

are the primary means by which Hawaiian caves receive nutrient input (Howarth 1973). Protection and restoration of surface plant communities is, therefore, an extremely important consideration for cave conservation in Hawaii, as it is elsewhere (Culver *et al.* 2000). Factors or activities that impact or modify surface vegetation over caves (e.g., fire, replacement of native or other perennial vegetation with grasses or some nonnative plants) can damage or destroy the underlying cave community.

Adaptations of Troglotic Animals

As discussed in the species descriptions of the Kauai cave wolf spider and cave amphipod, troglotes typically possess specialized anatomical characters that represent adaptations to life in the cave environment. Such anatomical adaptations include enlarged and/or elongate tactile-sensory appendages (e.g., legs or other appendages, antennae), and the lack of, or reduced, pigmentation and/or eyes (Barr 1968). Less obvious adaptations are also present in the physiology of troglotes and this has the potential to restrict their distribution within various cave zones (Huppopp 1985). Laboratory studies with Hawaiian crickets (*Caconemobius* spp.) were conducted that compared the abilities of closely related surface and cave-dwelling forms to cope with desiccation (Ahearn and Howarth 1982). Surface-dwelling species exhibited considerably lower evaporation/desiccation rates than did the troglotic species, and in one case, the surface species became dehydrated at half the rate of its cave-inhabiting relative. This low desiccation threshold largely confines these troglotes to the high-humidity environment of the deeper portions of caves, the dark and stagnant air zones. While such tests have not been conducted on the Kauai cave species, a logical assumption is that they have similar humidity tolerances, and this has been supported by field studies and observations conducted in the Kauai caves (see below). Similar adaptations in other troglotic faunas (Vandel 1965; Barr 1968; Huppopp 1985) support the universality of these traits in troglotic animals.

Given the great vulnerability of troglotes to desiccation, adjacent mesocavern habitats will contain appropriate microclimate conditions and provide habitat or serve as refugia for troglotes when conditions in the main cave passages become drier or otherwise less accommodating. For example, during a previous survey of one cave of the Koloa area, the Kauai cave amphipod was not observed (Miura

and Howarth 1978). However, on a subsequent survey, the floor of a small, dead end passage was saturated with 40 liters (10 gallons) of water, and 24 hours later amphipods had moved into this area, presumably from the surrounding mesocaverns (Howarth 1983a, 1983b). The foraging activities of both the Kauai cave wolf spider and the Kauai cave amphipod are restricted to dark, moist areas of large caverns and mesocaverns, and it is possible that the majority of their time is spent within such spaces.

Both Howarth (1983a) and Huppopp (1985) have postulated that troglotes may be adapted to cope with low levels of oxygen and/or elevated concentrations of carbon dioxide, similar to conditions that would be encountered in the stagnant air zone of caves. This ability has been substantiated from observations in known stagnant air zones (Howarth and Stone 1990), as well as under controlled laboratory experiments. Hadley *et al.* (1981) conducted experiments with Hawaiian wolf spiders, both troglotes (*Lycosa howarthi*) and a related surface-dwelling species (*Lycosa* sp.). These researchers found the surface-dwelling spider had a higher metabolic rate, requiring 2.5 times more oxygen than its cave-dwelling relative. The reduced need for oxygen would better allow these spiders to survive in stagnant air cave zones. Given the ability of at least some troglotes to cope with reduced oxygen and elevated carbon dioxide, as well as their ability to inhabit inaccessible mesocaverns, it is assured that many troglotes will be able to reside in areas not readily surveyed by biologists. Hence, cave habitats will extend well beyond those areas accessible by researchers (Howarth 1983a).

Species Distribution and Abundance

The Kauai cave wolf spider and Kauai cave amphipod are generally restricted to cave dark and stagnant air zones, or other subterranean habitats such as cracks, voids, and other mesocaverns containing microclimate conditions similar to those zones. However, both the cave wolf spider and amphipod may be found in sub-optimal cave habitats (e.g., cave transition zone) when conditions are appropriate (e.g., elevated humidity during periods of increased rainfall). All of the caves where the cave amphipod has been located contain penetrating plant roots and/or other decomposing plant material, which serves as a food source for this detritivore. Plant material upon which the amphipods feed need not be from native plants, although nonnative toxic or indigestible plants may be

inappropriate or damaging for amphipod foraging. The Kauai cave wolf spider can be found in caves where the cave amphipod does not occur, but other nonnative arthropods (e.g., cockroaches, wood lice, small spiders) can be used as food for this generalist predator.

Prior to the publication of the proposed rule to designate critical habitat for the Kauai cave wolf spider (67 FR 14671, March 27, 2002), the spider had been observed in only five caves in the Koloa area since its discovery in 1971. Through mapping of one of the caves, the Service considers two of the caves originally believed to be separate to actually be one system with two entrances. Since 1996, Service biologists have conducted annual surveys of the caves, and starting in 1998, we have conducted biannual monitoring visits to three of the known occupied caves. Observations recorded in these visits include a total count of animals within each cave, potential threats to the listed cave organisms or their habitat, and the cave's condition (e.g., human disturbance, presence of standing water). The following information is based on these monitoring visits.

In two of the four known occupied caves, wolf spiders have been seen on only three occasions, but have been more often observed in two other caves. Of the two more frequently occupied caves, in only one of these wolf spiders have been encountered during every monitoring visit with 14 to 28 individuals observed (USFWS data from January 18, 1996 to November 20, 2002). The second cave contained a smaller number of wolf spiders when they were found there (one to four per monitoring visit). Since April 2000, no wolf spiders have been observed in this cave. The decline of wolf spiders in this cave has been matched with a corresponding increase in the number of resident brown violin spiders, an alien, web-building species that likely preys upon both the Kauai cave wolf spider and amphipod (A. Asquith, *in litt.* 1994b; David Hopper, Service, *in litt.* 1999). Although these data are not conclusive, the declining numbers of the Kauai cave wolf spider and their increased absence in the second of the regularly occupied caves warrants concern with regard to population persistence.

Since the publication of the proposed rule, more surveys have been conducted and the spider has been verified to occur in two additional caves (Tom Shigemoto, Vice President, Alexander and Baldwin, pers. comm., 2002; Gordon Smith, Service, *in litt.* 2002), one of which was previously unknown