U.S. Fish & Wildlife Service

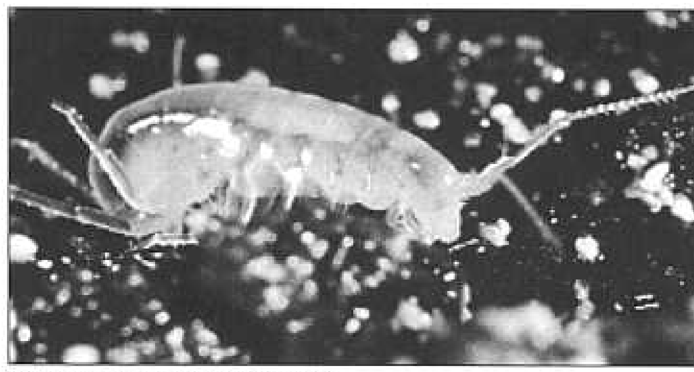
Draft Recovery Plan for the Kauai Cave Arthropods

Kauai Cave Wolf Spider
(Adelocosa anops)

and the

Kauai Cave Amphipod
(Spelaeorchestia koloana)

Kauai Cave Wolf Spider/©Bill Mull



Kauai Cave Amphipod/©Bill Mull

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DRAFT RECOVERY PLAN FOR THE

KAUAI CAVE ARTHROPODS:

The Kauai Cave Wolf Spider (*Adelocosa anops*)

and the Kauai Cave Amphipod *(Spelaeorchestia koloana*)

(November 2004)

Region 1
U.S. Fish and Wildlife Service
Portland, Oregon

Approved:XXXXXXXXXXXXXXXXXXXXXXXXX
Regional Director, Region 1
U.S. Fish and Wildlife Service

Date: ___________________

DISCLAIMER

Recovery plans delineate reasonable actions that are believed to be required to recover and/or protect federally listed species. We, the U.S. Fish and Wildlife Service, publish recovery plans, sometimes preparing them with the assistance of recovery teams, contractors, State agencies, and other affected and interested parties. Recovery teams serve as independent advisors to us. Plans are reviewed by the public and submitted to additional peer review before they are adopted by us. Objectives of the plan will be attained and necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Costs provided for action implementation and/or time for achievement of the outlined tasks and/or recovery objectives are only **estimates** and subject to change. Recovery plans do not obligate cooperating or other parties to undertake specific tasks and may not necessarily represent the view nor the official positions or approval of any individuals or agencies involved in the plan formulation other than our own. They represent our official position **only** after they have been signed by the Regional Director or Director as **approved**. Approved recovery plans are subject to modifications as dictated by new findings, changes in species status, and the completion of recovery actions.

Literature Citation should read as follows:

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This draft plan is also available at:
<http://pacific.fws.gov/ecoservices/endangered/recovery/default.htm>

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EXECUTIVE SUMMARY

CURRENT STATUS: The Kauai cave wolf spider (*Adelocosa anops*) and the Kauai cave amphipod (*Spelaeorchestia koloana*) are obligate cave-dwelling arthropods restricted to the Hawaiian island of Kauai. Although it is possible these arthropods occur in other regions, they have only been found in the Koloa Basin of the island of Kauai where lava tubes and other cave bearing rock are present. Currently, the Kauai cave wolf spider, a predator, is only regularly encountered in a single cave where 16 to 28 individuals (U.S. Fish and Wildlife Service, unpublished data 1998 and 2003) have been found during regular monitoring visits. During recent visits, the Kauai cave amphipod has been regularly observed in 2 caves, their numbers typically ranging from 8 to 40, but greater than 300 individuals have been encountered in 1 of these caves, likely in response to periodic food enhancement conducted by research biologists (U.S. Fish and Wildlife Service, unpublished data 1998 and 2003). No population estimates currently exist for these arthropods. Given the limited range of the spider, it is likely its population is extremely small and especially vulnerable. Since the Kauai cave amphipods have been found in caves scattered through the Koloa District, they likely have a considerably larger population and/or populations. The existence of amphipods in geographically separate areas, may make them less vulnerable than the Kauai cave wolf spider to catastrophic events that might impact a single cave. Urban and agricultural development as well as quarrying operations within the area threaten the habitat of these cave arthropods, and non-native species likely prey upon or compete with them for limited food resources. Human visitation and uses of caves are potentially serious threats as is urban and commercial pesticide use and the use of biocontrol agents. Extended drought may also threaten these species by altering the high-humidity environment to which these arthropods are adapted and facilitating invasion by nonnative species.

LIMITING FACTORS AND HABITAT REQUIREMENTS: Both the Kauai cave wolf spider and the Kauai cave amphipod have, or are believed to have, low reproductive rates compared to their non-cave dwelling counterparts. Food is believed to be limiting in most cave systems and this appears to be true in the Koloa caves as well. These species are believed to live in inaccessible mesocaverns as well as large cave passages which means their populations are

almost certainly greater than the numbers observed. However, few of the known caves in the Koloa District provide appropriate habitat for these arthropods which are typically only found in the Dark and Stagnant Air Zones (two of five cave zones typified by low air movement, elevated relative humidity, and reduced temperature fluctuations) of caves and require high humidity conditions. The limited number of occupied caves greatly limits our knowledge of the life history requirements of these arthropods.

Given the cryptic nature of caves and the uncertain distribution of inaccessible mesocaverns, our knowledge of the distribution and population status of these two species is greatly limited.

RECOVERY OBJECTIVE: The objective of this recovery plan is to provide guidance that will protect an adequate number of occupied caves (see Recovery Criteria section below) spread across the known range containing self-sustaining, stable (those in which observed population declines are followed by population increase to pre-decline levels) or increasing populations of both the Kauai cave wolf spider and amphipod, leading to the downlisting or recovery and ultimately delisting of one or both of these species. The number of caves needed to down-list and de-list both species is based on the best available information, including: the nine caves that have been located to date that are known to presently or historically support Kauai cave arthropods; and the presence of land formations, such as lava rock out-croppings, that indicate the potential presence of additional caves that may be suitable. These areas were identified in the critical habitat rule for these species (U.S. Fish and Wildlife Service 2003), and will be investigated for the presence of suitable habitat and cave arthropods, as funds become available. The need to identify additional occupied habitat for both species, but especially for the Kauai cave wolf spider, is strongly encouraged. Habitat enhancement will be a vital component of recovery for both species in most cases.

RECOVERY CRITERIA: Downlisting to threatened may be considered for both species when nine viable populations, spread across the known range, are shown to be: (1) self-sustaining; (2) stable or increasing; (3) protected from non-native/predatory species, human visitation to caves, bio-control agents, pesticides, development or other damaging land uses; and (4) with the habitat being utilized in a fashion consistent with conservation, as evidenced by monitoring over a 10-year period.

Delisting of both species may be considered when 12 viable populations, spread across the known range, are shown to be: (1) self-sustaining; (2) stable or increasing; (3) protected from non-native/predatory species, human visitation to caves, bio-control agents, pesticides, development or other damaging land uses; and (4) with the habitat being utilized in a fashion consistent with conservation, as evidenced by monitoring over a 20-year period. The 20-year monitoring period was determined to be necessary because land development is slated to occur, during the first 10 years of monitoring, on lands over areas that are known or suspected to contain caves that may support the Kauai cave arthropods. These activities may cause significant changes in cave environments and cause fluctuations in these species' populations. An additional period of at least 10 years following development will be needed to ensure that the cave arthropods, which have probable low fecundity, are stable, and that these species are responding appropriately to natural events that may be affecting their population levels. Also, a post-delisting monitoring plan and agreement to continue post-delisting monitoring must be in place and ready for implementation at the time of delisting. Monitoring populations following delisting will verify the ongoing recovery and conservation of the species and provide a means of assessing the continuing effectiveness of management actions.

ACTIONS NEEDED:

1) Protect known populations of the Kauai cave wolf spider and Kauai cave amphipod and their subterranean systems from human-caused destruction or degradation.

2) Improve or enhance the habitat of occupied caves or caves previously occupied through protection of above-cave habitats and implementation of landscaping actions that are likely to increase subterranean food resources.

3) Conduct research to address essential conservation needs for the species.

4) Conduct public outreach to facilitate better public understanding of and support for conservation of these cave arthropods.

5) Validate recovery objectives.

6) Develop a post-delisting monitoring plan.

Total Estimated Cost of Recovery ($1,000):

YEAR	NEED 1	NEED 2	NEED 3	NEED 4	NEED 5	NEED 6	TOTAL
01	238	15	372	10	10	1	**646**
02	288	15	372	10	10	1	**696**
03	248	10	370	10	10	1	**649**
04	238	10	340	10	10	1	**609**
05	218	10	340	10	10	1	**589**
06-20	2,010	75	1,130	60	150	16	**3,441**
Total	**3,240**	**135**	**2,924**	**110**	**200**	**21**	**6,630**

Recovery plans delineate reasonable actions presumed essential to recover and/or protect listed species. The costs and dates of recovery presented in this plan are preliminary estimates only. Additional information and project implementation are needed to provide a better estimate of down- and/or delisting costs. All estimates are provided with the assumption that additional occupied or restorable cave systems will be located.

Date of Recovery: Downlisting to threatened status may be reached by 2014, and delisting may occur by 2024 if recovery criteria are met.

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I. INTRODUCTION

A. Brief Overview

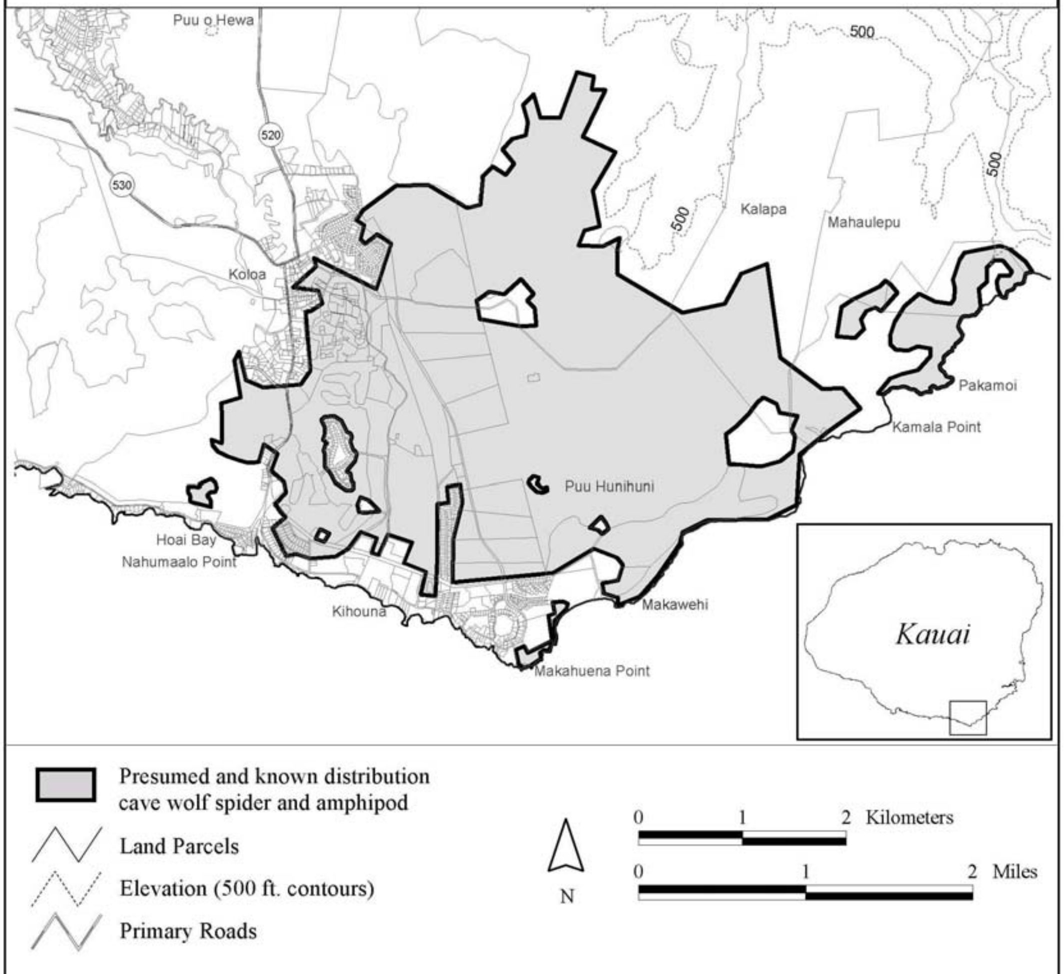
The Kauai cave wolf spider (*Adelocosa anops* Gertsch) and the Kauai cave amphipod (*Spelaeorchestia koloana* Bousfield and Howarth) (collectively the Kauai cave arthropods) represent monotypic species, both of which are only known from caves, subterranean cracks, and mesocaverns (voids and inaccessible passages) of the Koloa Volcanic Series on the island of Kauai, Hawaii (Bousfield and Howarth 1976). The cave amphipod is a detritivore, feeding on plant material, especially roots that penetrate into the caves, while the cave wolf spider is a predator which feeds opportunistically on other cave inhabitants, including the cave amphipod. As with other obligate cave-inhabiting species, the Kauai cave arthropods are restricted to specific habitats or zones within subterranean habitats.

We, the U.S. Fish and Wildlife Service, listed both the Kauai cave arthropods as endangered species on January 14, 2000 (U.S. Fish and Wildlife Service 2000) and designated critical habitat for both arthropods on April 9, 2003 (U.S. Fish and Wildlife Service 2003). Both species' recovery priority number is 1, indicating a high degree of threat and high recovery potential (U.S. Fish and Wildlife Service 1983).

The Koloa Series Lava Flows (Lagenheim and Clague 1987) represent the most recent volcanic activity on the island of Kauai, with the youngest rocks dating to about 600,000 years before present (Macdonald *et al.* 1960). Lava tube systems throughout most of the island are far older than those of the Koloa Series, most caves having long since collapsed or filled with sediments (Howarth 1981). Therefore, these unique species are restricted to a relatively small area of Kauai Island within the Koloa District (Figure 1) (Howarth 1981).

Although many caves in the Koloa District have been surveyed, most do not contain the optimal climatological conditions required by cave-dwelling organisms, including the Kauai cave arthropods. Of the caves surveyed to date, the cave wolf spider has only been documented to occur in five caves, and currently is only observed regularly in one of these caves. The cave amphipod has been documented to occur in nine caves, and is currently observed regularly

Figure 1. Presumed and known distribution of the Kauai cave wolf spider and Kauai cave amphipod



in two of these caves. Due in part to sampling regimes, only two of these caves contain “sizable” or regularly observed populations of amphipods. Other organisms frequently co-inhabit these caves. The endemic Hawaii cave isopod (*Hawaiioscia parvituberculata*) is occasionally observed, as are a number of non-native (alien) arthropods that are facultative cave-dwellers (“troglophiles”; *e.g.*, American cockroach (*Periplaneta americana*), brown violin spider (*Loxosceles rufescens*), and the spitting spider (*Scytodes longipes*)).

Since Polynesian and European arrival, the Koloa District has undergone drastic and rapid change (Cuddihy and Stone 1990). Palaeontological finds indicate, prior to Polynesian colonization, the area supported vegetation indicative of a wide range of habitats (xeric to mesic) (Burney *et al.* 2001), but human alteration of the landscape, typically with the use of fire for agricultural purposes, led to the removal of native vegetation (Cuddihy and Stone 1990). With European colonization, the rate of habitat destruction increased as new agricultural crops and practices were established (*e.g*., sugar cane cultivation, ranching). In addition, numerous non-native, invasive plants readily colonized these areas, contributing to alteration of the above-ground habitats (Howarth 1981). European agricultural practices, including burning of cane and over-grazing by goats and cattle, greatly accelerated the rates of erosion and soil loss (Cuddihy and Stone 1990; Burney *et al.* 2001). Sedimentation as well as intentional filling of caves has likely contributed to habitat loss for these and other cave-dwelling organisms (Bousfield and Howarth 1976; Berger *et al.* 1981; Howarth and Stone 1993). Modern development of the Koloa District is not restricted to areas suitable for agriculture (*i.e.*, well developed soils). Continued development for housing and tourism also occurs in rocky areas originally spared by earlier agricultural development, leading to the potential destruction of the remaining cave habitats in the area. While development is currently one of the most serious threats to the habitats of these arthropods, cave habitats are also vulnerable to alteration from increased human entry and vandalism (Howarth 1982; Culver 1992; D. Hopper, *in litt*.1999; Culver *et al*. 2000), pesticides, and non-native, invasive wildlife species, most of which either compete with the endangered cave species for food resources or directly prey on them (Howarth 1973; A. Asquith, *in litt*. 1994a; D. Hopper, *in litt*. 1999).

B. Description and Taxonomy

Kauai cave wolf spider

The Kauai cave wolf spider (*Adelocosa anops*) is a member of the wolf spider family, Lycosidae. Spiders in this family have a world-wide distribution and are characterized by a distinctive eye pattern, including two particularly large eyes located within the middle row of eyes (Foelix 1982). While wolf spiders are typically visual predators, the most conspicuous physical character of the Kauai cave spider is its complete lack of eyes (Figure 2). This character is unique among wolf spiders and, in part, provides justification for the recognition of a separate genus for this taxon (Gertsch 1973). Other species of wolf spider have reduced eyes, including another cave-adapted species on the island of Hawaii, but the Kauai cave wolf spider is the only lycosid in which the eyes are entirely absent. Adults of the Kauai cave wolf spider are about 12.7 to 19.0 millimeters (0.5 to 0.75 inches) in total body length with a reddish-brown carapace, pale to silvery abdomen, and beige to pale orange legs.

The hind margin of each chelicera (biting jaw) bears three large teeth, two situated basally, and the third at the distal end of the chelicera. The tibiae of the two anterior pairs of legs have four pairs of ventral spines, and the tarsi (ultimate segments) and metatarsi (mid-leg segment) of all legs bear unusually long, silky, and shiny trichobothria (sensory hairs). Doctor Frank Howarth of the Bishop Museum first discovered the Kauai cave wolf spider in Koloa in 1971, and it was formally described by Willis Gertsch of the Bishop Museum (Gertsch 1973).

Kauai cave amphipod

The Kauai cave amphipod (*Spelaeorchestia koloana*) (Figure 3) was discovered in some of the same caves as the Kauai cave wolf spider in 1971 (Bousfield and Howarth 1976). Because of the unusual attributes of a highly reduced pincher-like condition of the first gnathopod (thoracic appendage) and the second gnathopod being mitten-like in both sexes, this taxon is placed in its own unique genus (*Spelaeorchestia*) within the family Talitridae (Bousfield and Howarth 1976). This species is also distinctive in its lack of eye facets, lack of pigmentation, and extremely elongate, spiny, post-cephalic appendages. Adult cave amphipods are 7 to 10 millimeters (0.25 to 0.4 inches) in length with a

Figure 2. Photograph of a Kauai cave wolf spider with egg case; used with permission of Gordon Smith.

Figure 3. Photograph of a Kauai cave amphipod; used with permission of Bill Mull.

slender, laterally compressed body and a hyaline cuticle, giving it a shiny, translucent appearance. The second pair of antenna are slender and elongate, with the flagellum (terminal antennal segments) only slightly longer than the peduncle (proximal antennal segments). Peraeopods (abdominal walking legs) are very elongate, with slender, tapering claws. All pleopods (swimming legs) are reduced, with branches vestigial or lacking. Uropods (tail plates or appendages) 1 and 2 have well-developed stocks, and brood plates in the mature female are vestigial or entirely absent (Bousfield and Howarth 1976). The Kauai cave amphipod is a detritivore and has been observed feeding on the roots of *Pithecellobium dulce* (Manila tamarind) and *Ficus* sp. (fig), rotting roots, sticks, branches, and other plant material washed into, or otherwise carried into caves, as well as the fecal material of other arthropods. In large cave passages, most individuals are found in association with roots or rotting plant debris. When disturbed, this cave amphipod typically moves slowly away rather than jumping like other amphipods. Nothing is known of the reproductive biology of this amphipod, but the vestigial brood plates of the female suggest they give birth to a small number of large offspring (Poulson and White 1969; Bousfield and Howarth 1976).

The great majority of amphipods (order Amphipoda) are marine organisms. However, a large number have invaded both terrestrial and freshwater habitats, mostly in the tropics. Hawaii now has at least two species of widespread, introduced, terrestrial amphipods, but it also has no less than seven species of indigenous or endemic amphipods (including *Spelaeorchestia*; Nishida 1992). Amphipods have invaded cave environments throughout the world, and other cave-dwelling species are recognized as endangered or vulnerable to extinction (U.S. Fish and Wildlife Service 1997; International Union for Conservation of Nature (IUCN) 1994).

C. Life History

<u>Kauai Cave Wolf Spider</u>

Unlike most spiders, wolf spiders do not hunt with the use of a web, relying on their sensory structures, camouflage, stealth, and swiftness to capture prey. The Kauai cave wolf spider may either stalk its prey or utilize sit-and-wait ambush tactics (Howarth 1981). Lacking eyes, it is believed vibration as well as tactile and chemosensory cues are of primary importance in prey detection and capture. While the cave wolf spider will likely consume the endemic cave amphipod, as with most species of spider it will prey on virtually any other cave inhabitant it can capture and kill, including alien spiders.

The cave wolf spider has a very low rate of reproduction when compared to terrestrial wolf spiders of similar size (Howarth 1981; Foelix 1982). Howarth (in Gertsch 1973) reported a female with an egg sac containing 14 spiderlings and it is believed that 30 offspring or fewer are produced per brood (Howarth 1981; Wells *et al*. 1983); this is far less than the clutch size exhibited by most terrestrial wolf spiders which may have 100 to 300 spiderlings per brood. Based on captured individuals, it is estimated this species takes up to a year to reach sexual maturity (Howarth 1981). Similar K-reproductive strategies (low reproductive rate; high investment in off-spring; long period to maturity for off-spring) are observed in other cave-dwelling species (Howarth 1981).

<u>Kauai cave amphipod</u>

The Kauai cave amphipod is a detritivore, feeding on dead organic matter, typically plant material, found on the cave floor. Within the known caves, food for the amphipod is derived from either perennial plant roots or from plant material that has been washed, fallen, or otherwise transported into caves. Amphipods and other cave detritivores (*e.g.*, isopods, millipedes) are often numerous around decomposing woody material on the cave floor. While some of this woody material is derived from root masses of plants, some has been intentionally provided by researchers as a food source for the amphipods and other cave arthropods, since root systems are now greatly reduced or absent from some caves. In one of the known occupied caves, woody material is periodically washed in via a perennial stream.

It is also thought that the cave amphipod has a low reproductive rate. Although it is not known how many offspring are produced per brood, the presence of a vestigial brood plate or the complete lack of a brood plate suggest that a small number of large offspring are produced (Poulson and White 1969, Bousfield and Howarth 1976).

Kauai Cave Arthropods

As with other obligate cave-dwelling arthropods, the Kauai cave arthropods are largely restricted to the "Dark Zone" (see section D below for a description) of caves with limited air flow, only occasionally being found in areas where there is no surface light penetration, but where external climatic changes (daily) still influence the cave microhabitat (*i.e.*, "Transition Zone"). The occupied microclimates within caves of the Koloa District are relatively constant, with temperatures ranging from 23 to 26 degrees Celsius (73 to 78 degrees Fahrenheit) and high relative humidity (typically at or near 100 percent) (Bousfield and Howarth 1976; U.S. Fish and Wildlife Service, unpublished data 1998). Such micro-climatic conditions appear to be necessary for survival, or are preferred by these arthropods and other Hawaiian cave-dwelling species (Hadley *et al.* 1981; Ahearn and Howarth 1982). Howarth has shown that these arthropods occupy the mesocaverns in the surrounding rocky substrate and will readily enter larger passages, where they may be observed, when microclimate conditions become favorable (Howarth 1983).

Like other cave-dwelling organisms, the Kauai cave arthropods exhibit behaviors that suggest reduced metabolism relative to related above-ground taxa. This is apparent both in the spider's outward behavior as well as their rate of oxygen consumption (Hadley *et al*. 1981). As observed within its cave environment, the Kauai cave wolf spider does not expend large amounts of effort moving quickly through the cave environment as does its close epigean (surface-dwelling) relatives. While epigean wolf spiders are extremely active and swift-moving, the Kauai cave wolf spider spends long periods waiting motionless or moving slowly and deliberately over the cave floor. If disturbed, the spider may run for a short distance, but quickly stops and returns to its normal slow pace or again becomes motionless. Similarly, the Kauai cave amphipod is slow moving relative to other marine or terrestrial amphipods.

Both Howarth (1983) and Huppop (1985) have postulated that cave-dwelling species may be adapted to cope with low levels of oxygen and/or elevated concentrations of carbon dioxide, similar to conditions encountered in other caves (see section D). The ability to survive and thrive under these conditions has been substantiated from field observations in known Stagnant Air Zones (see section D below) (Howarth and Stone 1990) as well as under controlled laboratory experiments. Hadley *et al.* (1981) conducted experiments with Hawaiian wolf spiders, both cave-dwelling species (*Lycosa howarthi*) and a related surface-dwelling species (*Lycosa* sp.). These researchers found the surface-inhabiting spider had a higher metabolic rate, requiring 2.5 times more oxygen as did its cave-dwelling relative. The reduced need for oxygen would better allow these spiders to survive in Stagnant Air Zones. Given the ability of at least some cave-dwelling species to cope with reduced oxygen and elevated carbon dioxide, as well as their ability to inhabit mesocaverns, it seems likely many cave-dwelling species will be able to reside in areas not readily surveyed by biologists. Hence, cave animal habitats will typically extend well beyond surveyable passages and connect other large caverns and passages either accessible or inaccessible to researchers (Howarth 1983).

Both the Kauai cave wolf spider and amphipod are sensitive to habitat climatic conditions. They, as well as other cave-dwelling species, require a habitat with high ambient humidity or they quickly die of dessication (Barr 1968; Ahearn and Howarth 1982; Howarth and Stone 1990). Caves lacking high humidity conditions do not typically contain cave-dwelling species in Hawaii or elsewhere (Howarth 1983). For this reason, Hawaiian caves with even small amounts of air-flow typically lack cave-dwelling animals since air circulation usually reduces ambient humidity levels. In addition, caves with reduced humidity appear to be far more prone to invasion by alien cave-dwelling species. On Kauai, the alien cave-dwelling brown violin spider has been observed to become a dominant member in caves where conditions appear to be sub-optimal (*i.e.*, reduced relative humidity) for native cave-dwelling animals (see sections D and F) (U.S. Fish and Wildlife Service, unpublished data 1998).

D. Habitat Description

<u>The Koloa Basin of Kauai</u>

Caves currently known to be occupied by the Kauai cave wolf spider and amphipod include both lava tubes and subterranean passages in upraised, calcareous marine deposits (limestone and beachstone). The lava tubes and mesocaverns within the local basalt flows were formed by the Koloa Series Volcanic eruptions that occurred from between 600,000 years before present to 1.5 million years before present (Macdonald *et al.* 1960; Langenheim and Clague 1987). In addition to these lava tubes, there are a number of calcareous geologic features (*i.e*., up-raised marine deposits, limestone) present along portions of the southeastern coast which lie adjacent to the Koloa Volcanic flows. Like the volcanic cave-bearing rock in the area, the calcareous cave bearing rock also contain inaccessible mesocaverns and passages that provide appropriate habitat for cave-dwelling animals (Howarth 1991). It is likely the Kauai cave wolf spider and cave amphipod invaded younger limestone formations from adjacent, older lava tubes (Bousfield and Howarth 1976).

Although the Koloa Volcanics cover large portions of western Kauai, the flows of the Koloa Basin represent the youngest of those flows. Lava tubes are not common in the north and east-central portion of Kauai. This is attributable to the greater age of the flows (*i.e*., more developed soils) and weather patterns that keep these portions of the island wetter. These factors have resulted in the sedimentation and filling of older lava tubes. In contrast, the Koloa Basin lies in the rain shadow of Haupu Ridge and is much drier. Compared to the older flows of the Koloa Series to the north, soil development in the Koloa Basin has been poor. The Waikomo-Kalihi-Koloa soil association, which covers most of the Koloa Basin, is shallow, rarely exceeding 1 meter (3 feet 3 inches) (Foote *et al*. 1972). These factors have contributed to a relatively high density of lava tubes persisting in the area.

Cave Zonation

Howarth (1991) divided cave habitats into five distinct zones. These are: (1) the Entrance Zone, where light penetration is high and surface vegetation is typically present; (2) Twilight Zone, which extends from the point where vegetation ends to where light no longer penetrates; (3) Transition Zone, where there is no light penetrance, but where external climatic changes (daily) still influence the cave microhabitat; (4) Dark Zone, which maintains its own microhabitat with little influence by surface air temperatures; and (5) Stagnant Air Zone, an area similar to the Dark Zone, but where air circulation is extremely low and the ambient gas composition is primarily controlled by *in situ* decomposition of organic material and oxygen influx from the surface being limited (Howarth and Stone 1990; Howarth 1991). Cave-dwelling animals are typically found within and are most strongly associated with the Dark Cave and Stagnant Air Zones.

Both the Dark Cave and Stagnant Air Zones are characterized by low air movement which results in reduced temperature fluctuations and elevated relative humidity. Typically, this is the result of a particular cave section being a "dead end" passage and/or having internal geologic features, shapes, or orientation that greatly reduce air flow, such as a low ceiling(s), collapsed ceiling, or small squeeze passage(s). Under such conditions, water vapor may be trapped, creating conditions of high relative humidity. In some cases, the Dark Zone may have elevated carbon dioxide concentrations. The Stagnant Air Zone, or "bad-air" zone, is found either deep in a dead end passage or is otherwise largely isolated from passages that readily connect with the other cave zones. In the Stagnant Air Zone, high carbon dioxide and reduced oxygen concentrations prevent most facultative cave-inhabiting species (troglophiles) from colonizing these areas, but these conditions are apparently preferred by most cave-dwelling species (Howarth and Stone 1990). Both the Transition Zone and even the Twilight Zone may occasionally contain cave-dwelling species, but this observation is rare. Some cave-inhabiting species may share portions of the Dark and Stagnant Air Zones with cave-dwelling forms, but are typically far less abundant in these two zones (Howarth and Stone 1990). The reduced abundance or absence of noted non-native (alien) predators (see section F on Threats), suggests the alien predators may be poorly adapted to the Dark Zone (U.S. Fish and Wildlife Service, unpublished data 2000). This observation deserves further research and, if substantiated, could contribute to conservation efforts for the endangered fauna (see sections G and H).

The trophic organization of caves is much different than surface communities (caves typically regarded as food-limited). Terrestrial ecosystems rely on photosynthesizing plants to provide a foundation for the upper trophic levels of the food web. Deep caves lack plants and typically rely on nutrient input from surface environments. Nutrient import in many mainland cave systems comes from the use of cavern spaces by trogloxenic species (temporary cave visitors), such as roosting bats. These trogloxenes provide a food base which is derived from surface foraging areas and deposited in roosting caves in the form of guano (Culver 1986). These nutrient sources serve as growing media for nonphotosynthetic chemotrophs (an organism that oxidises such compounds as hydrogen sulfide to obtain energy; the organism does not use light to produce food) such as fungi and bacteria which, in turn, serve as a food source for other obligate cave animals, fulfilling a similar role as do plants in surface ecosystems. Other cave systems rely almost entirely upon plant and detrital debris being washed into the cave by surface water, which then provides a food base for animals living within the cave (Barr 1968; Howarth 1983; Culver *et al.* 2000).

Hawaiian caves lack trogloxenic organisms in numbers sufficient to provide an adequate food base, relying instead on the penetrating roots of surface plants which are then grazed upon by cave-inhabiting species. For this reason, Hawaiian cave habitats must be close enough to terrestrial plant communities to provide sufficient quantities of root biomass in order to support healthy cave-inhabiting communities. This requirement means that woody, long-lived plants need to be present over the cave to ensure a dependable food supply is available. While some food import can occur from organic and detrital material being washed into caves, this is a relatively uncommon scenario in Hawaiian cave ecosystems.

The majority of caves in the Koloa District known to regularly contain one or both of the Kauai cave arthropods, are shallow (*i.e.*, near surface) lava tubes that contain Dark Zone habitats with relatively warm, constant temperatures and high relative humidity. The Koloa District is unique in that it is one of the few places in Hawaii where limestone or karst geologic features occur as deep deposits, capable of forming extensive subterranean habitats.

Due to a number of factors, both anthropogenic and natural (*e.g.*, degradation of caves due to geologic processes; see section E), only three caves (which currently regularly support cave arthropods [U.S. Fish and Wildlife Service, unpublished data 1998 through 2003]) with Dark Zone attributes are known to exist, on the island of Kauai. Anthropogenic factors have greatly accelerated the rate of natural habitat degradation, range constriction, and fragmentation (see section F).

E. Current and Historic Range and Population Status

The Kauai cave wolf spider and Kauai cave amphipod represent monotypic species, both of which are only known from caves, subterranean cracks, and mesocaverns and historically were likely found throughout the Koloa Volcanic Series on the island of Kauai, Hawaii. Since its discovery in 1971, the Kauai cave wolf spider has been reported from five caves distributed across the Koloa Volcanic Series. These caves have been named: Koloa Cave 1, Koloa Cave 2, Kiahuna Mauka Cave, Kiahuna Makai Cave, and the Quarry Cave. Since its discovery in 1971, the Kauai cave amphipod has been reported from nine caves. These caves consist of: Cave 1927C, Cave 3179, Koloa Cave 1, Koloa Cave 2, Kiahuna Mauka Cave, Kiahuna Makai Cave, Saint Rafael Church Cave, By-Pass Cave, and the Quarry Cave.

The Kauai Cave Wolf Spider

Currently, the Kauai cave wolf spider is only known to regularly occupy a single cave system, referred to here as Koloa Cave 2 located in the southwest corner of the range of the cave arthropods. Since annual to biannual monitoring first began in 1996, this cave has routinely contained 16 to 28 spiders per monitoring visit (U.S. Fish and Wildlife Service, unpublished data 1996, 1998 through 2003). Although new-born spiders have not been observed, both subadult and adult spiders are regularly observed and females with egg sacs are occasionally seen. These observations suggest this cave and the surrounding cave-bearing rock contains a healthy breeding population of cave wolf spiders. In an adjacent cave (Koloa Cave 1), some 200 to 300 meters (260 to 390 feet) distant, there is only a single record from 1998 of an adult cave wolf spider being present (U.S. Fish and Wildlife Service, unpublished data 1998 through 2003). This is likely due to the drier conditions of the latter cave. Koloa Caves 1 and 2 are lava tubes that parallel one another and which are likely connected by small mesocaverns inaccessible to humans.

Prior to an April 2000 visit, a small, but persistent population of cave wolf spiders was known to be present in a third cave, Kiahuna Makai (Makai: coastal, in reference to down-slope of the mountainous interior) Cave, located in the middle portion of the range of the cave arthropods. Annual to biannual monitoring visits have been conducted from 1996 to the present. One to four individuals have been observed per visit through October of 1999, after which no wolf spiders have been observed in this cave (U.S. Fish and Wildlife Service, unpublished data 1996, 1998 through 2003). Providing a reason for the decline or disappearance of the wolf spider can only be speculative, but the regular presence of brown violin spiders in this cave, as well as a lengthy drought in the Hawaiian Islands, may have had a serious combined impact on the wolf spiders through competition, predation, and dessication of the cave environment.

The cave wolf spider has been recorded in Kiahuna Mauka (Mauka: mountain, in reference to up-slope of the coast) Cave, located approximately 883 meters (2,896 feet) from Kiahuna Makai Cave. This cave contains the largest known population of the Kauai cave amphipod, but the wolf spider has only been observed on one occasion (1998), in which two adult spiders were found during a single monitoring visit (U.S. Fish and Wildlife Service, unpublished data 1996 through 2004). The lack of regular observations of wolf spiders in this cave suggests those previously observed spiders may have been dispersing individuals that failed to become established in this cave. The presence of wolf spiders in this cave suggests the ability of these spiders to re-colonize this cave should conditions become optimal.

The Quarry Cave, a coastal cave derived from calcareous marine deposits, is located in the southeast corner of the range of the cave arthropods. This cave is located within a large limestone bench that follows the coastline. There have been sporadic visits to the Dark Zone of this cave where the wolf spider has recently been observed (Howarth, pers. comm., 2003).

The Kauai Cave Amphipod

The Kauai cave amphipod is currently known to regularly occupy two caves in the Koloa District. It commonly occurs with the wolf spider in Koloa Cave 2, but in relatively low numbers (8 to 32 individuals per monitoring visit) (U.S. Fish and Wildlife Service, unpublished data 1996 through 2004). During wetter years, the amphipod has been recorded from the adjacent Koloa Cave 1, but in even lower numbers, and it has not been recorded from that cave since 1996 (when two individuals were observed) (U.S. Fish andWildlife Service, unpublished data 2003).

Cave 1927C is a newly found cave and associated mesocaverns with the verified occurrence of the Kauai cave amphipod. A single amphipod was observed in the cave after humidity experiments were conducted by Bishop Museum staff in 2002, corroborating the prediction that these arthropods live within the intermediate-sized voids in lava and colonize caves where their preferred environment is approximated (Howarth 2003).

The Kauai cave amphipod was observed in Cave 3179 in June 1972 when part of the cave was moist. This cave has not been revisited until recently (2002). Currently, the cave is too short and dry to support the obligate cave species (Howarth 2003).

The cave amphipod has been most abundant in Kiahuna Mauka Cave where numbers have ranged from 11 to 306 individuals (U.S. Fish and Wildlife Service, unpublished data 2003). Prior to 1998, amphipod numbers ranged from 11 to 40 individuals, but after quantities (1 to 2 pounds) of supplemental food (dry wood) was deposited in this cave (spring of 1998), amphipod numbers climbed dramatically. It is possible that the observed increases were due to amphipods being drawn into the area from the surrounding mesocaverns by the increased food supply (Howarth 1983). However, at their peak (after food supplementation), juvenile and subadult numbers were nearly twice that of the adults, whereas prior to food supplementation, the adult to juvenile ratio was less pronounced. The high juvenile to adult ratio suggests the supplemental food may have led to a population increase of the resident amphipods. The surface area of this cave is currently managed as a golf course fairway. As a result, the above-surface area receives regular watering, resulting in a consistently saturated (*i.e.*, high relative humidity) Dark Zone, which is beneficial to the resident amphipods.

Seventy-one cave amphipods were recorded in the Kiahuna Makai Cave during a visit in January 1999 (U.S. Fish and Wildlife Service 1999). Annual to biannual monitoring visits have been conducted from 1996 to present. No amphipods were observed prior to 1999 and after this visit (U.S. Fish and Wildlife Service, unpublished data 1996-2004). Providing a reason for the decline or disappearance of the amphipod can only be speculative, but the regular presence of brown violin spiders in this cave, as well as a lengthy drought in the

Hawaiian Islands, may have had a serious combined impact on the amphipods through predation and dessication of the cave environment.

Two caves containing amphipods were observed only during a short window of time. The By-Pass Cave, located adjacent to Waikomo Road in the upper northwestern corner of the range of the cave arthropods, was discovered in the fall of 1999 when heavy equipment punctured the cave roof while grading the new Koloa By-Pass Road. This cave had previously been open to the surface and there were signs of human use of the cave from Polynesian to the modern era (post World War II), but the cave had been partially filled and sealed with topsoil as recently as 20 years ago. During surveys of the By-Pass Cave, conducted in November 1999, 40 cave amphipods were detected as well as some cave isopods (Dave Hopper, *in litt*. 1999). After these surveys were completed and the cave mapped, the cave was resealed and the road diverted to avoid impacts to the cave. A park was designed over the cave and native plants were used in landscaping which are likely to provide the necessary roots for food for the amphipods.

The second cave, Saint Rafael Church Cave, is located in the upper middle portion of the range of the cave arthropods and was only known to be surveyed on one occasion in which amphipods were found (A. Asquith, *in litt*. 1994a). Since then, the entrance to the cave has not been relocated and its current condition is unknown.

The last cave known to be occupied by the amphipod is the Quarry Cave. Sporadic visits to the Dark Zone of the Quarry Cave have found the amphipod to be present in numbers to suggest a population, but they are not always present at every visit. During a visit to the cave in 2003, this cave contained 20 amphipods (U.S. Fish and Wildlife Service, unpublished data 2003).

F. Reasons for Decline and Current Threats

1. Habitat Destruction by Agriculture

With the establishment of Polynesian populations in the Hawaiian Islands 1800 years ago, endemic plant communities throughout the lowlands began to be exposed to anthropogenic modifications (Kirch 1982; Cuddihy and Stone 1990; Allen 1997; Athens 1997). Wet lowlands were especially prized for taro cultivation, but some Polynesian settlements also diverted water to create more arable lands in drier habitats. Much of the land preparation resulted in the clearing of native perennial vegetation.

With European contact and colonization (starting in 1778), land modifications accelerated over large areas with a wider diversity of habitats being affected. While Polynesians utilized fire to clear land (Kirch 1982), the practice was also frequently employed by European settlers to clear land for cattle ranching and other agricultural crops. Clearing land with fire destroyed perennial plants growing above caves. The establishment of introduced ungulates such as cattle (*Bos taurus*), goats (*Capra hircus*), and sheep (*Ovis aries*), both managed and feral populations, have greatly altered the vegetative communities of the islands, resulting in the denuding of vast areas and soil disturbance, preventing plant regrowth and greatly accelerating erosion (Cuddihy and Stone 1990; Hobdy 1993). Along with the above modifications, Europeans also introduced alien plants and converted vast areas into grasslands to support ranching operations, resulting in the destruction of cave food chains since grasses and many of the dominant, non-native perennials do not provide adequate root systems for herbivorous cave-dwelling species such as the amphipod.

Beginning in 1835, the cultivation of sugar cane became an important economic venture in Hawaii, with pineapple cultivation becoming important some time around 1900 (Cuddihy and Stone 1990). Not only did this land use clear large surface areas of native, perennial vegetation, resulting in the destruction of root systems necessary for cave ecosystems, but the frequent crop rotation and heavy rain in many of these areas significantly increased erosion and soil loss. Increased erosion has resulted in increased soil deposition within many low elevation caves (Howarth 1981). It is known that soil deposition rates have increased dramatically over the past 200 years, with greater than 2 meters (6.5 feet) of soil being deposited at one site in the Poipu area during that period. This recent 2 meter (6.5 feet) deposition accounts for approximately 50 percent of the sediment deposited over a period of 6,700 years at this coastal site (Burney *et al.* 2001). Much of the Koloa/Poipu area was cleared and many caves with openings or mesocaverns located in areas of arable soil were filled with erosional deposits, intentionally filled for public safety concerns, or were used as garbage pits (Howarth 1973; A. Asquith, *in litt*. 1994b). All of the caves where the Kauai cave arthropods are currently known to exist show signs of filling with sediments (Howarth 1981).

2. <u>Habitat Destruction by Urbanization</u>

While former land use spared many rocky cave-containing areas located in substandard agriculture land, more recent land uses are not bound by the same constraints and pose a renewed threat. Many of the newer land uses do not rely on the presence of deep, well-developed soils. Current development includes the construction of roads, housing, golf courses, and a quarrying operation. In other areas, modern technologies have allowed for the importation of soils into otherwise unsuitable sites. As a result, the most recent development plans have the potential to include areas with rocky substrates that had not been modified previously for agricultural purposes.

Previous land modifications have certainly resulted in the destruction of cave and mesocavern habitats as well as the isolation of some of the cave-dwelling arthropod populations. Even with the protection of known, occupied habitat, habitat destruction most likely continues to be a threat to these species since unknown mesocaverns are certainly present and may provide important habitat, corridors, and refugia for these cave-dwelling species. Ongoing or anticipated development in the Koloa District projected over the next 10 years, will likely result in destruction and fragmentation of cave habitats. Destruction and filling of intervening caves and mesocaverns may confine populations of cave-dwelling species to caves without climatic refugia (*e.g.*, cracks and mesocaverns with high relative humidity), increasing chances of local extinction during periods of prolonged drought. Smaller, isolated populations of cave arthropods will have a greater likelihood of extinction due to chance events, and their isolation means these areas will not be able to receive recruits from or provide colonists to adjacent cave systems.

Caves are periodically exposed during construction activities and this can result in the dessication of cave habitats and provide access to alien species (see below). When caves are exposed during construction activities, most are backfilled with the intent to fill the subterranean mesocaverns that might weaken or compromise the overlying structure(s). Hence, construction frequently results in outright destruction of cave habitats.

Lastly, urbanization typically results in large areas being covered by asphalt or other artificial surfaces which lack or have only limited permeability. Rain water is diverted into storm drains and lined gutter or drainage systems, resulting in reduced local ground water recharge. This may greatly reduce humidity levels within caves, resulting in the dessication and loss of suitable habitat.

3. Human Visitation to Caves

Human visitation to and uses of caves are recognized as being a potentially serious threat (Culver 1986). Cave ecosystems may be affected by the following activities: used as sites for dumping and filling, contaminated by surface sources which enter caves via streams and/or ground-water seepage, and mining and quarrying. In addition, Polynesians utilized caves as burial sites and many of the caves in the Koloa District show signs of this use (Hammett and Tomonari 1978; Hammett *et al.* 1988). It is not known if Polynesian use of such cave systems impacted the Hawaiian cave arthropods. Caves often attract curiosity seekers who, in most cases, have no intent to damage the geologic or cultural features within caves, or harm the indigenous wildlife (Howarth 1982, 1983; Culver 1986). However, cave ecosystems are sensitive to even minor human intrusion and disturbance, and it is often necessary to limit human entry into caves to protect the resident organisms and their habitat.

The narrow passages in many caves will increase the chances that human visitors may inadvertently and unknowingly crush or injure ground-dwelling cave-inhabiting species. Human use of caves can result in the destruction of food resources such as root systems, which are critical to most Hawaiian cave systems. Cave visitors may leave trash or toxic materials in caves, both of which can have devastating effects. In Hawaiian caves, discarded food and trash can attract arthropods (*e.g.*, cockroaches) that can compete with the resident cave-dwelling animals, and elevated numbers of such scavengers may attract non-native predators (*e.g.*, centipedes, spiders) that may prey on the natural cave inhabitants (see Non-native, Invasive Organisms section below). Discarded trash can also attract social insects such as ants which have had a devastating impact in cave systems in Texas (U. S. Fish and Wildlife Service 1994) and have likely had similar impacts in Hawaii (Howarth 1985; Cole *et al.* 1992).

Nicotine, contained in cigarette smoke, is a powerful insecticide that can have devastating effects in the cave environment (Howarth 1982). Due to the confined and still air typically encountered in the Dark Zones of caves, cigarette smoke is not readily carried out of the cave and it may disperse into cave-dwelling animal-occupied mesocaverns, or upward onto the walls and ceiling of the cave, areas that would otherwise not be affected by human activities in the larger passages. In a similar fashion, use of open fires in caves and cave openings may have massive, unseen impacts on cave-dwelling species both from the release of toxic fumes as well as from drying the cave interior, reducing relative humidity (Howarth 1982).

4. Non-native, Invasive Organisms

Non-native predators are known to feed on mainland cave-dwelling species (U.S. Fish and Wildlife Service 1994) and certainly can be assumed to compete with resident cave-dwelling animals for common food resources which are already in low supply. In the Hawaiian Islands, Howarth (1981) has documented the potential replacement of an endemic cave-dwelling spider, *Erigone stygius*, by a non-native web-building cave-dwelling spider, *Nesticus mogera*. While the Kauai cave wolf spider will feed on introduced cockroaches, small alien spiders, and other introduced cave-dwelling species, there is good evidence to suggest that it is preyed upon by the non-native brown violin spider (*Loxosceles rufescens*; A. Asquith, *in litt*. 1994a, b; D. Hopper, *in litt*. 1999), which would also feed indiscriminately on resident arthropods that would otherwise serve as prey for the cave wolf spider. Web-building spiders, such as the brown violin, may pose a particularly serious threat since webs present a method of predation to which the Kauai cave wolf spider and cave amphipod are likely not adapted (Howarth 1981). Lastly, the introduced lesser brown scorpion (*Isometrus maculatus*) and centipedes (*Scolopendra* spp.) have both been observed in some of the caves inhabited by the endemic cave-dwelling species and the generalized diet of these predators would certainly include both the Kauai cave wolf spider and amphipod.

5. Pesticides and Bio-control Agents

Of great importance is household pesticide use and its potential impacts to cave ecosystems. Urban and household use of pesticides is often higher and less target-specific than pesticide use for agricultural crops (Hawaii Office of State Planning (HOSP) 1992). For example, numerous household and resort pesticide applications are for subterranean pests such as the Formosan ground termite (*Coptotermes formosanus*) as well as a variety of turf pests such as ants and cutworms, which feed on root systems. Hence, moisture runoff and recharge that originates in urban areas may inadvertently deliver high concentrations of insecticides or other pesticides (*e.g*., herbicides, fungicides) into cave and mesocavern habitats, with potentially devastating effects on the Kauai (and other) cave animals.

The presence of septic tanks and leaching fields associated with urban development in cave-bearing rock is likely of mixed benefit to the Kauai cave animals. Leaching fields would increase soil moisture levels and elevate the relative humidity within local caves, and could result in increased food import (*i.e.*, detritus). However, they are equally likely to be a source of toxic and caustic wastes in the form of household cleaners such as drain-cleaners, bleach, and discarded chemicals.

Bio-control agents (living organisms used to control pests) are usually perceived as preferable to the use of chemicals because they represent less of a threat to human health and generally do no stimulate resistance in pests. Some of these organism, however attack species other than their intended targets and have caused or contributed to the decline and extinction of several Hawaiian insects (Howarth 1983; Howarth 1991). For example, bio-control agents such as *Bacillus* bacteria, which have been used for mosquito control, have caused serious damage to non-target species of insects (Howarth 1991). Unlike most pesticides, bio-control agents will not break down or decay. Should they become established, they will likely remain resident in the area, spread to new areas with suitable host arthropods and become impossible to eliminate.

6. Random Events and Small Numbers

All of the caves may be threatened by prolonged drought, either brought about by global climatic changes or by local alteration of the vegetation that may reduce rainfall or otherwise result in reduced soil moisture content. Prolonged drought may desicate the cave interior, making it less accommodating to cave-dwelling animals (Howarth 1983). As a result of reduced humidity, Dark Cave and Stagnant Air Zones may become more prone to invasion by damaging, non-native species such as the brown violin spider mentioned above and in the Section G. on Site-specific Threats (below).

Small populations are demographically vulnerable to extinction caused by random fluctuations in population size and sex ratio and to catastrophes such as hurricanes (Soulè 1983; Gilpin and Soulè 1986). In addition, the low reproductive potential of both cave species (less than 10 percent of their surface relatives) means that they require more time and space to recover from a disturbance than would similar animals living on the surface (F. Howarth, *in litt.* 2001).

G. Site-specific Threats

1. Koloa Caves

Koloa Caves 1 and 2 are currently protected by the landowner in a cooperative agreement with the U.S. Fish and Wildlife Service. Both caves are gated. Despite this protective action, both of these caves are still vulnerable to other threats. The overlying area is dominated by alien grasses and non-native perennial vegetation which may lack roots that penetrate into the cave (grasses) or be toxic or not the preferred food (non-native perennials). Hence, the roots of native plants with which these arthropods evolved are no longer present and much of the non-native vegetation overlying these caves may not provide a ready source of such root material. Many of the non-native plants are highly vulnerable to fire, which is far more likely to occur with the current level of human activity in the area. Fire above the cave would likely kill any perennial plants that currently do provide roots into the caves and mesocaverns thereby jeopardizing the food base of the resident cave-dwelling arthropods.

Although not abundant, the brown violin spider has been found regularly in Koloa Cave 2. This spider is implicated in the predation of the cave wolf spider in Kiahuna Cave Makai (see below). All observations of this spider have been in the lower section, where the cave becomes drier and where the native cave-dwelling animals are less frequently encountered. While speculative, it is plausible the limited distribution of the violin spider is due to its poorer performance in cave areas which exhibit the characteristics of the true Dark Zone (*i.e.*, high humidity, reduced air movement).

Koloa Cave 1 is far drier than Cave 2 and the two endangered cave-dwelling arthropods have only been encountered rarely, when conditions were more optimal (*e.g.*, heavy rains contributing to elevated relative humidity). The threats discussed for Koloa Cave 2 are the same for Koloa Cave 1.

2. Cave 1927C

Cave 1927C is not gated and is vulnerable to unauthorized entry by humans. This cave is threatened by insufficient food sources. The overlying area is dominated by alien grasses and non-native perennial vegetation which may lack roots that penetrate into the cave (grasses) or be toxic or not the preferred food (non-native perennials). Many of the non-native plants are highly vulnerable to fire, which is far more likely to occur with the current level of human activity in the area. Fire above the cave would likely kill any of the non-native perennial plants that currently provide roots into the caves and mesocaverns thereby jeopardizing the food base of the resident cave-dwelling animals.

3. Cave 3179

Cave 3179 is also not protected by a gate and is vulnerable to unauthorized entry by humans. This cave is subjected to similar threats mentioned in Cave 1927C. These include insufficient food sources, and threats of fire.

4. Kiahuna Caves

Kiahuna Makai Cave is not gated, making the threats of human visitation, overuse, and vandalism more acute. The Makai Cave has recently shown signs of elevated human use which could impact the Kauai cave-dwelling arthropods if either of these species still utilize this cave. The more biologically significant

Kiahuna Mauka Cave is gated and a native plant restoration program has begun above the cave system.

The Kiahuna Makai Cave occurs below undeveloped, unprotected lands. The current drought conditions may be affecting the use of this cave by cave-dwelling species due to the reduced relative humidity of the Dark Zone. The non-native dry shrubland that overlies this cave is vulnerable to fire and its destruction could lead to accelerated degradation of the below-surface habitat by destroying the limited root-derived food base.

The Kiahuna Makai Cave contains a large number of the non-native, brown violin spiders, with as many as 26 of these spiders being counted during a single monitoring visit. Violin spiders make a strong, disorganized ground web, in which the remains and living specimens of the cave wolf spider have been found entangled (D. Hopper, *in litt.*, 1999). While no direct observations of predation by the violin spider on the endangered wolf spider have been observed, these observations and the steady decline of wolf spiders in the presence of violin spiders, suggests these non-native spiders may be a significant threat to the Kauai cave wolf spider and may play an equally damaging role to other native cave-dwelling species. The absence of the violin spider from the extremely humid dark zones of other caves, where both the Kauai cave wolf spider and amphipod are most frequent, suggests the Dark Zone conditions are less suitable for the violin spider.

The Kiahuna Mauka Cave is currently threatened by decreased food import due to the overlying golf course. The majority of this cave lies under a maintained lawn that lies adjacent to a golf course fairway. Prior to construction of the current golf course, this area was under cultivation for sugar cane. Hence, appropriate perennial vegetation, capable of providing root systems to herbivorous cavernicoles (plant-eating cave dwellers), have been absent from this site for many years. This population unit of amphipods has likely subsisted on old decaying roots and supplemental food provided by biologists. It is possible that this population unit would eventually decline or disappear if food was not periodically provided by biologists. A native plant restoration program has been implemented above the cave by the previous landowner to enhance the habitat of the species. To date, this enhancement activity has been subject to an infestation of the rose beetle (*Adoretus sinicus* [Burmeister]), a non-native insect which eats the native vegetation that has been planted. This infestation has substantially hindered the success of this project.

Factors that pose threats to other caves in the Koloa area are less of a concern in the Kiahuna Mauka Cave. Threat of unauthorized entry is of reduced concern in this cave since its opening lies in an area of monitored private land. Current management of this area has included regular watering (golf course maintenance) which has contributed to the maintenance of saturated soils and a high humidity cave interior which favors cave-dwelling species and increases rates of cellulose decomposition (a source of food to native detritivores such as the amphipod). Lastly, although employed by the golf course, herbicides are sparingly used and no traces of common pesticide components were detected in soil or tissue samples (from nonnative cockroaches) that were collected and analyzed from either of the Kiahuna caves (U.S. Fish and Wildlife Service 2000).

<u>5. Quarry Cave</u>

The habitat conditions within the Quarry Cave are not optimal for cave-dwelling arthropods throughout the entire cave, being drafty and of low relative humidity throughout most of the accessible passages. Food importation into this cave occurs primarily as a result of stream-born detrital material rather than from the root systems of perennial plants. Although the bedrock in which this cave is located is being quarried, the quarrying activities are minor and do not, at this time, appear to be near the known population unit of the amphipod. However, it is likely other mesocaverns within calacareous deposits were previously destroyed by the quarrying operation. Future increases in quarrying activity could negatively impact the underground spring that flows into this cave and/or cause the collapse of known or unknown caverns or mesocaverns. This cave is currently gated.

<u>6. By-Pass Cave</u>

This cave currently lacks an opening to the surface which protects it from direct human entry and/or vandalism. The primary known threat for this cave is low food abundance. Prior to re-closure of this cave, approximately 20 pounds of native wood were treated for non-native invertebrates (*i.e.*, frozen) and placed in the cave as a food source for the resident cave-dwelling species. The Koloa By-Pass Route was slightly rerouted and the land overlying the cave opening was annexed into an adjacent county park. Most of this cave lies beneath the county park and preservation of the cave should be compatible with use and management of the park.

7. Saint Rafael Church Cave

The current condition of the Saint Rafael Church Cave is unknown at this time. We have been unable to relocate the cave entrance which is believed to be near a cemetery. However, it is likely the cave is subject to common threats such as inadequate food source, lack of proper humidity, and if there is an accessible entrance to the cave, threats from human visitation and alien species.

H. Conservation Efforts

The Kauai cave wolf spider and cave amphipod were listed as endangered species on January 14, 2000 (U.S. Fish and Wildlife Service 2000). 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.

The Endangered Species Act provides several opportunities for the conservation of listed endangered and threatened animals and plants. Listed animal species receive 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 modifications or degradation where it actually kills or injures listed species by significantly impairing essential patterns that may affect breeding, feeding, or sheltering (50 Code of Federal Regulations (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 State Division of Forestry and Wildlife, Hawaii Revised Statues 195D4). Hawaii State Law prohibits taking of endangered wildlife and encourages conservation by State government agencies.

Critical habitat for the Kauai cave arthropods was designated on April 9, 2003 (U.S. Fish and Wildlife Service 2003). 50 CFR §424.02 defines critical habitat to be the specific areas currently occupied by a species on which are found those physical or biological features that are necessary for the recovery of the species and that may require special management considerations or protection, and those areas unoccupied by a species that the Secretary of Interior has determined to also be essential for the recovery of the species. "Conservation" is further defined as the use of all methods and procedures that are necessary to bring any endangered or threatened species to the point at which the measures provided by the Endangered Species Act are no longer necessary. The critical habitat designation consists of 14 units whose boundaries encompass an area of approximately 110 hectares (272 acres) on the island of Kauai, Hawaii. This critical habitat designation requires us to consult under section 7 of the Endangered Species Act with regard to actions carried out, funded, or authorized by a Federal agency.

A number of programs within the U.S. Fish and Wildlife Service provide funds and incentives for the protection of federally listed species. In 1995 a cooperative agreement with one private landowner was initiated and conservation measures agreed to by the landowner and the U.S. Fish and Wildlife Service are being implemented (U.S. Fish and Wildlife Service, *in litt*. 1995) . This conservation agreement and a subsequent agreement, focus on habitat protection and enhancement as recovery strategies for these two species.

A cave preserve management plan (the plan) was developed for three units, incorporating Koloa Caves 1 and 2 (considered together as a single unit), Cave 1927C, and Cave 3179 on property owned by Alexander and Baldwin. The goals of the plan are to reduce threats that affect the endangered cave arthropods, stabilize their populations, and maintain their ecosystem into the future. The long-range goal is recovery of the two species and eventual removal from the List of Threatened and Endangered Species. The plan relies on experimentally modifying the surface and interior environments in caves that do not currently support the two species. The proposed plan is adaptive, changing as the results of monitoring and research become available since recommendations for the conservation of these species is hampered by the lack of good ecological data concerning their requirements.

In 1997, the Federal Highways Administration informally consulted with the us to avoid or minimize their impacts to a cave uncovered during a road construction project (Koloa By-Pass Road; see "By-Pass Cave" section above). Working in cooperation with the county and a private landowner, this cave was protected from potential damage due to road construction when the road was slightly diverted to avoid the cave and minimize impacts to the area above the cave. Supplemental food was placed in the cave prior to re-sealing the entrance and the cave opening was annexed into an adjacent county park. Improvements to the area above the cave by the Kauai Department of Parks (the installation of a watering system and the planting of two genus of trees, *Senna* sp. and *Erythrina* sp.) are likely to enhance the amphipods habitat. These improvements will likely enhance the habitat for the resident amphipods because they will provide plant roots into the cave and help maintain a high humidity environment. Unfortunately, monitoring the biotic responses to these conservation and recovery efforts is not possible at this time because the cave was sealed.

A summary of the known distribution, status, threats, and current management actions for the Kauai cave wolf spider is presented in Table 1.

A summary of the known distribution, status, threats, and management actions for the cave amphipod is presented in Table 2. Based on the known distribution of the Kauai cave amphipod, it is plausible they exist in more population units and larger numbers, throughout a larger area than the cave wolf spider with occupied caves occurring as far distant as 5 kilometers (3.1 miles) from one another.

I. Recovery Strategy

This recovery plan outlines steps for the immediate and long-term protection and enhancement of cave habitats for the Kauai cave wolf spider and cave amphipod. Downlisting and delisting of the cave arthropods may be achieved through the protection and appropriate habitat enhancement of the known, occupied caves, as well as discovery of additional occupied caves, and reestablishment of stable or increasing population units into formerly occupied caves (*e.g.*, Kiahuna Makai Cave). Given the restricted distribution of these arthropods, the limited number of occupied sites, and the potential threat to their habitat from human activities, preservation of known occupied habitats is a priority for the recovery of these species.

Kauai Cave Wolf Spider

Given that the cave wolf spider is only regularly found in a single cave, it is extremely vulnerable to extinction, both from catastrophic events as well as from fluctuations in the resident population. It also means the wolf spider's recovery is contingent on the discovery of additional occupied caves, and/or the enhancement of known but unoccupied caves, to the point where they can support the wolf spider, and the implementation of appropriate protection and habitat enhancement. In order to preserve this species, the protection and enhancement of the single occupied cave is of fundamental importance and must be a priority focus of any recovery strategy.

Kauai Cave Amphipod

For the Kauai cave amphipod, protection and habitat enhancement of the known, occupied caves is a priority which will contribute to the downlisting of this species. Locating and protecting additional occupied caves will be necessary for the downlisting and delisting of the cave amphipod. In addition, the apparent population rebound observed in the Kiahuna Mauka Cave after food supplementation suggests this arthropod will respond favorably and quickly if conservation activities succeed in protecting and enhancing occupied habitat.

Table 1. Distribution, current status, threats, and management activities for the Kauai cave wolf spider (*Adelocosa anops*). Terms are defined as: Common: always observed during monitoring visits and in numbers suggesting a resident population; Rare: only observed periodically and not present in numbers that indicate a reproducing population; Historic: previously observed and believed to have been "common," but recently absent.

CAVE	SPECIES STATUS	KNOWN THREATS	CURRENT MANAGEMENT ACTIONS
Koloa Cave 1	Rare	Dry cave interior, non-native predators, low food abundance, drought, vulnerable surface habitats (fire), pesticides.	Access controlled by locking gate; surface area over cave protected by agreement with landowner.
Koloa Cave 2	Common	Dry cave interior, non-native predators, low food abundance, drought, vulnerable surface habitats (fire), pesticides.	Access controlled by locking gate; periodic food supplementation; surface area over cave protected by agreement with landowner.
Kiahuna Makai Cave	Historic	Dry cave interior, non-native predators, low food abundance, drought, vulnerable surface habitats (fire), pesticides, unauthorized human entry.	Surface area not currently threatened by development or modification.
Kiahuna Mauka Cave	Rare	Non-native predators, pesticides.	Surface area over cave managed as golf course; watering enhances cave habitat; access controlled by locking gate; cave habitat enhancement through surface habitat management from previous landowner.
Quarry Cave	Rare	Non-native predators, low food abundance, drought, habitat destruction (quarry), vulnerable surface habitats (fire), pesticides.	Access controlled by locking gate at one of three entrances; not currently managed or protected.

Table 2. Distribution, current status, threats, and management activities for the Kauai cave amphipod (*Spelaeorchestia koloana*). Terms are defined as: Abundant: always observed during monitoring visits and numbers often exceeding 100 individuals; Common: always observed during monitoring visits and in numbers suggesting a resident population; Present: not always observed during monitoring visits, but present in numbers to suggest a population; Rare: only observed periodically and not present in numbers that indicate a reproducing population; Historic: previously observed and believed to have been "common," but recently absent; Currently Unknown: previously observed, no current information.

CAVE	SPECIES STATUS	KNOWN THREATS	CURRENT MANAGEMENT ACTIONS
Koloa Cave 1	Rare	Dry cave interior, non-native predators, low food abundance, drought, vulnerable surface habitats (fire), pesticides.	Access controlled by locking gate; surface area over cave protected by agreement with landowner.
Koloa Cave 2	Present	Dry cave interior, non-native predators, low food abundance, drought, vulnerable surface habitats (fire, pesticides).	Access controlled by locking gate; periodic food supplementation; surface area over cave protected by agreement with landowner.
Cave 1927C	Rare	Dry cave interior, unauthorized human entry, non-native predators, low food abundance, drought, vulnerable surface habitats (fire), pesticides.	Surface area over cave protected by agreement with landowner.
Cave 3179	Historic	Dry cave interior, unauthorized human entry, non-native predators, low food abundance, drought, vulnerable surface habitats (fire, pesticides).	Surface area over cave protected by agreement with landowner.
Kiahuna Mauka Cave	Present to abundant	Non-native predators.	Surface area over cave managed as golf course; watering enhances cave habitat; access controlled by locking gate; periodic food enhancement; cave habitat enhancement through surface habitat management from previous landowner.
By-Pass Cave	Currently Unknown	Low food abundance.	Cave is closed; above surface watering and landscaping should enhance cave habitats.
Saint Rafael Church Cave	Currently Unknown	Dry cave interior, unauthorized human entry, non-native predators, low food abundance, drought, vulnerable surface habitats (fire), pesticides.	Not currently managed or protected.
Quarry Cave	Present	Non-native predator; low food abundance, drought, habitat destruction (quarry), vulnerable surface habitats (fire), pesticides.	Access controlled by locking gate at one of three entrances; not currently managed or protected.

For the Kauai cave arthropods, habitat enhancement of unoccupied caves may be a viable recovery tool. However, in caves not known to have been occupied by one or both of these species, such “restoration” activities should not be considered as a feasible tool until such enhancement methods are proven to be effective. Emphasis needs to be placed on protection and enhancement of known occupied caves and the discovery and protection of additional caves. In addition, non-native predators will need to be eradicated in a way that will not be a detriment to the native spider, such as targeted removal of violin spiders.

II. RECOVERY

A. OBJECTIVES AND CRITERIA

The objective of this recovery plan is to outline recovery actions that, when implemented will remove threats to the existing cave arthropod populations, and establish within their historic range, or locate, new populations, with the primary goal of removing them from the list of threatened and endangered species. The difference between down- and delisting is based on the number of viable populations, number of years, and the number of caves that meet the recovery criteria.

Downlisting and delisting for both species of Kauai cave arthropods may be considered when the following critiera are met:

1. Downlisting Criteria

Downlisting to threatened may be considered for both species when nine viable populations (populations contain representatives of all generations, sexes, and age classes over a sustained period of time) of each species, spread across the known range, are shown to be: (a) self-sustaining; (b) stable or increasing; (c) protected from non-native/predatory species, human visitation to caves, bio-control agents, pesticides, development or other damaging land uses; and (d) with the habitat being used in a fashion consistent with conservation, all as evidenced by monitoring over a 10-year period.

2. Delisting Criteria

Delisting of both species may be considered when 12 viable populations, of each species, spread across the known range, are shown to be: (a) self-sustaining; (b) stable or increasing; (c) protected from non-native/predatory species, human visitation to caves, bio-control agents, pesticides, development or other damaging land uses; and (d) with the habitat being used in a fashion consistent with conservation, all as evidenced by monitoring over a 20-year period (which is expected to assist in determining if the number of populations identified for down- and de-listing are adequate).

A 20-year monitoring period was determined to be necessary because land development is slated to occur, during the first 10 years of monitoring, on lands over areas that are known or suspected to contain caves that may support the Kauai cave arthropods. These activities may cause significant changes in cave environments and cause fluctuations in these species' populations. An additional period of at least 10 years following development will be needed to ensure that the cave arthropods, which have probable low fecundity, are stable, and that these species are responding appropriately to natural events that may be affecting their population levels. Also, a post-delisting monitoring plan and agreement to continue post-delisting monitoring must be in place and ready for implementation at the time of delisting. Monitoring populations following delisting will verify the ongoing recovery and conservation of the species and provide a means of assessing the continuing effectiveness of management actions.

The number of caves needed to down-list and de-list both species is based on the best available information, including: the nine caves that have been located to date that are known to presently or historically support Kauai cave arthropods; and the presence of land formations, such as lava rock out-croppings, that indicate the potential presence of additional caves that may be suitable. These areas were identified in the critical habitat rule for these species (U.S. Fish and Wildlife Service 2003), and will be investigated for the presence of suitable habitat and cave arthropods, as funds become available. Also, the number of caves with viable populations, spread across the known range, represents what is necessary to protect against stochastic events such as flooding, cave-ins, release of contaminants, hurricanes that remove above ground vegetation, and disease. The number of caves with viable populations, spread across the known range, also provide for opportunities of genetic exchange (possibly through translocation), resulting in the maintenance of genetic integrity for both species. In addition, since the wolf spider relies on the amphipod population for food, the number of caves with viable populations of amphipods, spread across the known range, provides for the ability of the spider to move from areas of low populations of amphipods to ones that can support predation.

It must be emphasized that the cave wolf spider is reliably known from only a single cave and appears to have recently disappeared or greatly declined from a previously occupied cave. Downlisting criteria may not be met unless additional caves are discovered and found to contain significant population units of the cave wolf spider, and the above recovery criteria achieved in those caves.

B. NARRATIVE OUTLINE OF RECOVERY ACTIONS

1. Protect known populations of the Kauai cave wolf spider and cave amphipod and their subterranean systems from human-caused destruction or degradation.

    1.1 Protect the cave interior and cave arthropods from uncontrolled human entry.
    Human entry and use of caves threaten the survival of cave-dwelling arthropods both by intentional impacts such as vandalism and collecting, as well as by unintentional impacts such as trampling of arthropods and their food resources and introduction of toxic materials (*e.g.*, smoke, batteries). Caves with populations of these arthropods should be closed to prevent unauthorized and/or uncontrolled human access. Whenever possible, a locking gate should be installed that employs durable materials that are not easily dismantled, while providing access to authorized persons to allow monitoring of the status of the arthropods and their habitat. Cave closure and access issues need to be developed with the support of local landowners, appropriate State agencies, and Hawaiian groups (*e.g.*, burial councils).

    1.2 Protect/enhance overlying plant communities.
    Overlying perennial native plant communities should be protected from loss, and enhanced. Overlying plant communities primarily made up of non-natives should be removed and native plant communities restored using plants known to serve as food sources for the cave arthropods. Partnerships should be formed with private land owners and other State and/or Federal agencies such as the State Department of Land and Natural Resources and the

Federal Natural Resources Conservation Service to provide restoration of non-native plant communities and maintenance of perrenial native plant communities overlying caves.

1.2.1 Develop and implement a fire control plan for surface habitats.
In addition to their protection from loss, whenever appropriate, these overlying habitats should be protected from wildfire which kills perennial vegetation and often results in burn areas being taken over by inappropriate vegetation communities (*e.g.*, grass lands). The restoration of appropriate vegetation communities (see Action 2.1 below) as well as working with landowners to develop a fire plan for their land should be encouraged and supported.

1.3 Prevent the introduction of non-native predators and competitors and carry out management actions that eliminate or reduce the presence of non-native predators and competitors.
During monitoring and other authorized visits, potentially harmful, non-native species should be removed. This is particularly pertinent for species such as the invasive brown violin spider, little brown scorpion, centipedes, or large cockroaches, all of which are non-native, generalist predators/foragers. If further research suggests the control of such organisms can be accomplished through habitat management such as reducing air movement and/or increasing humidity levels, then these manipulations should be incorporated into the management goals (see Actions 2.2 and 3.4 below).

1.4 Prevent the introduction of inappropriate bio-control organisms or bio-pesticides throughout the State of Hawaii.
The intentional release of bio-control organisms or bio-pesticides has a long history of negative effects on the endemic Hawaiian biota. While bio-control agents may provide great hope for the protection of the State's economy and the integrity of its native ecosystems, all proposed bio-control agents, both new

introductions as well as re-introductions, should be carefully considered and researched under section 7 of the Endangered Species Act with U.S. Department of Agriculture to ensure they pose no threat to native species, including the unique Hawaiian cave fauna.

1.5 Prevent contamination of the cave from human-associated activities such as runoff and soil percolation of pollutants or other harmful chemicals including harmful pesticides.

Inappropriate and/or overuse of chemical herbicides, insecticides, and fungicides can have devastating effects on species living in subterranean habitats (soils, caves, and mesocaverns). Heavy use of such chemicals should be avoided above and adjacent to known caves or mesocavern-containing habitats unless they are shown to be safe (*e.g.*, rapidly breakdown to inert components or are shown to have no effect on non-target organisms). Limited use of chemicals known to be safe may be permitted. Use of "safe" pesticides should only be used sparingly above or adjacent to known cave-bearing rock and a limited-use buffer area should be established around such areas.

2. Improve or enhance the habitat of occupied caves or caves previously occupied through protection of above-cave habitats and implementation of landscaping actions that are likely to increase subterranean food resources.

2.1 Manage surface vegetation that will provide root systems for herbivorous and detritivorous cavernicoles with an abundant and sustainable food resource.

Caves are typically regarded as being food-limited and recent work conducted in one of the Koloa caves supports this. Possibly the most important management activity for the recovery of these species is to manage the overlying habitat to encourage the growth of appropriate plants through weed control, outplanting/landscaping, and irrigation-the roots will penetrate into the cave and provide a source of fresh vegetation and detritus for the cave amphipods. Increases in the amphipod population or other cave-inhabiting detritivores should result in increases in prey for these spiders. To the extent possible, efforts should be made to outplant native and indigenous, nontoxic plants to enhance subterranean habitats for native cave-dwelling species. Non-native plants are known to provide food for the Kauai cave amphipod and can be used if the situation dictates such an action. As has occurred in some of the regularly monitored caves, pretreated detrital material may be placed in such caves to help supplement food reserves and to help maintain healthy populations of cave amphipods until appropriate overlying vegetation can be planted and become established, providing a long-term food supply to the cave. Establishment of healthy plant root systems is already known to be a valid management tool, but research should be conducted to determine the best species of plants to use (*e.g.*, plant preferences, plant performance) (see Action 3.2 below).

2.2 Maintain consistent high humidity within the Dark Zone and increasing relative humidity within Stagnant Air Zones . Terrestrial cave-dwelling organisms are largely restricted to cave environments with high relative humidity. Evidence to support this habitat criteria for the Kauai cave amphipod has been provided by Miura and Howarth (1978). Increasing the relative, ambient humidity is largely dependent upon reducing air velocity through the cave, but adequate soil moisture is also important. As such, caves that lack or have low amounts of air movement and occur in areas where rain, or other sources of moisture help maintain a high relative humidity, provide the best habitat for cave-dwelling species. Cave humidity can be elevated by: (a) restricting air-flow into and within the cave or passage way, and (b) adequately irrigating the surface habitat to ensure an appropriate level of soil saturation. Restricting air movement in caves to elevate ambient humidity levels has not been conducted for the purpose of habitat management for cavernicoles (cave dwellers) and should be attempted cautiously to determine if it has value as a management tool (see Action 3.4 below). Irrigation of above-cave habitats has not been conducted for the benefit of cave habitats, but it has likely contributed to improved habitat quality of Kiahuna Mauka Cave and By-Pass Cave. Not only would appropriate irrigation of surface habitats make cave climate more accommodating for these arthropods, but it would also ensure that the overlying vegetation community will remain healthy and minimize fire risk to the plant community.

3. Conduct research to address essential conservation needs for the species.

3.1 Conduct non-invasive, non-damaging mark-recapture studies to determine local population sizes and/or movement.
Conducting mark-recapture studies is essential for the estimation of population sizes of any species. To date, no such studies have been undertaken with Hawaiian cave animals, and have rarely been undertaken with other cave-dwelling animals occurring elsewhere. Developing non-damaging methods of marking these arthropods would allow biologists to obtain needed information on the population size of these species. Results from such a study could result in the reevaluation of conservation actions and might lead to reassessing our recovery criteria. In addition, successful mark-recapture studies could provide more information on the life history of these arthropods, specifically, provide some idea of home range and longevity.

3.2 Determine the most beneficial and appropriate plants to be used for habitat enhancement.
Numerous native or ornamental plants could be utilized for habitat enhancement over cave/mesocavern habitats. However, certain species are known to be particularly important with regard to providing nutrient input into Hawaiian cave systems. The native ohia tree (*Metrosideros polymorpha*) has roots known to be important food sources for a number of endemic cave-dwelling species on the island of Hawaii (Howarth 1981). Another endemic plant, maiapilo (*Capparis sandwichiana*) is suspected of being an important food resource in caves located in drier climates (Howarth 1981). Both of these plants have large roots that often

enter caves and grow for extensive distances along the cave floor where they are fed upon by herbivorous and detritivorous cavernicoles. These plants and others should be tested to determine how they perform in the Koloa District in order to refine restoration and recovery actions for caves in these areas.

3.3 <u>Develop and utilize non-invasive molecular techniques to determine the status of populations (not to be conducted with the wolf spider until additional, healthy populations are discovered</u>).
It is not known if the separate population units of the cave amphipod represent isolated populations or races, or if they should be considered a single, panmictic population (random or non-selective mating within a breeding population) which exhibits regular gene-flow between population units. Developing molecular techniques to address this question is an important research need that could affect the recovery criteria for the cave amphipod. Information obtained from such molecular studies would be important not only for management of the cave amphipod, including reevaluation of the recovery criteria, but would provide information on the extent and connectivity of cave systems in the Koloa District. This information would have important implications for the Kauai cave wolf spider, which appears to be far more restricted in its current distribution. Given the limited number of cave wolf spiders and their restricted range, it is not currently advisable to conduct such studies with this species. Any proposal to conduct such work with the wolf spider should be carefully evaluated by qualified biologists.

3.4 <u>Conduct studies to determine if manipulation of cave climate can be used to improve habitat for the endangered cave arthropods and/or control non-native species</u>.
High ambient humidity is known to be an important habitat parameter for cave-dwelling animals and has been shown to play a role in the distribution of the Kauai cave amphipod (Miura and Howarth 1978). Taking steps to increase cavern humidity is a recommended management activity (see Action 2.2 above) that

should be conducted and its effectiveness should be determined. Observations in the Kauai caves suggests that harmful, non-native species (*e.g*., brown violin spider) are not as abundant in areas where ambient humidity is high. Should additional observations and/or controlled experiments confirm the suitability of "humidity regulation," then managing caves to increase the internal ambient humidity could be a valuable management tool for increasing population numbers of endangered cave-dwelling species and/or reducing threats associated with nonnative predators/competitors.

3.5 <u>Conduct surveys for additional occupied caves or restorable cave systems</u>.

Given the limited number of cave systems from which the cave wolf spider and amphipod are currently known, finding more occupied caves will be necessary if the Kauai cave dwelling arthropods are to be down- or delisted. If additional occupied caves are not discovered, increased emphasis should be placed on protecting and restoring caves that have good potential for supporting populations of one or both of these arthropods in the future.

3.6 <u>Continue the current monitoring regime (biannual or more frequent) to determine population trends in caves and assess recovery actions.</u>

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). Standardized surveying and monitoring techniques should be developed to continue the monitoring of known occupied caves and caves that were previously occupied. While the current monitoring activities do not provide sound population estimates, they do provide some measure of population health within these caves. Monitoring will be necessary to determine whether the cave arthropods populations remain stable over time. This monitoring should occur at least biannually so any drop in population numbers can be quickly identified and management actions taken. Each cave arthropod population identified by completed surveys should be monitored at least biannually to establish information on population trends and possible threats. In addition, continued monitoring will be particularly important as recovery activities are implemented, providing some measure of success or failure of the management activities and allowing for the implementation of adaptive management.

3.7 Conduct feasibility studies for the translocation of Kauai cave wolf spiders and amphipods to unoccupied caves.
Given the current, known distribution of the both Kauai cave wolf spider and Kauai cave amphipod, it will not be possible to achieve the outlined downlisting or delisting criteria for the wolf spider, and the delisting criteria for the amphipod, unless additional occupied caves are discovered or spider populations become established in currently unoccupied caves. It is possible that wolf spiders and amphipods will disperse into known caves once recovery actions are implemented. However, should the wolf spider and amphipod remain absent from caves where conditions appear to be optimal, biologists should consider the feasibility of establishing new populations in such cave systems via translocation. This is not a conservation activity that has received attention and should be pursued only after serious consideration involving a number of qualified biologists (*e.g*, those with expertise with cavernofauna and/or with carrying out translocations).

3.8 Evaluate research results and implement adaptive management as necessary.
The results of the above research actions should be evaluated and incorporated into the management process and used in the development of recovery objectives.

4. Conduct public outreach to facilitate better public understanding of and support for conservation of these cave arthropods.
The current plight of the obscure cave wolf spider and cave amphipod, and the ecosystem upon which they depend, is not known to the residents

of Koloa and Poipu. Effective outreach should contribute to public support for their conservation and serve to further inform local residents and businesses regarding their conservation needs, the regulatory requirements of the Endangered Species Act, and, very importantly, available recovery tools such as Safe Harbor Agreements, Habitat Conservation Plans, Federal funding through the Landowner Incentive Program and Recovery Land Acquisition grant program, and voluntary actions that the landowners can take to conserve the species.

5. Validate recovery objectives.
The scientific validity of the recovery objectives should be reviewed and downlisting and delisting criteria should be revised, as appropriate, as more information becomes available.

6. Develop and implement post-delisting monitoring plan as necessary.
Prior to delisting of the Kauai cave wolf spider or cave amphipod, post-delisting monitoring plans should be in place and ready for implementation. Monitoring of populations following delisting will verify the ongoing recovery and conservation of the species and provide a means of assessing the continuing effectiveness of management actions.

Table 3 provides a cross-reference of recovery actions and listing factors.

Table 3. Cross-reference of recovery actions and listing factors for the Kauai cave wolf spider and the Kauai cave amphipod.

LISTING FACTOR	THREAT	STILL A THREAT	ACTION NUMBERS	RECOVERY CRITERIA
A	Past land modification due to agricultural practices	yes	1.2, 2.1, 2.2, 3.2	See pages 33-34 for downlisting and delisting criteria
A, D	Development	yes	1.2, 2.1, 2.2, 3.2	
A	Wildfire	yes	1.2.1, 2.1, 2.2, 3.2	
B	Collection	yes	1.1, 4	
B	Human visitation to caves	yes	1.1, 4	
C	Nonnative predators	yes	1.3, 2.2, 3.4	
E	Pesticide, herbicide, and fungicide use	yes	1.5	
E	Use of biocontrol agents	yes	1.3, 1.4,1.5	
E	Susceptibility to naturally occurring events such as storms or earthquakes	yes	1.2, 3.1, 3.3, 3.4, 3.5, 3.7	

III. IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows outlines actions and estimated cost to downlist and/or recover the Kauai cave arthropods. It is a guide for meeting the objectives discussed in Part II of this plan. This schedule indicates action priority, action numbers, action descriptions, duration of actions, the agencies/organizations involved and/or responsible for committing funds and/or carrying out the described activities, and lastly, provides 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 Kauai cave arthropods, protect habitat for these species, 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	An action that will be implemented on a routine basis once begun.
O	An action that is currently being implemented and will continue until action is no longer necessary.
DLNR	Hawaii Department of Land and Natural Resources, Division of Forestry and Wildlife
ES	U.S. Fish and Wildlife Service, Ecological Services, Pacific Islands Fish and Wildlife Office, Honolulu, Hawaii
PL	Private Landowners
HDOA	Hawaii Department of Agriculture
NRCS	Natural Resource Conservation Service
RD	U.S. Geological Survey, Biological Resources Division
BM	Bishop Museum
USDA	Department of Agriculture
PNI	Participant not currently identified (academic, contractor, or other institution)
†	Indicates that some projects may have been completed or are in the process of being implemented.
‡	Total probably represents low estimates since some actions, with their associated funding, have not been completely implemented.

Implementation Schedule for the Draft Recovery Plan for the Kauai Cave Arthropods

Priority #	Task #	Action Description	Action Duration (years)	Responsible Party	Total Cost Thru Year 20 ($1,000's)	Costs Estimates ($1,000's)					
						Year 01	Year 02	Year 03	Year 04	Year 05	Years 06-20
1	1.1	Protect the cave interior and cave animals from uncontrolled human entry.	O	ES*, PL	120†	20	20	20	20	20	20
1	1.2	Protect/enhance overlying plant communities.	O	ES*, PL, NRCS	780	100	100	100	100	80	300
1	1.2.1	Develop and implement fire control plan for surface habitats.	O	ES*, PL	500	60	100	60	40	40	200
1	1.3	Prevent introduction of non-native predators and competitors and carry out management actions that eliminate or reduce the presence of non-native predators and competitors.	C	ES	105†	8	8	8	8	8	65
1	1.4	Prevent intentional introduction of bio-control organisms and bio-pesticides	C	ES	500	25	25	25	25	25	375
1	1.5	Prevent contamination of the cave from human-associated activities such as runoff and soil percolation of pollutants or other harmful chemicals including harmful pesticides.	C	ES, PL*	260	10	20	20	30	30	150
1	3.6	Continue current monitoring regime (biannual or more frequent) to determine population trends in caves and assess recovery actions.	O	ES	775	5	5	5	5	5	750
1	3.8	Evaluate research results and implement adaptive management as necessary.	C	ES, PL*	200	10	10	10	10	10	150

Implementation Schedule for the Draft Recovery Plan for the Kauai Cave Arthropods

Priority #	Task #	Action Description	Action Duration (years)	Responsible Party	Total Cost Thru Year 20 ($1,000's)	Costs Estimates ($1,000's)					
						Year 01	Year 02	Year 03	Year 04	Year 05	Years 06-20
2	2.1	Manage surface vegetation that will provide root systems for herbivorous and detritivorous cavernicoles with an abundant and sustainable food resource.	O	ES*, PL	91	10	10	7	7	7	50
2	2.2	Maintaining consistent high humidity within the Dark Zone and increasing relative humidity within stagnant air zones.	O	ES*, PL	44	5	5	3	3	3	25
3	3.1	Conduct non-invasive, non-damaging mark-recapture studies to determine local population sizes and/or movement.	C	ES, BM*, BRD, PNI	500	40	40	40	40	40	300
3	3.2	Determine the most beneficial and appropriate plants to be used for habitat enhancement.	O	ES*, BRD, PNI	340	60	60	60	30	30	100
3	3.3	Develop and utilize non-invasive molecular techniques to determine the status of populations (not to be conducted with the wolf spider until additional, healthy populations are discovered.	C	PNI	700	100	100	100	100	100	200
3	3.4	Conduct studies to determine if manipulation of cave climate can be used to improve habitat for the endangered cave animals and/or control non-native species.	O	ES*, PNI	480	60	60	60	60	60	180

Implementation Schedule for the Draft Recovery Plan for the Kauai Cave Arthropods

Priority #	Task #	Action Description	Action Duration (years)	Responsible Party	Total Cost Thru Year 20 ($1,000's)	Costs Estimates ($1,000's)					
						Year 01	Year 02	Year 03	Year 04	Year 05	Years 06-20
3	3.5	Conduct surveys for additional occupied caves or restorable cave systems.	O	ES, DLNR*, PNI	204	12	12	10	10	10	150
3	3.7	Conduct feasibility studies for the translocation of wolf spiders and amphipods to unoccupied caves.	20	ES, BM*, PNI	700	100	100	100	100	100	200
3	4	Conduct public outreach to facilitate better public understanding of and support for conservation of the cave animals.	O	ES*, PNI	110	10	10	10	10	10	60
3	5	Validate recovery objectives.	C	ES	200	10	10	10	10	10	150
3	6	Develop and implement a post-delisting monitoring plan as necessary.	C	ES	21	1	1	1	1	1	16
TOTAL COST TO RECOVERY					**6,630‡**	**646‡**	**696‡**	**649‡**	**609‡**	**589‡**	**3,441‡**

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C. Personal Communication

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