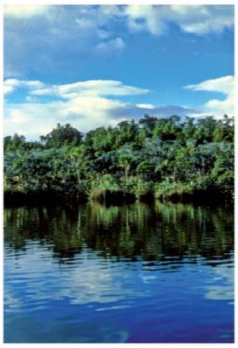

Progress on the eradication of Argentine Ants

Envirolink Advice Grant: 1471-NLRC172

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Progress on the eradication of Argentine Ants

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July 2014

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Landcare Research Contract Report:	LC1876

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Contents

Summary

Project and Client

- This report forms the basis for an Envirolink project (1471-NLRC172) initiated by the Northland Regional Council.

Objective

- The aim of this project is to use surveillance-data freedom modelling to increase the efficiency of post-treatment surveys to provide an increased likelihood of eradicating Argentine ants from large areas (e.g. islands, or mainland communities).

Methods

- We used the spatially explicit surveillance data model developed by Anderson et al. (2013) to estimate the probability that Argentine ants had been eradicated from the Schoolhouse Bay area (Kawau Island) given the absence of Argentine ants from the four monitoring trips (in March 2013, October 2013, November 2013, and February 2014) conducted since ant control was applied.

Results

- No Argentine ants have been detected at Schoolhouse Bay since the control operation took place.
- The median probability of eradication (POE) of Argentine ants from Schoolhouse Bay was 0.957 (using parameter set2). There was also a high level of confidence in the POE result, with a high Credible Interval Value (CIV) of 0.87 (i.e. 87% of the POE estimates were greater than the threshold value of 0.9).
- The probability of eradication increased sharply as each survey was conducted.
- Combined modelling of all surveys and sampling devices indicates there are several small spatial gaps that have had less survey effort. Such gaps might be a refuge for a small Argentine ant population. These gaps are generally on the north-facing slope behind the residential houses.

Conclusions

- Currently, we put the success at Schoolhouse Bay down to baiting during the spring period (i.e. spring baiting). However, because this is the only trial of “spring baiting” it remains to be seen if subsequent control programmes at other sites also achieve the same result.
- Surveillance-data modelling provided important information on: i) overall probability of eradication, ii) spatial gaps in surveys, and iii) trade-off between the number of surveys and validation of eradication.

Recommendations

- Utilise spring baiting for control of Argentine ants and document the results for applied management.
- Continue to measure the sensitivity of different survey methods for detecting Argentine ants to be able to make further estimates of the probability of eradication.
- For future eradication programmes, we recommend exploring the concept of delaying post-treatment surveys for Argentine ants for several years in order to maximise probability of detection while minimising resource use.
- Measure population recovery of Argentine ants to help understand the speed of potential population recovery and spread after control.

1 Introduction

Ants are recognised globally as significant exotic invaders (Holway et al. 2002). Invasive ants have particular significance for New Zealand, where there are few native ants (Ward 2009a), and many globally invasive ant species are not yet present. Thus, keeping further invasive ant species from establishing in New Zealand has been a priority (Lester 2005; Stringer et al. 2010, 2011; Ward 2007, 2009b; Ward et al. 2006, 2008), as has slowing the spread of Argentine ants within New Zealand (Ward et al. 2010).

1.1 Argentine ants

The Argentine ant, Linepithema humile (Mayr), is considered a significant global pest (Roura-Pascual et al. 2011). The species is highly invasive and has been accidentally introduced by human trade to many countries throughout the world (Suarez et al. 2001; Holway et al. 2002; Roura-Pascual et al. 2011). Where Argentine ants have been introduced they have invaded numerous habitats, including coastal sage scrub in southern California, riparian woodland in California, matorral in Chile, fynbos in South Africa, subalpine shrubland in Hawaii, and oak and pine woodland in Portugal (Holway et al. 2002). In terms of their impacts on biodiversity, the primary effect of Argentine ants is the displacement of native ant species (Holway et al. 2002; Stringer et al. 2009).

Whether through direct predation, resource or interference competition, Argentine ants exclude the majority of other ants from an area, resulting in the ‘disassembly’ of native ant communities (Sanders et al. 2003). Consequently, there are ecosystem flow-on effects. For example, in California, horned tailed lizards, which rely on native ants as a food source, have reduced growth and survival in the presence of Argentine ants (Suarez & Case 2002). In South African fynbos, Christian (2001) identified a shift in plant community composition, with a decline in large-seeded plants that are spread by native ants, but not Argentine ants. In anthropogenic environments, Argentine ants can impact horticulture through association with the phloem-feeding Hemiptera (e.g. aphids, scale insects, mealybugs), particularly on citrus and grapes, and the destruction of beehives and irrigation systems (Vega & Rust 2001). In urban areas, Argentine ants can create a major nuisance due to their attraction to food and sheer numbers living in houses (Smith 1965).

It has been 25 years since Argentine ants were first discovered in Auckland, New Zealand (Green 1990). Through human-mediated dispersal, they are now relatively widespread, but patchily distributed, in many North Island towns and cities, and also in several locations in the South Island (Ward et al. 2010).

In New Zealand, Argentine ants are known to occupy a range of ‘open-habitat’ ecosystems, including native habitats and anthropogenic environments (e.g. urban, horticulture) (Lester et al. 2003; Ward et al. 2005; Stringer et al. 2009). Recent studies have shown Argentine ants can interfere with the success of biological control agents released for the control of boneseed, Chrysanthemoides monilifera ssp. monilifera, (Paynter et al. 2012) and also potentially increases the reproductive output of boneseed (Stanley et al. 2013). Argentine ants have also been shown to interrupt the decomposition processes via displacement of invertebrate communities (Stanley & Ward 2012).

Argentine ants spread by two mechanisms. First, human-mediated dispersal occurs across large spatial scales such as introductions into new countries and long distances within a country (Suarez et al. 2001; Ward et al. 2005). Second, at a local scale, spread occurs through budding (when a new colony breaks off from a central colony). Unlike many ant species, the reproductive stages of Argentine ants (i.e. queens) do not disperse by flying, so self-dispersal (via budding) limits the invasion rate of Argentine ants to ~150m or less per year (Suarez et al. 2001). This has enormous implications for the overall management of Argentine ants. Slowing the large-scale spread of Argentine ants (by humans) essentially restricts them to localised areas that can then be the focus of control or eradication operations.

1.2 Eradication of ants

Invasive ants are generally regarded as being very difficult to eradicate. Eradication is often possible from small scale plots (Hoffman 2011), and when a species is discovered early in its establishment phase such as post-border incursion (e.g. Lester & Keall 2005). Historically, the majority of eradication attempts at larger scales have failed, mostly because the species has spread too fast or because treatment was stopped due to environmental concerns about the toxicants being used (Hoffman 2011).

However, a number of modest-scale eradications have now been successfully documented (e.g. Little fire ant, 2 ha, Abedrabbo 1994; Little fire ant, 22 ha, Causton et al. 2005; Argentine ant, 12 ha, Davis et al. 1993; African big headed ant, 30 ha and Tropical fire ant, 3 ha, Hoffmann & O'Connor 2004) indicating larger-scale eradication of invasive ants may be possible, given adequate resources.

In contrast to invasive ants, eradication of vertebrates is well established, with many examples of eradication from numerous species and from increasingly larger areas (Parkes 1990). For vertebrates, six strategic rules must be met for eradication to be possible (Parkes 1990; Edge et al. 2011):

- all target animals must be put at risk to the methods being applied
- target species must be killed at rates faster than their rate of increase at all densities
- the risk of recolonisation must be zero
- social and economic conditions must be conducive to meeting the critical rules
- where the benefits of management can be achieved without eradication, discounted future benefits should favour the one-off costs of eradication over the ongoing costs of sustained control; and
- animals surviving the campaign should be detectable and dealt with before an increased population size becomes obvious.

Rules 1–3 are crucial rules and must be met for eradication to proceed. Rules 4–6 are regarded as desirable.

Rules or criteria for the eradication success of ants are far less developed. However, Hoffman (2011) attributed eradication success for invasive ants to eight criteria being met:

- a single line of project management authority
- over-arching legal authority
- sufficient resources
- early intervention (i.e. small, isolated populations)
- susceptibility of the target organism to control procedures
- detectability of the target organism at low densities
- prevention of reinvasion; and
- prevention of invasive succession.

Hoffman's (2011) criteria are more heavily orientated towards operational resources (lines of authority, resources) and on early intervention, which currently gives a far greater chance of success for invertebrate eradication efforts (Tobin et al 2014).

Only two criteria are the same:

- detectability of the target organism at low densities, and
- prevention of reinvasion

Interestingly, "detectability" is not regarded as a crucial rule for vertebrates but is only a desirable rule. Perhaps this relates to the difference in body sizes between vertebrates and ants, because currently for ant eradication programmes "detectability" is critical to ensure success (Stanley & Ward 2008; Hoffman 2011; Stringer et al. 2011; Ward & Stanley 2013).

1.3 Detection and Proof of Eradication

In the initial control operation(s) typically ~99% of invasive ants are controlled, and the surviving ant colonies remain restricted to a *very* small area (<few metres). Thus, post-treatment surveys for ants need to be extremely thorough and repeated. Finding these 'survivors' (i.e. the last 1% of ants) is currently a major challenge for eradication programmes, and because of this, much time and resources are spent on finding and controlling only 1% of ants.

Thus, having a better understanding of, and improving, "detectability" is one of the most critical factors to increase the success of eradication.

Typically "eradication success" is declared after a certain time when the pest has not been found, for example, 2 years post-treatment (this as has been the minimum standard used for most published ant eradications, Hoffmann et al. 2010). **However, the lack of detection does not prove a pest is actually absent**. It may still be present in an area somewhere but cannot be easily detected.

Modelling the probability of eradication success (i.e. **proof of freedom** from the pest) is crucial in achieving confidence in eradication.

This type of modelling is also very useful in understanding the resources needed to achieve certain confidence levels. For example, modelling will help avoid prematurely declaring success due to insufficient survey effort or, conversely, avoid wasting resources on surveys when the pest has been eradicated from an area.

2 Objectives

The aim of this project is to use surveillance-data freedom modelling to increase the efficiency of post-treatment surveys to provide an increased likelihood of eradicating Argentine ants from large areas (e.g. islands, or mainland communities).

- The guidelines will be based on the concepts of 'search theory' and probabilistic modelling for detecting rare objects (i.e. ants) in a landscape.
- Using existing field-collected data (from Schoolhouse Bay, Kawau Island), a set of "rules" on the amount of resources required, and on when and how these resources should be allocated for a control or eradication programme will be developed.

3 Methods

3.1 Kawau Island

Kawau Island is one of the larger islands in the Hauraki Gulf, <2 km from the mainland and about 45 km north of Auckland. The climate is warm temperate/sub-tropical with the majority of the island covered in scrub (mainly kānuka, mānuka).

Schoolhouse Bay is one of many bays on Kawau Island with a small residential area (approximately 20 houses).

Argentine ants were found at Schoolhouse Bay in 2010, and further delimiting surveys across Kawau Island, and within Schoolhouse Bay, were carried out in 2011 (Browne & Craddock 2011).

Auckland Council has been the lead agency in charge of the eradication programme, responsible for the delimiting surveys, the control operation, public education and awareness, prevention of re-invasion, and follow-up surveys for Argentine ants.

3.2 Control Operation and Post-Control surveys

For control, the concept of "spring baiting" was utilised at Schoolhouse Bay. Over the cooler winter period, nests of Argentine ants aggregate together and typically occupy the warmest, driest locations of the infested area. This aggregation provides an ideal situation for control because there are fewer, but larger, nests in an area. This, in theory should give greater control success. However, this aggregation of nests begins to break up in late spring and early summer, as Argentine ants expand their territory over summer. Thus, "spring control" aims to control nests while they are still aggregated and just before the summer expansion period.

Richard Toft of Entecol was contracted by Auckland Council to undertake the control operation. Control of Argentine ants at Schoolhouse Bay took place on 3 October 2012 with a team of 12 people. Xstinguish Argentine ant bait was laid across the infested area and a 50 m buffer zone (~3 ha in total) at ~2 m intervals (Fig. 1).

Several post-control surveys have been undertaken at Schoolhouse Bay to monitor i) the initial outcome of spring baiting control, and ii) inform the goal of eradicating Argentine ants.

Several different methods of surveillance were carried out during these surveys, including visual hand searching; baited pottles (with non-toxic "Inform" bait); and a sniffer-dog (trained by Auckland Council).

Several 'paths' were used to cover the entire Schoolhouse bay area. These paths were documented with GPS and used for all three surveillance methods (Table 1; Fig. 2). Surveillance along each path for each survey period was not the same due to logistics and resources. Areas covered by houses were excluded from the area of inference because no internal searching of houses has been carried out (i.e. in model input was risk of infestation = 0).

Information from these surveys has been used within the modelling component of this project. The modelling estimates the sampling sensitivity for each survey and updates the probability of eradication with each survey result.

3.3 Proof of Eradication Modelling

Concept

We used the spatially explicit surveillance data model developed by Anderson et al. (2013) to estimate the probability that Argentine ants had been eradicated from the Schoolhouse Bay area given the absence of Argentine ants from four surveys (in March 2013, October 2013, November 2013, and February 2014) conducted since control was applied.

The model estimates the overall sensitivity of the surveillance (i.e. the probability of detecting Argentine ants given they are present) using a 1-m grid-cell resolution across the modelled landscape. Following a survey where ants are not detected, the sensitivity of the surveillance method is used to update the probability of ant eradication using Bayes theorem.

Model inputs

Under the framework of Anderson et al. (2013) there are two key spatial sensitivity parameters:

- the maximum probability of detecting an ant or its nest (g0) if the surveillance device was placed directly on top of it, and
- a spatial decay parameter (σ), which modifies how the probability of detection declines with distance from the surveillance device.

The spatial sensitivity parameters for the baited vials was derived by fitting a half-normal function to the curve shown in Figure 2 of Stringer et al. (2011) describing the probability of detecting foragers from a small nest of the red imported fire ant (Solenopsis invicta) using baited vials placed out for 1–2 hours at different distances from the nest, giving fitted values of g0=0.548 and σ=1.331 (Fig. 3). At the 1-m2 cell resolution, these parameters give a 0.70 chance of detecting an ant nest if it is in the same cell as a baited vial and the vials are spaced 2m apart along the path.

Although the above parameters were developed for fire ants, we believe they are biologically relevant to Argentine ants. Our reasoning is that when ant colonies (no matter what species) are very small, they have a very small foraging area, and thus their detection (by baits, visual searching, etc.) is harder.

We developed two model sets. In the first instance (parameter set1) we assumed the same g0 and σ values as those described by Stringer et al (2011) and assumed 2-m spacing between detection points for all three surveillance methods.

Second (parameter set2), we attempted to better represent the detection range of two surveillance methods (visual searching, sniffer dog), for which information was specifically available for Argentine ants (Ward & Stanley 2013; Landcare Research, unpublished data).

We modified values from Stringer et al. (2011), restricting visual searching to a 1-m decay and increasing the decay of the sniffer dog to 4 m, and changed “device” spacing to give an equal detection probability along the path bearing (distance=0) as a result of the overlapping detection kernels.

Parameter set2 used in parameter estimates of g0=0.733, σ=0.4 and a “search” spacing of 1m for visual searching, and g0=0.750, σ=1.65 and a “search” spacing of 2 m for the sniffer dog (Fig. 3), equivalent to a per-cell probability of 0.75 and 0.9 of detecting an ant nest if the person or dog respectively is in the same cell as the ant (based on Ward & Stanley 2013).

In both parameter sets, σ and g0 parameter values were allocated a standard deviation equivalent to a 10% Coefficient of Variation around the mean value to account for the large uncertainty in model parameters.

Other technical input values

A relatively pessimistic “prior” probability of eradication being successful was specified using a Pert distribution with a most likely value of 0.25 (range 0–0.75). The “prior” is our estimated probability that ants were still present on the island at the time of the post-treatment surveys.

The design prevalence or the minimum number of 1-m2 cells within the Schoolhouse Bay Area likely to be infested if ants were still present was set to one (i.e. one surviving colony).

The annual probability of re-introduction of ants into Schoolhouse Bay was assumed to be very low (because of ongoing Auckland Council education and surveillance in the area), described by a Pert distribution with a most likely value of 0.01 (range 0–0.012).

Point locations of the baited vials used in this study were derived by spacing 500 vials along the Schoolhouse Bay search paths using the ArcGIS 10.2.1 “Construct Points” function. The visual and dog searches did not conform to the model structure of detection devices, being linear and continuous rather than discrete points in space; however, we assumed continuous search along a path was equivalent to a series of detection devices distributed evenly along a path.

4 Results

4.1 Control Operation and Post-Control surveys

No Argentine ants have been detected at Schoolhouse Bay since the control operation took place. This is despite intensive searching from four survey periods. This was a surprising result, as in past control operations a small number of 'survivor nests' remained.

4.2 Proof of Freedom Modelling

Probability of eradication

The overall sensitivity of the surveillance was very similar between parameter set1 and parameter set2; therefore, the results below mention only parameter set2, which we believe gives more realistic measurements of device sensitivity.

Overall, the median probability of eradication (POE) of Argentine ants from Schoolhouse Bay was 0.957 (i.e. 96%). There was also a high level of confidence in the POE result, with a high Credible Interval Value (CIV) of 0.87 (i.e. 87% of the POE estimates were greater than the threshold value of 0.9). This is based on the combined efforts of four survey periods, three search methods, as outlined in Table 1.

The probability of eradication increased sharply as each survey was conducted (Fig. 4), in line with theoretical concepts that increased search effort gives increased detection probability. Figure 4 shows at least 3–4 surveys are needed to get >0.8 probability of eradication.

Spatial gaps in searching at Schoolhouse Bay

Combined modelling of all surveys and sampling devices indicates there are several small spatial gaps that have had less survey effort (see Fig. 5). Such gaps, which might be a refuge for a small Argentine ant population, are generally on the north-facing slope behind the residential houses (yellow-orange-white colours of Fig. 5). The terrain in this section is the most difficult to move through and conduct surveys, and thus needs further survey effort.

Table 1. Details of which surveillance methods were utilised along different pathways (see Figure 2) and survey periods. An '×' means surveillance was undertaken

Pathway	Surveillance Method	March 2013	October 2013	November 2013	February 2014
1	Bait		×	×	×
2	Bait		×	×	×
3	Bait			×	×
4	Bait			×	
1	Visual	×	×	×	×
2	Visual	×	×	×	×
3	Visual	×	×	×	×
4	Visual	×		×	×
1	Dog		×	×	×
2	Dog		×	×	×
3	Dog				×
4	Dog		×	×	×

Figure 1. Aerial map of Schoolhouse Bay showing area infested with Argentine ants (orange) and buffer zone where control also took place but which did not have Argentine ants (pale yellow).

Figure 2. Map of Schoolhouse Bay study site and location of paths where searching for Argentine ants was conducted (based on GPS locations). Grey shaded areas are houses.

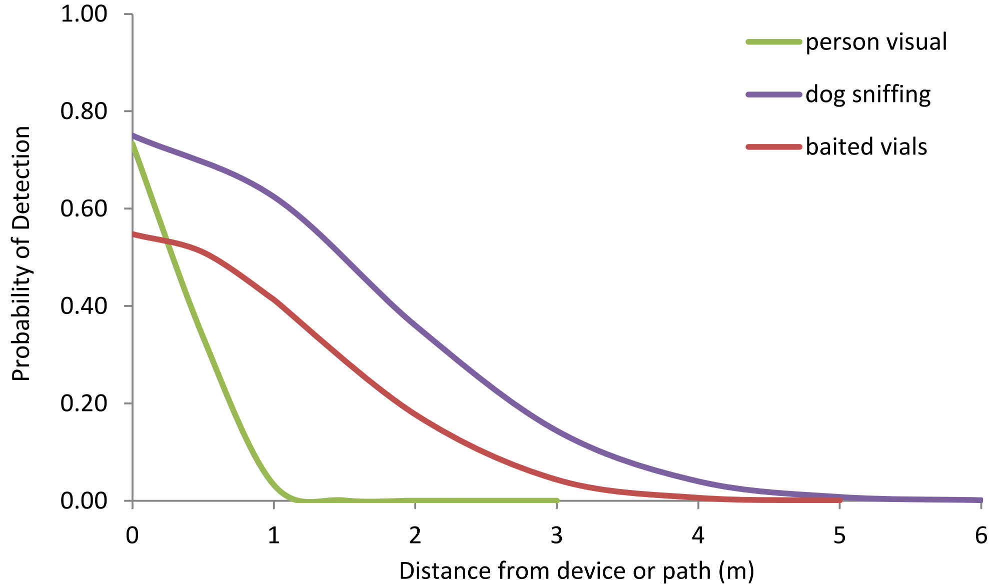

Figure 3. Half-normal function describing the probability of detecting an argentine ant or nest with distance from a device (baited vials) or from a point along a path (person visual, sniffer dog).

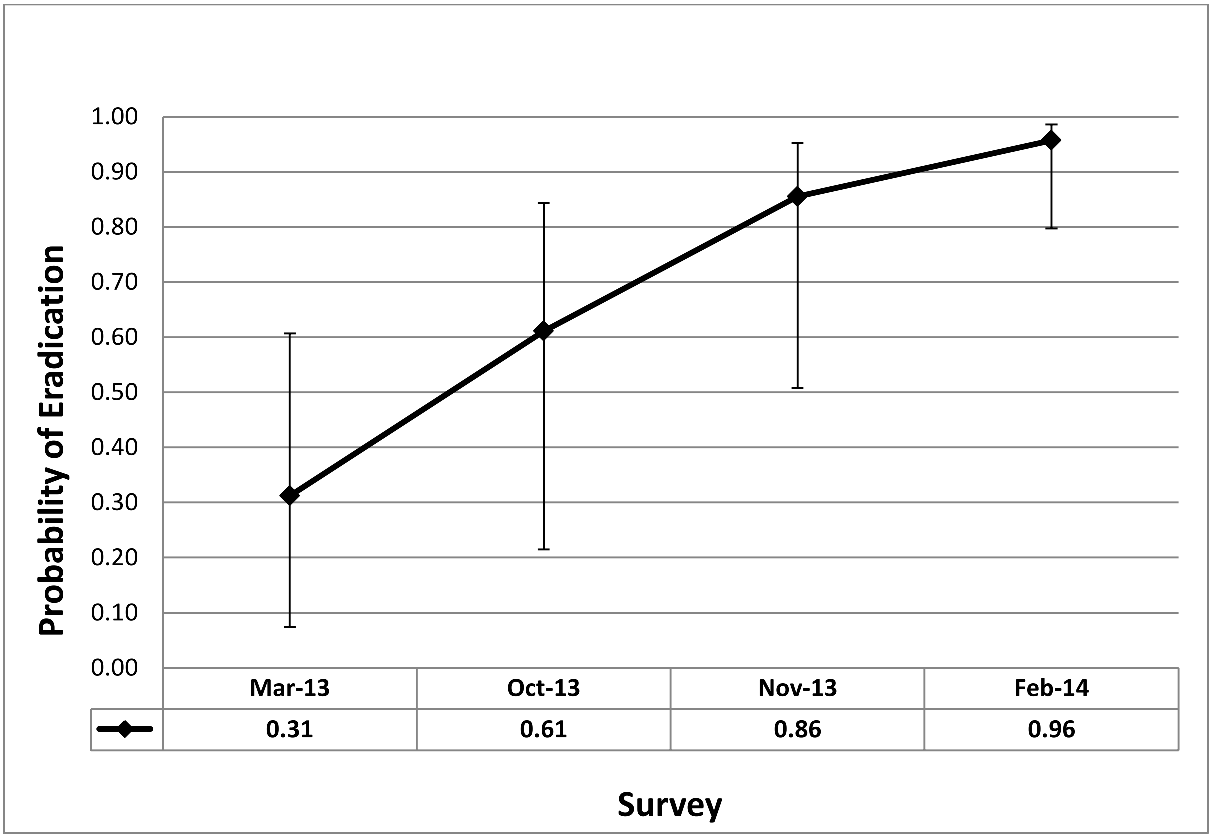

Figure 4. Predicted median probability (with 5th and 95th quantiles) of Argentine ant eradication in the Schoolhouse Bay area given negative surveillance across 4 surveys and system sensitivities for parameter set2.

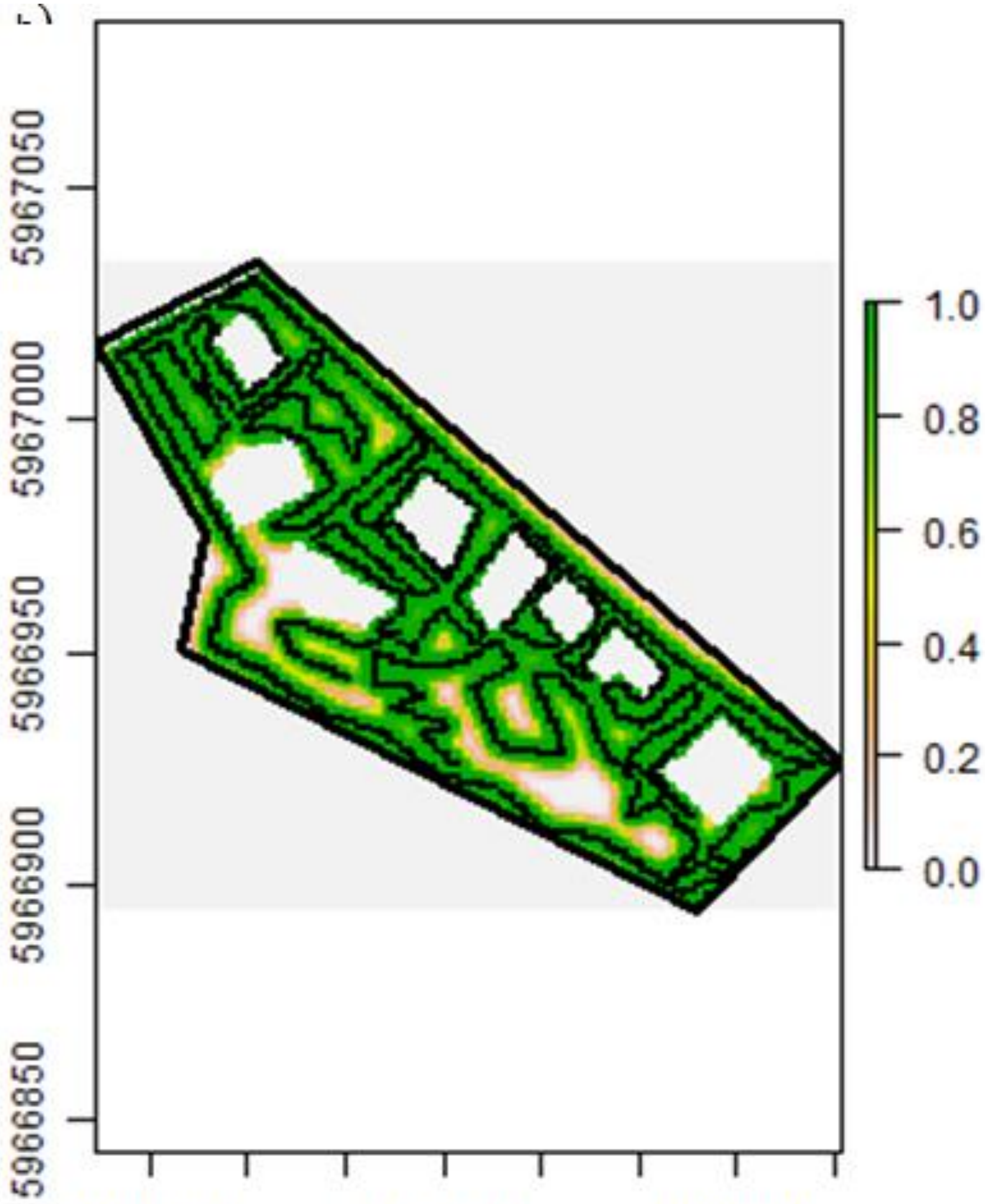

Figure 5. Combined system sensitivities for the detection of Argentine ants across the Schoolhouse Bay study area (high probability of detection = green; low probability = yellow-orange-white) from baited vials, visual searching and the sniffer dog using parameter set2. The large 'square' white areas are houses, which were excluded from analyses.

5 Conclusions

5.1 Eradication Success at Schoolhouse Bay

Previous control operations elsewhere in New Zealand have typically found a small number of 'survivor nests' remain, which meant eradication has remained elusive. Thus, it is surprising not to have found Argentine ants at Schoolhouse Bay subsequent to the control operation (3 October 2012). Currently, we put this success at Schoolhouse Bay down to baiting during the spring period (i.e. the spring-baiting concept). However, because this is the only trial of "spring baiting" it remains to be seen if subsequent control programmes at other sites achieve the same result.

Another survey (the fifth) was already scheduled (~October 2014) for Schoolhouse Bay before this modelling was undertaken. This survey should be completed in order to allow i) a full 2 years of post-treatment surveys, and ii) to provide even more confidence for any 'declaration' of eradication at Schoolhouse Bay. The results of the modelling (Fig. 5) will be used to guide this fifth survey, and intensive searching will be undertaken in the areas identified in Figure 5.

5.2 Rules for eradicating Argentine ants

Eradication of Argentine ants is feasible. Two main factors make this possible:

- Argentine ants are susceptible to current chemical control methods
- The biology of Argentine ants restricts them to *very localised areas*, and unless they are transported long distances by humans, this means they typically occur in small isolated populations – ideal for control or eradication operations (Hoffman 2011).

Many populations of Argentine ants across New Zealand are currently in small isolated populations, for example, in small towns and communities, or restricted to certain suburbs of a city. These scenarios are essentially akin to "offshore islands" (i.e. isolated), with the opportunity for eradication.

Modelling provided useful information to help develop rules, specifically about resource allocation for the detectability of the Argentine ants at very low densities.

Models provided information on three main areas:

1. *Overall probability of eradication*. This provides authorities with a level of confidence in the overall result and justification for the allocation of resources required to meet this probability level. It also allows the setting of stop/go points in terms of planning. For example, if a target probability of 90% had been set, resources can be withdrawn when that target is met, or additional resources used to ensure the target is achieved.

2. *Spatial gaps in surveys*. This provides the identification of areas where search effort has been too low, and thus allows subsequent surveys to be directed to

search these areas. This ensures there are no refuges available for a pest population, and ultimately gives increased confidence of the overall probability of eradication.

3. *Trade-off between the number of surveys and probability of eradication*. This allows an indication of the resources needed to achieve certain confidence levels. For example, modelling will help avoid declaring success prematurely due to insufficient survey effort or, conversely, avoid wasting resources on surveys when the pest has been eradicated from an area.

5.3 Resources for post-treatment surveys

Proving eradication has been achieved (i.e. proof of freedom) is challenging, and typically requires more resources than the initial control operations.

Given Argentine ant control/eradication must compete with ongoing demands from multiple pest/weed issues, is it feasible for authorities to provide resources for post-treatment surveys to prove eradication?

For future eradication programmes, our suggestion is to **delay** post-treatment surveys **for at least several years**.

After the initial control operation, Argentine ant colonies will remain extremely small, and will say so for at least several years. **Thus, trying to detect Argentine ants *within* this *immediate* post-treatment period is the most difficult and the most resource intensive**.

Delaying post-treatment surveys would allow Argentine ant numbers to build-up so that their detection would ultimately become much easier while utilising fewer resources. However, there is a **trade-off**: leaving post-treatment surveys for ‘too long’ would allow Argentine ants to re-colonise the same pre-control area (i.e. population recovery).

There is a window of time where post-treatment surveys should ideally be completed: i) not immediately after post-treatment where detection is most difficult, but ii) not so long after treatment that Argentine ants are able to re-colonise.

Currently, we have no estimates of what this window of time would be. However, it is important to measure the population recovery of Argentine ants after control to determine how long they would take to re-occupy the same range (e.g. 3, 5, 10 years?). Measuring population recovery would allow eradication programmes and post-treatment surveys to proceed. It would also maximise the probability of eradication while minimising resource use.

6 Recommendations

- Utilise spring baiting for control of Argentine ants and document the results for applied management.
- Continue to measure the sensitivity of different survey methods for detecting Argentine ants to be able to make further estimates of the probability of eradication.
- For future eradication programmes, we recommend exploring the concept of delaying post-treatment surveys for Argentine ants for several years in order to maximise probability of detection while minimising resource use.
- Measure population recovery of Argentine ants to help understand the speed of potential population recovery and spread after control.

7 Acknowledgements

Thanks to Northland Regional Council (Steve Henderson, Don McKenzie) for supporting this Envirolink project in order to allow modelling, write-up, and tech-transfer of field collated data. Thanks to Auckland Council staff for organising the Schoolhouse Bay eradication programme (Jeff Cook, Brian Shields, Nick Waipara) and also the many volunteers for helping with surveys. Auckland Council has been the lead agency on Kawau Island and in charge of the eradication programme, responsible for the delimiting surveys, control operation, public education and awareness, prevention of re-invasion, and follow-up surveys for Argentine ants. We are very grateful to them for providing an opportunity to conduct scientific research and use it to inform operational outcomes. Thanks also to Richard Toft of Entecol for details of the control operation. This work was also supported by the Ministry for Science and Innovation through funding of the Managing Invasive Weeds, Pests and Diseases Portfolio at Landcare Research.

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