TRIALS to ERADICATE INFESTATIONS of the ARGENTINE ANT, *LINEPITHEMA HUMILE* (HYMENOPTERA: FORMICIDAE), in NEW ZEALAND

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Abstract The Argentine ant (*Linepithema humile*) is a highly invasive species, a major urban pest, and capable of impacting native systems. It was first found in New Zealand in 1990, and in March 2000, a population was discovered on a 200-ha island reserve of conservation significance. This led to a call for the development of a strategy to eradicate infestations of Argentine ants. In summer 2001 (January-March) five isolated infestations, three in urban industrial sites and two in coastal scrub vegetation were treated with single applications of protein bait incorporating the insecticide fipronil (0.01%). Application rates were higher in the coastal habitat (~6 kg/ha) than the urban areas (2.5 to 3 kg/ha). The abundance of ants was monitored at all treatment sites, a non-treatment site with Argentine ants, and three non-treatment sites without Argentine ants. At all treatment sites Argentine ant numbers were reduced to very low levels (< 1% of pre-treatment levels on non-toxic baits) and 9 months after treatment ant numbers remained low. Re-treatment is necessary to achieve eradication and is underway at some of the sites. Additional trials using the same bait but with a lower concentration of fipronil are also underway to determine if this modification will result in eradication following initial treatment.

Key Words Baiting Fipronil Eradication

INTRODUCTION

The Argentine ant (*Linepithema humile* (Mayr)) is a highly invasive species from South America that has established in many locations worldwide (Suarez et al., 2001), is a major urban pest, and has detrimentally affected native systems (Davis and Van Schagen, 1993; Human and Gordon, 1997; Suarez et al., 2000). It was first found in New Zealand in Auckland, North Island, in 1990 (Green, 1990) and has since spread widely within Auckland. Smaller infestations have been detected elsewhere, including two populations in the South Island (Harris, 2001). In March 2000, Argentine ants were found on Tiritiri Matangi Island, a 200-ha island reserve of conservation significance. Consequently, the New Zealand Department of Conservation called for the development of a strategy to eradicate entire infestations of Argentine ants.

Baiting is considered the most likely method to achieve eradication (Davis et al., 1993). The Western Australian Department of Agriculture developed a protein bait formulation (hereafter called WA Bait) that was highly attractive to Argentine ants. The bait has a high liquid content and a short field life. Use of the WA Bait with the insecticide sulfluramid achieved 100% kill of workers and queens in laboratory trials (Davis and Van Schagen, 1993). A field trial in Western Australia eradicated all but a few isolated spots after two treatments (P. Davis, pers. comm.). Subsequently production of sulfluramid ceased and we selected the insecticide fipronil (0.01%) as a potential substitute, because it has been successfully trialed in baits for ants (e.g., Hooper-Bui and Rust, 2000). This paper reports the results of initial treatment of several small Argentine ant infestations using the WA Bait incorporating fipronil.

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Table 1. Details of study sites

Site	Habitat (ha)	Size of infestation	Treatment/non--treatment	Argentine ants present	Date treated	Number of monitoring baits
Tiritiri Matangi Island:						
Jetty infestation	Coastal scrub vegetation	9.3	T	Yes	30/01/01 (6.3 ha), 14/02/01 (3 ha)	45
Northeast Bay infestation	Coastal scrub vegetation	0.5	T	Yes	1/02/01	10
(adjacent to Jetty infestation)	Coastal scrub vegetation	-	NT	No	-	20
Nelson port	Urban/Industrial	12	T	Yes	26/3/01	28
Nelson port	Urban/Industrial	-	NT	No	-	18
Mt Maunganui:						
Port	Urban/Industrial	44	T	Yes	19/3/01	30
Tui St	Urban/Residential	< 1	T	Yes	5/4/01	15
Northport	Urban/Industrial	10.5	NT	Yes	-	15
Mt Maunganui	Urban/Industrial	-	NT	No	-	15

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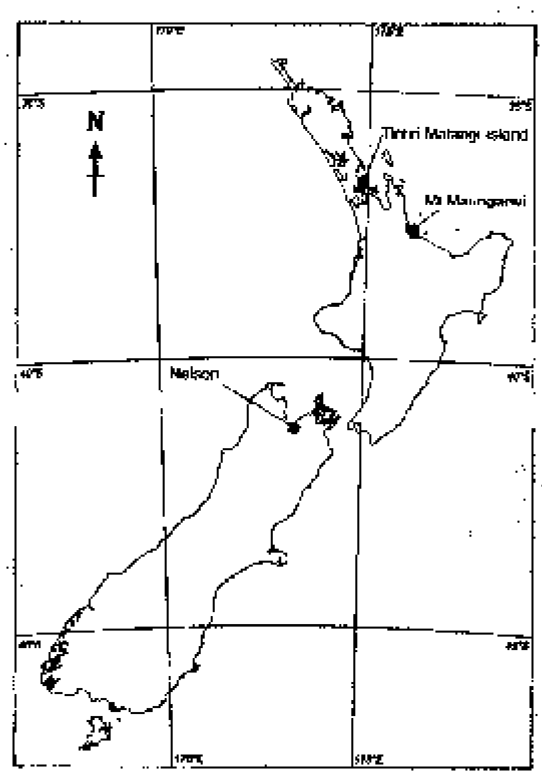

Figure 1. Location of study sites.

MATERIALS and METHODS

Six isolated infestations of the Argentine ant at three localities in New Zealand were selected (Figure 1). Four were in urban/industrial sites and two in coastal scrub vegetation. Five were treated and one was monitored as a non-treatment control. In addition, three sites without Argentine ants and adjacent to infestations were monitored (Table 1). At each site a set of monitoring locations were selected that were easily accessible, along the edge of roads or tracks (Table 1). A monitoring bait consisted of a vial containing ~5 g of non-toxic WA Bait. Baits were left out for 3 hr., after which time the lid was placed on the vial to trap the ants. All ants were identified and counted. Monitoring baits were placed out at all sites at least once before poisoning and at the same locality at least 4 times after poisoning, from February 2001 to December 2001. In addition, the presence of ant activity and the appearance of colonies were recorded at some of the sites by hand searching when monitoring baits were placed out.

In summer 2001 (January-March), just before treatment, the boundaries of each Argentine ant infestation were determined using a mixture of non-toxic baiting and hand searching. The area of infestation was treated as well as a buffer zone about 20 m wide around it. Teams of 3-7 people spaced 3 m apart treated the infestation and buffer by placing bait every 2 m. Using a caulking gun, about 2 g of bait was placed on the ground at each spot, if possible in a shady position, as bait dries rapidly and becomes unpalatable if exposed to full sun. In the urban sites, areas of concrete and inside buildings were not treated. Two parts of the infestation by the jetty on Tiritiri Matangi were treated at night: the highly exposed coastline to minimise bait dehydration, and the open grassed areas to minimise foraging on the baits by pãkeko, *Porphyria porphyria*. The total amount of bait used and the time to lay bait was recorded.

ANOVA and Tukey tests of pairwise means comparisons were used to determine significant among sites differences in the abundance of Argentine ant on baits.

RESULTS

Considerably more time was taken and bait used to treat the sites with native vegetation (~ 18 hrs/ha; 6.3 kg of bait /ha) than the urban sites (~ 4.5 hrs/ha; 2.5 kg of bait/ha). The application rate in the natural vegetation was about double the planned rate, partly due to the undulating terrain. The bait was highly attractive to *L. humile,* large numbers of foragers were seen feeding within a few minutes of bait being placed near an active trail. Activity on baits ceased within 12 hours of bait being put out. After 24 hours of baiting very little ant activity was seen around the treated sites. Ten days after the initial poisoning, it was evident that the toxin was still having some effect, as dying ants and abandoned dead brood were observed at the Tiritiri Matangi site.

Prior to toxic baiting, the numbers of Argentine ants caught varied significantly between sites ($F = 6.3$, d.f. = 6, $p < 0.001$), with a small infestation at Tui St catching the least ants (Table 2). After treatment, ant numbers immediately dropped to similar low or undetectable levels at all the treatment sites (0.2% of pre-poison levels after 7-15 days) and remained at low levels 8-9 months after treatment (0.01% of pre-poison levels after 265-282 days) (Table 2, Figure 2). The non-treatment site continued to have Argentine ants present in significantly higher numbers than the treatment site on all occasions after treatment ($p < 0.05$, Tukey test). There was some reduction after treatment at the non-treatment site (62% of pre-poison levels after 7-15 days; 20% of pre-poison levels after 200-250 days), which corresponded to the onset of cooler temperatures (Figure 3). Reductions in trap catches at the non-treatment site were not to the same degree as the treated areas, and numbers began to increase again after winter, unlike the treated areas.

Significantly fewer other ants were caught on bait within the Argentine treatment sites prior to treatment than in sites without Argentine ants ($F=5.56$, d.f.=1, $p <0.05$; Figure 4). When other ants were present they were generally at the edge of the Argentine ant infestation or the Argentine ant infestation was small. It was likely the treatment had an impact on other ants as their numbers dropped within the treated sites after poisoning (10% of pre-poison levels after 7-15 days). By the end of the monitoring, in the absence of Argentine ants, numbers appeared to be increasing (22% of pre-poison levels after 265-282 days), and queens of several species were

Table 2. Abundance of ants at the treatment and non-treatment sites (mean number of ants per bait ± SE)

Site	Treatment/non -treatment	Argentine ants (ants/bait)	
		Pre-poison (1-7 days)	Post-poison (7-15 days)
Tiritiri Matangi Island:			
Jetty infestation	T	81 ± 42 [a]	0 ± 0 [a]
Northeast Bay infestation	T	315 ± 27 [b]	0 ± 0 [a]
Nelson port	T	319 ± 43 [b]	0 ± 0 [a]
Mt Maunganui:			
Port	T	225 ± 37 [a,b]	3 ± 3 [a]
Tui St	T	229 ± 55 [a,b]	0 ± 0 [a]
Northport	NT	182 ± 50 [a,b]	113 ± 50 [b]

Sites with the same letter after the mean are not significantly different at the 95% level (Tukey tests of pairwise means comparisons).

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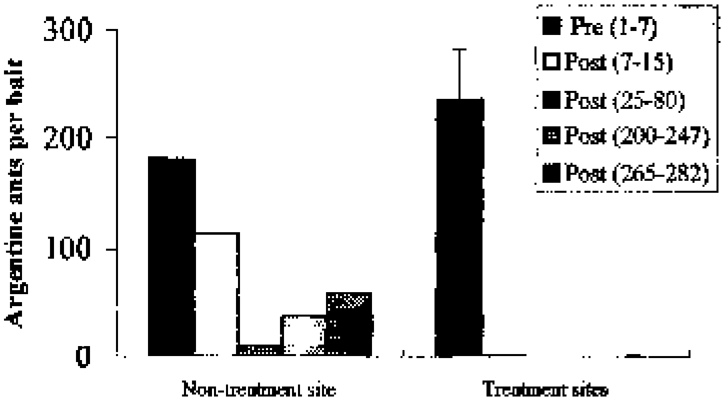

Figure 2*. Number of Argentine ants caught on non-toxic protein baits at various times (days) pre- and post-treatment at the treatment sites (n = 5) and non-treatment site (n = 1). Data are mean ± SE.*

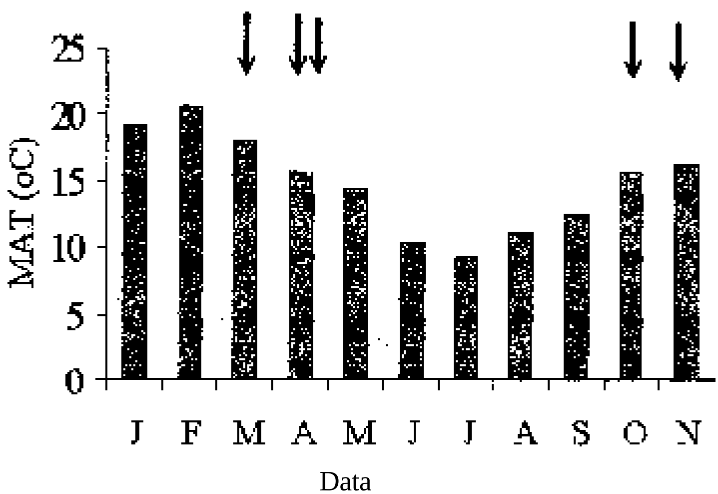

Figure 3*. Mean monthly air temperatures (MAT, °C) at Tauranga airport for 2001. Tauranga airport is near the Mt Maunganui sites. The arrows indicate the dates when Argentine ants were sampled at the non-treatment site (see Figure 2).*

observed within the infested area. The abundance of other ants on monitoring baits away from the Argentine ant infestation was highly variable and, like the non-treatment Argentine site, showed some decline over winter (Figure 4). Thirteen other ant species were sampled on the monitoring baits (Table 3).

On 22 March, both infestations on Tiritiri Matangi were inspected in detail. Within the jetty infestation Argentine ants were generally absent and the mouldy remains of nests were seen

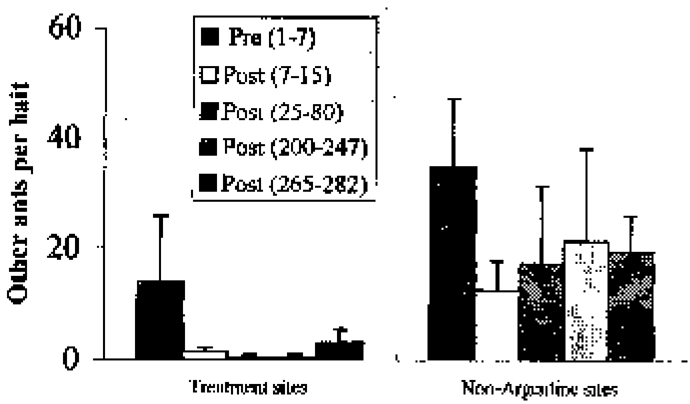

***Figure 4**. Number of ants other than Argentine ants caught on protein baits at various times (days) pre- and post-treatment. Data are mean ± SE.*

Table 3. Other ant species sampled on non-toxic WA baits

Ant species	Native/ adventive	Location		
		Tititiri Matangi	Mt Maunganui	Nelson Port
Cardiocondyla minutior Forel	A	-	✓	-
Hypoponera eduardi (Forel)	A	-	✓	-
Iridomyrmex anceps (Roger)	A	-	✓	-
Mayriella abstines Forel	A	✓	-	
Monomorium ?antipodum Forel	N	✓	✓	-
Monomorium antarcticum (F.Smith)	N	✓	-	✓
Ochetellus glaber (Mayr)	A	✓	-	-
Pachycondyla castanea (Mayr)	N	✓	-	-
Paratrechina vaga Forel	A	-	✓	✓
Pheidole rugosula Forel	A	-	✓	-
Technomyrmex albipes (Smith)	A	-	✓	-
Tetramorium bicarinatum (Smith)	A	-	✓	-
Tetramorium grassii Emery	A	✓	✓	-

under stones. Occasional small aggregations of workers, representing the remains of previously larger colonies, were found and one active colony that appeared to have been unaffected. The active colony was near the mean high-water line in an area of the jetty infestation with high Argentine ant densities that did not receive bait at night, as other coastline areas had. At North-east Bay, only one small colony with a single queen and less than 100 workers was found.

DISCUSSION

It is clear from observations of high Argentine ant activity on baits and from the rapid reduction in ant activity the day after poisoning that the reduction in numbers on monitoring baits was largely due to the treatment. The fipronil bait was highly effective at killing workers and queens, but not all colonies appear to have received sufficient bait. Foragers may have died too

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quickly, and therefore the fipronil was not spread to every colony or to every individual within colonies, or the bait became unpalatable too quickly in some micro-sites, and/or foragers of some colonies did not locate or feed on the bait at all. Traditionally, slow-acting toxins have been considered ideal for achieving effective ant control (Stringer et al., 1964), so the rapid action of fipronil may reduce the chances of achieving eradication. An increase in the number of baits per unit area and/or a decrease in the concentration of fipronil in the bait, so that it takes longer to kill individuals and there is a greater exchange of the bait between nests, as demonstrated by Ripa et al., 1999, may improve effectiveness. Further trials are underway to test the effect of these modifications on Argentine ant populations. This assumes that the limitation to success is not the presence of some form of physical or behavioural refugia that protect some ants from exposure to bait (e.g., colonies living totally arboreally, or within buildings, and not foraging at all on the ground where bait is placed). If this proves to be the case, an additional and modified control strategy would be required to achieve eradication.

At the non-treatment site, fewer Argentine ants were sampled in April (Autumn) despite no visible decrease in forager activity being observed (P. Dykzeul, pers. comm.). This likely reflects seasonal patterns. Oviposition slows over winter and development rates of eggs, larvae, and pupae also slow. Oviposition does not occur below a daily mean temperature of 18.3 ^{o} C, and population abundance reaches a seasonal low during winter (Vega and Rust, 2001). As a consequence, there will be some reduction in the population size of an untreated site over winter and a reduction in the demand for protein, which is needed for egg and larval development.

Eradication of whole infestations of Argentine ant in the past has only been achieved with persistent contact insecticides, products that have since been removed from the market due to the environmental consequences of this persistence (Davis et al., 1993). Non-persistent sprays kill workers, but seldom kill whole colonies unless they are directly sprayed. A non-persistent bait formulation, Maxforce Granular Insect Bait, was highly attractive to Argentine ant foragers and reduced worker populations, but failed to achieve eradication of populations in field trials after one or two applications at rates of 4.5 kg/ha. There was also a rapid resurgence in activity suggesting queens were not significantly affected (Krushelnycky and Reimer, 1998a, 1998b). A trial in Western Australia with the WA Bait incorporating sulfluramid achieved eradication of all but a small area of the treated site after one area-wide application and one spot treatment of remaining populations (P. Davis, pers. comm.).

To achieve eradication all queens must be killed. Re-treatment of the sites treated in this study is unlikely to be effective until at least the season following the initial treatment, as numbers are very low and foraging in disarray. Ant densities are likely to decline further over winter and protein bait will be in low demand. The data collected using monitoring baits have adequately reflected the dramatic reduction in Argentine ant numbers measured more directly by visual inspection of nest sites and foraging activity on tree trunks. However, although no Argentine ants have been detected on baits at some sites since treatment, hand searching revealed that they were still present in very low densities. Nine months after treatment small foraging trails appeared in some parts of the treated sites, but most of the treated area remains free of ants. Treatment of the whole infestation a second time may be unnecessary, but the presence of small isolated colonies makes detection of their presence, and deciding which areas to re-treat, difficult and time consuming. Some of the trial sites will be re-treated in summer 2001/February to attempt to kill all survivors, and others will be monitored without further treatment to determine how rapidly Argentine ant populations recover without further intervention.

Fipronil kills all the ant species recorded on the WA Bait. However, most species would eventually be eliminated wherever Argentines ants flourish (Human and Gordon, 1996; Holway, 1999). As most of these species have nuptial flights (unlike Argentine ants) they could rapidly recolonise an area should local eradication be successful. All other species were in low numbers compared with Argentine ants, even outside the infestation, reflecting both the very high densities of Argentine ants at the sites compared with other species, and their efficient recruitment of food sources.

New Zealand has a depauperate ant fauna with only about 32 species established, of which 10 are native (Harris and Berry, 2001). Most of the ant species recolonising after removal of Argentine ants will therefore be adventive, especially in urban areas. However, sampling of these species may be useful as indicators of the recovery of other components of the invertebrate community that are undoubtedly affected by the presence of Argentine ants (Cole et al., 1992; Human and Gordon, 1997).

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