METHODS

Study area

The west slope of Haleakala, from the park entrance at 2050 m to the summit at 3055 m, includes strong gradients in both elevation and rainfall. Mean annual rainfall ranges from less than 1000 mm near the summit to approximately 1750 mm in the vicinity of Hosmer Grove campground near the park entrance (Giambelluca et al. 1986). Mean annual air temperature at park headquarters, at 2120 m elevation, is 12.4º C, and drops to 8.7º C at the summit (Halenet 2003). These gradients combine to form a variety of microhabitats and transition zones.

Elevations from 2050 m to approximately 2300 m often sit within the clouds of the inversion layer, and consequently enjoy higher precipitation in the form of rainfall and fog. These areas support subalpine shrubland of varying density; more windward shrublands near Hosmer Grove and Waikamoi Preserve have denser shrub cover, with nearly complete vegetative groundcover; as one progresses leeward toward the southern flank of the mountain, precipitation decreases, the shrubland becomes less dense and vegetative groundcover thins dramatically. The dominant shrub species in this elevational zone are *Styphelia tameiameiae* (Cham. & Schlechtend.), *Sophora chrysophylla* (Salisb.), *Vaccinium reticulatum* (Sm.), *Dubautia menziesii* (A. Gray), *Dodonea viscosa* Jacq. and *Coprosma montana* Hillebr. Additional overstory plants include *Santalum haleakalae* Hillebr. and the occasional *Metrosiderus polymorpha* Gaud. Common groundcover plants include the introduced grasses *Holcus lanatus* L. and *Anthoxanthum odoratum* L., native grasses *Deschampsia nubigena* Hillebr. and *Agrostis sandwicensis* Hillebr., native sedges *Carex wahuensis* C.A. Mey and *Carex macloviana* Dum. d'Urv., the indigenous bracken fern *Pteridium aquilinum* (L.) Kuhn, plus numerous additional native and introduced herbs.

Above the inversion layer, from roughly 2300 m elevation to the summit, clearer and drier air tends to predominate. As a result of the decreasing moisture and temperature, the shrubland thins and transitions to alpine habitat. Shrubs become stunted and increasingly sparse, and groundcover thins from regular clumps of bunchgrass and herbs to mostly bare expanses of cinder and rock with the occasional grass, sedge, rush, fern or other small herb. Dominant shrub species in these areas are *S. tameiameiae*, *D. menziesii*, *V. reticulatum*, and less commonly as elevation increases, *S. chrysophylla*. Groundcover plants include *D. nubigena*, the endemic rush *Luzula hawaiiensis* Buchenau, the endemic aster *Tetramalopium humile* (A. Gray) Hillebr., and other native and introduced ferns and herbs.

Sampling

We conducted standardized arthropod sampling in two elevational zones on the west slope and crater rim of Haleakala volcano, within Haleakala National Park. These zones roughly spanned elevations of 2250 to 2450 m and 2675 to 2875 m (Fig. 1). The lower elevation zone was situated entirely within subalpine shrubland, but included a range of wetter and drier areas that varied in their degree of vegetative cover, while the upper zone was situated on or near the crater rim in an area of transition from open shrubland with some grass cover to largely bare cinder and rock terrain with sparse shrubs and herbs. These two areas are referred to as the lower and upper zones in this report.

Most sampling occurred within 5 m by 5 m plots (Fig. 1). Twenty four plots were initially established in each elevational zone, in an approximately random fashion. Sixteen of these plots in each zone were situated within Argentine ant (*Linepithema humile* [Mayr]) infested habitat, whereas eight plots were in nearby habitat uninvaded by Argentine ants. To maintain an equal number of plots outside of Argentine ant infested habitat in each year, some of these plots had to be moved between years as the ant population boundaries advanced, and Figure 1 therefore shows more than 24 total plot locations in each zone. In each plot, we conducted pitfall sampling, litter extraction and shrub beating. We installed three pitfall traps in each plot (300 ml [10 oz], 80 mm diameter cups; 50:50 propylene glycol:water solution as preservative), spaced at least 2 m apart, and left open for two weeks. One pitfall in each plot was baited around the rim with blended fish (monamon) while the other two were unbaited. We also collected leaf litter from three areas in each plot, mixed it together and removed one liter; this was placed in a Berlese funnel for 24 hours (we previously determined that 99% of the leaf litter catch exited the litter within the first 24 hours). Finally, shrub vegetation within each plot was beaten between 1000 and 1600 h. Each focal shrub species received five beats (spread among multiple individuals of each species within each plot, if possible) onto a 1 m^2 nylon beating sheet, from which we aspirated all arthropods. Focal shrub species were *S. chrysophylla, D. menziesii, V. reticulatum* and *S. tameiameiae* in the lower zone, and *S. tameiameiae* and *D. menziesii* in the upper zone.

Sampling periods for these 5 m by 5 m plots were as follows: 17 September-1 October 2002 for lower zone plots, 18 September-2 October 2002 for upper zone plots; 6-20 July 2003 for lower zone plots, 14-28 June 2003 for upper zone plots; 10-24 July 2004 for lower zone plots, 13-27 June 2004 for upper zone plots.

Samples from a total of 48 plots were collected during 2002, 48 plots during 2003, and 24 plots during 2004. These samples were sorted to varying degrees in different years. Samples in 2003 were completely sorted and all arthropods were identified (according to limitations described below); however the number of plots for which samples were sorted varied among sampling techniques – all 48 plots for vegetation beating samples, 40 plots for pitfall trap samples and 24 plots for litter extraction samples. Samples in 2002 and 2004 were sorted with an emphasis on finding new or rare species, and the remaining arthropods were not counted.

In addition, we made 29 opportunistic hand collections from 2001 to 2004, spanning the area from the park service area to the summit (Fig. 1). These collections targeted apparently new or interesting species.

Identification

Arthropods in most taxonomic groups were identified to the level of species. We did not identify several groups beyond the level of family or order, however, either because the groups were difficult and had previously been treated by a specialist (parasitic Hymenoptera and Pseudococcidae; addressed in Beardsley [1980]), or because individuals were too numerous and taxonomically intractable (Acari). These unidentified arthropods were preserved and catalogued for future researchers.

All generic and species determinations were either made by a specialist, or by P. Krushelnycky (PDK). For all determinations made by PDK, original species descriptions and keys were consulted, or comparisons were made with reference material at the Bernice P. Bishop Museum, the University of Hawaii Insect Museum, the Hawaii Department of Agriculture collection, or the Haleakala National Park insect collection. Whenever possible, both original literature and reference material were consulted. Voucher specimens are deposited in the Bernice P. Bishop Museum, the Haleakala National Park Insect Collection, the Essig Museum of Entomology, and the University of Hawaii Insect Museum. Species presence and distribution data from this inventory will be entered into NPSpecies, the National Park Service Biodiversity database.

Richness estimation

The observed number of species in inventories of highly diverse taxonomic groups, such as arthropods, is almost always a serious underestimation of true species richness (Colwell and Coddington 1994, Chazdon et al. 1998, Brose et al. 2003, Walther and Moore 2005). Diverse communities typically contain many rare species, and some of these will inevitably be missed. As a consequence, a variety of statistical techniques have been developed or adapted to produce less biased estimators of true species richness. These estimators include parametric, non-parametric and species accumulation curve-fitting techniques, all of which extrapolate richness estimates from species incidences or abundances in the inventory (Colwell and Coddington 1994).

Using the 2003 dataset only, for which samples were completely sorted and counted, we created species by sample abundance matrices for analysis. For estimation of total species richness as well as richness within subsets of species defined by native status, we pooled all samples collected in each plot, including all sampling techniques. Here we used only the 40 plots for which both vegetation beating and pitfall samples were sorted; 16 of these plots lacked litter extraction data, but this technique yielded the fewest species and the absence of these data is not likely to have overly distorted our results. For estimation of richness yielded by the different sampling techniques, we pooled all samples that used the same technique within each plot. Here we used all plots for which samples were sorted: 48 for vegetation beating, 40 for pitfall traps and 24 for litter extraction. For all analyses, we excluded taxa that were not identified to species or morphospecies (Acari, parasitic Hymenoptera and Pseudococcidae). We used the program EstimateS (Colwell 2005) to calculate species richness estimates. This program provides richness estimates using seven non-parametric methods as well as a curve-fitting method. To calculate the richness estimates and to produce smoothed taxon sampling curves, we set EstimateS to randomize sampling order 100 times and to sample without replacement.