

and the other was known only to be occupied by amphipods. Therefore, the spider has verified occurrences in six caves.

The Kauai cave amphipod has been recorded from six caves in the Koloa area but was only regularly encountered in only three of these caves. In one of these three caves, where the amphipod was found with the wolf spider, their numbers have ranged from 8 to 67 during the biannual monitoring visits. In another regularly occupied cave, amphipod numbers have increased steadily from 10 to 20 individuals per visit in pre-1998 counts to over 300 individuals during a visit in November 2000 (Service, unpub. data).

In the three caves less frequently occupied by the amphipod, the lack of observations of the species is probably due to several factors. In one of these caves, relative humidity is often below 100 percent, which is a suboptimal condition for troglobites. Amphipods have been found in this cave when humidity conditions are optimal, such as after heavy rains which saturate the soil and increase the relative humidity in the dark zone. In a second cave, amphipods appear to be resident but were only observed during two visits that were conducted soon after the cave had been exposed by heavy machinery, and prior to the cave being re-closed for road construction (A. Asquith, *in litt.* 1999). The last of these three caves has been visited infrequently and amphipods have been observed during some, but not all, visits (Bousfield and Howarth 1976; D. Hopper, *in litt.* 1998a; D. Hopper, *in litt.*, 2000a).

Since the publication of the proposed rule, the Service was notified of a seventh cave where the amphipod's occurrence was previously recorded (Bousfield and Howarth 1976). No additional information has been provided on this particular cave nor do we know the current status of the cave. Therefore, the amphipod has been known from seven caves.

Despite the data obtained in our biannual monitoring counts, the quantities of animals reported do not represent sound population estimates. The methods needed to conduct non-damaging, mark-recapture studies for accurate estimates of population size have not been developed for these animals, and no attempt to conduct such studies have been undertaken.

Cave systems may be separated by various physical barriers such as subterranean streams, or areas with developed soils that have filled in the mesocavern passages or habitats of these old caves (Mueller-Dombois and Howarth 1981). The degradation and

loss of naturally occurring mesocavern habitats and corridors has likely been accelerated by development or other land uses that often require clearing of vegetation, blasting, and filling of trenches and construction sites. These activities, as well as modern agricultural practices, exacerbate the rates of sediment mobilization (Kirch 1982; Cuddihy and Stone 1990), resulting in the filling of caves and mesocaverns (Howarth 1973; Mueller-Dombois and Howarth 1981; Burney *et al.* 2001).

Because distinct species can evolve in adjacent lava tubes even when cave animals can move extensively through mesocaverns (Hoch and Howarth 1993), it is reasonable to consider the separate localities of these animals as different populations, even though intervening areas of potential habitat cannot be surveyed. Thus, we have currently verified a total of six spider populations and seven amphipod populations that are distributed throughout the Koloa district as follows: the Koloa Caves #1, #2, the newly discovered spider cave, and adjacent areas west of Waikomo Stream are considered to harbor three populations of the spider and two populations of the amphipod; the seaward Kiahuna Caves #267 and #276 likely harbor two populations of the spider and one of the amphipod; the Kiahuna Cave #210 harbors a separate population each of the spider and amphipod; the Mahaulepu Cave harbors a separate population each of the cave amphipod and the spider (Service, unpublished data, 1998–1999; G. Smith *in litt.* 2002); a small cave near the St. Raphael church harbors a population of the cave amphipod; and a small cave near the Koloa bypass road harbors a cave amphipod population.

Threats

Small populations are also demographically vulnerable to extinction caused by random fluctuations in population size and sex ratio and to catastrophes such as hurricanes (Soule 1983; Gilpin and Soule 1986). In addition, the low reproductive potential of both cave species (less than five 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).

One of the major threats facing the Kauai cave wolf spider and the Kauai cave amphipod is the introduction of invasive alien species (F. Howarth, *in litt.* 2001). For example, an alien terrestrial nemertine worm (*Argonemertes dendyi*) from Australia was discovered in the 1980s on the

island of Hawaii (Howarth and Moore 1983). This animal can live and reproduce in caves and presumably feed on any invertebrates, such as the Kauai cave wolf spider and the Kauai cave amphipod. The impact on cave fauna is not known at this time (Howarth and Moore 1983). If portions of the habitat are more or less isolated and protected, the chances are greater that any one threat would not affect all occupied caves at the same time and animals that survive may eventually re-colonize their former habitat. This situation would also apply for other surface disturbances, such as oil spills, pollution, and pesticide application.

Human impacts in the Koloa caves, and resulting impacts on the Kauai cave wolf spider and Kauai cave amphipod, are another concern. Caves are frequently sought out by curiosity seekers, and over-use of caves occurs readily due to their fragile nature (Howarth 1982; Culver 1986). In addition, both natural and cultural features (e.g., human burials and associated artifacts) of caves are often damaged or destroyed by collectors or vandals (Howarth 1982; N. McMahon, Hawaii Dept. Historic Preservation, pers. comm., 2001). Unauthorized visitation and vandalism is such an issue in caves that the Cave Resources Protection Act (16 U.S.C. 4301 *et seq.*; 102 Stat. 4546) was passed with the main intent of protecting cave-associated natural and cultural resources. Unauthorized entry and vandalism of the Koloa caves has been documented (D. Hopper, *in litt.*, 1998b, 2000a), and public interest in visiting caves is reflected in the publication of the location of two of these caves in a recent tourist guide (Doughty and Friedman 1998).

Human visitation to caves, even when not intentionally destructive, often results in severe impacts to the resident troglobites or other cave inhabitants. For example, nicotine is a potent insecticide that is easily introduced into the cave environment through cigarette smoke or discarded cigarette butts. Given the confined space and poor air circulation in caves supporting suitable troglobite habitat, the effects of cigarette smoke are far more pronounced in caves (Howarth 1982; Howarth and Stone 1993). The impacts of cigarette smoke are not restricted to the main cavern; the smoke will also impact mesocavern habitats, where its effects cannot be seen. Although less toxic than cigarette smoke, wood fire smoke may be equally damaging since far more smoke is produced and detrital food reserves may be burned. The use of cigarettes, as well as fire activity, have been documented