

INTERACTION BETWEEN THE HAWAIIAN DARK-RUMPED PETREL AND THE ARGENTINE ANT IN HALEAKALĀ NATIONAL PARK, MAUI, HAWAII

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Abstract. The invasive immigrant Argentine ant (*Linepithema humile* Mayr) has spread to occupy roughly 120 ha, or 15%, of the nesting habitat of the endangered Hawaiian Dark-rumped Petrel (*Pterodroma phaeopygia sandwichensis*) in Haleakalā National Park on the island of Maui, Hawaii. The colony at Haleakalā is responsible for most of the known reproduction of the endemic seabird, and concern arose that the Argentine ant may reduce petrel breeding success at this important site. Investigations in ant-infested areas of the petrel colony, however, showed that the nesting success rate (53.7%) was not significantly different from the nesting success rate in adjacent ant-free areas (50.0%). While the ant occurred more frequently at the entrances of burrows with recent petrel activity, high numbers of ants or foraging trails within the petrel burrows were seen only rarely. Cold soil surface temperatures may inhibit ant foraging into the deeper parts of the burrows, where incubation and chick development occur. At current levels, the Argentine ant is not believed to significantly influence the nesting success rate of the Hawaiian Dark-rumped Petrel.

Key Words: Argentine ant; Hawaiian Dark-rumped Petrel; *Linepithema humile*; *Pterodroma phaeopygia sandwichensis*.

The Argentine ant (*Linepithema humile* Mayr) was first recorded in Haleakalā National Park in 1967 (Huddleston and Fluker 1968) and has since proved to be highly invasive and destructive to native biota (Fellers and Fellers 1982, Cole et al. 1992). As an aggressive predator and scavenger, *L. humile* reduces populations of native arthropods in high-elevation subalpine shrublands (Cole et al. 1992). The entire endemic biota of the Hawaiian Islands is believed to have evolved in the absence of ant predation; endemic arthropod species, for example, are highly vulnerable to the effects of immigrant ants (Gillespie and Reimer 1993). Recently, concerns were raised that this immigrant ant may also reduce the breeding success of a native seabird, the endangered Hawaiian Dark-rumped Petrel (*Pterodroma phaeopygia sandwichensis*).

The disturbance of nesting behavior and direct depredation of hatchlings by ants has been documented in a number of species of birds, including seabirds. While most of these cases involve the red imported fire ant (*Solenopsis invicta* Buren; Ridlehuber 1982, Sikes and Arnold 1986, Drees 1994, Dickinson 1995, Lockley 1995), several other species of ants have also been implicated, including *Monomorium pharaonis* (Linnaeus) (Parker 1977), *S. xyloni* (McCook) (Hooper 1995), and *S. geminata* (Fabricius) (Stoddard 1931, Kroll et al. 1973). The Argentine ant could have a similar effect. Its polygynous unicolonies form high densities of cooperating nests that dominate habitat and have the ability to recruit large numbers of workers to attractive food sources. In fact, *L. humile* has

been observed to recruit quickly and heavily to the pipped eggs of the endangered ground-nesting Hawaiian Goose (Nēnē; *Branta sandvicensis*) on the island of Hawaii, requiring human intervention to prevent depredation on the emerging goslings (F. Duvall, pers. comm.).

The Hawaiian subspecies of the Dark-rumped Petrel has been listed as endangered since 1967 (USFWS 1983b). Once apparently abundant throughout the islands at lower elevations, the Hawaiian Dark-rumped Petrel's numbers have declined precipitously with the advent of hunting by Polynesians, loss of breeding habitat, and depredation by introduced mammals (Banko 1980c, Olson and James 1982a, Simons 1985, Hodges 1994). Today, the high-elevation cliffs (2,400–3,055 m) near the summit of Haleakalā Volcano on Maui serve as one of the last, and largest, remaining parcels of breeding habitat for the imperiled bird. Although significant numbers of adult Hawaiian Dark-rumped Petrels have been sighted on other Hawaiian Islands, Haleakalā National Park protects approximately 95% of the estimated 450–650 known breeding pairs in the islands (Simons and Hodges 1998).

Currently, the greatest threat to the petrel's survival is introduced mammalian predators such as rats, mongoose, and feral cats and dogs (Hodges 1994). Because the petrel has a conservative reproductive strategy typical of Procellariiformes, with monogamous pairs producing a maximum of only one chick per year, depredation of adults and chicks is particularly damaging to the health of the colony (Simons 1984). Consequently, predator removal is an important

part of the park's management plan for the petrel.

Beginning in the late 1980s, park employees noticed Argentine ants over large areas of the petrel colony. In the early 1990s the ant distribution was mapped and discovered to occupy an entire section of cliff face from crater rim to crater floor. Today this area comprises approximately 120 ha, or 15% of the known petrel nesting habitat in the park (Hodges 1994). Despite the cold temperatures and extreme weather that can limit ant foraging at this elevation, the Argentine ant is expanding its range. Concerns were raised by biologists and managers that this ant could become another major threat to the survival of this endangered seabird. Possible effects included direct depredation of newly hatched or emerging chicks; disruption of courtship and mating behavior; incubation of eggs, and the brooding and feeding of chicks; and abandonment of nesting burrows in ant-infested areas. The purpose of this study was to determine if Hawaiian Dark-rumped Petrel nesting success was being affected by the Argentine ant.

METHODS

The Dark-rumped Petrel nesting season at Haleakalā begins in late February and ends in mid-November (Simons 1985). In July 1994, 110 potential petrel burrows were located within the area infested by the Argentine ant at 2,440 to 2,740 m. In December 1994, 71 of these burrows were determined to be active. Of the 71 active burrows, 55 were randomly selected for monitoring during the entire 1995 nesting season.

This study followed the protocol utilized by the Resources Management Division of Haleakalā National Park for long-term monitoring of the park's petrel colony (Hodges 1994). Because the petrels excavate winding burrows from 1 to 10 m deep in the volcanic cinder substrates (Simons 1985), opportunities for seeing the nest chamber are rare. Accordingly, monitoring is largely based on external signs of burrow activity. Records were taken on whether or not each burrow had been entered, as well as on the presence of various signs of petrel activity such as fresh droppings, feathers, and down; egg shell fragments; and petrel tracks at the burrow entrance. Data were collected during monthly surveys of all 55 study burrows from March to October and subsequently during biweekly surveys until the end of November, resulting in a total of 11 monitoring surveys.

A row of toothpicks placed across the burrow entrance at an interval of 3 cm served as a trip entry indicator (as in Simons 1983, Hodges 1994). Disruption of this row was used to determine whether a burrow had been entered. By using toothpick monitoring paired with other evidence of petrel activity such as droppings, tracks, feathers and egg shells, active burrows were easily recognized over the course of the season.

Burrows that remained active into late October and November and that had characteristic gray chick down

at the entrance were believed to have fledged a chick (Hodges 1994). Nesting success, defined here as the percentage of active burrows (active with breeders and nonbreeders) that fledged a chick, was compared among the ant-infested study area and the adjacent ant-free areas of the petrel colony monitored by National Park Service personnel during the 1995 season.

At all study burrows, ant presence or absence inside and outside the burrow entrance was recorded. This was defined as inside or outside the row of toothpicks spanning the entrance, which delineated the border between the perpetually shaded, relatively constant microhabitat of the burrow interior and the highly variable microhabitat outside the burrow (variable in vegetation, exposure to sun, other weather conditions, food sources). The presence of ten or more ants inside a burrow and the presence of foraging trails leading directly into a petrel burrow were also noted.

In 1997, soil surface temperatures were measured inside and outside 14 burrows during two days of warm weather in August, the warmest month of the year. Temperatures inside burrows were measured using a LI-COR soil heat probe resting on the shaded ground, recorded every 0.5 m from the burrow entrance until the nest chamber or a distance of 2.0 m was reached. Soil surface temperatures outside the burrow entrances were measured with an Everest Interscience infrared surface thermometer. These temperatures were recorded in exposed direct sunlight, exposed overcast sunlight, and shaded soil directly outside the burrow entrances. All temperatures were measured during the time period of 12:00 to 17:00, the warmest part of the day for ground temperatures.

RESULTS

Fifty-four of the 55 study burrows (98.2%) were active during the 1995 nesting season. Of the 54 active burrows, 29 (53.7%) fledged a chick. In the adjacent ant-free areas monitored by the National Park Service in 1995, 36 of 72 active burrows (50.0%) fledged a chick. There was no significant difference between these nesting success rates in ant-infested and ant-free areas of the petrel colony ($\chi^2_1 = 0.055$, $P > 0.05$).

Each of the 54 active burrows was checked on 11 occasions for a total of 593 burrow checks. These burrows were entered by petrels 419 times and not entered 174 times. Of the checks in which active burrows had been entered, at least one Argentine ant was found inside the burrow on 230 occasions, or 55.9% of the time. Of the checks in which active burrows had not been entered, ants were found inside the burrow on 62 occasions, or 35.6% of the time. There was a significant difference between the rates of incidence of ants inside entered and not entered active burrows ($\chi^2_1 = 17.52$, $P < 0.01$). The single inactive study burrow had ants within its entrance in only 1 of the 11 monitoring checks in 1995.

Twenty-one of the 54 active burrows were found to have ten or more ants inside their en-

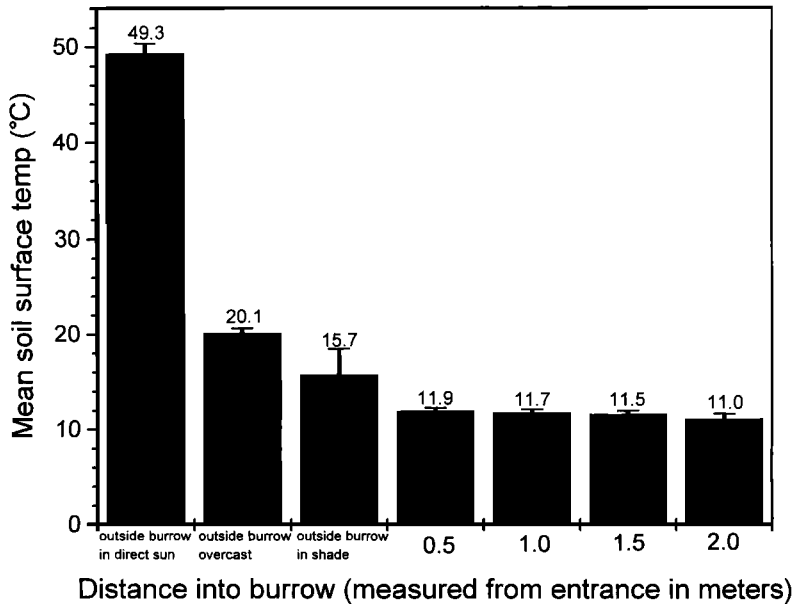


FIGURE 1. Mean soil surface temperatures inside and outside Dark-rumped Petrel burrows during August in Haleakalā National Park, Maui, Hawai'i. Bars indicate one SE ($N = 14$).

trances on at least one occasion. Fifteen of these burrows (71.4%) fledged a chick. Five of the 21 burrows were found to have a visible foraging trail of ants leading directly into the burrow on at least one occasion, and four of these (80.0%) fledged a chick. The fifth burrow contained large pieces of egg shell approximately 1 m inside the entrance, which appeared to be the destination of the foraging trail.

Means of the soil surface temperatures measured inside and outside 14 burrows in August 1997 are shown in Figure 1. Temperatures drop sharply from the exposed sun-heated cinders just outside burrow entrances to the shaded soil as near as 0.5 m inside burrow entrances. Soil surface temperatures steadily decrease with increasing distance into the burrow.

DISCUSSION

Observations determining whether the Argentine ant directly encounters petrels or petrel chicks in the nest chamber were not obtainable in this study. All data collected, however, indicate that such interactions are unlikely. There was no significant difference between the nesting success rates in ant-infested and ant-free areas of the petrel colony. In addition, 98.2% of the study burrows active in the 1994 season were active again in 1995. Because adult Hawaiian Dark-rumped Petrels use the same burrow year after year (Simons 1985), this high return rate may indicate that the ant's presence is

not discouraging the adult petrels from returning to their burrows.

While the ant presence data show that the ant seems to be attracted to active petrel burrows, with ants occurring significantly more frequently inside the entrances of recently active burrows, this is likely related to the attraction of the Argentine ant to the guano, feathers, fish oil, broken eggs, and invertebrates characteristic of active petrel burrows. Because these data only indicate the presence of a single ant inside the burrow entrance, they do not provide evidence for the mass recruitment that would be necessary for serious disturbance of petrel nesting activity. Furthermore, increased ant presence did not appear to detract from breeding success. Among the 21 burrows that were found to have ten or more ants inside their entrances on at least one occasion, 71.4% fledged a chick. While this nesting success rate represents a small sample size and should therefore be viewed with caution, it is nevertheless considerably higher than that of the study area as a whole. Similarly, of the five burrows found to have a visible trail of foraging ants leading directly into them on at least one occasion, four fledged a chick.

In all instances where ant trails were found, it was impossible to determine the distance to which the ants were foraging inside the burrows. Even with flashlights, it was difficult to see much past 1 m into the burrow. Burrow temperature data, however, suggest that the Argentine

ant does not forage far into petrel burrows. As can be seen in Figure 1, there is a large difference in soil surface temperature between the exposed sun-heated cinders outside burrow entrances and the shaded soils inside burrow entrances. Additionally, soil surface temperatures steadily decrease with increasing distance into the burrow. These burrow temperatures fluctuate relatively little throughout the day (Simons 1985), as the burrows are always shaded and air currents into and out of the burrows are probably minimal.

The mean temperatures of approximately 11 to 12° C (Fig. 1) thus encountered by a foraging ant inside a petrel burrow are near the minimum temperature required for Argentine ant foraging and above ground activity (Newell 1908, Markin 1970; P. Krushelnycky, unpubl. data). These temperatures correspond fairly closely to the average temperature of 9.59° C measured at petrel burrow nest chambers during the month of October by Simons (1985). It should be pointed out that while fluctuations of soil surface temperatures over time within individual and averaged burrows are small, the range of soil surface temperatures encountered in different burrows is considerably larger. This is dependent on the shape and depth of each burrow. Deep, narrow burrows can have soil surface temperatures of 8 to 9° C, whereas wide, shallow burrows may have soil surface temperatures of up to 13.5° C.

So while temperature data indicate that some burrows may be more thermally accessible to

ants (and therefore more vulnerable) than others, both the nesting success data and the ant presence data suggest that these differences are not important. Perhaps this is because even the warmest burrows are still cold enough to discourage extensive foraging by ants. Indeed, we suspect that cold burrow temperatures are the major reason why high numbers of ants occurred inside burrow entrances so infrequently: foraging trails were seen inside burrows only eight times throughout the study period.

The foraging trails observed on these several occasions were most likely destined for food sources relatively close to the burrow entrances. While ants were seen opportunistically feeding on the carcass of one petrel chick found at its burrow entrance, we presently have no evidence that the Argentine ant is responsible for petrel chick mortality or disruption of breeding behavior. It would nevertheless be wise to periodically monitor the ant-infested section of the colony to ensure that nesting success remains at a level comparable to that of adjacent ant-free areas. Continued research into the ecological interactions of the Hawaiian Dark-rumped Petrel should remain an important aspect of the conservation of this endangered species.

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