

pers. comm. 1998), where there are many recorded associations of eggs, larvae, and adult moths with this plant species. This tree species is primarily threatened by habitat conversion associated with development; competition from nonnative species such as *Schinus terebinthifolius* (Christmas berry), *Pennisetum setaceum* (fountain grass), *Lantana camera* (lantana), and *Leucaena leucocephala* (Kona hao le); browsing by cattle; fire; random environmental events such as prolonged drought; and reduced reproductive potential resulting from the small number of existing individuals (59 FR 10325).

Although *Nothocestrum* spp. are not currently reported from Kahoolawe, there were very few surveys of this island prior to the intense ranching activities, which began in the middle of the last century, and the subsequent use of the island as a weapons range for 50 years. Prior to their removal, goats also played a major role in the destruction of vegetation on Kahoolawe (Cheetah and Stone 1990). It is likely that the reappearance of some vegetation as a result of the removal of the goats and the cessation of military bombing activities have allowed the moth to inhabit the island. On Kahoolawe, moth larvae feed on the nonnative *Nicotiana glauca*, which appears to adequately support production and growth of the larval stage during nondrought years. However, the native *Nothocestrum* are more stable and drought-resistant than the *Nicotiana glauca*, which dies back significantly during especially dry years (A. Medeiros, pers. comm. 2001). Therefore, it appears likely that long-term survival of the moth on Kahoolawe will require the planting of *Nothocestrum latifolium* (A. Medeiros, pers. comm. 1998).

### Threats to the Conservation of Blackburn's Sphinx Moth

#### Habitat Loss and Degradation

Dry to mesic forest habitats in Hawaii have been severely degraded by past and present land management practices, including ranching, the impacts of introduced plants and animals, wildfire, and agricultural development (Cheetah and Stone 1990). Because of these factors, *Nothocestrum peltatum* on Kauai and *N. brevifolium* on Hawaii are now federally listed as endangered species (59 FR 9327; 59 FR 10325). Although all *Nothocestrum* spp. are not presently listed as endangered or threatened, the entire genus is declining and considered uncommon (Medeiros *et al.* 1993; HHP 2000). For example, while *N. latifolium* presently occurs at

moderate densities at Ka naio NEAR (HHP 1993), there has been a complete lack of seedling survival and the stand is being degraded by goats (F. Howarth, pers. comm. 1994; Steven Montgomery, pers. comm. 1994; Medeiros *et al.* 1993). Goats have played a major role in the destruction of dryland and mesic forests throughout the Hawaiian Islands (Van Riper and Van Riper 1982; Stone 1985).

Because the moth was once so widespread and sphinx moths are known to be strong fliers, we believe it is likely that inter-island dispersal of the species occurred to some degree prior to the loss of much of its historical habitat. Currently, the areas of dry to mesic shrub and forest habitats below 1,525 m (5,000 ft) elevation that are suitable for Blackburn's sphinx moth are approximately 148,585 ha (367,161 ac).

#### Localized Extirpation

In addition to, or perhaps because of, habitat loss and fragmentation, Blackburn's sphinx moths are also susceptible to seasonal variations and weather fluctuations affecting their quality and quantity of available habitat and food. For example, during times of drought, nectar availability for adult moths are expected to decrease. During times of decreased nectar availability, life spans of individuals may not be affected, but studies with butterflies have shown marked decreases in reproductive capacity for many species (Center for Conservation Biology 1994). In another study, Jansen (1984) reported that host plant availability directly affected sphingid reproductive activity. In fact, for some lepidopteran (butterflies and moths) species, if nectar intake is cut in half, reproduction is also cut approximately in half. Such resource stress may occur on any time scale, ranging from a few days to an entire season, and a pattern of continuous long-term adult feeding stress could affect the future viability of a population (Center for Conservation Biology 1994).

Often, habitat suitability for herbivorous insects is determined by factors other than host plant occurrence or density. Microclimatic conditions (Thomas 1991; Solbreck 1995) and predator pressure (Roland 1993; Roland and Taylor 1995; Walde 1995) are two such widely reported factors. In a study of moth population structure, habitat patch size and the level of sun exposure were shown to affect species occupancy, while patch size and the distance from the ocean coast were reported to affect moth density. Moth populations in small habitat patches were more likely to become extinct (Forare and Solbreck 1997).

#### Nonnative Arthropods

The geographic isolation of the Hawaiian Islands restricted the number of original successful colonizing arthropods and resulted in the development of an unusual fauna. Only 15 percent of the known insect families are represented by the native insects of Hawaii (Howarth 1990). Some groups that often dominate continental arthropod faunas, such as social Hymenoptera (group-nesting ants, bees, and wasps), are entirely absent from the native Hawaiian fauna. Accidental introductions from commercial shipping and air cargo to Hawaii have now resulted in the establishment of over 2,500 species of alien arthropods (Howarth 1990; Howarth *et al.* 1994), with a continuing establishment rate of 10 to 20 new arthropod species per year (Nishida 1997). In addition to the accidental establishment of nonnative species, private individuals and government agencies began importing and releasing nonnative predators and parasites for biological control of pests as early as 1865. This resulted in the introduction of 243 nonnative species between 1890 and 1985, in some cases with the specific intent of reducing populations of native Hawaiian insects (Funasaki *et al.* 1988; Lai 1988). Alien arthropods, whether purposefully or accidentally introduced, pose a serious threat to Hawaii's native insects, through direct predation, parasitism, and competition for food or space (Howarth and Medeiros 1989; Howarth and Ramsay 1991).

#### Ants

Ants are not a natural component of Hawaii's arthropod fauna, and native species evolved in the absence of predation pressure from ants. Ants can be particularly destructive predators because of their high densities, recruitment behavior, aggressiveness, and broad range of diet (Reimer 1993). Because they are often generalist feeders, ants may affect prey populations independent of prey density, and may locate and destroy isolated individuals and populations (Nafus 1993a). At least 36 species of ants have become established in the Hawaiian Islands, and three particularly aggressive species have severely affected the native insect fauna (Zimmerman 1948).

For example, in areas where the big-headed ant (*Pheidole megacephala*) is present, native insects, including most moths, have been eliminated (Perkins 1913; Gagné 1979; Gillespie and Reimer 1993). The big-headed ant generally does not occur at elevations higher than