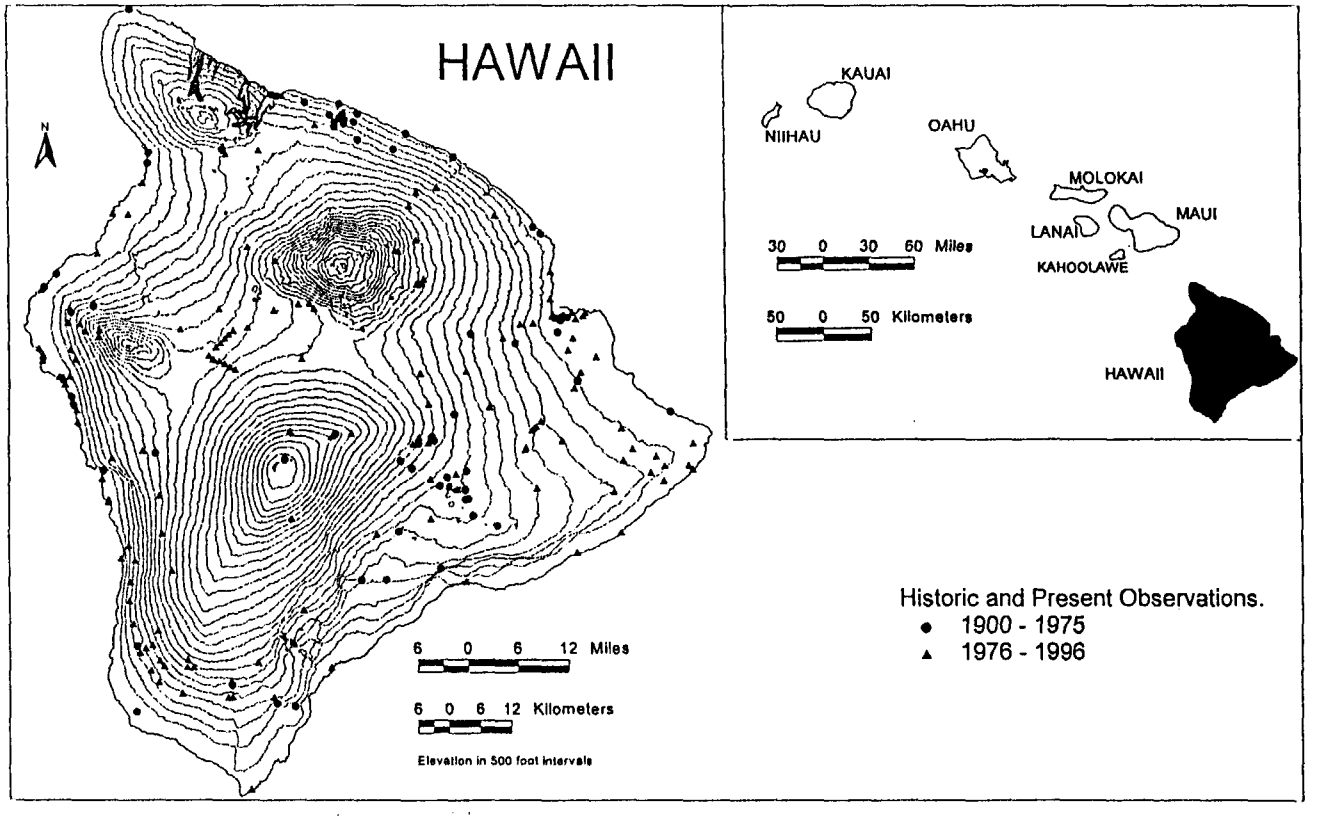

Figure 2. Historic and current distribution of Hawaiian hoary bats on Hawaii (Hawaii Natural Heritage Program 1996).

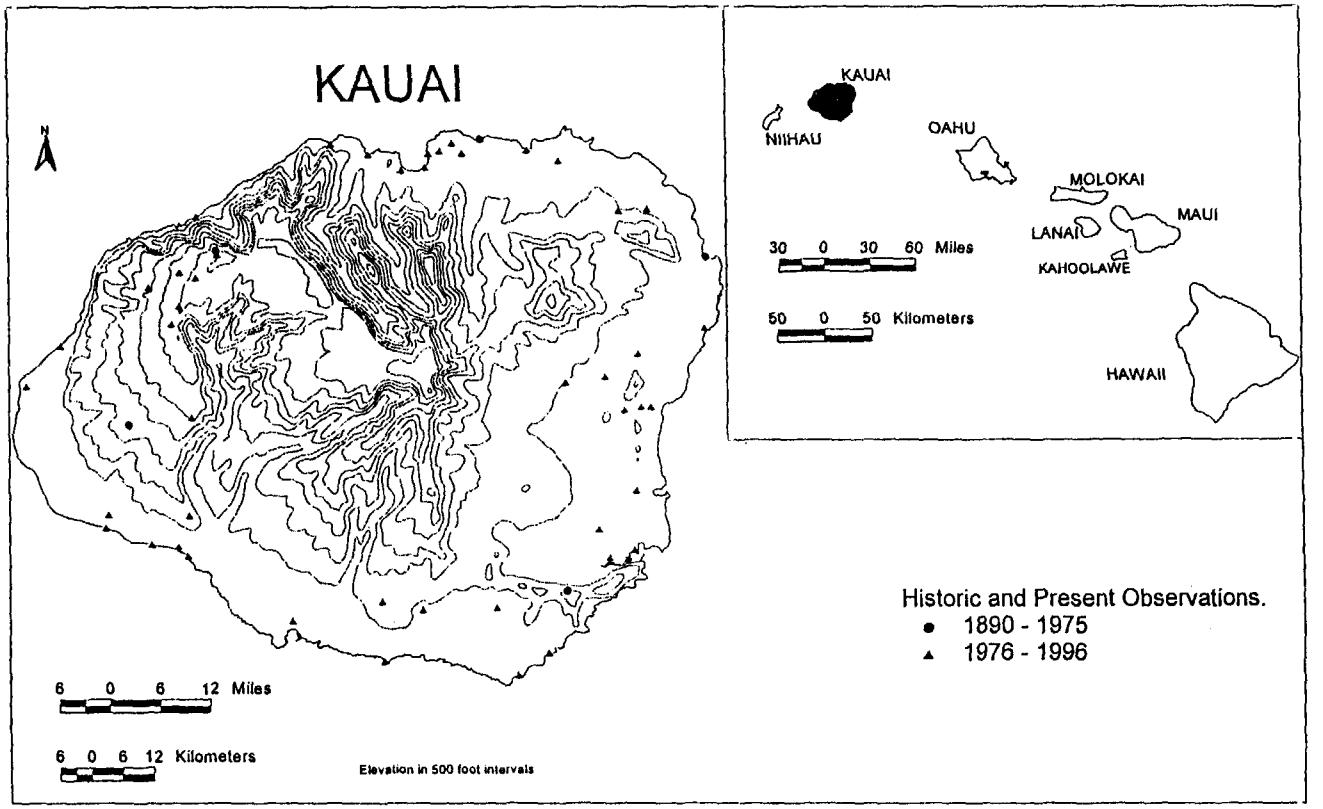

Figure 3. Historic and current distribution of Hawaiian hoary bats on Kauai (Hawaii Natural Heritage Program 1996).

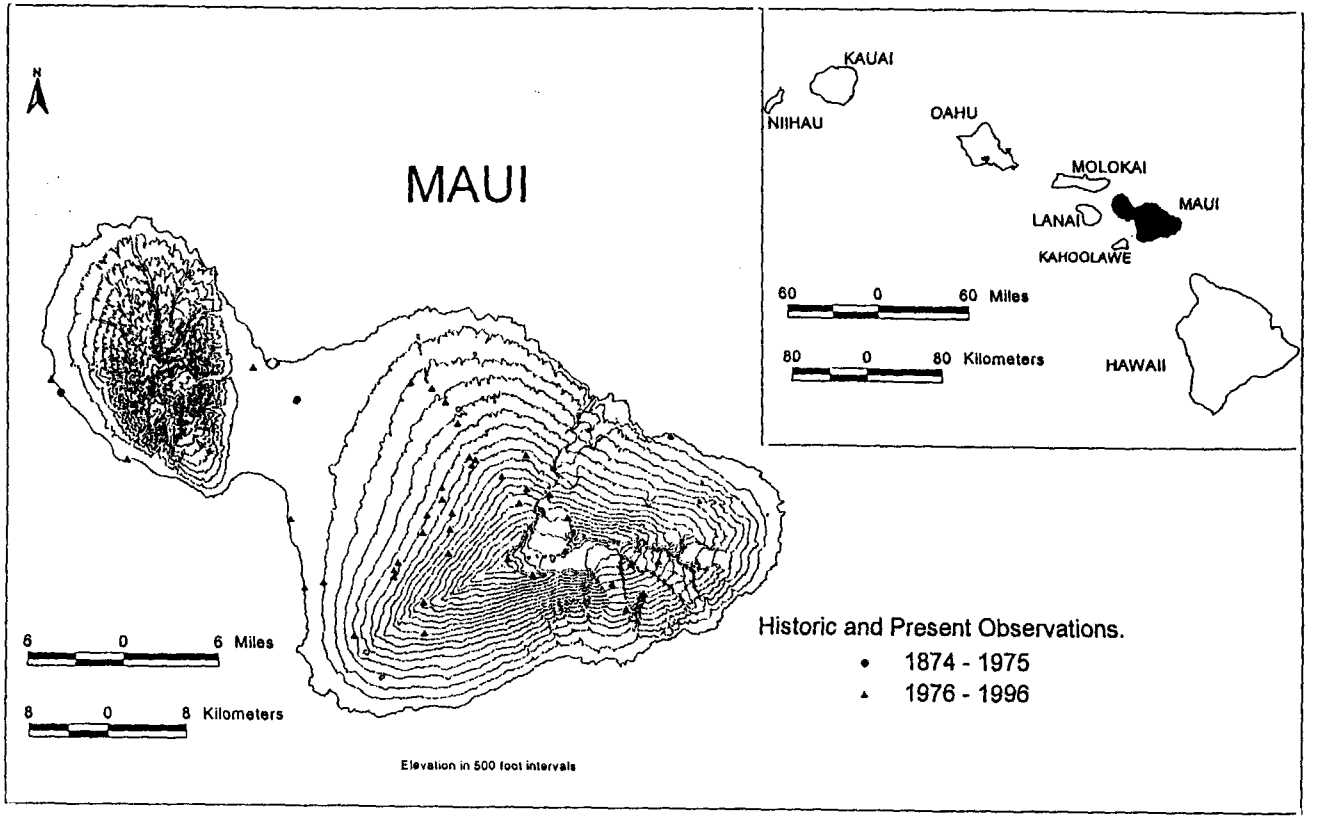

Figure 4. Historic and current distribution of Hawaiian hoary bats on Maui (Hawaii Natural Heritage Program 1996).

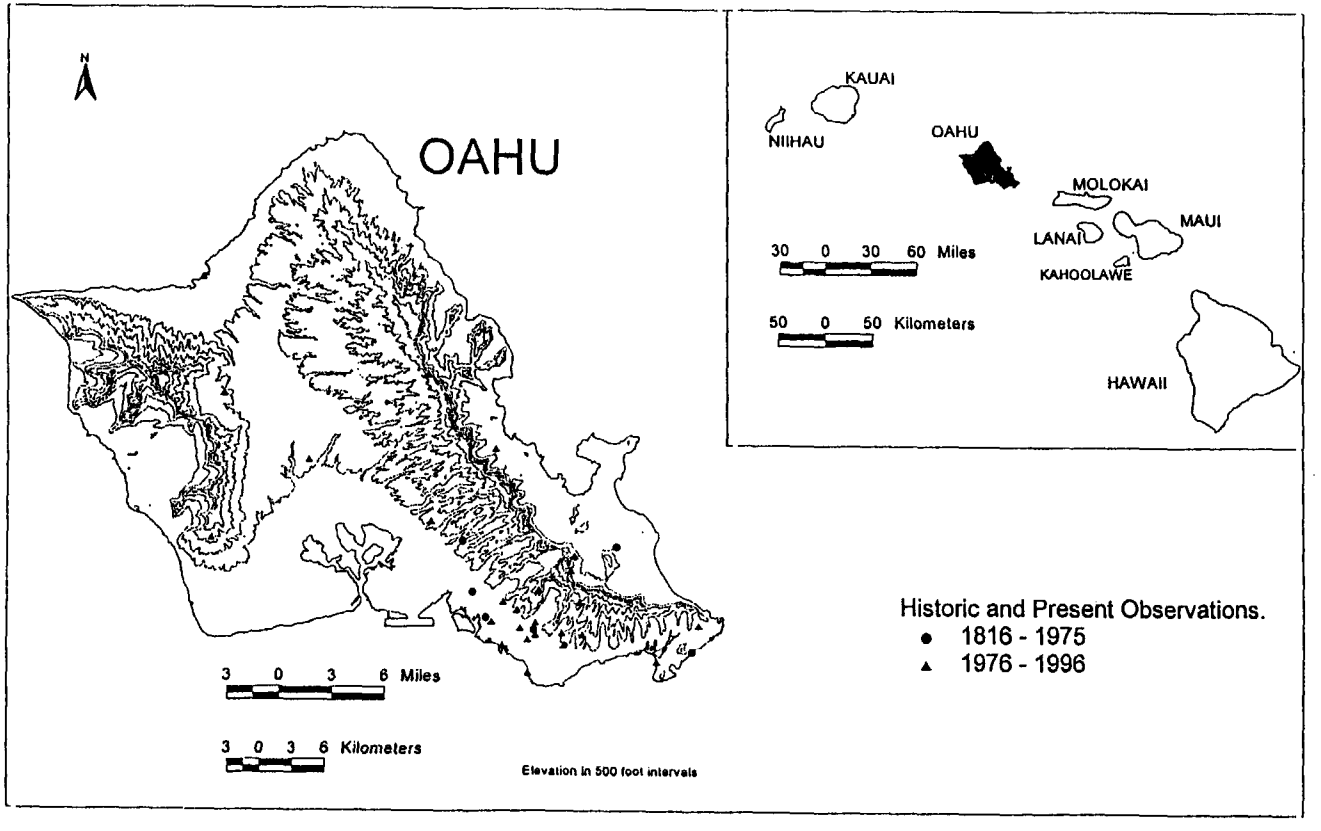

Figure 5. Historic and current distribution of Hawaiian hoary bats on Oahu (Hawaii Natural Heritage Program 1996).

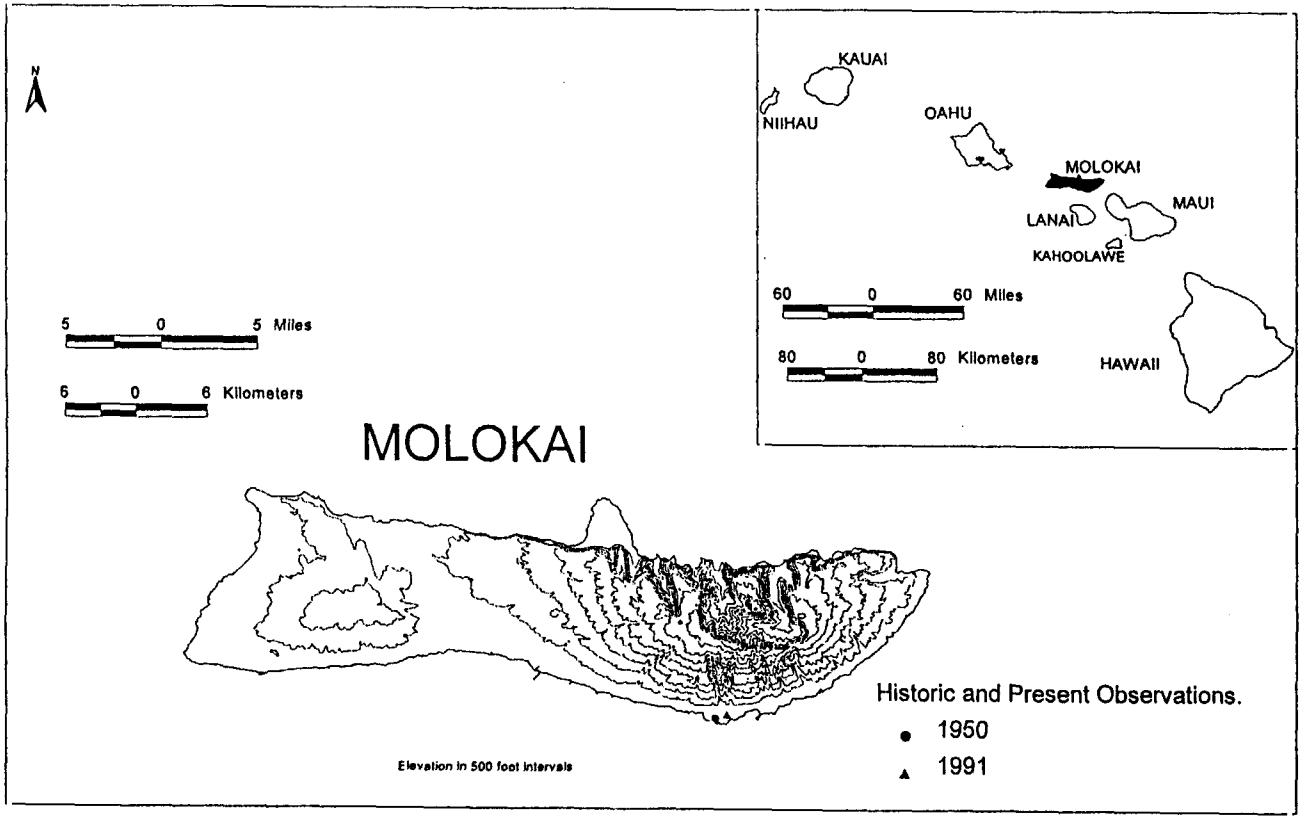

Figure 6. Historic and current distribution of Hawaiian hoary bats on Molokai (Hawaii Natural Heritage Program 1996).

Hawaiian hoary bats may be broader than indicated on these maps due to bias from unequal sampling effort in different portions of each island, the nocturnal nature of this species, and because effective ultrasonic detection methods have been readily available for little more than 10 years.

The largest populations of Hawaiian hoary bats are thought to occur on Kauai and Hawaii (Tomich 1974). On Hawaii, most observations of these bats have been made between sea level and 2,286 meters (7,500 feet) elevation, although bats have been seen at elevations as high as 4,023 meters (13,200 feet) (Baldwin 1950; Theresa Cabrera Menard, U. of Hawaii, personal communication [pers.comm.] 1997; Fujioka and Gon 1988; Kepler and Scott 1990; Tomich 1974). Population numbers are not known, but the bat is believed to have declined in numbers over the past 100 years, probably as a result of habitat loss. The availability of roosting sites is believed to be a major limitation in many bat species, but other possible threats to the Hawaiian hoary bat include pesticides (either directly or by impacting prey species), predation, alteration of prey availability due to the introduction of nonnative insects, and roost disturbance.

The Hawaiian hoary bat was listed as endangered on October 13, 1970 (U.S. Fish and Wildlife Service 1970) and has been assigned a recovery priority number of 9, indicating a subspecies with a moderate degree of threat and a high potential for recovery (U.S. Fish and Wildlife Service 1983). Critical habitat has not been designated for this species.

B. Description and Taxonomy

The Hawaiian hoary bat is a medium-sized (14–22 grams [0.5–0.8 ounces]), nocturnal, insectivorous bat. Hoary bats are heavily furred and possess a hair color that is a mixture of brown and gray tinged with white, producing a frosted or 'hoary' appearance. Hoary bat ears are short, thick and rounded, and edged with black. The Hawaiian hoary bat may be somewhat more red in color than the North American subspecies (Tomich 1986c). Hawaiian hoary bats are

approximately 45 percent smaller in mass in comparison with the North American hoary bat (Jacobs 1993a). Females are larger than males (females average 17.9 grams [0.6 ounces]; males weigh approximately 14.2 grams [0.5 ounces]). Forearm lengths are similar in both males and females, averaging between 48.5 and 50.5 millimeters (1.90 to 1.97 inches) (Jacobs 1993a). Hawaiian hoary bats have a wingspan of about 26.9–34.6 centimeters (10.5–13.5 inches).

The Hawaiian hoary bat belongs to the suborder Microchiroptera, which includes all bats except Old World fruit bats. The taxonomic treatment of the genus *Lasiurus* varies: Koopman (1993) recognized seven species, including five North American species; Jones, Jr. *et al.* (1992) recognized seven North American species occurring north of Mexico; and Nowak (1994) recognized thirteen species under *Lasiurus*. The Hawaiian hoary bat is one of three recognized hoary bat subspecies; *Lasiurus cinereus cinereus* occurs throughout North America, and *Lasiurus cinereus vilosissimus* occurs in South America (Hall 1981).

The Hawaiian hoary bat is endemic to the Hawaiian Islands and is thought to be derived from the North American hoary bat (Morales and Bickham 1995). Jacobs (1993a) presented morphological evidence suggesting that significant divergence of the Hawaiian hoary bat from the mainland form has occurred, and Tomich (1986c) suggested that classification of the Hawaiian hoary bat as a full species may be appropriate. Morales and Bickham (1995), however, found a relatively low degree of genetic divergence between the Hawaiian hoary bat and the North American hoary bat, and they argue that subspecific status for the Hawaiian hoary bat is most appropriate.

C. Life History

Although no comprehensive studies of the Hawaiian hoary bat have been undertaken, various studies have addressed limited aspects of the bat's ecology. Diet has been examined by Whitaker and Tomich (1983), Belwood and Fullard (1984), and Jacobs (1993b); Belwood and Fullard (1984) and Fullard (1989)

investigated echolocation patterns. Numerous authors have compiled information from surveys and documented occurrence (Baldwin 1950, Bryan 1955, Cabrera 1996, Duvall and Gassmann-Duvall 1991, Fujikoa and Gon 1988, Fullard 1989, Kepler and Scott 1990, Reynolds *et al.* 1994, 1997, 1997/1998). Jacobs (1993a, 1994) examined ecological morphology and roosting ecology. T. Cabrera Menard (pers. comm. 1997) began examining seasonal distribution of the Hawaiian hoary bat on Hawaii in late 1997.

The Hawaiian hoary bat is a solitary bat that roosts among foliage in trees. During a 2-week period, Jacobs (1993b) found that two radio-tagged hoary bats returned to the same roosting area each night, possibly using the same roosting tree; however, this pattern may not be representative of all Hawaiian hoary bats. Kunz (1982) suggested that roost site fidelity may vary seasonally and with reproductive condition; fidelity to a home area may be more prevalent than fidelity to a specific roost among foliage roosting bats.

Jacobs (1993b) found that Hawaiian hoary bats typically depart roost sites shortly before sunset and return before midnight, but this also is based on a small number of observations. T. Cabrera Menard (personal communication 1997) has noted that emergence times vary seasonally on Hawaii.

Although the North American hoary bat forages almost exclusively in open habitats away from vegetation (Barclay 1985), the Hawaiian hoary bat has been observed foraging in a variety of both open and more vegetatively cluttered habitats, including open fields near native or nonnative vegetation, over the open ocean (in bays near shore), over lava flows, and at streams and ponds; Hawaiian hoary bats have been documented foraging from 1 meter to over 150 meters (3 feet to over 483 feet) above the ground or water (Baldwin 1950, Fujioka and Gon 1988, Kepler and Scott 1990, Jacobs 1993a, 1994, Reynolds *et al.* 1997/1998).

Black (1972) and Whitaker (1972) argued that the North American hoary bat feeds primarily on moths, and Belwood and Fullard (1984) have shown a similar

pattern for the Hawaiian hoary bat on Kauai. Barclay (1985) and Whitaker and Tomich (1983), however, found no strong selection for moths in a study in Manitoba, Canada, and on Hawaii, respectively. Jacobs (1993a) suggested that the Hawaiian hoary bat has a more diverse diet compared to the North American hoary bat, possibly due to morphological differences between the two subspecies; the Hawaiian hoary bat has a smaller body size and relatively larger skull size.

Pregnant bats have been documented on Hawaii and Kauai, but are not known from the other islands (Baldwin 1950, Kepler and Scott 1990). On Hawaii, males may be fertile year-round (Tomich 1986a), but breeding probably occurs most frequently between September and December, with parturition (birth of young) occurring in May or June. One female may have been pregnant in April, and large fetuses were found in females collected in May and June (Baldwin 1950, Kepler and Scott 1990, Tomich 1986b). Lactating (producing milk) females have been documented between late June and early August, and females examined between September and December were postlactating (Tomich 1986b). The mainland form of the hoary bat produces two young (Bogan 1972), and this pattern is apparently exhibited in the Hawaiian hoary bat as well.

Most temperate insectivorous bats exhibit sperm storage and delayed fertilization in which adults breed in the fall and sperm is stored in the female bat's reproductive tract until spring, when ovulation and fertilization occurs. This reproductive pattern is presumed in the mainland form of this species, but has not been established in the Hawaiian subspecies.

The North American hoary bat is migratory, with individuals in Canada and the northern United States likely traveling south to the central and southern United States and points south (Findley and Jones 1964, Nowak 1994, Shump and Shump 1982). Such long distance movement is unknown in the Hawaiian hoary bat, but seasonal elevational migration, as well as interisland movement, may occur (Kepler and Scott 1990, Kramer 1971, Tomich 1986b).

Hawaiian hoary bat activity apparently varies seasonally, but the nature and timing of this variation is unclear. Kepler and Scott (1990) noted that most observations of Hawaiian hoary bats occur from August through December. On Hawaii, 82 percent of observations occurred during this time, although the greatest sampling effort occurred from May through August (Kepler and Scott 1990). Reynolds *et al.* (1997) surveyed bats between August and December in the Puna district of Hawaii and detected fewer bats during November and December. Telfer (1992) noted decreases in bat observations between May and September in some areas on Kauai. Fullard (1989) detected bats at several locations on Kauai in March, a time when bat sightings are reportedly rare on Hawaii (Kepler and Scott 1990). Cabrera Menard (1997) also noted both altitudinal and seasonal differences in bat activity.

Kepler and Scott (1990) suggested that reduced activity may be due to bats entering torpor (a dormant state with reduced metabolic rates) during the cooler winter months. Kepler and Scott (1990) also proposed that increased fall activity observed in bats may be due to the appearance of newly volant (flying) young. Kramer (1971) suggested that Hawaiian hoary bats may undergo a limited seasonal interisland migration. Jacobs (1994) suggested that seasonal variation in bat activity occurs over a wide range of elevational and geographic conditions, arguing against intraisland migration. Geographical separation of the sexes occurs in the North American hoary bat (Findley and Jones 1964), but whether this pattern exists in the Hawaiian hoary bat is unknown.

D. Habitat Description

Whether native vegetation is required by, or is important to, Hawaiian hoary bats is not known. Kepler and Scott (1990) found that bats were most frequently observed in association with nonnative vegetation, with relatively few occurring in native vegetation. In contrast, Fullard (1989) stated that the only two locations on Kauai where bats were consistently observed were near native forests and that he rarely found them in towns or over open fields. He concluded that, on Kauai,

the Hawaiian hoary bat was uncommon and was found primarily in open wet areas near forests and only occasionally in drier areas. Fullard (1989) also commonly detected bats on Kauai at ocean outlets of forested rivers.

Similarly, Jacobs (1994) found that Hawaiian hoary bats on Hawaii are more frequently associated with native vegetation, and native ohia trees (*Meterosideros polymorpha*) were used frequently by two radio-tagged bats on Hawaii (Jacobs 1993a). Reynolds *et al.* (1997/1998) found no significant difference in the number of bats detected in native, mixed, or alien forest types in the Puna district on Hawaii. Roosting has been documented in numerous tree species, including hala (*Pandanus tectorius*), kukui (*Aleurites moluccana*), pukiawe (*Styphelia tameiameiae*), and Java plum (*Syzygium cumini*) (Baldwin 1950, Bryan 1955, Kramer 1971).

Tomich (1986c) stated "The [Hawaiian] hoary bat is highly unselective in the kind of tree it chooses for roosting" and suggests that the replacement of native trees with introduced species may not present a significant hazard to bat populations. He further argued that in lowland areas that have been deforested enough "tree cover and wild gulch habitat [exists] to provide adequate shelter." Tomich (1986b) presented no data to support his contention that Hawaiian hoary bats are not selective in choosing roost sites, but he did acknowledge that the effect on the Hawaiian hoary bat from the significant deforestation that has occurred on the Hawaiian Islands is unknown.

E. Current and Historic Ranges and Population Status

The Hawaiian hoary bat is known from the islands of Hawaii, Maui, Oahu, Kauai, and Molokai, but may be resident on only Hawaii, Kauai, and Maui. There are no verified records for Lanai and Kahoolawe, but the habitat on these islands may be adequate to support bats (Tomich 1986a). A possibly large population occurred on Oahu prior to the early 19th century, but this is based on a single observation of an unknown number of bats at an unknown location (Tomich 1986c).

Nevertheless, Kepler and Scott (1990) suggested that at least some decline has occurred there. Presently, the largest populations are thought to occur on Kauai and Hawaii (Kepler and Scott 1990, Tomich 1974, 1986a).

Population estimates for all islands have ranged from hundreds (Altonn 1960) to a few thousand (Tomich 1969), but these estimates are not based on systematic surveys, and although these estimates may represent informed impressions, they are based on limited and incomplete data. No studies have been conducted that directly address population size of this subspecies, and methods for estimating population numbers of a patchily distributed animal like the Hawaiian hoary bat are virtually nonexistent (Findley 1993). Ultimately, few historic or current distribution records exist, limiting the ability to accurately infer the historic or present distribution of this subspecies (Tomich 1986b).

Observations of the Hawaiian hoary bat were apparently widespread on Hawaii and Kauai between 1939 and 1986 (Tomich 1986a). On Hawaii, most observations of bats have been made between sea level and 2,286 meters (7,500 feet) elevation, although this may reflect a relative lack of effort placed in locating bats at higher altitudes; bats have been seen at elevations as high as 4,023 meters (13,200 feet) (Baldwin 1950; Tomich 1974; Fujioka and Gon 1988; Kepler and Scott 1990; T. Cabrera Menard, pers. comm. 1997). They occur in both wet and dry areas of the island, but are believed to be more abundant on the drier leeward side (Jacobs 1994). Fullard (1989) reported that on Kauai, the bat is "not common" and is apparently limited to the northern forested zones of the island, but more recent anecdotal evidence suggests that bats are common there (A. Asquith, U.S. Fish and Wildlife Service, pers. comm. 1997).

Kepler and Scott (1990) suggested that bats found on Oahu, Maui, and Molokai may be migrant or vagrant individuals; however, more recent data suggest that bats are resident on Maui (Duvall and Gassmann-Duvall 1991). Two bats have been documented from Molokai, where one was seen over open ocean offshore

(Kepler and Scott 1990), and the other was found in a residence on the island (Hawaii Heritage Program 1996).

Because most studies of Hawaiian hoary bat distributions have examined only portions of one island during certain times of the year and because of potential seasonal, geographical, and temporal variations, inferences regarding the current distribution of the Hawaiian hoary bat should be drawn with caution. In many cases, limited distribution may be, at least partially, an artifact of localized search efforts by researchers.

F. Reasons for Decline and Current Threats

Since no accurate population estimates exist for this subspecies and because historical information regarding its past distribution is scant, the decline of the bat has been largely inferred. Tomich (1986a), for example, suggests that if bat numbers have decreased significantly on Oahu, it may be due to deforestation that occurred in the early nineteenth century, but he also states that there is little information available beyond the currently known distribution of the bat on the Hawaiian Islands. Observations and specimen records do suggest that bats are now absent from historically occupied range, but estimates of abundance in formerly occupied areas are lacking. The magnitude of any population decline is not known.

Bat populations can be threatened by habitat loss, pesticides, predation, and roost disturbance (Bat Conservation International 1991). In general, availability of roosting sites rather than food availability, predation, or other factors is believed to be the primary limitation in the distribution and abundance of many bat species (Fenton 1970, Fenton and Barclay 1980, Humphrey 1975, Kunz 1982). The decline of the Hawaiian hoary bat may be due primarily to the reduction of tree cover in historic times (Tomich 1986b, Nowak 1994).

Pesticide use, alone or in combination with the factors discussed above, may have had an indirect impact via reducing or otherwise altering prey populations. Direct effects from contamination could also be a factor: at least two federally endangered insectivorous bat species have suffered mortality due to pesticide ingestion (Clark *et al.* 1978). The introduction of nonnative insects could also have altered prey availability. Predation is not believed to be a significant threat to the mainland populations (Shump and Shump 1982), but could be a more significant factor for the Hawaiian subspecies. Ultimately, however, there is no available data that bears directly on the question of a population decline, and Kepler and Scott (1990) clearly pointed this out when they stated "Whether the hoary bat has declined because of introduced predators,....agricultural practices, deforestation, or other human induced stresses is completely unknown."

G. Conservation Efforts

The Hawaiian hoary bat was listed as endangered on October 13, 1970 (U.S. Fish and Wildlife Service 1970). An endangered species is defined in Section 3 of the Endangered Species Act as any species that is in danger of extinction throughout all or a significant portion of its range. A threatened species is defined as any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. Critical habitat has not been designated for the Hawaiian hoary bat.

The Endangered Species Act provides several opportunities for the conservation of listed and endangered threatened wildlife. Listed species receive recognition and protection against take. The term "take" is defined as to harass, harm, shoot, wound, kill, trap, capture, or attempt to engage in any such conduct. "Harm" is further defined to include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns such as breeding, feeding, or sheltering (50 CFR 17.3). Federal agencies must ensure that their actions do not jeopardize the continued existence of a listed species or adversely modify its designated critical habitat. The Endangered

Species Act also prohibits possessing, selling, delivering, carrying, transporting, or shipping in interstate or foreign commerce any listed fish or wildlife species, except as permitted under provisions of section 10 of the Endangered Species Act.

When a species is listed as endangered or threatened under the Endangered Species Act, it is automatically added to the State of Hawaii's list of protected species (Hawaii Revised Statutes Chapter [HRS] 195D). Hawaii State law prohibits taking of endangered wildlife and encourages conservation by State government agencies. ("Take" as defined by Hawaii State law means "to harass, harm, pursue, wound, kill, trap, capture, or collect endangered or threatened. . . species. . .or to attempt to engage in any such conduct" [HRS 195D].)

H. Overall Recovery Strategy

Research is the key to reaching the ultimate goal of delisting the Hawaiian hoary bat because currently available information is so limited that even the most basic management actions cannot be undertaken with the certainty that such actions will benefit the subspecies. The initial focus for developing standardized survey and monitoring techniques and collecting basic life history information will be on Hawaiian hoary bat populations on the island of Hawaii, which apparently has the largest population of Hawaiian hoary bats. As survey and monitoring techniques are developed for Hawaiian hoary bats on Hawaii, the techniques can be applied to bat populations on Kauai, Maui, and to the other islands to determine bat abundance and distribution and to monitor population changes over time. Completion of research tasks will not only establish the distribution and abundance of Hawaiian hoary bats, but will also provide information on specific roosting habitat associations and food habits.

With basic information on the location of Hawaiian hoary bats and their resource needs, threats can then be identified and managed. Management actions that may be needed to address threats include protection of key roosting and foraging areas, particularly if Hawaiian hoary bats or their food resources depend on native

vegetation. Predation, the potential impacts of pesticides to bats or their food resources, and other threats may also need to be addressed.

Additional tasks will include the development of educational programs to inform the public about the biology of Hawaiian hoary bats, their value to Hawaiian ecosystems, and recovery efforts. As the results of research and management are evaluated, the progress of recovery of Hawaiian hoary bats can be assessed, and more definitive downlisting and delisting criteria can be developed.

II. RECOVERY

A. Objectives and Criteria

The ultimate objective of the actions proposed by this recovery plan is to delist the Hawaiian hoary bat. Downlisting from endangered to threatened status and delisting decisions cannot be made without a basic understanding of the Hawaiian hoary bat's distribution, abundance, and habitat needs.

Because we have only limited knowledge of the life history of this subspecies with respect to specific requirements for its short-term and long-term survival, only tentative criteria for downlisting and delisting are established here. Research addressing these questions must be undertaken prior to consideration of downlisting or delisting.

Interim Downlisting Criteria

A widespread population of Hawaiian hoary bats must be naturally reproducing and stable or increasing in size on the island of Hawaii for a minimum of 5 consecutive years before downlisting is considered.

Interim Delisting Criteria

Hawaiian hoary bat populations on Hawaii, Kauai, and Maui must be well-distributed, naturally reproducing, and stable or increasing in size for at least 5 consecutive years following downlisting before delisting is considered.

These criteria should provide for the maintenance of the majority of the genetic diversity of the Hawaiian hoary bat, and should provide some assurance that a single catastrophic event will not destroy all members of this subspecies. These criteria may change as more is learned about life history and ecology of this species.

B. Step-down Outline

1. Conduct research essential to conservation of the subspecies.

    11. Develop standardized survey and monitoring protocols to determine bat abundance and distribution on the island of Hawaii.

    12. Implement survey and monitoring programs to determine Hawaiian hoary bat abundance and distribution on Hawaii, Kauai, and Maui.

    13. Determine specific roosting habitat associations.

    14. Determine annual natural history cycle.

    15. Determine food habits on the island of Hawaii.

    16. Conduct research on other islands.

2. Protect and manage current populations and identify and manage threats.

    21. Identify and assess threats.

    22. Control and manage threats.

221. Protect key roosting and foraging areas.

222. Control predators

223. Reduce the effects of pesticides, if needed.

224. Minimize other threats, as appropriate.

3. Conduct a public education program.

4. Evaluate the progress of recovery and revise recovery criteria as necessary.

C. Step-down Narrative

1. Conduct research essential to conservation of the subspecies.

Basic natural history of the Hawaiian hoary bat, especially its current distribution, habitat associations, and potential threats, must be understood in order to proceed with downlisting and delisting. Since the largest Hawaiian hoary bat population apparently exists on the island of Hawaii, certain research tasks may be carried out on this island and the results used to manage habitat on the other Hawaiian Islands that harbor hoary bat populations.

11. Develop standardized survey and monitoring protocols to determine bat abundance and distribution on the island of Hawaii.

Biological surveys that result in verified records are the only reliable means to determine the presence of a species and to monitor population trends over time (Bogan *et al.* 1988). However, previous population estimates of Hawaiian hoary bats have not been based on systematic surveys or are based on limited and incomplete data. Standardized surveying and monitoring techniques should be developed.

It is generally not possible to determine actual population numbers for a species of this nature, and historic numbers for the Hawaiian hoary bat are not known. However, activity levels can be determined, and population status inferred, by monitoring echolocation calls using electronic echolocation detectors. These bat detectors allow bat activity to be quantified as number of aural bat detections per unit time or area. Standardized methods, for example sampling for 5-minute time periods at points established along a predetermined route or by remotely operated detectors located at one site over time, allow spatial and temporal comparisons of bat activity; one can assess the relative abundance of bats and compare regions, islands, or habitats with respect to the number of bats detected for a given amount of effort. Additional studies should be carried out using these standardized electronic methods (e.g., Fenton *et al.* 1983, Fenton *et al.* 1984, Fenton 1987, Kunz and LaVal 1988, Thomas 1988, Thomas and West 1984, 1989, Hayes 1997, Reynolds *et al.* 1994, 1997) to ensure comparable results.

Electronic monitoring of bats can be confounded by the difficulty of identifying specific species (e.g., Fenton and Bell 1981), but this is not a factor in Hawaii. Mist-netting can also be used to address questions of distribution, comparing number of bats captured per net per night, but this is more labor intensive and results are not always comparable (Kunz and Brock 1975). Additionally, visual and electronic monitoring are nonintrusive. Studies using radar show promise and should be further developed as they may also provide greater resolution of population abundance and distribution (Reynolds *et al.* 1997).

12. Implement survey and monitoring programs to determine Hawaiian hoary bat abundance and distribution on Hawaii, Kauai, and Maui.

Using the methodology developed on the island of Hawaii under task 11 (above), island-wide surveys and monitoring studies should be carried out on the islands of Kauai and Maui, as well as the island of Hawaii, to determine relative bat population levels and distribution. In order to be effective, these studies must encompass all habitats and elevations where Hawaiian hoary bats potentially occur. These studies also will reveal general information on foraging patterns and habitat associations.

Monitoring will be necessary to determine whether bat populations remain stable over time. Once current bat distribution and activity levels are known, monitoring programs should be implemented within occupied areas to monitor trends, such as population fluctuations, range increases or retractions, or newly identified threats. This monitoring should occur regularly in order that any drop in population numbers can be quickly identified and management actions taken. Each island population identified by completion of surveys should be monitored at least annually for 5 consecutive years, and then once every 3 years to establish information on population trends and possible threats. Comparison of data collected over a 5-year period will determine if the bat populations on Hawaii, Kauai, and Maui are stable, increasing, or decreasing.

13. Determine specific roosting habitat associations.

The availability of roosting habitat is considered key to the survival of bats. Developing an effective means to identify Hawaiian hoary bat roosts is important. Mist-netting and attaching radio transmitters to bats (e.g., Jacobs 1993b, Mattson *et al.* 1996), will allow bats to be followed to specific roosting locations, providing more specific information on

roosting requirements. More expansive studies, similar to those by Jacobs (1993b) and proposed by T. Cabrera Menard (*in litt.* 1995), will help determine the degree, if any, to which this bat relies on native vegetation. Such research should be conducted for at least one annual cycle in order to determine seasonal variation in roosting behavior. This research will also provide additional information on seasonal variation in distribution and activity levels, as well as foraging behavior.

14. Determine annual natural history cycle.

A combination of the methods outlined in tasks 12 and 13 will address the annual cycle of this bat. Evidence suggests that bat activity varies seasonally and that bats may enter torpor or move between islands or exhibit elevational migration. Research that intensively monitors bat activity at a variety of elevations and in the different habitats potentially available to the bats through at least one annual cycle will identify any seasonal habitat needs. Inferring the reproductive cycle of bats will be possible by mist-netting bats at least monthly for one year. Male and female reproductive status can be determined by physical examination (Racey 1988) and the time of appearance of young into the population documented (Anthony 1988, Worthington 1991).

15. Determine food habits on the island of Hawaii.

In conjunction with mist-netting efforts undertaken for other research (tasks 13 and 14), information from captured bats can be used to determine diet. Insect prey availability can be estimated using a variety of methods (Kunz 1988) and compared, using fecal examination, to food ingested (Whitaker 1988). This research should occur for at least one annual cycle for each habitat type where bats occur to monitor seasonal prey availability and use, which will assist in interpreting seasonal patterns in bat

abundance and activity. Additionally, a concurrent examination of pesticide use in these areas will reveal potential reductions in insect prey.

16. Conduct research on other islands.

Current evidence suggests that populations on other Hawaiian islands, such as Oahu and Molokai, are probably transient, but they may support undocumented populations. Using the information gathered from research on Hawaii, Kauai, and Maui, areas on other Hawaiian islands that support appropriate habitat can be monitored for bat activity and habitat associations inferred.

2. Protect and manage current populations and identify and manage threats.

Present information regarding threats that may affect the stability of the bat populations on Hawaii, Kauai, and Maui are lacking. But some management activities may be identifiable with currently available information.

21. Identify and assess threats.

Based on information gathered under task 1, it may be possible to determine immediate threats to the survival and recovery of the Hawaiian hoary bat. Possible threats include habitat degradation (particularly if native vegetation is found to be important habitat), predation, lack of adequate food resources, and pesticide contamination.

22. Control and manage threats.

Once identified and level of severity assessed, threats must be controlled and managed.

221. Protect key roosting and foraging areas.

Habitat loss, especially the loss of roosting habitat, may present the greatest threat to this subspecies. Once important roosting and foraging areas are identified (task 1), steps should be taken to protect these sites from degradation and disturbance. Steps may include fencing of management units for the purpose of removing domestic and feral ungulates, the development of conservation agreements designed to limit development activities and ensure the long-term security of habitats, and the establishment of conservation planning areas.

Research completed under task 1 should determine whether Hawaiian hoary bats are dependent on native vegetation and fauna. If these bats or their food resources are dependent on native vegetation, protection and management of adequate areas of native vegetation for roosting and/or foraging and, possibly, restoration of native vegetation may be necessary. Conversely, if alien species are found to be important for roosting or as food resources, then these alien species may require management if restoration of native species, which provide similar functions, is not possible or practicable.

222. Control predators.

Although not believed to be a significant threat in the mainland populations of this bat, Hawaiian forms of plants and animals are often predator-naive. The Hawaiian hoary bat, as a tree roosting species, is potentially threatened from predation and disturbance from cats and rats. In addition, the introduced common barn-owl (*Tyto alba*) and native short-eared owl (*Asio flammeus*), both nocturnal or crepuscular predators, may pose a threat to foraging bats. The native

Hawaiian hawk (*Buteo solitarius*) is diurnal, but may pose a threat to early flying bats.

If research determines that these animals threaten Hawaiian hoary bats, then management actions should be implemented to eliminate or minimize negative impacts. Control of mammalian predators in and around important roosting sites would likely include the use of live traps, snap traps, and rodenticides. Methods to control avian predators would need to be carefully developed and implemented in a manner that would minimize the likelihood of harm to the native short-eared owl and endangered Hawaiian hawk.

223. Reduce the effects of pesticides, if needed.

If pesticide use is determined to limit Hawaiian hoary bat distribution through altering prey base or direct contamination, as determined via methods such as those discussed in Clark *et al.* (1981), then mitigation measures must be identified and implemented in coordination with the Hawaii Department of Agriculture, U.S. Department of Agriculture, and Environmental Protection Agency.

224. Minimize other threats as appropriate.

Should other threats to the survival of the Hawaiian hoary bat , such as disease and/or parasitism, be identified as research tasks are completed, appropriate management actions will need to be developed and implemented. Additional threats from human activities may be identified that will require management.

3. Conduct a public education program.

An informed public will be more receptive to conservation of the Hawaiian hoary bat. Public perception of bats in general has often been negative, such that encounters with bats are likely to be viewed as negative experiences. This may be less the case in Hawaii, in part because of the absence of rabies and because bats are so infrequently observed. Educational programs can present bats in general, and the Hawaiian hoary bat in particular, as beneficial and interesting members of Hawaii's ecosystems. Visitor centers at State and National Parks, at U.S. Fish and Wildlife Service Refuges, or other State and Federal installations open to the public and where the bat occurs, can devote space for exhibits, prepare pamphlets and other educational materials, and inform people about this unique and exclusively Hawaiian mammal. Additionally, 'bat walks' can be conducted, providing the public with an opportunity to observe and monitor bats in their natural setting. State and Federal agricultural and health agency staff that work with the public would benefit from a program that aims to distribute information to the agricultural industry about Hawaiian hoary bats, their status, and their potential benefits.

4. Evaluate the progress of recovery and revise recovery criteria as necessary.

The recovery criteria identified in this plan should be viewed as preliminary targets, subject to revision pending the accomplishment of the research, management, and planning tasks identified above.

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IV. IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows outlines actions and estimated cost for the Hawaiian hoary bat recovery program, as set forth in this recovery plan. It is a guide for meeting the objectives discussed in Part II of this plan. This schedule indicates task priority, task numbers, task descriptions, duration of tasks, the organizations involved and/or responsible for committing funds, estimated minimum time to reach delisting goals, and lastly, estimated costs. When more than one organization is listed as the responsible party, an asterisk is used to identify the lead entity.

The actions identified in the implementation schedule, when accomplished, should lead to a better understanding of the current distribution and status of the Hawaiian hoary bat, protect habitat for the subspecies, stabilize the existing populations, and allow for an increase in population sizes and numbers. Monetary needs for all parties involved are identified to reach this point, whenever feasible.

Priorities in Column 1 of the following implementation schedule are assigned as follows:

Priority 1	An action that must be taken to prevent extinction or to prevent the species from declining irreversibly.
Priority 2	An action that must be taken to prevent a significant decline in species' population/habitat quality, or some other significant negative impact short of extinction.
Priority 3	All other actions necessary to provide for full recovery of the species.

Key to Acronyms Used in Implementation Schedule:

C	A task that will need to be performed continuously
O	Ongoing task
BRD	United States Geological Survey, Biological Resources Division
DOFAW	Division of Forestry and Wildlife, Hawaii Department of Land and Natural Resources
ES	U.S. Fish & Wildlife Service, Ecological Services, Pacific Islands Ecoregion, Honolulu, Hawaii
UH	University of Hawaii
TBD	Agency, funding, or timing of task to be determined

Recovery Plan Implementation Schedule for the Hawaiian Hoary Bat

Priority #	Task #	Task Description	Task Duration	Responsible Party	Total Cost Thru FY 2013	Costs Estimates ($1000's)				
						FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Need 1 Conduct research essential to conservation of the subspecies										
1	11	Develop standardized survey and monitoring protocols	0	ES BRD DOFAW *UH	450 450 150 150	150 150 50 50	75 75 25 25	75 75 25 25	75 75 25 25	75 75 25 25
1	12	Implement survey and monitoring programs	5	ES *BRD DOFAW UH	1650 1650 1140 390	350 350 200 150	200 200 110 60	200 200 110 60	200 200 110 60	150 150 60 60
1	13	Determine roosting habitat associations	1	ES *BRD DOFAW UH	150 150 75 50	150 150 75 50				

Recovery Plan Implementation Schedule for the Hawaiian Hoary Bat

Priority #	Task #	Task Description	Task Duration	Responsible Party	Total Cost Thru FY 2013	Costs Estimates ($1000's)				
						FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
1	14	Determine annual natural history cycle	1	ES *BRD DOFAW UH	150 150 75 50	150 150 75 50				
1	15	Determine food habits on the island of Hawaii	1	ES *BRD DOFAW UH	50 50 20 20	50 50 20 20				
2	16	Conduct research on other islands		ES *BRD DOFAW UH	105 105 70 70			50 50 25 25	25 25 15 15	10 10 10 10
TOTAL NEED 1					**7370**	**2440**	**770**	**920**	**850**	**810**

Recovery Plan Implementation Schedule for the Hawaiian Hoary Bat

Priority #	Task #	Task Description	Task Duration	Responsible Party	Total Cost Thru FY 2013	Costs Estimates ($1000's)				
						FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Need 2 Protect and manage current populations and identify and manage threats										
1	21	Identify and assess threats	5	*ES BRD DOFAW	475 475 325			150 150 100	100 100 75	75 75 50
1	221	Protect key roosting and foraging areas.	C	*ES DOFAW	TBD TBD					
1	222	Control predators	C	*BRD ES DOFAW	TBD TBD TBD					
1	223	Reduce the effects of pesticides, if needed	C	ES	TBD					
1	224	Minimize other threats, as appropriate	C	ES DOFAW	TBD TBD					
TOTAL NEED 2					**1275**			**400**	**275**	**200**

Recovery Plan Implementation Schedule for the Hawaiian Hoary Bat

Priority #	Task #	Task Description	Task Duration	Responsible Party	Total Cost Thru FY 2013	Costs Estimates ($1000's)				
						FY 1999	FY 2000	FY 2001	FY 2002	FY 2003
Need 3 Conduct a public education program										
3	3	Conduct a public education program	C	*ES DOFAW	28 28	10 10	5 5	1 1	1 1	1 1
TOTAL NEED 3					**56**	**20**	**10**	**2**	**2**	**2**
Need 4 Evaluate the progress of recovery and revise recovery criteria, as necessary										
3	4	Revise recovery criteria	2	ES	TBD					
TOTAL NEED 4					TBD					
TOTAL COST					**8701**	**2460**	**780**	**1322**	**1127**	**1012**

APPENDIX A

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Kailua-Kona Public Library
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Hilo Public Library
300 Waianuenue Avenue
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Lanai Public and School Library
Fraser Ave.
Lanai City, HI 96763

Kahului Public Library
90 School St.
Kahalui, HI 96732

Kihei Public Library
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Molokai Public Library
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Kauai Regional Library
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APPENDIX B

SUMMARY OF COMMENTS

The U.S. Fish and Wildlife Service received comments on the Draft Recovery Plan for the Hawaiian hoary bat from the State of Hawaii Land Use Commission, the U.S. Department of the Air Force, Dr. Dave Johnson, Dr. P. Quentin Tomich, Ms. Theresa Cabrera Menard, and Ms. Michelle Reynolds. Most of these comments consisted of additional information on the ecology and life history of the Hawaiian Hoary bat, as well as editorial suggestions; these changes have been incorporated into the plan.

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