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ORIGINAL CONTRIBUTION

Protocols for Argentine ant eradication in conservation areas

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Abstract

The Argentine ant (*Linepithema humile*) is a widespread, abundant and ecologically disruptive invader that is present throughout major portions of coastal California and on half of the California Channel Islands. On Santa Cruz Island, the Argentine ant had invaded about 2% of the island's area in four distinct locations as of 2012. Given the negative ecological effects resulting from Argentine ant invasions, we sought to develop a cost-effective method of eradication. Here, we describe the results of large-scale, field-tested methods for Argentine ant eradication and post-treatment detection. Our eradication protocol employs a novel toxicant-delivery system: an aqueous solution of sucrose and 6 ppm of thiamethoxam mixed with hydrating polyacrylamide beads. Ants feed on the solution present on the bead's surface for about 24 h after which time bead dehydration prevents feeding. We distributed hydrated beads by helicopter over 74 ha of infested areas plus a 50-m buffer on 14 occasions between June 2013 and September 2014. Treatments reduced Argentine ant activity to subdetectable levels within four months. In 2014, we conducted a high-intensity detection protocol using lures (n = 55 363) in areas treated in 2013. This effort did not detect Argentine ants. In 2015, we conducted a medium-intensity detection protocol using lures (n = 2250) in areas treated in 2013 and 2014 but not searched in 2014; this sampling effort did not detect Argentine ant activity except for a single remnant infestation (c. 0.3 ha in area), which was retreated in 2015. The cost of treatments was approximately $1400 per ha; this cost is comparable to other ant eradication efforts. The cost of our preferred detection method, which used lures spaced every 10 m, was $500 per ha. These results demonstrate sufficient protocol efficacy to justify expansion of treatments to other infested areas in ecologically sensitive areas.

Introduction

Ants and other social insects globally rank among the world's most environmentally destructive introduced species, and the Argentine ant (*Linepithema humile*) represents one of the most widespread and damaging of these invaders (Holway et al. 2002; Krushelnycky et al. 2005; Ward et al. 2006; Wilson et al. 2009). The Argentine ant displaces native ants and disrupts ecosystems in a variety of ways throughout its extensive introduced range (Holway et al. 2002; Lach et al. 2010). Despite these effects, land managers lack reliable tools to control or eradicate the Argentine ant and other introduced ants without negatively affecting native species and ecosystems (Mack et al. 2000; Brockerhoff et al. 2010; Pluess et al. 2012).

Introduced ants have characteristics (e.g. supercoloniality, omnivory) that contribute to their success as invaders and may also favour persistence under sustained control and eradication campaigns (Holway et al. 2002; Tsutsui and Suarez 2003; Silverman and Brightwell 2008). Moreover, microhabitat heterogeneity typical of natural areas may result in local variation in diet, foraging and nesting behaviour in species such as the Argentine ant (Heller and Gordon 2006; Tillburg et al. 2007). Because eradication programmes in general benefit from being able to anticipate animal behaviour and to remove reproductive individuals (Bomford and O'Brian 1995; Hoffmann 2015), variation in Argentine ant behaviour increases the complexity and difficulty of landscape-scale eradication.

Successful eradication efforts for vertebrate populations (Veitch and Clout 2002) have produced generally accepted guidelines for the implementation of eradication programmes (Parkes 1990; Bomford and O'Brian 1995; Cromarty et al. 2002; Morrison 2007). For insects, however, eradication attempts still outnumber documented successes (Wenner et al. 2000; Haack et al. 2010; Hoffmann et al. 2011, 2016; Gaigher et al. 2012). Nearly 90% of successful ant eradication programmes were completed on infestations less than 10 ha and less than ten successful eradications were completed over more than 40 ha (Hoffmann et al. 2016). Most eradications are conducted when ant infestations are small and less costly to remove. Further, there is slight diversity in both the target species and toxicant used in successful eradications (Hoffmann et al. 2016) suggesting that additional tools are needed to broaden the scope, scale and increases ant eradication success rate. While Hoffmann et al. (2016) offered guidelines for ant eradications, uncertainty exists with respect to adequate protocols for treatment and post-treatment detection to increase successes and ant eradication programme uptake. The mixed success of past ant eradication attempts may, in part, result from the use of pesticides not tailored to the target ant species or to characteristics of the invaded habitat that prevent complete elimination of the target invader (Stanley 2004; Causton et al. 2005; Krushelnycky et al. 2005; Hoffmann 2011). Moreover, standards for post-treatment detection vary widely; some programmes do not search for remnant populations, while others employ intensive detection efforts for up to two years after treatment (Hoffmann 2011; Hoffmann et al. 2016). Lack of consensus regarding treatment and post-treatment detection guidelines for ant invasions impedes the planning and implementation of ant management programmes. As a result, there is an urgent need to develop effective eradication protocols and to translate the lessons learned from these efforts into practical guidelines useful to managers working in different parts of the world.

Ant eradications at large scales will always be difficult to achieve, and the initiation of any such programme must be carefully evaluated (Parkes 1990). Meaningful criteria to justify an eradication include the following: (i) invasion by introduced ants threatens unique biological resources, (ii) the extent and physical complexity of the infested area does not preclude feasibility, (iii) sufficient logistical and financial support exists for the launch and maintenance of an eradication and post-treatment detection programme by managers and landowners and (iv) invaded areas have a low potential for re-invasion. As with vertebrate eradication programmes, eradication efforts that target ants must put all reproductive individuals at risk, and mortality resulting from treatments must outpace reproduction (Parkes 1990). Due to their small size, tendency to nest underground and variable levels of activity, ants tend to be difficult to detect at low densities (e.g. those that can result from incomplete treatment efforts). Lastly, ant eradication programmes must include long-term detection programmes to confirm eradication has been achieved (Parkes 1990; Morrison 2007).

Here, we discuss field protocols for Argentine ant eradication from Santa Cruz Island, California. This site meets the above suitability criteria for successful eradication. First, the effects of Argentine ant invasions on Santa Cruz Island are well documented. Only a few of the 31 native ant species known to the island are found in areas invaded by Argentine ants (Hanna et al. 2015a), and floral visitation by the Argentine ant disrupts pollination services and reduces seed set in at least one native plant species (Hanna et al. 2015b). This latter type of ecological effect represents a particular concern given the number of endemic plant species on Santa Cruz Island (Junak et al. 1995). Second, the aerial extent and topography of invaded areas are considered surmountable obstacles (Randall et al. 2011). Third, the landowners of Santa Cruz Island, The Nature Conservancy and the National Park Service, have an established record of successful eradication projects (Morrison 2007; Randall et al. 2011) and remain firmly committed to the long-term goal of island-wide eradication of habitat-modifying non-native species. Lastly, risk of re-invasion following eradication seems low. Based on the pattern of invasion and spread on Santa Cruz Island (Wetterer et al. 2000), the Argentine ant was likely introduced only once, several decades ago, and the island is now subject to strict biosecurity measures.

In this study, we present the results of large-scale, field-tested methods for Argentine ant eradication and post-treatment detection that build on pilot work described in Boser et al. (2014). We describe a novel toxicant-delivery system and an efficient method of field deployment coupled with a multiyear detection protocol capable of detecting low-density Argentine ant infestations. The treatments employ palatable liquid bait mixed with a toxicant at a concentration calibrated to have a delayed toxic effect. By deploying the bait in small aliquots via helicopter over infested areas on multiple occasions, we leverage the interconnected nature of Argentine ant supercolonies to distribute toxicant to queens and other workers within multiple nests. We also present two years of post-treatment detection data and discuss the efficacy and cost of three different detection approaches. We present and discuss these methods so that they can be evaluated for use in other locations affected by ant invasions.

Methods

Santa Cruz Island (249 km^2) is the largest of the California Channel Islands and lies approximately 30 km offshore of mainland California. The island's rugged topography supports a variety of plant assemblages including coastal sage scrub, chaparral, annual grasslands, oak woodland, riparian woodland and bishop pine (*Pinus muricata*) forest (Junak et al. 1995). The climate of Santa Cruz Island is Mediterranean with hot, dry summers and cool, moist winters; most of the annual precipitation (mean = 51 cm) falls between November and April (Boyle and Laughrin 2000).

Delimitation surveys on Santa Cruz Island conducted in 2009 and 2010 revealed that the Argentine ant occupied four spatially disjunct locations (table 1; fig. 1). Prior to the start of the eradication treatments in 2012, the total area infested by Argentine ants equalled approximately 410 ha, or about 2% of the island's area (Boser et al. 2014). The largest infestation (Valley Anchorage; 336 ha) is also the oldest, likely dating back several decades to a now dismantled US Navy facility. Argentine ants were accidentally transported from Valley Anchorage to the Navy site (16 ha) in the mid 1980s and to the Field Station (38 ha) in 1995 via human transport of building material. The infestation in Canada del Puerto (20 ha) likely resulted from more recent downstream dispersal from the Field Station infestation by winter floods. The four separate infestations encompass topographically varied terrain, and most of the major vegetation types present on Santa Cruz Island. In 2012, we conducted a pilot study that involved treating 4 ha of the Field Station infestation and 3 ha of the Navy site infestation (Boser et al. 2014). That study used roughly the same toxicant bait as is described below, but the bait was distributed entirely by hand, and areas were treated only four times. In this manuscript, we focus on a systematic and comprehensive eradication effort conducted in 2013 and 2014 that treated the entirety of three sites, the Navy, Field Station and Cañada del Puerto infestations (fig. 1). We treated the Valley Anchorage infestation in 2015 and 2016 using methods similar to those described in this manuscript.

Delimitation of infestations

Prior to the start of the eradication efforts in 2013, we delimited the Navy, Field Station and Cañada del Puerto infestations (fig. 1). The delimitation surveys were conducted by visually searching for ants on vegetation and bare ground. We also placed lures (cotton balls soaked in 25% sucrose solution) in certain areas (e.g. in dense vegetation) for approximately an hour and returned to verify the presence of ants (Randall et al. 2011). Ant presence was recorded in handheld GPS units, and location tracks of all technicians were mapped to verify that areas had been thoroughly searched. Surveys were not conducted during periods when ant activity was typically low (e.g. around midday when temperatures were above 30°C) (Boser et al. 2014). We used these initial presence/absence surveys to estimate an infestation boundary line. We then placed perpendicular transects every 20 m along the initial infestation boundary and searched for ants another 50 m into the presumably uninvaded habitat.

Table 1 Site descriptions of each Argentine ant infested site on Santa Cruz Island, California

Site	Area*	Elevation	Vegetation	Years treated
Cañada del Puerto	16	50 m	Oak woodland, riparian	2013–2014
Field Station	38	70 m	Oak woodland, scrub	2012–2014
Navy	20	166–472 m	Oak woodland, scrub	2012–2014
Valley Anchorage	336	0–330 m	Oak woodland, scrub	2015–2016

*Maximum area of infestation as of 2013–2015. Area in Ha.

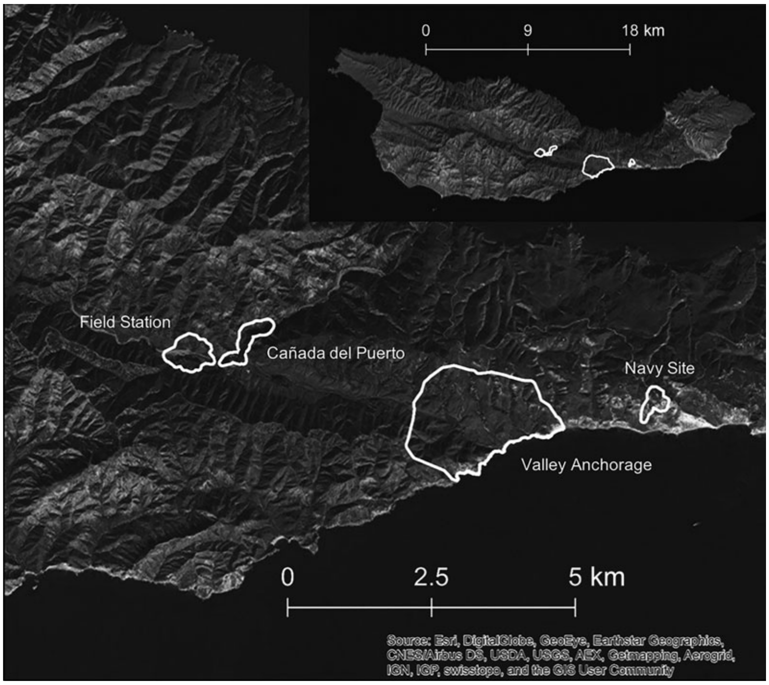

Fig. 1 The location of four spatially disjunct Argentine ant infestations on Santa Cruz Island, California as of 2013. The inset depicts the entire island.

If additional Argentine ants were detected outside of the original boundary line, we adjusted the boundary accordingly. Colonies reproduce only by budding, a mode of dispersal that limits rate of spread and allows the infestation to be delimited in (Holway 1998; Suarez et al. 2001). After we mapped the three infested areas, we added a 50-m wide, continuous buffer around the perimeter of each infestation (fig. 2a).

Eradication protocols

Treatments consisted of an aqueous solution of 25% sucrose and 6 ppm of thiamethoxam (Syngenta Crop Protection LLC, EPA Reg. No. 100-1306) mixed with hydrating polyacrylamide beads (1 cm in diameter; JRM Chemical©) that retain the toxicant in liquid form (Boser et al. 2014; Rust et al. 2015). In areas with steep slopes and little vegetation (e.g. portions of the Navy site), however, polyacrylamide shards (1 cm in diameter; JRM Chemical©) were mixed with beads because the shards were thus less likely to roll down steep terrain and more likely to remain accessible to ants in these areas. However, polyacrylamide beads were used to treat most areas because they better retain their integrity when aerially deployed. The treatment solution was mixed on site in large bins using an electric mixer; polyacrylamide beads or shards were added after the sucrose and toxicant were in solution and over a period of 8–12 h the beads soaked up and hydrated with that solution. Laboratory tests indicate the resulting concentration of toxicant in the hydrated beads is not significantly different from the aqueous solution (Rust et al. 2015). Hydrated polyacrylamide beads remained coated with a thin layer of the solution that was available to ant workers for approximately 24–28 h, after which point dehydration of the beads prevented feeding. We carried out the treatments under an Experimental Use Permit from the United States Environmental Protection Agency (EUP 100-1306) and a Research Authorization from the California Department of Pesticide Regulation No. 89927-EUP-1.

Hydrated beads were distributed by helicopter fitted with a long-lined hopper. Each deployment dropped 6 ppm thiamethoxam toxicant bait at a rate of 148 l per ha throughout the three treatment areas (including the 50-m buffer). Areas adjacent to open water (e.g. sections of Cañada del Puerto with surface flow) were treated by hand. Irrespective of the method of delivery, deployments scattered thiamethoxam-treated beads such that individual beads were generally no farther apart from one another than 0.5 m. All areas were treated 14 times. In 2013, treatments took place every 2–3 weeks from June to November 2013 for a total of 12 treatments. We conducted two additional treatments in 2014, one in early September and another in early October.

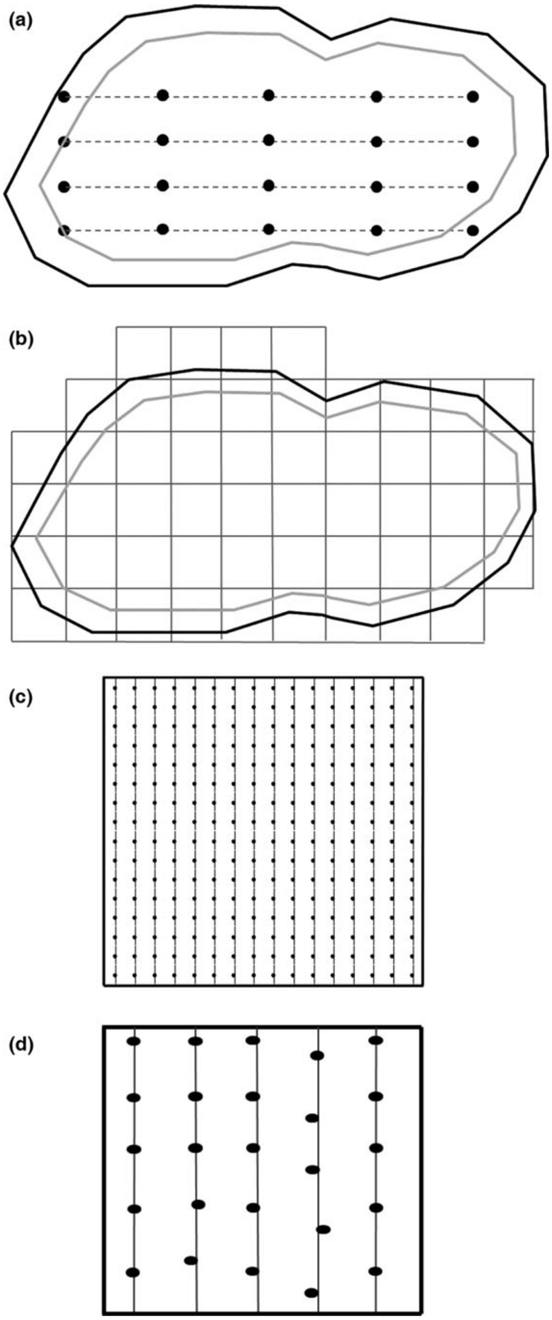

Fig. 2 (a) Diagrammatic representation of a hypothetical treatment area. The solid grey line indicates a delimited infestation, and the solid black line indicates a continuous 50-m buffer surrounding the infestation. Black dots represent fixed monitoring points used in low-intensity monitoring; dotted grey lines indicate the configuration of belt transects. (b) Diagrammatic representation of a hypothetical treatment area (see a) gridded into 50 × 50 m cells used in the high-intensity and medium-intensity monitoring. (c) Diagrammatic representation of a single 50 × 50 m cell used in the high-intensity monitoring. Black dots represent lures, and grey lines represent belt transects. (d) Diagrammatic representation of a single 50 × 50 m cell used in medium-intensity monitoring. Black dots represent lures, and grey lines represent belt transects.

Post-treatment assessments

To evaluate treatment effect on Argentine ant activity, we conducted three types of post-treatment assessments: low-intensity monitoring, and high- and medium-intensity detection protocols. These three assessments were specifically designed for different phases of the eradication effort. The primary aim of the low-intensity monitoring protocol was to reveal declines in Argentine ant abundance within a year of treatment, whereas the aim of the high-intensity and medium-intensity detection protocols was to detect any remaining remnant infestations present after treatments were completed.

We performed low-intensity monitoring just prior to the initial treatments (May 2013) and then on four occasions after, but within one year of the initial treatments: just after the second treatment in late June 2013, just after the fourth treatment in late July 2013, just after the seventh treatment in late August 2013 and finally in late May 2014. To conduct low-intensity monitoring, we set up fixed monitoring points (n = 220) within each of the three, targeted infestations. As an untreated reference, we also established fixed points (n = 70) within the Valley Anchorage infestation. In all four areas, points were arranged in parallel lines 40 m apart; points within a line were spaced 40 m apart. Due to concerns about accessing steep terrain in portions of the Navy site, we elected to place points at this location only on relatively level terrain. This approach resulted in monitoring points located entirely within the 2012 pilot treatment area at the Navy site.

We used three different methods to detect ants as part of the low-intensity monitoring. (i) *Lures* consisted of 50-ml centrifuge tubes that each contained a cotton ball soaked in 25% sucrose solution. In each monitoring round, we placed one lure at each fixed monitoring point for 2–3 h; we then retrieved the lures and identified and counted all ants present. (ii) *Visual searching* involved searching for ants on vegetation and bare ground within 10 m of each monitoring point for three min or until an Argentine ant was detected. (iii) *Visual belt transect searching* involved searching for ants on vegetation and bare ground within 2-m bands along the transect lines connecting fixed monitoring points (fig. 2a). To test for changes in Argentine ant activity before and after treatment, we used Wilcoxon rank sum tests to compare the pre-treatment sample with each post-treatment sample at each infested sites (i.e. treated sites and the untreated reference site). These pairwise comparisons permit detection of changes in the magnitude of each response variable (i.e. method of assessing ant activity) within each of the four sites over time.

In August 2013, we transitioned to the high-intensity detection protocol because visual searches of treated areas failed to detect any Argentine ants. The high-intensity detection protocol consisted of the following methods. The three infested areas that were treated in 2013 and 2014 were divided into 50 × 50 m cells (n = 308; fig. 2b) and within each cell, we placed 256 lures in a 3 m × 3 m grid configuration (fig. 2c). The lures consisted of 0.5-l vented jars (Scotty, Sidney, British Columbia, Canada) containing 3 g of one part sugar and three parts cooked egg, and one cotton ball soaked in 25% sucrose solution containing (Z)-9-hexadecenal, a pheromone of Argentine ants that elicits their trail-following response (Choe et al. 2012). The sucrose solution with the pheromone was prepared by mixing 0.06 ml of microencapsulated formulation of (Z)-9-hexadecenal (5.6 mg/ml; Suterra, LLC., Bend, OR) per litre of 25% sucrose solution. The presence of pheromone in the lure was expected to increase the probability of detection of Argentine ants, but this will be a focus of a separate work that is currently under preparation. Jars of a relatively large size were used to minimize disturbance of lures by island foxes (*Urocyon littoralis*). Following techniques developed on Tiritiri Matangi Island, New Zealand (C. Green, *pers. comm.*), we left lures in the field for 24 h and then counted, identified and recorded the location of all ant species found in jars. We conducted the high-intensity detection protocol in August and September 2013, and May through September 2014 (fig. 2c).

The results of the high-intensity detection protocol coupled with a programmatic need to reduce the cost and effort of detection efforts necessitated the development of a medium-intensity detection protocol in 2015. Medium-intensity detection used the same cells and lure design as in the high-intensity but differed in that 25 lures were placed in a 10 × 10 m grid configuration within each 50 × 50 m cell (fig. 2d). Lure placement used grid spacing, but we attempted to place lures in vegetation microenvironments considered attractive to the Argentine ant (e.g. *Baccharis pilularis*, *Foeniculum vulgare*, *Quercus* spp., *Calystegia macrostegia*; Boser et al. 2014) wherever possible as long as these locations were within 4 m of grid points. We conducted the medium-intensity detection protocol in all cells not searched in 2014 from June through September 2015.

Assessing non-target species' attraction to bait

To gauge the extent of non-target use of bait by terrestrial invertebrates aside from the Argentine ant, we surveyed arthropods present at thiamethoxam-treated beads following three treatment deployments in 2013: 1 July, 29 July and 7 October. On each date, we censused arthropods present at beads within single 1-m^2 quadrats at each of the 220 fixed monitoring points in the low-intensity monitoring at 1 and 15 h after treatment deployment. The exact placement of the 1-m^2 monitoring quadrats was changed for each treatment deployment but remained ≤15 m from fixed monitoring points. In these surveys, arthropods were identified to species.

Results

Treatments conducted in 2013 led to significant reductions in Argentine ant activity within one month of initial treatment (fig. 3). These results were observed at the Field Station and Cañada del Puerto sites and appeared to be consistent across each of the three low-intensity monitoring methods that we employed (fig. 3). After eight treatments, ant abundance was so low that only three individual Argentine ant workers were detected using lures. We failed to detect the Argentine ant at the Navy site during the pre-treatment and post-treatment monitoring efforts, probably because the area surveyed in 2013 fell entirely within the area treated in the 2012 pilot study (Boser et al. 2014). In contrast to treated sites, Argentine ant activity in the untreated Valley Anchorage infestation either did not change or increased within the same time interval that activity sharply decreased at the Field Station and Cañada del Puerto sites (fig. 3).

In 2014, we conducted high-intensity detection at 54 ha of the Navy, Field Station and Cañada del Puerto infestations. This effort deployed 55 363 lures in 71% (221/311) of all cells and expended 4302 person h in the field. This considerable effort yielded no Argentine ant detections. Given these results, in 2015, we shifted to a medium-intensity detection protocol that allowed us to survey the remaining 29% (90/311) of cells. This effort deployed 2250 lures and expended 540 person h in the field. Medium-intensity detection revealed no Argentine ant activity except for a single remnant population, which occupied five contiguous cells adjacent to a linear row of mature blue gum (*Eucalyptus globulus*) trees on the south-east periphery of the Field Station site (fig. 4). We subsequently retreated this 0.5 ha infestation (with a buffer) three times in late summer 2015.

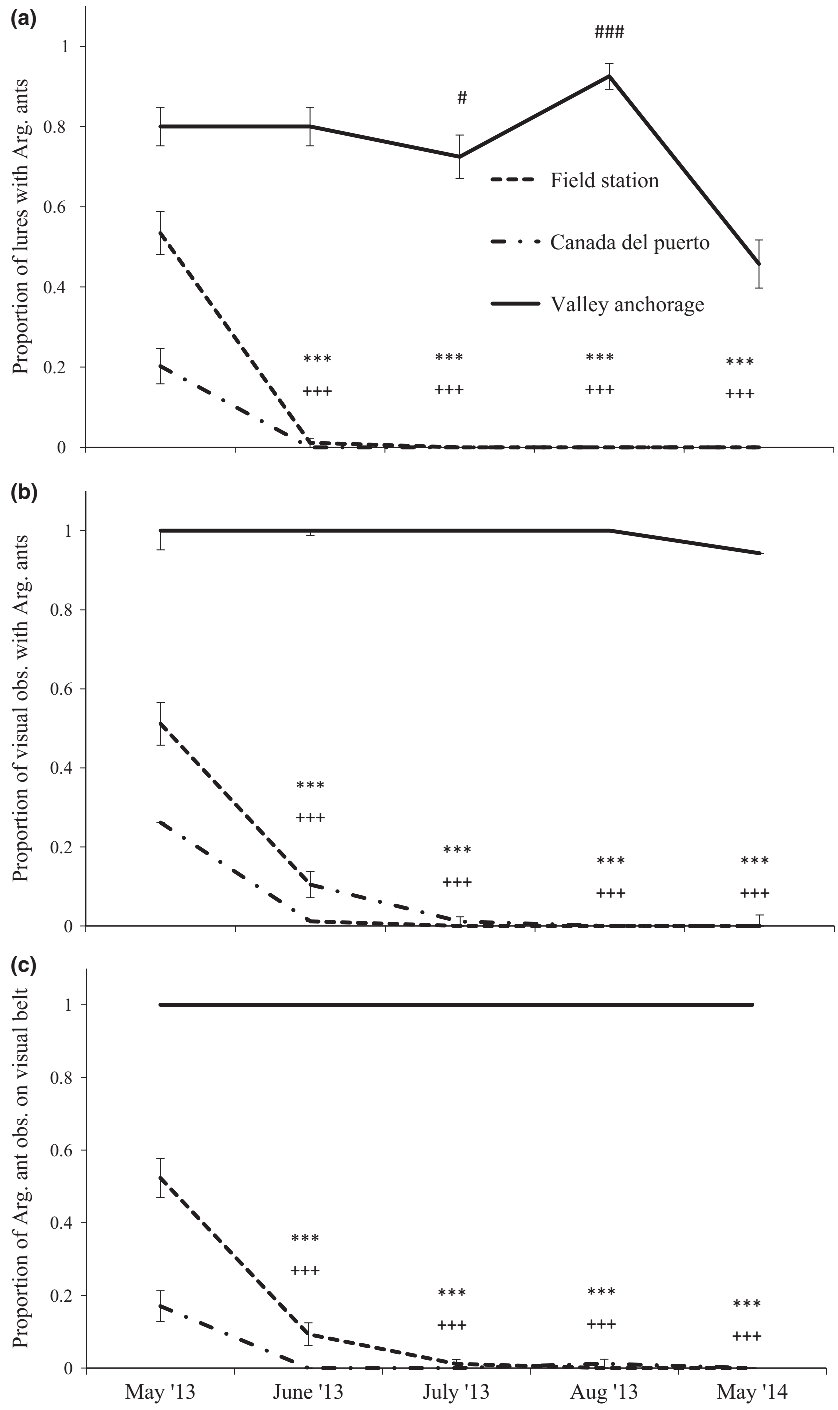

Fig. 3 Proportion of Argentine ant detections at the Field Station, Cañada del Puerto and a reference site Valley Anchorage from May 2013 (pre-treatment) to May 2014. Argentine ant activity estimated in three different ways: (a) lures, (b) visual searches at monitoring points and (c) visual searches at belt transects. Error bars represent SE, and significance level is indicated by hashtags, asterisks or crosses: #/*/+ $P < 0.05$, ###/***/+++ $P < 0.0005$.

Instantaneous counts of arthropods present at bait revealed that ants were the only group present, and Argentine ant workers represented 80% of observations. Two native ant species, *Formica moki* and *Monomorium ergatogyna,* represented the remaining 20% of observations.

Discussion

Our treatment protocol reduced Argentine ant activity over 74 ha of treated area, and after 14 treatments, no Argentine ants have been detected in 73.5 ha. The rapid post-treatment declines in

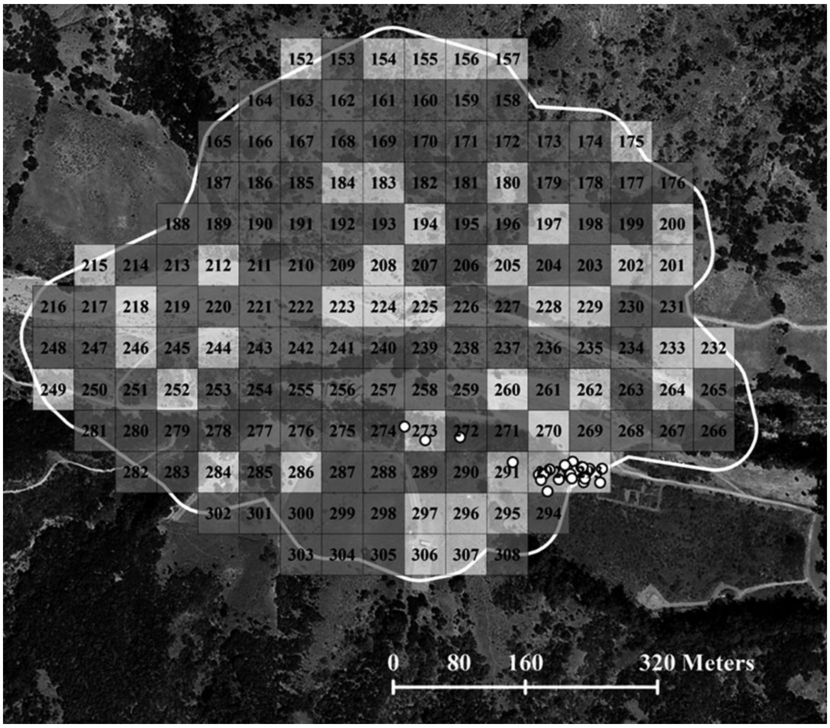

Fig. 4 The location of a remnant Argentine ant infestation detected in 2015 at the Field Station site. Individual points represent Argentine ant workers present at lures in August 2015. The white line indicates the delineated infestation (as of 2013) with a 50-m buffer. Cells are numbered for reference purposes. Dark grey cells were monitored in 2014; light grey cells were monitored in 2015.

Argentine ant activity observed here (fig. 3) resemble those reported in other ant eradication efforts both in terms of rate and magnitude (Vanderwoude et al. 2010; Krushelnycky et al. 2011). The results of the high- and medium-detection protocols suggest that this invader may have been eliminated from the majority of treated areas. Nonetheless, a multiyear, post-treatment detection programme will be required to document whether these reductions equate to the elimination of the Argentine ant.

We treated infested areas on 14 occasions at approximately 2–3 week intervals; this treatment frequency and intensity are higher than typical for ant eradication programmes (Hoffmann and O'Connor 2004; Causton et al. 2005; Hoffmann 2011). We justify this approach for the following reasons. First, the Argentine ant has proven difficult to eradicate, as evidenced by the low number of reported successful eradications (Hoffmann et al. 2011, 2016; Krushelnycky et al. 2011). Frequent treatments may be necessary to outpace reproduction in multiple queen colonies. Second, the liquid bait used in this study is available to Argentine ant workers for a relatively short period of time after it is distributed. Limited bait availability may necessitate a greater number of treatments to ensure that enough toxicant eventually reaches all of the queens. Lastly, multiple bait deployments may be advantageous given that there is some variation in bait coverage especially in rugged terrain and dense vegetation.

Although the results of the post-treatment detection programme were encouraging, the protocols did reveal one remnant infestation (fig. 4). A number of factors may explain the persistence of this remnant infestation. First, errors in delimitation in 2013 may have prevented us from recognizing that the location of this infestation was actually invaded. The location of this remnant infestation supports an unusually dense thicket of non-native fennel (*Foeniculum vulgare*), which might have interfered with our ability to detect the Argentine ant during the delimitation. If so, these ants would have escaped treatments in 2013 and 2014, and the remnant infestation would have then had the opportunity to spread back into the treated areas in 2015, when it was detected during the medium-intensity detection protocol. Second, the row of mature blue gums (~60 m in height) adjacent to this remnant infestation could have physically impeded aerially deployed beads from being deposited at the base of the trees. The existence of this remnant infestation perhaps argues for the implementation of a buffer >50 m and the use of multiple detection methods wherever possible, as recommended for vertebrate eradication programmes (Russell et al. 2005; Howald et al. 2007).

Based on surveys of non-target species on and around toxicant-containing beads, we do not anticipate that direct contact with toxicant-containing beads will result in large non-target effects. These results are broadly consistent those of Boser et al. (2014), who also found relatively few non-target arthropods at toxicant-containing beads. Incidental observations made in 2012–2014 indicate the endemic island foxes frequently consume the bait and pass it in their scat. The fox population is carefully monitored as part of fox recovery efforts (Coonan et al. 2010), and to date, the treatments and subsequent bait consumption have produced no detectable effects on foxes. Some non-target effects may result from this eradication effort, but the methods (colourless solid bead and solution) used to deploy the toxicant are designed to minimize unintended environmental impacts (e.g. contact with pollinators) and will likely be transitory given the relatively short environmental half-life of thiamethoxam (Goulson 2013) and the low concentration used.

This programme appears to offer conservation land managers a new tool to achieve a rare outcome; the elimination of large infestations (>40 ha) of Argentine ant. Prior to initiating any ant eradication programme, it is imperative to determine whether funding is available to complete the proposed project. Including all 14 treatment deployments, our treatment protocol cost approximately \$1400 per ha. These per ha costs were exceeded by the costs of the high-intensity detection protocol (c. \$2200 per ha) but not by the cost of the medium-intensity detection protocol (c. \$500 per ha). Future costs of this eradication programme will include continuation of the medium-intensity detection protocol, which is scheduled to continue through 2018 and will be adapted to accommodate any additional data on detection or persistence probability. Depending on the particular circumstances, eradication plans might be more cost-effective if they increase the number of treatments to increase the likelihood of eliminating remnant infestations and to decrease costs associated with long-term detection efforts. The protocol described here was recently adopted by an Argentine ant eradication programme on San Clemente Island, where approximately 450 ha was infested (Merrill 2015). As described here, our protocol represents a versatile and potentially adaptable method for ant eradication in different environmental contexts.

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