# The Effects of Invasive Ants on the Nesting Success of Tristram's Storm-petrel, *Oceanodroma tristrami*, on Laysan Island, Hawaiian Islands National Wildlife Refuge

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The possible impact of invasive ants on the avifauna of the Northwest Hawaiian Islands was investigated by studying the breeding success of Tristram's Storm-petrel *Oceanodroma tristrami* on Laysan Island. The tramp ant *Monomorium pharaonis* (L.) was found to be abundant in storm-petrel nesting areas on Laysan Island. There were 380 observations made on incubating adults and 798 observations for chicks, for a total of 1178 observations from 116 storm-petrel nest sites. No ant harassment events involving incubating adult storm-petrels were recorded. Thirteen instances of more than 5 ants on Tristram's Storm-petrel chicks were recorded. One harassment event was recorded, involving approximately 200 ants. The chick left the nest site immediately following the event, did not return, and presumably died. The number of nest failures attributed to *M. pharaonis* was 1% ($n$ = 116). There was a significant relationship between nest type and ant interactions ($G$ = 24.45, $p$ = <0.0001, $n$ =55), with incidents only recorded from birds nesting under vegetation. It was hypothesized that the ant interactions recorded in this study were a result of Tristram's Storm-petrel chicks being in close proximity to *M. pharaonis* nests rather than direct predation. Thus no evidence was found of a severe impact of invasive ants on the breeding success of storm-petrels at Laysan Island. Despite no direct ant impact particular attention should be given to the interactions between *M. pharaonis* and bird species reliant on vegetation for nesting cover, and studies therefore should include additional breeding bird species.

Key words: Invasive ants, Laysan Island, *Monomorium pharaonis*, *Oceanodroma tristrami*, Tristram's Storm-petrel

## INTRODUCTION

ANTS are highly successful and disruptive invaders of ecosystems (Moller 1996; Williams 1994). Their effects can be wide-ranging and extend throughout ecosystems, and may include negative population-level effects on larger vertebrates including birds. The ability of invasive ants to negatively affect birds has been documented in a wide range of species (e.g., Drees 1994; Allen et al. 2000; Suarez et al. 2005). How invasive ants impact birds is often unclear and understudied, but predation of chicks, reduced suitability of nest sites, and resource competition and displacement are confirmed or suspected (reviewed in Holway et al. 2002). Though potentially biased by the predominance of studies focusing on *Solenopsis invicta* (Buren), ground-nesting birds with chicks confined to the nest appear to be more vulnerable and suffer higher rates of mortality than other species. In this regard, Tristram's Storm-petrel *Oceanodroma tristrami* appears to be exceptionally susceptible to the negative effects of invasive ants. A species of conservation concern (U.S. Fish and Wildlife Service 2002), Tristram's Storm-petrel has a relatively long breeding season (average incubation length of 44 days and an average fledge length of 83 days; McClelland et al. in prep). In addition, the species is also one of the smallest birds breeding in the Northwest Hawaiian Islands (92 g) and has a low tolerance to disturbance (Marks and Leasure 1992).

In summary, the objectives of this study were: 1) to quantify the effects of invasive ants on the nesting success of Tristram's Storm-petrel; 2) to assess the effectiveness of three toxic ant baits for the control of alien ant populations on Laysan Island.

## STUDY AREA

Observations were conducted at Laysan Island (25°46 N, 171°03' W) in the Hawaiian Islands National Wildlife Refuge. Located 1495 km northwest of Honolulu, Laysan is an extremely remote 397 ha coral sand island with a 70 ha hypersaline lake in the centre. Once left completely denuded of vegetation by introduced rabbits (*Oryctolagus cuniculus*; Ely and Clapp 1973), Laysan is in the midst of an island restoration project undertaken by the U.S. Fish and Wildlife Service. In 2004, approximately 217 ha, or 66% of available area, was vegetated (McClelland unpublished). The re-vegetated area, however, differs from the original plant community. The dominant vegetative community

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is bunchgrass (*Eragrostis variabilis*), but includes dense mixed-vegetation communities (*Scaevola taccada*, *Ipomea pes-capae*, *Sicyos pachycarpus*) bordering much of the lake. Laysan has the highest number of invasive ant species historically documented in the Hawaiian Islands National Wildlife Refuge (Nishida 2001). Introductions likely began synonymously with human visitation starting circa 1828 (Ely and Clapp 1973) and four species had been recorded by the first arthropod survey in1896 (Emery 1899). The eleventh and last ant species to be recorded on Laysan was *Tetramorium similimum* (Mayr), first recorded in 1990 (Conant and Rowland unpublished data).

## METHODS

The study was conducted from November 2003 to May 2004 at the southern end of the lake in the largest of the Tristram's Storm-petrel subcolonies. The study area was dominated by native bunchgrass with sparse low-lying plants such as *S. pachycarpus* and *Tribulus cistoides*. Two pairs of 30 x 30 m plots were established with plots separated by 50m and pairs separated by 100m.

A plot in each pair was randomly selected as treatment (ant removal), with the other acting as a control. The original study design was a comparative analysis between treatment and control plots. When ant eradication efforts failed, the experiment continued as an observational study of interactions between Tristram's Storm-petrel and invasive ants.

Laysan had not been extensively surveyed for ants since 1990 (Conant and Rowland unpublished report), leaving the ant community that would be encountered relatively unknown. Due to Laysan's extreme isolation, a resupply vessel could not return to the island until 6 months after the initiation of this study. Therefore, three toxic baits that together had been documented to be effective against all species historically documented on the island were preselected for the experiment. These were Amdro Fire Ant Bait (0.7% hydramethylnon in a corn grit matrix with soybean oil [American Cyanimid]), Maxforce Fine Granule Ant Bait (0.9% hydramethylnon in macerated silkworm pupae (*Bombyx mori*) and fish meal matrix [The

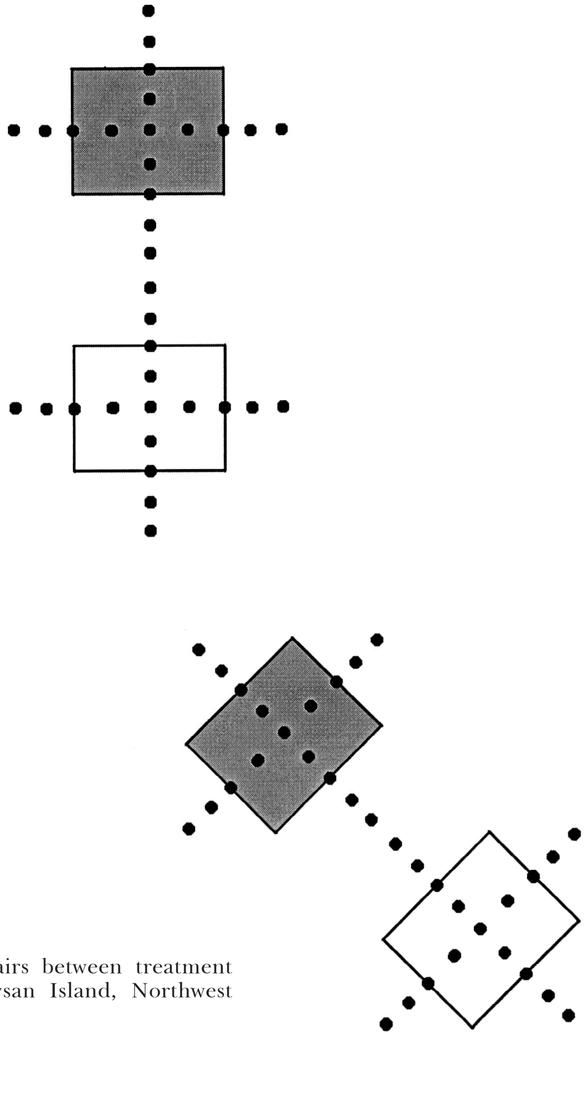

*Fig. 1.* Arrangement of pitfall trap pairs between treatment (grey) and control plots on Laysan Island, Northwest Hawaiian Islands.

Clorox Company]), and Advance **375A Select Granular** Ant Bait (0.011 % abamectin $B_1$ in a corn grit matrix with soybean oil, meat meal, and sugar [Whitmire Micro-Gen Laboratories]). Laysan is one of only two breeding sites of the endangered Laysan Finch *Telespiza cantans*, an extremely curious species with omnivorous habits (Morin and Conant 2002). Because Laysan Finch attraction to the poison baits was anticipated if baits were left exposed on the surface, broadcasting was not considered an option. Instead, all baits were placed in tamper-proof bait stations, enclosed in a wire cage with a wooden top to provide another barrier against finches and help protect the bait stations from the elements. Each station was provided with 5 ml of Amdro Fire Ant Bait, and 2.5 ml each of Advance and Maxforce, presented in separate compartments to track bait preference. The amount of bait consumed was estimated as either <10%, 25%, 50%, 75%, or >90% consumed by inspecting the amount of bait remaining in each compartment. Traps were spaced every 6 m for a total of 36 in each treatment plot.

The substrate on Laysan is sandy, and pitfall traps had to be relatively large to avoid being completely filled with blowing sand. Each pitfall trap consisted of a 7.6 cm diameter ABS tubing containing a 266 ml plastic cup. Each trap was enclosed in a wire cage constructed of 1.3 cm mesh to prevent disturbance by Laysan Finches. A total of 34 trap pairs were arranged in a cross pattern through each set of plots (Figure 1) and spaced every 12m, with replicates 1 metre apart. Trapping was initiated November 20 and continued every four weeks until April 14, with traps active for 48 hours.

Storm-petrels can be negatively affected by grubbing, a traditional method of burrow monitoring where an arm is inserted into the burrow to check for an incubating adult, egg, or chick (Wilbur 1969**;** Boersma et al. 1980; Blackmer et al. 2004). Tristram's Storm-petrel may be especially susceptible to disturbance from grubbing as the only previous study on this species recorded high levels of abandonment using this method (Marks and Leasure 1992). In order to keep disturbance to a minimum, all breeding sites were located and monitored in the daytime with the use of a 2.5 cm diameter infrared video probe (Peep-a-roo, Sandpiper Technologies, Inc.) briefly placed in the entrance of each burrow. In addition, at no time were adults handled or touched. Presence of an egg was inferred by the presence of an adult in incubating posture over a central nest cup at a breeding site for three consecutive nest checks over a 12-day period. Breeding sites were monitored at 4-day intervals. Adults and chicks were observed for at least 10 seconds for signs of ant harassment. If ants were observed on a chick, the chick's behaviour was documented before it was briefly removed from the nest site to better estimate the number of ants present and document possible signs of injury.

Cool burrow temperatures may protect burrowing seabirds from the negative effects of invasive ants (Krushelnycky et al. 2001). To investigate Tristram's Storm-petrel burrow temperature, Stowaway TidbiT Temp Loggers (Onset Computer Corporation) were placed in 3 burrows behind the nest bowl. Temperature was recorded every 60 seconds for the length of the study.

To test the frequency of ant foraging in burrows, a sample of occupied and unoccupied Bonin Petrel *Pterodroma hypoleuca* burrows was randomly selected (Tristram's Storm-petrel was considered too sensitive to disturbance). A closed plastic container measuring 9.0 × 4.0 × 1.5 cm containing 1 $cm^3$ of Spam and 1 ml each of peanut butter and honey was inserted. Access holes were punched in eight evenly spaced locations along the sides of the box. Boxes were placed in the burrow between 11:00 and 12:00 HST and retrieved after two hours. For each burrow the location, entrance dimensions, if a bird was present, and if so, whether it was an adult or chick were recorded. All burrows were located in bunchgrass habitat.

Differences in ant levels between treatment and control plots for each sampling period were analysed using a Generalized Linear Model with a Poisson error distribution and a loglink function in the statistical programme S-Plus version 7.0 (Insightful Corporation 2005), with $\Pr > X^2$ values calculated separately in Minitab

Table 1. Changes in pitfall trap captures between treatment and control plots before and following eradication efforts on Laysan Island, Northwest Hawaiian Islands.

| | AVG/Trap ± SD<br>Treatment | Control | Pr >ChiSq | t value | Deviation |
|---|---|---|---|---|---|
| Nov 25 | 297.9 ± 197.9 | 306.0 ± 195.0 | 0.020 | -2.32 | 0.85 |
| Dec 24 | 169.9 ± 198.5 | 175.0 ± 160.5 | 0.123 | -1.54 | 1.04 |
| Jan 21 | 232.9 ± 237.4 | 214.9 ± 200.0 | <0.001 | 5.04 | 0.90 |
| Treatment | | | | | |
| Feb 18 | 63.9 ± 61.8 | 47.5 ± 48.4 | <0.001 | 9.54 | 0.88 |
| Mar 24 | 203.4 ± 174.7 | 207.0 ± 196.0 | 0.323 | -0.99 | 1.06 |
| Apr 14 | 216.2 ± 224.5 | 174.3 ± 161.4 | <0.001 | 12.59 | 0.96 |

version 13 (Minitab Inc. 2000). Student's t distributions for 5% Type I error were also calculated in Minitab. Preliminary tests showed significant differences between treatment and control plots prior to treatment (Table 1), possibly due to unmeasured environmental differences e.g., bunchgrass density, food availability for ants, slope, etc. To increase confidence that treatments were the source of a change in ant population levels, the level of significance was set at above 1.5 or below 1/1.5 deviations from the intercept calculated using the link function $Y = e^u$ in Microsoft Excel 2000 (Microsoft Office, 2000). Binomial logistic regression models with a logit link function in Minitab 13 were used to analyse relationships between ant interactions and Tristram's Storm-petrel nest type, and ant visitation and Bonin Petrel burrow characteristics. Values reported in the *RESULTS* section are means ± SD.

## RESULTS

Ant species recorded in the study area in order of abundance were *M. pharaonis*, *Tertramorium bicarinatum*, *Cardiocondyla nuda* (Mayr), and *Hypopernera punctatissima* (Roger). Though it had a limited distribution and had yet to spread to the study area when last surveyed (Conant and Rowland unpublished report), *M. pharaonis* was the dominant ant in the plots, representing 99.9% of all individual ants collected.

Ant eradication from treatment areas was not successful, nor were the baits found to have any effect, as ant populations in the treatment plots did not differ from controls by the predetermined factor during any collection period (Table 1). In fact, the average number of ants in treatment plots was higher than controls in two of the three post treatment sampling periods.

Despite frequently being found in and establishing colonies under the bait traps, *M. pharaonis* rarely if ever consumed Amdro or Maxforce, and was only occasionally witnessed taking Advance, regardless if attractants were added. At no time were foraging trails observed leading to the bait traps. The amount of bait decreased insignificantly (<10%) in the majority of traps between checks and missing bait was attributed to Black Larder Beetles *Dermestes ater* that were often found dead inside the trap.

There were 380 observations of incubating adults and 798 observations of chicks made over the study, for a total of 1178 observations of 116 nest sites. No instances of ant harassment of incubating Tristram's Storm-petrel adults were recorded, though on one occasion ants were found harassing an adult that had become entrapped in sand. On November 3rd, a prospecting Tristram's Storm-petrel was caught in a burrow collapse and buried to its neck, with only its head above the sand. The bird was found shortly after midnight with approximately 75 *M. pharaonis* on its head, concentrated predominately around its eyes. The bird was extracted and after its eyes were flushed with water, appeared uninjured.

Thirteen instances of more than five ants being present on Tristram's Storm-petrel chicks were recorded, constituting six of the 57 nest sites with chicks. The median number of ants on chicks was 12 but ranged as high as 200 (approximated). On the chicks with the four highest counts, ants were concentrated around the chick's abdomen and cloaca, with numerous dead ants caught in the chicks down. The chick where 200 ants were observed was the only chick which appeared harassed. On that occasion the chick demonstrated foot-stomping behaviour. When checked approximately 2 hours later, the chick was found missing from the nest site. As it was not observed again it was presumed to have died.

The number of nest failures attributed to invasive ants was 1% of all nests ($n = 116$), or 3% of all chick nests ($n = 57$). There was a significant relationship between nest type and ant interactions ($G = 24.45$, $p = <0.0001$, $n = 56$), with birds nesting under vegetation in surface scrapes constituting all recorded incidents.

Average burrow temperature was 24.1° C ± 1.3 in earthen burrows with little fluctuation over a 24-hour period (AVG = 0.5° C ± 0.4, $n = 3$). The lowest recorded burrow temperature over the course of the study was 21.7° C.

Among the burrows in which bait containers were placed, 85.9% were found to contain foraging ants ($n = 64$), namely *M. pharaonis* (95.3 %), and *T. bicarinatum* (4.7 %). Median number of collected ants per occupied burrow was 28.5 and ranged as high as 180. No significant relationship between invasive ant visitation and burrow dimension was found, nor was there a significant relationship between ant visitation and occupation by a bird.

## DISCUSSION

Conclusions from this study are limited because of the failure to eradicate invasive ants from the study plots and the restriction to a single field season. However, this study did document that interactions between invasive ants and Tristram's Storm-petrel on Laysan are capable of negatively affecting Tristram's Storm-petrel breeding success. Though previously identified as a possible cause of mortality to Mississippi Kites *Ictinia mississippiensis* (Parker 1977), the single incident here of a chick death following its harassment by 200 ants was the first confirmation of *M. pharaonis* contributing to the mortality of nestling birds. However, *M. pharaonis* did not appear attracted to seabirds as potential prey items. The disturbance caused was primarily through aggravation as opposed to direct predation, similar to interactions between *A. gracilipes* and Sooty Terns *Sterna fuscata* in the Seychelles (Gerlach 2004). Though Tristram's Storm-petrel burrow temperatures were well within the tolerable range of *M. pharaonis* (Peacock et al. 1955), and ants regularly foraged in burrows, ant interactions with Tristram's Storm-petrel adults or chicks in burrows were not recorded. Nor were any chicks lost at the pipping stage when chicks are most often attacked by invasive ants (Hooper-Bui et al. 2004). Moreover, there was a significant relationship between breeding site type and presence of ants on chicks, with all observed interactions occurring at surface sites under dense vegetation. Because of the sandy soil of Laysan, *M. pharaonis* was heavily reliant on the bunchgrass plants that surface-nesting Tristram's Storm-petrels used for cover, and most plants housed an ant nest in study plots. It is likely that the ant interactions recorded in this study are a result of Tristram's Storm-petrel chicks being in close proximity of *M. pharaonis* nests rather than direct predation.

Though uncommon overall, the interactions recorded between Tristram's Storm-petrel and *M. pharaonis* raise concern. This study recorded substantially higher population levels of *M. pharaonis* in the month of November compared with other months (Table 1). If *M. pharaonis* typically maintain those higher population levels in other years, there is strong potential for the level of ant disturbance on Tristram's Storm-petrel to be detrimental. The breeding success of Tristram's Storm-petrel on Laysan was relatively low and borders the level of sustainability (McClelland et al. in prep). Though by themselves these ant interactions cause few nest failures, when combined with an already low reproductive rate they may be enough to draw the colony below the level of sustainability. Only a longer-term study would establish whether ant populations during 2003-2004 were typical, lower than average, or higher than average.

Another concern is the effect of *M. pharaonis* on other breeding bird species. If chicks in close proximity to *M. pharaonis* nests are subject to harassment events, *M. pharaonis* may decrease the breeding success of several bird species that make use of vegetative cover for nesting. These include seabirds such as the Red-tailed Tropicbird *Phaethon rubricauda* (Schultz 2000), Christmas Shearwater *Puffinus nativitatis* (Seto 2001), Brown Noddy *Anous stolidus* (Chardine and Morris 1996), Sooty Tern (Feare et al. 1997) and the two endemic and endangered land birds, the Laysan Finch (Morin 1992) and Laysan Duck *Anas laysanensis (*Moulton and Weller 1984). Laysan Finches in particular would be susceptible, as they are up to six times smaller than Tristram's Storm-petrel chicks at hatch (Morin and Conant 2002).

*Monomorium pharaonis* was listed as a target species of Advance by the manufacturer, and Maxforce had been proven effective in controlling this species in urban conditions (Oi et al 1996). However, neither was successful in controlling *M. pharaonis* on Laysan. Numerous factors could have affected bait preference, the greatest of which may have been the composition of the bait. Advance and Amdro are both oil-based baits and research has shown that carbohydrate and proteins are the best attractants of *M. pharaonis* (Chong et al. 2002). In addition, the baits suffered from poor longevity in Laysan's humid climate and likely contributed to the lack of appeal. Maxforce began caking and showing signs of mould in less than a week, as it has in other environments in Hawaii (Krushelnycky and Reimer 1998). Bait particle size may also have been a factor as *M. pharaonis* has been demonstrated to prefer bait sizes between 420 and 590 ìm, while Maxforce and Amdro have particles of 1000 to 2000 ìm (Hooper-Bui et al. 2002).

Another possible reason for the lack of bait acceptance on Laysan was an overabundance of alternative food items. Carrion is extremely common on Laysan year round due to the high populations and diversity of seabirds found on the island (see Fefer et al.1983). The amount of carrion likely reaches peak levels in winter due to large numbers of dead albatross chicks. These seabird carcasses are also abundant sources of sarcophagus insects and their larvae. Such copious resources could play a large role in bait acceptance.

This study confirmed that *M. pharaonis* is capable of contributing to nestling mortality of ground nesting birds on Laysan Island. Additional research is required into the effects of weather and seasonality on the population levels and dietary preferences of *M. pharaonis* and how this in turn affects the breeding success of Laysan's bird populations. Studies in the summer months when the Laysan Finch and Laysan Duck breed would be especially useful, as previous studies have shown seasonality has a large impact on the level of ant-induced chick mortality (Allen et al. 1994). In addition, broadening the study to other habitat types and ant species is needed. For instance, in bait card surveys of the island, the non-native Beach Heliotrope *Tournafortia argentea* was found to house exceptionally high populations of *M. pharaonis* compared to bunchgrass areas (McClelland and Jones unpublished). This was likely due to the greater soil stability, vegetative cover, and foraging opportunities. As well, the invasive ant community differs in the areas of dense vegetation around the lake area, with *T. bicarinatum* and *Monomorium floricola* becoming more common.

Though numerous studies into the control of *M. pharaonis* have been conducted, unfortunately most have occurred in laboratory or temperate urban environments (e.g., Buczkowski et al. 2005; Eow et al. 2005; Lim and Lee 2005, etc.). The current study on Laysan demonstrated the difficulty of controlling *M. pharaonis* in a natural setting and the need for further research under conditions where numerous environmental factors may affect bait acceptance.

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