Improving ant eradications: details of more successes, a global synthesis and recommendations

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Invasive ant management has a poor track record, partly exacerbated by the lack of publication of project outcomes detailing both what did and didn't work. Here we detail 11 eradications of five species, which are all the remaining eradications that we are aware of that have not been published. Data from these eradications are combined with all other published successes to provide a brief summary of the 76 records of ant eradications achieved without the use of organochlorines, and compared with successes achieved within the organochlorines era. The majority of eradications (42) are very small (< 1 ha), in some cases being just one or a few nests. Two species, Pheidole megacephala *and* Anoplolepis gracilipes, *were the targets of most eradications (30 and 24 respectively). It is only in the last decade that the size of eradications has greatly increased, but the largest eradication covered only 41 ha. In contrast, approximately 3000 infestations covering approximately 15,800 ha were eradicated over the equivalent time using organochlorines, the largest eradication covering approximately 300 ha. We then discuss the current global status of ant eradication management options, and identify what we see as the actions that will provide the greatest immediate enhancement of invasive ant management, which are proactive management and greater incorporation of ant biology into eradication protocols.*

Fig. 1. Yellow crazy ant *Anoplolepis gracilipes* worker (left) and queen (right). Photo: Phil Lester

Introduction

Ants are disproportionally represented as invasive taxa and equally disproportionate is our appalling record of dealing with their invasions, with only 12 publications confirming eradications despite nearly a century of efforts (Hoffmann et al. 2010).
However, our poor track record of effectively dealing with invasive ants may not only be due to the real difficulty of the task, but be partially because of a lack of publication of project outcomes (Wittenberg and Cock 2009).
In contrast to scientific research on exotic species that must be formally published to be recognised, eradication programs are not required to communicate their results, good or bad, to a global audience, and consequently a vast amount of valuable information about ant eradications, including successful completions, remains either as grey literature or unrecorded. This lack of dissemination of information, especially of lessons of failure that indirectly results in others making similar mistakes, is no doubt hindering the advancement of ant eradications.
Here we detail 11 eradications of five species, which are all the remaining eradications that we are aware of that have not been published. We define an eradication as the complete extirpation of a spatially and reproductively isolated population in a landscape with or without the persistence of other spatially and reproductively discrete populations. Eradication was deemed to have been achieved two years after the final treatment, irrespective of the date of any formal declaration of eradication. Additionally, we present a brief summary of the cumulative record of ant eradications, and the global status of ant eradication management options. Finally, we identify what we see as the actions that will provide the greatest immediate enhancement of invasive ant management.

Eradications

Argentine ant, Victoria Park, Western Australia
A 1 ha infestation of Argentine ant *Linepithema humile* around a shopping centre in the Perth suburb of Victoria Park in Western Australia was baited with 5 g/kg hydramethylnon contained within the Department of Agriculture and Food Western Australian (DAFWA) bait matrix. Two treatments were conducted in July and August 1994. No *L. humile* have been found in multiple visual surveys since the second treatment.

Argentine ant, Perth, Western Australia
A 6 ha *L. humile* infestation encompassing the Sir Charles Gairdner Hospital in Perth, Western Australia was delimited and treated in August 1996 using 10 g/kg sulfluramid within the DAFWA bait matrix. A small area required retreatment 43 and 88 weeks later. No Argentine ants have been detected by visual surveys in this area since.

Argentine ant, Brisbane, Queensland
A 41 ha *L. humile* infestation in the Brisbane suburb of Geebung, Queensland was treated in December 2002 using the DAFWA bait matrix containing 10ppm fipronil.
A second treatment covering 7ha of surviving ants was conducted in March 2003. Post-treatment assessments of this work are potentially insufficient, but no *L. humile* have since been found in visual assessments, the last assessment occurring on July 15 2008.

Red imported fire ant, Yarwun, Queensland
An infestation cluster of Red imported fire ant *Solenopsis invicta* covering approximately 0.5 ha, as well as an additional two isolated nests approximately 1.5 km from the cluster (considered as a single infestation) were discovered at Yarwun, Queensland in March 2006. All visible mounds were treated with direct injection using fipronil, and a granular bait containing hydramethylnon was dispersed in heavily infested areas. Additionally, six prophylactic treatments extending to 1 km from the main infested area were conducted between May 2006 and November 2007 using granules containing s-methoprene or pyriproxyfen. The last *S. invicta* was detected in September 2006, prior to the cessation of the delimiting surveillance in November 2006. Visual post-treatment assessments confirming eradication were conducted in May and June 2009.

Tropical fire ant, Perth, Western Australia
An infestation comprising a single Tropical fire ant *Solenopsis geminata* nest was detected at a commercial nursery in the Perth suburb of Wanneroo, Western Australia, during surveillance for Red imported fire ant *S. invicta* in May 2005. The nest and the surrounding 50 x 50 m area were treated the following day using the DAFWA bait matrix containing 10 ppm fipronil. Two days later, the surrounding 3,000 potted plants were rod-injected with chlorpyrifos at a rate of 40 mL (of 500 g/L chlorpyrifos) per 100 L of water. The bay, once cleared of these plants, was then sprayed with fipronil, followed by a broadcast of Amdro®. No *S. geminata* have since been found.

Tropical fire ant, Port Hedland, Western Australia
A 1,500m^2 *S. geminata* infestation was detected in a nursery in Port Hedland, Western Australia during surveillance for Red imported fire ant *S. invicta* in August 2005. The nursery was sprayed with 5 g/L chlorpyrifos and 500 potted plants were rod injected. Due to continued *S. geminata* activity, a sec-

ond application was applied in early September and a third using pyriproxyfen baits followed by a fipronil spray several days later. No *S. geminata* have been seen since the third treatment, with the last formal inspection occurring in August 2007.

Tropical fire ant, Waianae Mountains, Oahu, Hawaii
A small (approximately 0.05 ha) *S. geminata* population was found on a bare, sunny knoll surrounded by mesic forest at roughly 600 m elevation in March 2006. Because this location is very distant from typical open, lowland habitat where *S. geminata* predominantly occurs in Hawaii, a joint effort was initiated by the Department of Land and Natural Resources and the Oahu Army Natural Resources Program in which the population was treated twice with Amdro®. Monitoring for two years post-treatment, and an additional thorough survey almost four years later has failed to detect *S. geminata*.

Yellow crazy ant, Goodwood Island, New South Wales
A <1 ha Yellow crazy ant *Anoplolepis gracilipes* (Fig. 1) infestation was detected by quarantine monitoring at Goodwood Island Wharf in July 2004. Broadscale treatments using unregistered baits containing fipronil and s-methoprene were conducted between September 2004 and December 2005. A single treatment using a contact insecticide spray was conducted by a pest controller on the last nest found in January 2006. Five post-treatment surveys over the next two years failed to detect *A. gracilipes* and it was declared eradicated.

Yellow crazy ant, Portsmith, Cairns, Queensland
An infestation of *A. gracilipes* covering approximately 6 ha was detected at Portsmith Cairns Queensland in April 2001. This was the first detection of this ant in Queensland. The infested area received several rounds of treatment using granulated bait containing fipronil or s-methoprene and direct nest treatment using liquid fipronil. No *A. gracilipes* have been observed at this site since 2005.

Yellow crazy ant, Woree, Cairns, Queensland
An infestation of *A. gracilipes* covering approximately 6.5 ha was detected at Woree, Cairns, Queensland in March 2006. The infested area received several rounds of treatment using granulated bait containing fipronil or s-methoprene bait and direct nest treatment using liquid fipronil. No *A. gracilipes* have been observed since the end of 2006, including within formal post-treatment assessments using a grid of lures (with tuna, cat food or jam as an attractant) in 2007 and 2008.

Lepisiota frauenfeldi, Guam
Lepisiota frauenfeldi was found established in a cargo container holding area at Guam International Airport in October 2005. The area was treated twice in March and April 2007 with two baits containing boric acid and hydramethylnon respectively. Post-treatment surveys conducted tri-monthly revealed no *L. frauenfeldi* until April 2008. The area was re-treated with another two baits containing thiamexotham and orthoburic acid respectively. Tri-monthly post-treatment surveys have not detected the ant since.

Global status of ant eradications

Prior to the development of modern treatment products, ant eradications were attempted primarily using organochlorines, with mixed success. Efficacy of individual treatments could indeed be quite high, but failure to prevent the production and dispersal of new sexuals resulted in unabated spread, and re-infestation of effectively treated areas (Williams et al. 2001). As far as we are aware, only *L. humile* populations were eradicated using organochlorine sprays, presumably because this species does not disperse via a nuptial flight. Of all such programs, the only one with a published record is the one conducted in Western Australia from 1954 to 1988 (van Shagen et al. 1994).

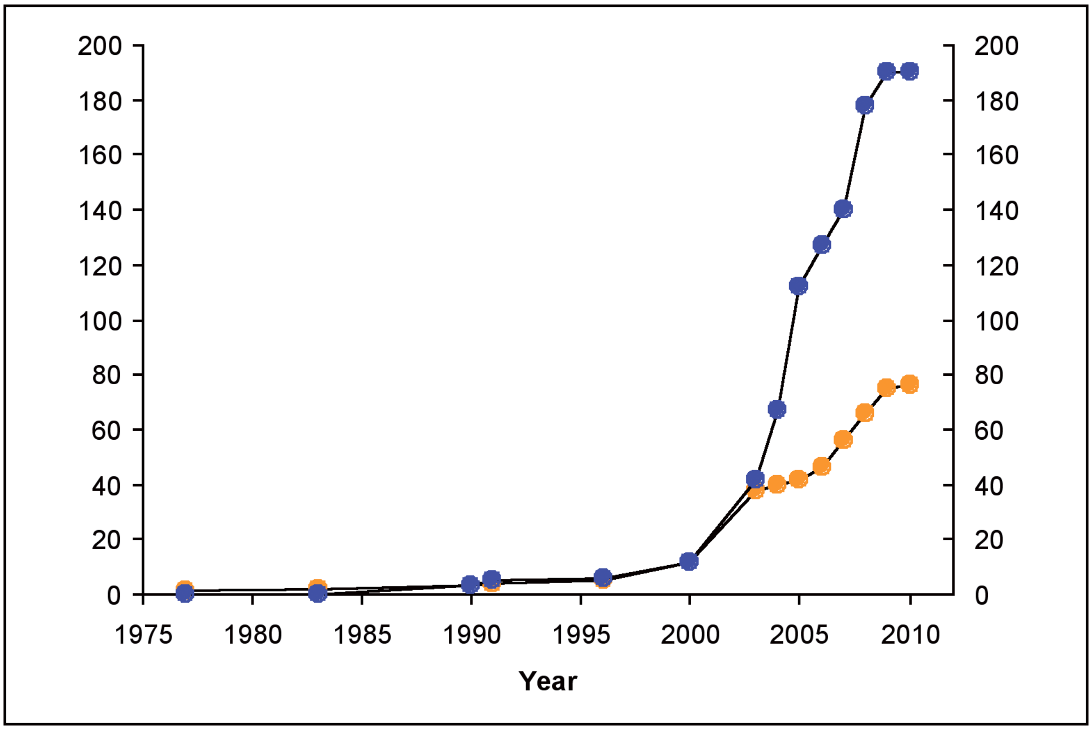

Fig. 2. Cumulative number (orange points) and area (blue points) of published eradications of established ant populations globally. Eradication was deemed to have been achieved two years after the final treatment. If treatment dates were not provided then the year of paper submission was used. An area of 0 ha was used where the size of an infestation was not detailed. Data used are from those projects detailed here, the publications listed in Hoffmann et al. 2010, as well as Plentovich et al. (2009); Hoffmann (2010) and Hoffmann (in press).

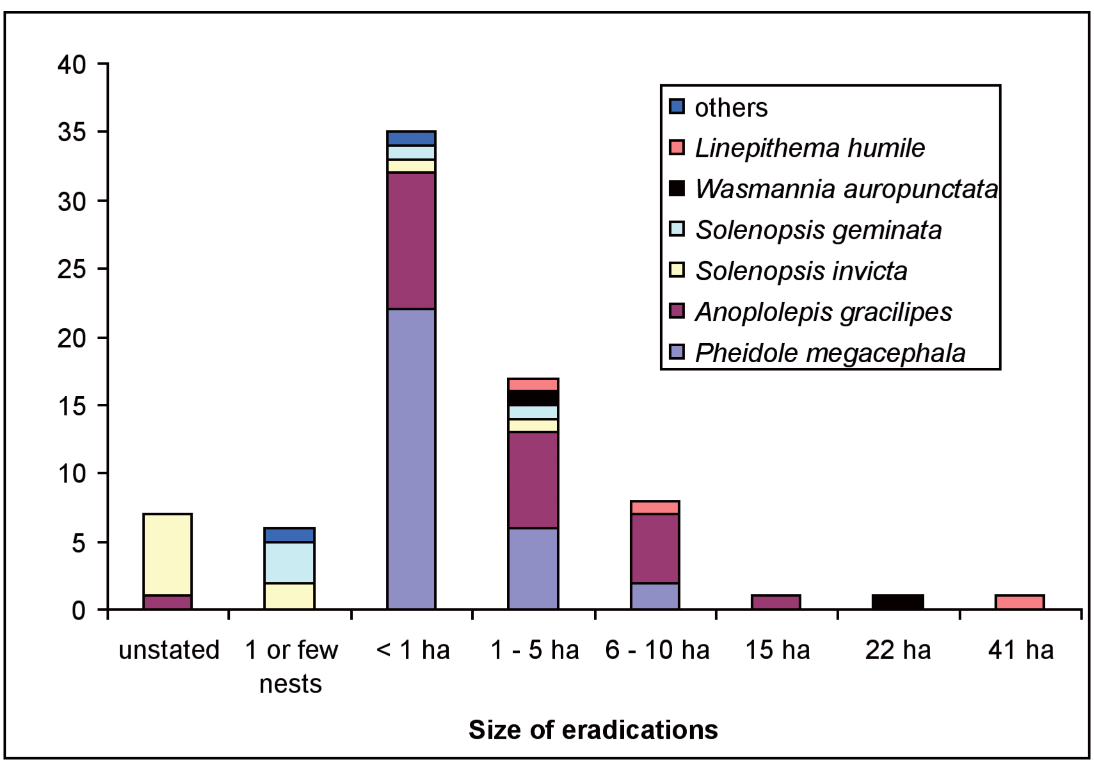

Fig. 3. Number of ant eradications in multiple size classes for multiple key species

This program reduced a combined infested area of approximately 17,300 ha to 1,458ha, of which approximately 75% couldn't be treated for environmental or residue reasons. Data for individual infestations remains unavailable, but the number of discrete eradications was approximately 3000, having an average area of about 10 ha, the largest being approximately 300 ha. Despite overall eradication not being achieved due to this program being cancelled, largely due to the lack of treatment products following the deregistration of organochlorines, we acknowledge the successful completion of the many individual eradications.

The eradication achievements within the 34-year Western Australian program that used organochlorine sprays far outweigh that of the combined global efforts using other products and methods over the past 34 years (Figure 2). Only 76 localised eradications covering 189 ha have been formally published, the great majority (72) being achieved within the last decade. It is also only in the last decade that the size of these eradications has greatly increased. The majority of eradications (42) are very small (<1 ha), in some cases being just one or a few nests (Figure 3). Two species were the targets of most eradications, *Pheidole megacephala* (30 eradications) and *A. gracilipes* (22). Interestingly the two largest eradications (41 and 22 ha) are of two species which have been eradicated the least (only two completed eradications of both species), *L. humile* and *W. auropunctata* respectively.

Eradication sizes will undoubtedly increase in the future, but then as now, there is a great difficulty in providing adequate demonstration that complete extirpation of an animal the size of an ant has occurred over large areas. Indeed, it is likely that larger eradications have already occurred against *A. gracilipes* in Arnhem Land, but are too large to adequately assess with the limited resources available. Unless new technologies or techniques are developed to alleviate this issue, it is likely that longer and longer timeframes will be required for ever larger eradications to be adequately demonstrated.

Chemical treatments directly targeting ants

Prior to the deregistration of organochlorines, broad-scale ant management programs attained the unenviable reputation of having among the greatest non-target impacts of all management efforts globally (Carson 1962; Markin et al. 1974; Summerlin et al. 1977). Since the deregistration of organochlorines, broad-scale ant treatments have changed from spraying liquid products, predominantly contact insecticides, to the broadcast spreading of granular baits. Solid baits are more targeted at ants (Williams et al. 2001), resulting in far fewer non-target issues (Marr et al. 2003; Stork et al. 2003; Forgie et al. 2006; Plentovich et al. 2010).

The increased targeting towards ants is achieved either from the bait matrix used (e.g. corn grit targeting seed-harvesting species and fishmeal for species seeking protein) which will not necessarily be consumed by other biota, or from the active constituent being predominantly non-toxic to other land-based biota (e.g. juvenile insect hormone analogues).

Ideally, treatment products would attract the target ant species and repel non-target organisms, but no such options are yet available for ant management, nor are we aware of any such products for use against any other invasive taxa.

Since the change to granular baits, one of the greatest remaining hindrances to treatment efficacy has been the lack of universally attractive and effective treatment products. Species have different preferences for carbohydrates and protein, and there can be marked seasonal differences of dietary preferences within a species (Stein et al.1990). Efficacy is additionally affected by a colony's food management strategies (e.g. stored vs utilised immediately) and nutrition pathways to the queen(s). Most baits have been developed to target fire ants (*Solenopsis* spp.), and unfortunately these baits usually have lower efficacy against other species (Rey and Espadaler 2004), particularly species that prefer aqueous sugar matrices, or are not greatly attracted to corn grit or to the oil in other dehydrated solids (e.g. *Tapinoma melanocephalum* and *A. gracilipes*). Multiple products developed most recently appear to have wider target acceptability and efficacy, which is hoped will lead to greater eradication success. Interestingly, all eradications to date of fire ants (*Solenopsis* spp.) have been achieved only by drenching all nests with liquid toxicant.

Companion methods

All ant eradications to date have been achieved using chemicals, and unfortunately non-chemical management options, especially bio-control, alone are considered unlikely to achieve eradication. The following techniques are those that we believe will provide the greatest support for eradications based on chemical treatments.

The most promising techniques target the carbohydrate supply to ants, which is a key driver of ant population densities.

Carbohydrate supply to ants can be interrupted in two ways. The first way is by reducing or eliminating populations of mutualistic phytophagous insects. Chemical control of phytophagous insects is currently possible using sprays or systemic insecticides within urban and agricultural areas (Cooper et al. 2008), but this is an unacceptable option within intact ecosystems. Thus, this technique will likely only become fully viable following the identification of biocontrol options for phytophagous insects that are effective in the presence of ants.

The second way of interrupting carbohydrate supply is by preventing ants sourcing honeydew directly from plants by the use of fire, where appropriate.

Fire, as well as other techniques such as drainage restriction (Holway and Suarez 2006), also alter habitat conditions, and can reduce the abiotic suitability of the environment to the invader and reduce nest site availability. Simultaneously, these environmental changes may increase biotic resistance from aggressive native ant species (Menke et al. 2007).

Actions needed to enhance invasive ant management

Improvements in ant eradication will inevitably occur as treatment products, methods and technologies develop (Figure 4). However, we highlight here four proven strategies that can immediately improve ant management, three of which involve a shift from reactive to proactive management. Notably, these actions are just as applicable for all other biological invasions as they are for ants.

The first is port-of-exit biosecurity. The continual occurrence of new invasions within countries like Australia with stringent biosecurity at ports-of-entry (Stanaway *et al*. 2001), demonstrate that border biosecurity as an independent strategy is far from adequate. But why should we only wait for exotic species to come to us when their arrival can also be actively avoided at the port-of-exit? New Zealand biosecurity measures recently extended into four ports in three surrounding nations, resulting in a 98.5% reduction in contamination rates of inbound goods within just 12 months (Nendick 2008).

Clearly, significant reductions of contamination rates could potentially be achieved globally if ports-of-exit ensured they were free of organisms declared as pests in trading destinations.

Second is proactive surveillance. Early detection of incursions is often a critical factor for eradication success (Simberloff 2003; Lodge et al. 2006), but proactive surveillance for new incursions has been historically rare. Instead, most governments rely predominantly or even solely on passive surveillance, being the discovery and reporting of incursions by the public. Yet simultaneously, governments often apply a disincentive to report strange biota through charges for identification services.

Fig. 4. Aerial treatments against yellow crazy ant *Anoplolepis gracilipes* in Arnhem Land, Australia, using a motorised bait dispenser slung under a helicopter. The helicopter flies along pre-determined flight paths guided by a differential GPS

Proactivity of governments to monitor high risk areas, both at and beyond the port-of-entry, would greatly enhance prospects of early detection, and hence eradication. Clear examples include the recent *S. invicta* detections and eradications in New Zealand (Pascoe 2003; Biosecurity New Zealand 2009), and the *A. gracilipes* detection, and probable eradication, in Darwin, Australia (Walters 2008).

Third is preparedness. A high level of preparedness enhances a jurisdiction's ability to rapidly initiate on-ground measures should an incursion occur, thereby enhancing the possibility of eradication. Such preparedness largely results from a proactively prepared Pest Risk Analysis (PRA: Leung et al. 2002). A PRAs basic role is to consolidate global knowledge of the biology, ecology and impacts (beneficial and negative) of target species, and use this to assess the overall potential benefit or impact within a landscape, should it establish there. If the risk of a species establishing within a region is considered unacceptable, a PRA also details on-ground procedures that actively prevent incursions, detect incursions, allow rapid response to a detection, and effectively manage established populations. In other words, a PRA developed prior to an incursion results in a jurisdiction being fully aware of the potential issues, implementing measures that prevent incursions, and being fully prepared for action should an incursion occur. While there is an almost inexhaustible list of species that can potentially invade or be analysed, PRAs should at the very least be conducted for the few species that are well known, or considered potentially to be, invasive.

Arguably the greatest benefit for ant eradications is that a PRA identifies a potential lack of treatment options available in a location, such as a proven treatment product being unregistered in the jurisdiction, or simply not being registered for use against the target species. This knowledge can subsequently be used to proactively obtain permits or registrations for product use, and even supply of treatment products prior to an incursion, thereby eliminating unnecessary delays in the commencement of treatments following a detection. Such preemptive registrations have been implemented by the New Zealand government for many invasive ants following their first experience of dealing with an *S. invicta* incursion in 2001 (S. O'Connor, personal communication).

Another proactive action that increases preparedness is public education of key species. Public support is highly advantageous because it induces greater adherence to quarantine and biosecurity measures, and it facilitates access to, and treatment of, property without the need for legal enforcement. Public vigilance is also a useful tool to detect new incursions, satellite populations, or populations persisting post-treatment. The overwhelming usefulness of public education makes it an important requirement throughout all phases of ant management.

Fourth is a greater incorporation of ant biology into eradication protocols. Very few protocols for ant eradications are truly based on ant biology, and this has been highlighted as a contributing factor to eradication failure (Davidson and Stone 1989; Tschinkel 2006). Not only is knowledge of ant biology important to ensure that eradication protocols are appropriate, it also underpins the integrity of eradication declarations. Examples of biological information that should be incorporated into protocols and why include: phenology, to determine the appropriate timing for the use of some treatment products as well as the entire treatment program, and to aid the criteria for declaring eradication; annual abundance cycles, to identify key treatment times, as well as to determine whether declines in populations post-treatment are due to treatments or merely natural population fluctuations; and nest densities and foraging distance, to ensure post-treatment assessments are sufficient to detect persistent and potentially cryptic populations. Biological information can often be obtained from scientific literature, however, there will always be some uncertainty associated with applying information from elsewhere, especially when an invasion is within a new environment. As such, there is no substitute to an active adaptive approach (Hoffmann and Abbott 2010), whereby site-specific research is embedded within a management program. Indeed, understanding key aspects of *S. invicta* biology within Australia is now considered to be fundamental to the success or failure of the Australian *S. invicta* eradication program (Davidson et al. 2010).

Conclusions

Our ability to conduct ant eradications is rapidly improving, with the number and size of eradications increasing greatly in the past decade. However, it is clear that most successes remain relatively small, with the greatest to date in the post-organochlorine era being only 41 ha. The lesson here for new eradication attempts is that unless there are significantly different and improved methodologies and/or products than those used in the past, any large-scale program currently has a very low chance of success.

Part of the issue preventing eradication success is that ant eradications remain reactive in that they are only initiated after an incursion is detected, usually accidentally, and often in the absence of a pre-prepared PRA which results in unnecessary delays in management action. Invasive ant management would immediately improve globally through a shift from reactive to proactive management, thereby eliminating much of the threat before it arrives, and having a high level of preparedness should an incursion occur.

References

Biosecurity New Zealand (2009) Red imported fire ant response update: April 2009.

Carson R. (1962) Silent Spring. Houghton Mifflin, Boston.

Cooper ML, Daane KM, Nelson EH, Varela LG, Battany MC, Tsutsui ND, Rust MK (2008) Liquid baits control Argentine ants sustainably in coastal vineyards. California Agriculture. 62:177-183

Davidson NA, Stone ND (1989) Imported fire ants. In: Dahlsten DL & Carcia R (eds) Eradication of exotic pests: analysis with case histories. Yale University Press, New Haven, Connecticut, pp 196-217

Davidson R, Griffin L, Jennings C, McNaught M, Nelson P, Wylie R (2010) Red imported fire ant: burning questions. Biosecurity Queensland Control Centre, Brisbane

Forgie SA, O'Halloran K, Ward DF, Stanley MC, Stanley J, Rees S, Daly C (2006) Environmental impact assessment for baits used during RIFA (red imported fire ant, *Solenopsis invicta*) incursions. Report to Biosecurity New Zealand. Landcare Research, Tamaki, Auckland

Hoffmann BD (in press) Eradication of populations of an invasive ant in northern Australia: successes, failures and lessons for management. Biodiversity and Conservation

Hoffmann BD (2010) Yellow crazy ant, *Anoplolepis gracilipes*, eradications in NE Arnhem Land. Ecological Management and Restoration 11: 82-83

Hoffmann BD, Abbott KL (2010) Active adaptive management for invasive ant management. In: Lach L, Parr CL & Abbott KL (eds) Ant ecology. Oxford University Press, pp297-298

Hoffmann BD, Abbott KL, Davis P (2010) Invasive ant management. In: Lach L, Parr CL & Abbott KL (eds) Ant ecology. Oxford University Press, pp287-304

Hoffmann BD, O'Connor S (2004) Eradication of two exotic ants from Kakadu National Park. Ecological Management and Restoration 5:98-105

Holway DA, Suarez AV (2006) Homogenization of ant communities in Mediterranean California: The effects of urbanization and invasion. Biological Conservation 127:319-326

Leung B, Lodge DM, Finnoff D, Shogren JF, Lewis MA, Lamberti G (2002) An ounce of prevention or a pound of cure: bioeconomic risk analysis of invasive species. Proceedings of the Royal Society of London B 269:2407-2413

Lodge DM, Williams S, MacIsaac HJ, Hayes KR, Leung B, Reichard S, Mack RN, Moyle PB, Smith M, Andow DA, Carlton JT, McMichael A (2006) Biological invasions: recommendations for U.S. policy and management. Ecological Applications 16:2035-2054

Lowe S, Browne M, Boudjelas S, De Poorter M (2001) 100 of the World's Worst Invasive Alien Species. A selection from the Global Invasive Species Database. IUCN/SSC Invasive Species Specialist Group (ISSG), Auckland, New Zealand

Markin GP, O'Neal J and Collins HL (1974) Effects of Mirex on the general ant fauna of a treated area in Louisiana. Environmental Entomology 3:895-898

Marr RM, O'Dowd DJ, Green P (2003) Assessment of non-target impacts of Presto®01 ant bait on litter invertebrates in Christmas Island National Park, Indian Ocean. Report to Parks Australia North. Monash University, Victoria

Menke SB, Fisher RN, Jetz W, Holway DA (2007) Biotic and abiotic controls of Argentine ant invasion success at local and landscape levels. Ecology 88:3164-3173

Nendick D (2008) Win-win from offshore container management programme. Biosecurity 84:12

Pascoe A (2003) Red imported fire ant response stood down. Biosecurity Magazine 45:7

Plentovich S, Hebshi A, Conant S (2009) Detrimental effects of two widespread invasive ant species on weight and survival of colonial nesting seabirds in the Hawaiian Islands. Biological Invasions 11:289-298

Plentovich S, Swenson C, Riemer N, Richardson M, Garon N (2010) The effects of hydramethylnon on the tropical fire ant, *Solenopsis geminata* (Hymenoptera: Formicidae), and on non-target arthropods on Spit Island, Midway Atoll, Hawaii. Journal of Insect Conservation 14:459-465

Rey S, Espadeler X (2004) Area-wide management of the invasive Garden ant *Lasius neglectus* (Hymenoptera: Formicidae) in northeast Spain. Journal of Agricultural and Urban Entomology 21:99-112

Simberloff D (2003) How much information on population biology is needed to manage introduced species? Conservation Biology 17:83-92

Stanaway MA, Zalucki MP, Gillespie PS, Rodriquez CM (2001) Pest risk assessment of insects in sea cargo containers. Australian Journal of Entomology 40:180-192

Stein M, Thorvilson HG, Johnson J (1990) Seasonal changes in bait preference of the red imported fire ant, *Solenopsis invicta* Buren (Hymenoptera: Formicidae). Florida Entomologist 73:118-123

Stork N, Kitching R, Cermak M, Davis N, McNeil K (2003) Impact of aerial baiting for control of the Crazy ant, *Anoplolepis gracilipes*, on the vertebrates and canopy-dwelling arthropods on Christmas Island. Tropical Rainforest Ecology and Management CRC, Cairns and Brisbane, Queensland

Summerlin JW, Hung ACF, Vinson SB (1977) Residues in nontarget ants, species simplification and recovery of populations following aerial applications of Mirex. Environmental Entomology 6:193-197

Tschinkel WR (2006) The fire ants. The Belknap Press of Harvard University Press. Cambridge, England

Van Schagen, JJ, Davis PR, Widmer MA (1994) Ant pests of Western Australia, with particular reference to the Argentine Ant (*Linepithema humile*). In: Williams DF (ed) Exotic ants: biology, impact, and control of introduced species. Westview Press, Boulder, Colorado, pp 174-80

Walters AC (2008) Detecting and monitoring the incursion and spread of invasive ants in the Northern Territory. Department of Natural Resources, Environment, the Arts and Sport, Darwin

Williams DF, Collins HL and Oi DH (2001) The Red imported fire ant (Hymenoptera: Formicidae): an historical perspective of treatment programs and the development of chemical baits for control. American Entomologist 47:146-159

Wittenberg R, Cock MJW (2001) Invasive alien species: a toolkit of best prevention and management practices. CABI Publishing, Wallingford, Oxon, UK

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