General Contingency Plan for Exotic Invasive Ants

Queensland Department of Agriculture and Fisheries
Nursery & Garden Industry Australia

Nursery & Garden Industry Australia

Queensland Government

Acknowledgements
This contingency plan was written by Andrew Manners and Fiona Giblin, Queensland Department of Agriculture and Fisheries in 2019 as part of the Hort. Innovation and Nursery levy funded project, “Building the resilience and on-farm biosecurity capacity of the Australian production nursery industry (NY15002).” Thanks go to John McDonald, NGIA, and Liz Williams (DAF) for helpful comments and direction in the production of this contingency plan.

Table of Contents

1 Purpose and background of this contingency plan

This contingency plan provides general background information on ant biology to assist with preparedness for an incursion into Australia of various species of Exotic Invasive Ants (EIAs). There are thousands of exotic ant species that may become invasive if introduced to Australia, many of which have little documented biological or ecological information available. Therefore, this plan provides guidelines associated with ants around two key biological criteria, 1) dispersal and 2) diapause.

1) Natural dispersal: Some species have a nuptial flight and therefore the ability to establish a new colony at a significant distance away from the mother colony. In addition, some species can disperse by rafting along waterways and may be dispersed long distances in this fashion. Other species only spread short distances by budding.

2) Diapause: Some species have a physiological resting stage (diapause), generally during colder months, in which the species is inactive and undetectable.

It is recommended to use this plan in conjunction with materials produced by the National Invasive Ant Biosecurity Plan (NIABP). While there are a number of common biological features expressed by the numerous EIAs, this contingency plan is necessarily general so as to avoid being too prescriptive when dealing with the idiosyncrasies of a specific incursion. Where a species is detected for which there is a significant body of biological and response information, there may be limited value in using this contingency plan. With that said, this plan focuses on production nursery situations and may be valuable from that perspective.

Regardless, any Response Plan developed using information in whole or in part from this Contingency Plan must follow procedures as set out in PLANTPLAN and be endorsed by the National Management Group prior to implementation. This contingency plan was developed for the Nursery & Garden Industry Australia (NGIA). In the event of an incursion, operations not covered by the NGIA (e.g. retail outlets) will not be eligible for Owner Reimbursement Costs, as defined in the Emergency Plant Pest Response Deed, if affected by actions carried out under an approved Response Plan.

An additional purpose of this document is to set out a framework by which production nurseries can continue to trade in the event that their business is located in an EIA quarantine area.

2 Impacts of Exotic Invasive Ants (EIAs)

Impacts of EIAs have been reviewed in detail in Australia (Anonymous 2012, 2018) and overseas (Bertelsmeier and Courchamp 2014; Bertelsmeier et al. 2015; Park et al. 2014; Wielgoss et al. 2014; Wylie et al. 2016). It is widely accepted that invasive ants can have significant negative impacts on animal diversity in natural areas, reduce agricultural yields, can seriously impact human health and have social implications, e.g. changing the way outdoor areas are used and limiting time spent outdoors. Furthermore, in Southeast Queensland alone, red imported fire ants (*Solenopsis invicta*, RIFA) have been estimated to have cost the production nursery industry A$18 million per annum in mitigation, compliance, and lost market costs (NGIA 2015, Whiley *et al.* 2016). Overall, preventing EIAs from establishing and becoming widespread is extremely important.

3 Critical tasks

This contingency plan is necessarily general to allow for response to a large number of ant species for which limited biological information may be known. Furthermore some species of ants may show different biological trends in different regions of the world. For example, *Myrmica rubra* has different colour variation in different countries and has been shown to have nuptial flights in Europe but not in the USA. As such, each new incursion must be treated with caution, even when the species identification appears straight-forward. Use best available information about the biology of the species to establish quarantine areas and response actions (particularly baits) and evaluate their efficacy continually. This has been shown to be of great value in the eradication of populations of RIFA in Queensland (Wylie et al. 2016). Therefore, critical tasks include:

1. Establishing if relevant diagnostic protocols exist. Currently, no diagnostic protocols are nationally endorsed. These are part of on-going work through the NIABP.

2. Confirming dispersal ability. If in doubt, assume that the species undergoes nuptial flights until confirmatory data is available for developing populations in Australia.

3. Determining when ants are active on a seasonal basis (i.e. diapause activity).

4. Determining when ants are active on a daily basis (i.e. diurnal, nocturnal or both). This will have implications for inspection processes.

5. Determining pesticide availability and how they can be used under a variety of situations relevant to the specific incursion (see Table 4).

4 Australian nursery industry

The Australian nursery industry is a significant and diverse horticultural sector with total greenlife sales valued at $2.29 billion annually[1]. The industry employs approximately 27,000 people in approximately 1,777 businesses[1]. The industry is located predominantly along the Australian coastline and in major inland regions servicing urban and production horticulture. It is estimated that 1.618 billion plants were sold nationally in the 2015/2016 year and the production area covered 6,229 Ha (outdoor) and 1,273 Ha (indoor)[1].

5 Pest information/status – EIAs

5.1 Pest details

There are nine species (or genera) of EIAs considered as a priority species that have been endorsed by Plant Health Committee (Anonymous 2018). Other species are also considered a priority but they are either under eradication or are widely established in Australia.

Table 2. High priority species of Exotic Invasive Ants identified by the National Invasive Ant Biosecurity Plan, version 12, April 2018

[1] https://www.ngia.com.au/Attachment?Action=Download&Attachment_id=2170

Scientific name	Common names & acronyms	Functional group
Brachyponera chinensis	Asian needle ant	Flights, no diapause
Camponotus pennsylvanicus and other species of *Camponotus* as identified by a pest risk assessment	Carpenter ants	Flights, diapause
Lasius neglectus	Invasive garden ant	No flights, semi-diapause
Myrmica rubra	European fire ant	May or may not have flights, no diapause
Nylanderia fulva	Tawny crazy ant or Raspberry ant	No flights, no diapause
Solenopsis richteri	Black imported fire ant	Flights, no diapause
Tapinoma sessile	Odorous house ant	Flights, no diapause
Technomyrmex species (excluding *Te. difficilis* and *Te. vitensis*)	Species often misidentified as *Te. difficilis* (difficult white-footed ant)	Flights, no diapause known
Tetramorium tsushimae	Japanese pavement ant	Flights, no diapause known

5.2 Biology and spread of EIAs generally

5.2.1 Characteristics

Most invasive ant species have most of the following biological characteristics:

- They consume a wide variety of food items, are predators, scavengers, often feeding on honeydew produced by sucking bugs.
- They have an opportunistic nesting behaviour, producing nests within or under a large variety of things including, but not limited to, tree bark, compost, forest litter, under rocks, concrete, wood or other items, amongst rubbish, in electrical appliances, underground and some species can move their nest when disturbed or with certain environmental conditions.
- They thrive in human-disturbed environments including pastures, turfgrass, fragmented landscapes and forest edges, amongst household items left outside etc. They also can disperse into natural environments and recolonise human-disturbed areas.
- Their nests can be small and easily moved by people amongst rubbish, plant material including nursery plants, soil, composted media, shipping containers etc. This can result in their spread over relatively large areas before they reach densities that lead them to becoming nuisance pests (and being reported by members of the public).
- Their nests may have a large number of queens (polygyny) and may extend into supercolonies (polydomous).
- They are very aggressive towards other species, but much less aggressive to their own.

- They have the potential to significantly reduce biodiversity in the ecosystems they inhabit.

Despite these broad biological characters that are shared by many ant species, there are other aspects of their biology that are quite variable and will modify the way in which surveillance and response actions are completed. For example, even though RIFA may have polygyne colonies, evidence indicated that only monogyne colonies were present at the Yarwun population (Telford and Nelson 2010). Monogyne colonies are more likely to produce winged queens that may found a new colony some distance away.

It is recommended that genetic testing of nests is undertaken from an early stage in the response for a number of purposes. Genetic analyses may assist in determining the country/ies of origin, the number of introductions, whether the colony is a polygyne or monogyne and to establish whether nests were founded by budding or nuptial flights. This information will assist response decision making.

There are often exceptions to consider, such as behavioural variation within a species. Therefore, if only one or a very small number of queens were responsible for the introduction, the biology in Australia may differ slightly from that in other countries (i.e. there may be a founder effect). If there are significant deviations in behaviour, ecology and perhaps even morphology from the introduced and native ranges, it is important to consider that it may be a cryptic species. Cryptic species can be very similar in many ways (e.g. morphology) but may be very different in others (aspects of their biology or behaviour).

5.2.2 Dispersal

One of the most significant biological traits of ants that can have major impacts on a response is their dispersal ability. All of the invasive ants have the ability to bud into supercolonies (as mentioned above) and may spread about 3-500m per year. Therefore, all of the subsidiary colonies must be killed to eradicate the colony.

Many species also produce a winged reproductive stage that can go on nuptial flights and potentially make a new nest up to 5km away (e.g. RIFA) (Vogt et al. 2000). Research in Queensland based on genetic analyses of RIFA indicated that most flights only occurred over a much shorter distance (Telford and Nelson 2010). Obviously, this has a huge impact on the area of land that must be monitored and potentially treated. There is also variation between species in the season that nuptial flights occur and the length of time required for a new nest to produce winged reproductive individuals (only 6 months in some species, while over 12 months in other species). These factors may need to be considered to modify the response beyond what is considered in this contingency plan.

In addition, some species of ants may form ‘rafts’ and disperse over water, e.g. RIFA. Rafting involves a large number of workers carrying queen and immature individuals in a ball, disc or long trail. The immature individuals collect bubbles of air and may be interconnected to form large portions of the rafts. Workers will continually rotate immature individuals and individuals that become submerged collect air from the substrate to get back to the surface. The presence of immature individuals in a raft markedly increases its survival. Rafts may move long distances until land contact is made, potentially surviving for weeks (Adams et al. 2011).

All EIAs (commonly referred to as tramp ants) can hitch hike whereby nests are built in material subsequently transported by people. Some species are more likely to hitch hike than others with species nesting in building materials, containers and ‘rubbish materials’ being a higher risk of spread than those that only nest underground.

5.2.3 Diapause and diel activity

Some species are active with workers foraging on a daily basis throughout the year (or when certain temperature thresholds are met). Other species go into diapause, generally over winter. Diapause is a state of rest in which the nest effectively becomes inactive. The exact period of time that diapause occurs may differ with species; some appear to become inactive related to low temperatures, whereas others are probably linked to day length. This too has implications for surveillance and treatment aspects of the response program.

Some species forage primarily at night (nocturnal) and may not forage at all during daylight hours. Other species forage only during the day (diurnal), while others may forage both night and day. This has implications in the way inspections are completed, particularly for businesses seeking to use inspections as a method to continue trading.

5.2.4 Nesting habits

There are many common nesting sites amongst EIAs. These are provided as a general guide and should not exclude monitoring other areas as indicated by specific knowledge of the species in question or based on the response scenario. Most EIAs can readily make nests in human disturbed environments including, but not limited to:

- Under logs, wood, stones, pavers and items placed on the ground that retain moisture
- Within pot plants
- Soil, growing media, compost, leaf litter
- Within electrical equipment, water meter boxes and fire hydrants
- Tree crotches, rotten tree limbs, under palm leaf sheathes
- Underground in grasslands and lawns
- In gardens or environments where aphids are abundant
- Sometimes within walls or termite nests
- Within shipping containers, furniture, vehicles and other items
- Within cracks in paths and next to external walls of buildings
- In fodder and other agricultural product

5.3 Specific information on each species

Table 3. Priority ant species or genera indicated in the National Invasive Ant Biosecurity Plan that are exotic and not currently under eradication in Australia (some species in the NIABP are under eradication)

Species	Brief description	Natural habitat	Disturbed habitat	Other biology	Diet	Human assisted dispersal	Natural dispersal	References

Species	Brief description	Natural habitat	Disturbed habitat	Other biology	Diet	Human assisted dispersal	Natural dispersal	References
Brachyponera chinensis, Asian needle ant	Dark brownish-black, workers 3-5mm.	Nest in the forest floor from spring to autumn, then move to dead trees or below the soil surface for winter. Prefer moist, damp areas.	In and around houses and buildings, pavement crevices and around sprinkler systems.	Super colonies. Change the number queens through the year.	Feed on termites (mainly) and other insects.	Common	Nuptial flights, budding.	http://animaldiversity.org/accounts/Pachycondyla_chinensis/
Camponotus pennsylvanicus and other species of *Camponotus* as identified by a pest risk assessment, Carpenter ant	Varies. Generally relatively large black ants. *C. pennsylvanicus* is 1-2cm long, has a dull black head and body and whitish or yellowish body hairs.	Nest in trees, dead wood, underground, in voids of tree trunks and leaf axil bases in palms. Sometimes difficult to find. Sometimes under rocks and logs.	Within structural wood. Although they do not eat it, they do hollow it out.	Species in regions reaching sub-zero temperatures enter deep diapause in winter that allows them to supercool. Nuptial flights in spring. Produces satellite nests, sometimes with multiple queens. Species biology varies greatly	Varies with species; many feed on aphid honeydew and scavenge on other soft-bodied insects. Feed up to 100m from their nest.	Infested wood	Nuptial flights, satellite colonies	
Lasius neglectus, Invasive garden ant	2.5-3.5mm long brown ants. Produces many queens in each nest.	Nests become super-colonies difficult to delimit. Often underground or in trees, under stones, in grasslands and forests, particularly where aphids are abundant.	In gardens, particularly where aphids present. In single trees, rubbish etc. Most often reported associated with urban environments.	Become inactive at and below 10°C.	Mainly aphid honeydew, will also eat other small insects, arthropods. Tends not to become very abundant in the absence of aphids.	Common – in soil, pot plants, containers, rubbish and any other potential nest sites.	No nuptial flights. Spread slowly. Probably require a queen with workers tending her to establish new colony. Probably less than 1km/year	(Harris Unspecified) https://www.cabi.org/isc/datasheet/29888
Myrmica rubra, European fire ant	Workers are reddish brown or yellowish brown, 4-5mm long with heavily sculpted head and mesosoma. Shiny abdomen.	Forest edges, rarely present within larger forests.	Under debris placed on lawns, including rocks, boards, logs and anything that maintains moisture. Found in gardens and agricultural areas, open grassy areas.	Polygynous and polydomous. Queens overwinter before laying eggs for the first time. Require two years to start colony. Appear to prefer coastal areas – high humidity, moist soil, reduced exposure to sun.	Predator and scavenger. Feed on honeydew of homoptera.	Common – in soil, infested potted plants, mulch and landfill.	Nuptial flights in autumn (August to Sept in Europe). No nuptial flights in USA.	http://entnemdept.ufl.edu/creatures/urban/ants/Myrmica_ruba.htm

Species	Brief description	Natural habitat	Disturbed habitat	Other biology	Diet	Human assisted dispersal	Natural dispersal	References
Nylanderia fulva, Tawny crazy ant or Raspberry ant	2-3mm long, reddish brown ants, relatively long legs.	Probably in twigs and bark cavities of trees	Occur under objects, rocks, timber, debris, within electrical equipment, and under other objects that retain moisture. Tend not to occur in buildings, though forage into buildings. Parks, gardens etc	Do not build centralised nests. Erratic foraging trails. Rarely forage during cooler winter months.	Honeydew of bugs (can build shelters around them), plant nectaries, damaged over-ripe fruit, insects and small vertebrates.	In any container or material; garbage, yard debris, compost, bales of hay etc.	No nuptial flights observed in Texas. Budding at 20-3m per month.	Mississippi Ento musem Florida Ento Dept antwiki
Solenopsis richteri, Black imported fire ant	Polymorphic, ranging in size from 1.5-5mm. Workers are dark-reddish-brown to predominantly black.	Grasslands and seasonally waterlogged grassland.	Mainly in open areas, grasslands, lawns, pastures, roadsides, highway median strips, fields etc.	Polymorphic, prevalent in warm areas where rainfall is not extreme. Colony takes 2 years to mature. Entry exit tunnels can be 5-10m away from mound. Mound building activity stimulated by rainfall. Outbreaks may occur following rain, required to excavate a nest. Can hybridise with RIFA. Poly or monogyne. Can retreat underground on hot dry days. No indication of diapause, can survive to relatively low temperatures (mean low average monthly temp of 0.8°C).	Similar to RIFA; omnivorous including arthropods and aphid/bug honeydew, seeds and plant parts like developing or ripening fruit, dead plant and animal tissues.	Common - containers, pot plants, straw, nesting material, electrical equipment on the ground etc.	Nuptial flights, budding. Flights occur year round, but usually on warm sunny day following rain. Can produce alates within 6-8 months. Flood waters.	https://www.cabi.org/isc/datasheet/50571 http://www.iucngisd.org/gisd/species.php?sc=784 http://www.tsusinvasives.org/home/database/solenopsis-richteri
Tapinoma sessile, Odorous house ant	Dark brown, about 2-3mm.	Wide variety of ecosystems including sandy beaches, open fields, woodlands and bogs.	Under and within objects, logs and sometimes buildings. Pastures. Potentially anywhere.	May be mono- or polygynous, polygynous when associated with people.	Feed on honeydew, dead and live insects, decaying fruit and vegetable. Sweet substances.	Common	Nuptial flights	

Species	Brief description	Natural habitat	Disturbed habitat	Other biology	Diet	Human assisted dispersal	Natural dispersal	References
Technomyrmex species (excluding *Te. difficilis* and *Te. Vitensis* that are already established), White footed ant – about 100 species	Species vary, but often dark brown to black bodies with the ends of their legs noticeably lighter in colour, sometimes white. Some species are light brown or reddish brown in colour. Generally 2-4mm in length.	Most species are arboreal or sub-arboreal, limited number restricted to leaf litter. Most common in moist forest regions. Also in rotting logs, under loose bark and in soil under stones.	Within walls, roof spaces, electrical equipment (including ovens, clock radios etc), rolled up awnings, pot plants and in-between flat packed items. Pest in houses.	Nest in soil, twigs or branches, in carton nests under leaves or on tree trunks. More active at night. Polydomous, super colonies. Difficult to control with chemicals when numbers are high.	Almost always forage on trees and shrubs. Scavenge for protein, normally insects and their eggs. They also farm sucking insects for their honeydew.	Within cut flower containers, pot plants, electrical equipment etc.	Nuptial flights . budding.	antwiki Te. albipes
Tetramorium tsushimae, Japanese pavement ant	Dark brown to nearly black, 2-3mm long, distinct ridges on head and thorax.	Most species of this genus nest in soil, decaying wood or leaf litter. Some in trees or termite nests.	*T. caespitum* prefers areas without vegetation.	Polygyne, nests usually take up 1-5m^2 and are 0.45-0.9m deep.		Usual in soil, gravel, nursery stock, turfgrass etc.	Nuptial flights, mate in swarms. Budding	Few details online.

5.4 Diagnostic information

Given the large number of species covered by this contingency plan, no specific diagnostic characters will be provided here. Check relevant diagnostic protocols which are currently (as of August 2019) under development. Another directive of NIABP is to improve Australia's overall EIA preparedness through diagnostic capacity (i.e. training individuals nationwide).

For the identification of Australian ants the publication by Shattuck (1999) is recommended. However, this book does not include exotic ants or EIAs found in Australia since it was published. The key is suitable for Australian species; this will assist in distinguishing natives from potential exotics. For species not covered in the book it is recommended to use the following framework (until nationally recognised protocols are available):

- Use the AntWiki identification tool, starting with the key to subfamilies. The subfamily keys vary with the region, therefore if the identification at hand does not make sense it may be necessary to try a different region. Start with the Australian region key:
    - http://www.antwiki.org/wiki/Category:Key_to_subfamilies
- Then use the keys to genera for the relevant subfamily

There are many keys available on this website depending on the region and taxonomic group in question. Where an identification does not make sense when working through the key it is recommended to seek expert assistance from a specialist diagnostician.

As indicated above in section 5.2, cryptic species exist among some groups of ants. Therefore critically examine all information available and re-examine the evidence if biological information in the introduced populations does not match those in other parts of the world.

It is recommended to use molecular identification tools (e.g. Gotzek et al. 2012) to confirm identification of any suspected EIAs.

6 Surveillance and collection of samples

6.1 Surveillance

Initially, surveillance should be focused within 500m of an Infested Premises (IP) and expanded as required to establish the extent of the infestation. This is a general rule that will detect the most common form of dispersal of invasive ants, budding. Budding often will occur at rates of 500m per year. The quarantine area can be extended based on the density of nests and distance from initial detection, within a framework of known biological parameters about the species in question. This approach will also detect visible nests that have been established by winged females on nuptial flights that have only flown a short distance.

The area for surveillance may need to be increased depending on a number of factors including the suspected period of time that the nest has been established. For example if there was evidence that the nest had been established for a period of 3 years, it is recommended to increase the initial area of surveillance by 500m per year.

If the species is suspected to have nuptial flights, then 5km is recommended. Assess prevailing wind conditions. If there are regular, strong winds in one or more direction a greater distance should be surveyed.

It is also recommended to complete surveillance along waterways, as the species may disperse by rafting. Shorelines are ideal for ant establishment. Given that rafts may survive for long periods on water no specific distance is recommended here.

New nests of some ant species will not become readily visible for 6-12 months. In addition, surveillance over winter may not be appropriate for some ant species, owing to inactivity/diapause during these seasons. On the other hand, some species produce higher mounds to capture solar radiation and are therefore easier to detect during relatively cool periods (e.g. RIFA). Therefore surveillance may need to be completed for a relatively long period of time, dependent on the species, to delimit an infestation.

Initially, it is expected that visual surveillance will be completed regardless of the species. Then more targeted surveillance can be added as required, perhaps including some of the surveillance tools described below.

Where more than one nest has been detected it is recommended to continue surveillance for at least 18-24 months after the last detection, and probably 3 or more years if the species has a diapause stage or the species has a long establishment period during which it may be very inconspicuous.

6.2 Surveillance tools

6.2.1 RIFA response

A number of detailed surveillance tools were created to manage the RIFA response in southeast Queensland (Anonymous 2016). These include:

- Public awareness campaigns targeted to specific areas
- Remote sensing surveillance using thermal imaging from helicopters to detect points of interest that can then be ground-truthed
- A linked and integrated habitat and disturbance model to better predict areas that are most likely to be colonised by mated queens
- Population genetic analyses which were critical for determining which population each colony was associated with, geographic source of the incursion, bottle-neck analysis and relatedness between colonies and production of family trees (to interpret if they were formed from budding, nuptial flights or human assisted movement). These were critical for the management of the response and assisted in demonstrating technical feasibility of eradication for three genetically distinct RIFA populations in Queensland (Gladstone/Yarwun, Port of Brisbane).
- Odour detection dogs for surveillance in high-risk areas and for follow-up surveillance to verify if treatment has been effective.

6.2.2 Monitoring by nursery producers

In the event that production nursery businesses fall within an EIA quarantine zone it is recommended to establish a protocol similar to ICA40 for continuing to trade. Measures would include (some or all):

- Purchasing all materials and items from a source free of the EIA e.g. soil, containers, media, plants, machinery and other equipment.
- Carefully inspecting all purchases prior to incorporating into the nursery.
- Carefully inspecting outgoing plants prior to delivery.
- Regularly inspecting and/or baiting/trapping.
- Maintaining records of all inspections and of nursery grounds.
- Reducing habitats that are prone to EIA nest establishment as outlined in section 5.2.
- Maintaining a buffer between the property line and production areas. While a significant buffer greater than, say, 30m would be ideal, it is acknowledged that many businesses will not be able to achieve this. Where very short buffer zones are an option it is recommended to increase monitoring to mitigate risk.

Visual inspections will only be sufficient if the ant species is active during the day and risk of infestation is relatively low. It will be important to ascertain if very young, immature colonies are detectable using visual inspections; some species may not be easily observed even with moderate handling/disturbance. If the ant is only active at night it may be necessary to develop baits and traps to better establish their presence or absence. This would have to be completed within a framework for the specific (confirmed) species. This may involve low-tech bottles with a variety of bait substances, sugar, protein or a mixture combined with a pesticide.

Theoretical work to detect RIFA with bait traps indicated that they should be set every 30m (Ujiyama and Tsuji 2018). While this may be most optimal for detection it may be impractical from a business operations perspective, at least when the business is large and risk is relatively low. A variable approach is recommended where businesses in high risk areas may need to complete more frequent monitoring or greater number of bait traps than those in lower risk areas. Furthermore, foraging distances may change with the size of the colony and season (Tschinkel 2011). Other factors, such as food availability may also change foraging distance. As a result, trap density must be somewhat plastic.

If businesses have a high risk of infestation, i.e. there are nests close to their property, they should work with the biosecurity organisation to complete a sufficient management strategy. This will probably include a range of the strategies discussed above.

6.2.3 Visual surveillance

Visual surveillance should be completed in all high risk areas (as indicated in 5.2.4 Nesting habits) at least 500m around the detection area/s. Surveillance can be extended where relevant based on initial data. Surveillance at least 200m is recommended around all high risk areas surrounding trace-forward and trace-back sites. Staff should be trained in the detection of nests for the particular ant species in question.

Teams of staff (minimum two) should walk in emu parade style between 2-6 metres apart (maintaining straight lines where possible). Inspect all areas that could have a nest and observe all ants. Collect a sample from all nests that are even a little suspicious. Staff should carry one or more sticks or similar device to inspect and probe to reduce risk associated with being stung. Visual surveillance can be completed when the ground is visible and when the species is active during the day.

6.2.4 Surveillance using above-ground lures or pitfall traps

Where the ground or vegetation hinders or reduces confidence in visual surveillance above ground lures or pitfall traps should be used. In addition, these monitoring methods are effective for species that are only active at night or is otherwise undetectable using standard visual surveillance. The exact lure and/or trapping system will vary with the species in question. Lures or baited pitfall traps attract species based on their dietary preference and can either have a pesticide/killing agent or have observations at set intervals to identify attending ants. In terms of attractant, ‘Cheerio’ sausages were used for RIFA, but other species may prefer peanut paste, a sweet substance (e.g. honey or sugar water), tuna or a combination of items. If the ant species is active during the day, the lure can be left in the field without a pesticide and surveyed after a minimum of one hour. The minimum length of time may need to be increased depending on temperature, humidity conditions, other variables influencing bait attractiveness and ant feeding behaviours.

In the absence of information to indicate an optimal rate of lures, it is recommended to place lures every 10 metres, in a 10x10m grid pattern (McNicol 2013). Assess maps of the area to be surveyed with lures using aerial photography. This should assist in decisions of whether to use a strict grid layout or to follow the general lay of the land, water bodies or heavily vegetative sections.

Lures are best placed by teams of three people (McNicol 2013). One person to perform the role of spotter to assess and clear vegetation of safety hazards and pace out the 10 metres. The second person to carry the lure equipment and place the lure and the third person to record and maintain data records. Care needs to be taken when entering areas of heavy vegetation and surveillance sticks should be used to gauge a safe walking path.

- Ensure each lure is placed in contact with the ground (i.e. vegetation needs to be cleared slightly).
- Lures can also be place up to 1-2 m into vegetation (2 m is optimum), this may be more important for those species that tend to be found in vegetation.
- If possible place the lures in shady places during the warmer months.
- In cooler weather placing lures in sun is acceptable.
- Place lure within vegetation verges and areas that are penetrable rather than on open dry dirt areas, e.g. grass clumps.
- If placed in direct sunlight then the addition of a shade plate is required. The shade plate is a paper plate that is affixed to the lure by pushing the pot marker through the centre of the paper plate prior to assembly procedure.
- Take care where vegetation is impenetrable or potentially hazardous.

It is recommended to lure in moderate temperatures, as foraging will not be as high during relatively low or high temperatures. As an example then, RIFA luring in SEQ was only completed before 10am or after 3pm in summer, spring and autumn to avoid the hottest parts of the day. And between 11am and 3pm in winter to be in the warmest part of the day. These times would need to be modified by the biology of the ant in question and the geographic region.

6.2.5 Surveillance for difficult, inaccessible, or non-surveyable sites

An area where there is extensive and / or heavy vegetation must be surveyed using in-ground lures for up to 7 days. Tracks are cleared through heavily vegetated areas to lay lures across grid 10 metres apart. Teams are resourced and trained to clear vegetation with the use of brush cutters. The lure is a food source and, as with the application of baits for treatment, placement is only conducted throughout the warmer periods.

6.2.6 Activities for public awareness following a detection

A range of activities can be beneficial:

- On-line or app reporting tools such as MyPestGuide should be established and promoted to allow submission of reports of suspected EIA detections. Public awareness campaigns were very important for detections and to prevent spread of RIFA nests.
- Factsheets to provide information on the pest, symptoms, impacts and reporting mechanisms.
- Media releases to describe the impact of the pest, surveillance programs and activities within the Response program.
- Advice to the public not to treat a nest themselves and not to take samples. Advise the public to report any suspicious nests.
- Broader awareness campaigns including literature (brochures and factsheets) in several languages, depending on the communities affected.

6.2.7 Stakeholder engagement

EIAs are area pests. Therefore, they have the potential to impact everyone in the region, from landholders and local councils to commercial and industrial estates (particularly businesses that have equipment stored outdoors), roadside verges, rail-side land, production nurseries, landscapers, social amenity land, the environment and so on. Therefore, a complete list of stakeholders is not possible because EIAs can potentially affect anyone depending upon the exact situation. Prioritise stakeholders based on the risk of spread of the EIA nests to areas outside the quarantine zone.

High risk stakeholders include those that move materials that may contain nests on a regular basis including (but not limited to):

- Landscapers, mining operations and other entities that move soil, turf or growing media.
- Production and retail nurseries, primary producers, growers in the area.
- Local council, particularly around roadside areas, public parks etc, waste management from infested areas, including distribution of mulch from waste transfer stations.
- State or federal government, particularly if the infested area includes state/national forests, railway lines or other restricted access areas.
- Relevant community groups, e.g. groups that maintain community gardens, Land Care groups, gardening groups (particularly those that move plants).

- Organisers of local markets that may have plant retailers.

- Port authorities and supply chain companies.

6.3 Collection of samples – nests and lures

As much as possible collect samples without disturbing the nest (this is particularly important for those species that readily move the nest when it is disturbed).

- Use a pot marker, paintbrush or stick for ants to crawl onto.

- Collect as many individuals of different sizes as possible as this assists in making an accurate and confident identification.

- Transfer individuals into a vial with 70% ethanol and some individuals into 95% ethanol (for genetic analyses).

- Secure the sample vial and label appropriately, preferably including GPS location data and other actions to ensure chain of custody.

When collecting samples from lures it is recommended to wear latex gloves. Approach the lure with caution so as not to disturb the lure container or ants (as they may retreat when disturbed. Be prepared to take a sample before lifting the lure from the ground and to inspect underneath the lure. Place ants in 70% ethanol.

Mark highly suspicious samples in such a way as to prioritise their identification, e.g. with an "S" marked on the bottle.

7 Course of action – immediate response to a detection

For a range of specifically designed procedures for the emergency response to a pest incursion and a general communication strategy refer to PLANTPLAN (Plant Health Australia 2014).

7.1 Tracing

Detection and delimiting surveys are required to delimit the extent of the outbreak, ensuring areas free of the pest retain market access and appropriate quarantine zones are established. Since EIAs are area pests the tracing has to be flexible and somewhat general.

Forward tracing should focus on items and materials that could house an EIA nest and are regularly moved to other regions or areas in which ants would readily establish a new nest, for example:

- premises linked directly with the initial detection, particularly where movements of growing media, soil, sand, container plants, equipment and containers have occurred.

- high risk habitats within 2 or 5km of the detection (to detect nests that may have resulted from nuptial flights) – these may vary with the species in question.

For trace-backs, focus should include:

- talking to local staff/people that may have experienced ant stings (or have had pets/livestock stung) to determine how long an infestation may have been present.

- inspecting any material (products, equipment, container plants, soil, growing media and machinery) received within a 12 month period, or longer if there is a diapause period.

- inspecting nearby human-disturbed environments.

7.2 Quarantine and movement controls

It is recommended to place at least a 5km or 2km quarantine area around the infested property for species with and without nuptial flights, respectively). Where there is a high degree of certainty that no nuptial flights have occurred and certainty that the infestation is very limited in area, a smaller quarantine area may be considered.

In the first instance movement controls should be placed on the following items moving out of the control area.

- Soil
- Turf
- Potted plants
- Mulch
- Baled hay or straw
- Animal manures
- Mining or quarry products
- Composted materials.
- Other items specific to the biology of the species, e.g. certain types of timber for carpenter ants.

Forward tracing should focus on items and materials that could house an EIA nest and are regularly moved to other regions or areas in which ants would readily establish a new nest.

7.3 Treatment

7.3.1 Strategies

Treatment has two main strategies, direct nest injection (DNI) and baiting. It is recommended to take an adaptive approach. For very small infestations it may be possible to simply treat all nests in the infested area by direct injection and baiting the quarantine area on a few occasions (e.g. 2-3 times per year for 2-3 years). For more extensive infestations baiting may need to occur more frequently (4 times per year) or over a greater length of time (depending on the biology of the species and environmental conditions). This will be influenced by bait efficacy and diapause, with fewer bait sufficient for species that have a long diapause.

Thus, it is critical to establish the efficacy of each treatment used. For RIFA, scientific testing indicated the following:

- Bait application using an IGR 90% effective after 1 application
- Bait application using a Toxicant greater than 90% after 1 application
- Direct Injection – 96% effective after 1 application
- Visual surveillance – 80% effective (terrain dependent)

- Canine odour detection – 100% effective

This knowledge enabled cost benefit analyses of different strategies and a more efficient eradication of RIFA from any given area (McNicol 2010). When direct injection has to be completed the most effective method was to wait 8 weeks post DNI, bait the area and have odour detection dogs survey the area. No further action was required if RIFA was not detected. Obviously, the exact details are not transferable to all ants as there will be different treatment efficacy of each method for different ant species. However, the general approach is valid.

7.3.2 Pesticides registered against ants (including invasive ants)

There are many products with general registration for ants suitable for use against EIAs (Table 3). It is recommended to assess any efficacy data available for the detected species to determine the best product for DNI and baiting. Baits are classified as toxicant and/or IGR. Toxicant baits cause direct mortality to individuals that ingest or are otherwise exposed to the product. IGRs cause indirect mortality, causing the queen to become sterile, with the nest dying out over a relatively long period (about 2-4 months).

Table 4. Active ingredients registered and potentially suitable for the use against EIAs

Active ingredient	Example trade name	Mode of action group	Production nursery growing media only	Domestic and public places, commercial and industrial areas	Other notes
Bendiocarb	TaserPro	1A	No	All ants, but situations slightly different. Food processing factories, restaurants, laundries, food stores, ships, hospitals etc.	
Chlorpyrifos	Chlorpyrifos	1B	Yes, *Solenopsis* spp. only (PER14256)	All ants, some labels vary with situations	
Diazinon	Diazinon	1B	No	All ants	
Fipronil	Anthem	2B	Yes (PER81707)	All ants, but some labels only have partial situation coverage	Toxicant bait
Allethrin and permethrin	Cyndan	3A	No	All ants	
Alpha-cypermethrin	Out of bounds	3A	No	All ants	
Beta-cyfluthrin	Prolong	3A	No	All ants, including food processing situations	
Bifenthrin	Bifenthrin	3A	No	All ants, but some labels vary specifying certain species or situations	
Deltamethrin	Deltaforce	3A	No	All ants	
Esfenvalerate	Allrounder	3A	No	All ants	
Lambda-cyhalothrin	Demand	3A	No	Yes	
Pyrethrins + piperonyl butoxide	Py-Omni	3A	No	Yes	
Imidacloprid	Antmaster	4A	Yes (PER81707)	Yes	Liquid toxicant bait

Active ingredient	Example trade name	Mode of action group	Production nursery growing media only	Domestic and public places, commercial and industrial areas	Other notes
Thiamethoxam	Optigard ant bait gel	4A	No	Sugar feeding ants in commercial, domestic, industrial and public buildings	Gel toxicant bait
Pyriproxyfen	Distance Plus Ant Bait	7C	?No	Yes (*S. invicta)*	Granular IGR bait
Hydramethylnon + Pyriproxyfen	Synergy Pro Ant Bait	20A and 7C	No	All nuisance and tramp ants	Granular toxicant + IGR bait
Boron as borax	Ascend	8D	No	All ants	Gel bait
Hydramethylnon	Protect-us invader ant bait	20A	No	All ants, partial situations	Granular IGR bait
Indoxacarb	Arilon	22A	No	Yes	Granular toxicant bait
Metaflumizone	Siesta granular ant bait	22B	Yes	Yes	Granular toxicant bait

7.3.3 Direct nest injection (DNI)

DNI with fipronil has an immediate knock-down effect. DNI usually kills the queen/s and most of the workers present, including those returning to the colony as it is an odourless contact pesticide (McNicol 2010; Anonymous 2015). Some workers in tunnels can survive, but are highly unlikely to reform a mound that has the ability to reproduce. Some species may adopt a newly mated queen in rare situations. Fipronil is a good active ingredient to choose in the absence of any efficacy data on the species.

It is recommended to use DNI in the following situations and it is also recommended to use an IGR bait around the nest that has a DNI treatment out to 100m:

- In areas where there are high risk human health concerns and perhaps also in areas of high risk animal health concerns – DNI should be undertaken immediately.
- In areas where there is a possible threat, but no immediate danger, IGR baits should be applied followed by DNI 7-10 days later. They are not used simultaneously because the toxicant will kill or affect workers that harvest and store the IGR bait, hence reducing bait delivered to the queen.
- In areas where winged reproductive ants are present with a likelihood to imminently go on a nuptial flight.
- Where it is necessary to continue business activities to allow movement of restricted items from a commercial site.

Do not use DNI in the following situations (baiting must be relied upon in these areas):

- Where there are very dense nests. Nests will be missed, risk to applicators are relatively high and application will be very time consuming (and costly).
- Where nests are very diffuse. Finding each and every nest is unlikely.
- Where the nest cannot be located (i.e. when ants are nocturnal or greatly concealed).

7.3.4 Baiting

Insect growth regulator (IGR) baits are the recommended treatment of isolated new nests, dense and diffuse infestations. IGR baits are collected by workers within 3-48 hours of the bait being applied and taken back to the nest. They are then fed to the queen which becomes sterilized. The nest can take several months to die, as it relies on the remaining workers (that tend the nest/queen, and collect food) to naturally die. Known nests are used to determine bait efficacy and can be used to infer success over a larger area. IGR baits are ideal for the treatment of ants that forage on the ground (most EIAs) and are effective against ants that are diurnal or nocturnal (or both). However, for species that are nocturnal, it is recommended to place traps late in the day as possible to reduce native species from taking the bait before the EIA has the chance to take it.

IGR bait treatments are recommended within quarantine zones ideally 3 times per year on high density infestations (sites with greater than 10 mounds recorded in the current season) and sites that have persistent infestations. Again, this recommendation must be somewhat plastic depending on the nature and size of a site.

IGR bait treatments are recommended 4 times per year on identified disturbed sites that are at high risk of becoming infested/reinfested. For example on disturbed residential or industrial development sites that become infested with EIAs, repeat bait applications over the whole site for the life of the development is the most cost effective approach (even after the ants are initially eradicated from the site).

Repeat IGR baiting can be completed up to three months apart, minimum of 6-8 weeks apart. The IGR must be maintained in a colony at a sufficient level for long enough to cause sterilization of the queen’s ovaries. Therefore, treatment during the most active period of the year is ideal, It is recommended to complete all baiting activities with sufficient time to complete follow-up validation of efficacy prior to diapause (if it occurs in the species). It also allows flexibility in treatments such that they occur prior to any nuptial flight period (which is also recommended).

IGR baits should only be applied in winter if the species is active (i.e. they do not have a diapause stage). Optimize the timing of the application with the temperature range of foraging workers; literature may be available to indicate the soil temperature required for optimal foraging. For example, the RIFA science team in SEQ found that the lower threshold for optimal baiting was 20° C at 10 cm soil depth. Baiting below that threshold was rarely completed.

7.4 Containment strategies

For some exotic pest incursions where eradication is considered impractical, containment of the pest may be attempted to prevent or slow its spread and to limit its impact on other parts of the state or country. The decision on whether to eradicate or contain the pest will be made by the National Management Group, based on scientific and economic advice.

8 Technical debrief and analysis for stand down

Refer to PLANTPLAN (Plant Health Australia 2016) for further details
The emergency response is considered to be ended when either:

- Eradication has been deemed successful by the lead agency, with agreement by the Consultative Committee on Emergency Plant Pests and the Domestic Quarantine and Market Access Working Group

- Eradication has been deemed impractical and procedures for long-term management of the pest risk have been implemented

A final report should be completed by the lead agency and the handling of the incident reviewed.

Eradication will be deemed impractical if, at any stage, the results of the delimiting surveys lead to a decision to move to containment/control.

9 References

Adams BJ, Hooper-Bùi LM, Strecker RM, O'Brien DM (2011) Raft Formation by the Red Imported Fire Ant, Solenopsis invicta. Journal of Insect Science 11:171. doi:10.1673/031.011.17101

Anonymous (2012) Review of the Threat Abatement Plan to Reduce the Impacts of Tramp Ants on Biodiversity in Australia and its Territories 2006-2011. Department of Sustainability, Environment, Water, Population and Communities,

Anonymous (2015) Red Imported Fire Ant Eradication Program Operational Protocol - Treatment Department of Agriculture and Fisheries, Queensland

Anonymous (2016) Report of the Independent Review Panel. Agricultural Ministers Forum,

Anonymous (2018) National Invasive Ant Biosecurity Plan - Draft.

Bertelsmeier C, Courchamp F (2014) Future ant invasions in France. Environmental Conservation 41 (2):217-228. doi:10.1017/s0376892913000556

Bertelsmeier C, Luque GM, Hoffmann BD, Courchamp F (2015) Worldwide ant invasions under climate change. Biodiversity and Conservation 24 (1):117-128. doi:10.1007/s10531-014-0794-3

Gotzek D, Brady SG, Kallal RJ, LaPolla JS (2012) The Importance of Using Multiple Approaches for Identifying Emerging Invasive Species: The Case of the Rasberry Crazy Ant in the United States. PLOS ONE 7 (9):e45314. doi:10.1371/journal.pone.0045314

Harris R (Unspecified) Invasive Ant Risk Assessment. Biosecurity New Zealand, New Zealand

McNicol C (2010) National Red Imported Fire Ant Eradication Program Policy Number 4 - Direct Nest Treatmnet and Surveillance Actions. Biosecurity Queensland, Department of Agriculture and Fisheries, Queensland

McNicol C (2013) 2013 'FA-O-S-001'. Standard Operating Procedure prepared by the Biosecurity Queensland Control Centre. Department of Primary Industries and Fisheries, Queensland

Park S, Hosoishi S, Ogata K (2014) Long-term impacts of Argentine ant invasion of urban parks in Hiroshima, Japan. Journal of Ecology and Environment 37 (3):123-129. doi:10.5141/ecoenv.2014.015

Telford G, Nelson P (2010) Proposal for the Establishment of Pest Free Area Status. Yarwun Restricted Area for Red Imported Fire Ant. Biosecurity Queensland, Department of Agriculture and Fisheries, Queensland

Tschinkel WR (2011) The organization of foraging in the fire ant, Solenopsis invicta. J Insect Sci 11:26-26. doi:10.1673/031.011.0126

Ujiyama S, Tsuji K (2018) Controlling invasive ant species: a theoretical strategy for efficient monitoring in the early stage of invasion. Scientific Reports 8 (1):8033. doi:10.1038/s41598-018-26406-4

Vogt JT, Appel AG, S. West M (2000) Flight energetics and dispersal capability of the fire ant, Solenopsis invicta Buren. Journal of Insect Physiology 46 (5):697-707. doi:https://doi.org/10.1016/S0022-1910(99)00158-4

Wielgoss A, Tscharntke T, Rumede A, Fiala B, Seidel H, Shahabuddin S, Clough Y (2014) Interaction complexity matters: disentangling services and disservices of ant communities driving yield in tropical agroecosystems. Proceedings of the Royal Society B-Biological Sciences 281 (1775). doi:10.1098/rspb.2013.2144

Wylie R, Jennings C, McNaught MK, Oakey J, Harris EJ (2016) Eradication of two incursions of the Red Imported Fire Ant in Queensland, Australia. Ecological Management & Restoration 17 (1):22-32. doi:10.1111/emr.12197