Assessing the Effectiveness of Tramp Ant Projects to Reduce Impacts on Biodiversity

A report prepared for the Australian Government Department of Sustainability, Environment, Water, Population, and Communities

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ACRONYMS AND ABBREVIATIONS

AA	Argentine ant
ABHA	African big headed ant
ACT	Australian Capital Territory
ARMP	Approved Risk Management Plan
BMP	Biodiversity Management Plan
BACI	before-after-control-impact
CASAP	Crazy Ant Scientific Advisory Panel
CI	Christmas Island
CINP	Christmas Island National Park
CfOC	Caring for Our Country
DAFF	Department of Agriculture, Fisheries and Forestry
EA	electric ant
EPBC	Environment Protection and Biodiversity Conservation
ha	hectare
IWS	Island Wide Survey
LHIB	Lord Howe Island Board
m	meter
MERI	Monitoring and Evaluation Reporting and Improvement
NEAEP	National Electric Ant Eradication Program
NIA	Norfolk Island Administration
NRIFAEP	National Red Imported Fire Ant Eradication Program
NTAC	National Tramp Ant Committee
NSW	New South Wales
NT	Northern Territory

Qld	Queensland
RIFA	red imported fire ant
SA	South Australia
SAP	Scientific Advisory Panel
SRE	Short range endemic
TACC	Tramp Ant Consultative Committee
TAP	Tramp Ant Threat Abatement Plan
Tas	Tasmania
TASAP	Tramp Ant Scientific Advisory Panel
Vic	Victoria
VRMP	Voluntary Risk Management Plan
YCA	yellow crazy ant
WA	Western Australia
WTMA	Wet Tropics Management Authority
WTWHA	Wet Tropics World Heritage Area

EXECUTIVE SUMMARY

This review principally covers six tramp ant abatement projects funded in part by CfOC, namely the red imported fire ant (*Solenopsis invicta*) in southeast Queensland, electric ant (*Wasmannia auropunctata*) in northeast Queensland, yellow crazy ant (*Anoplolepis gracilipes*) in northeast Arnhem Land, Northern Territory and on Christmas Island, African big-headed ant (*Pheidole megacephala*) on Lord Howe Island, and Argentine ant (*Linepithema humile*) on Norfolk Island. The review evaluates the management and control, impacts on biodiversity, and community engagement parts of these programs. In a concluding section we discuss where programs have been most effective in gaining biodiversity recovery, how this may be replicated across other tramp ants programs, and the degree to which the programs have been appropriate, effective, and efficient within their scope and area of attention to meet and contribute to reducing impacts on biodiversity, with particular emphasis on the programs' achievements, lessons learned, and overall legacy.

This review also considers other infestations and other tramp ant species as potential candidates for abatement programs.

Management and control

The five ant species that are the subject of the management programs in this evaluation are among the 100 worst invasive species in the world. They all have documented adverse environmental impacts in their introduced range. Their nests have multiple queens (polygyny) and workers of the same species can move among nests without encountering intraspecific aggression (unicoloniality). An extremely dense or vast area of unicolonial nests is termed a supercolony. Unicoloniality is thought to be one of the reasons that invasive ants can reach higher abundance than native ants.

The division of labour in ant colonies means that after mating and founding their nest, reproductive females (queens) remain safely within the nests whereas the non-reproductive workers forage for food and interact with the environment. To be an effective means of controlling ants, a chemical bait must be non-repellent at the product concentration, have a delayed action of at least 24 hours to enable food sharing throughout the colony before ants begin to die, and be fatal to the target ants at concentrations as little as 1/100th of the original dose.

Four of the programs are aiming for complete eradication at the program site (National Red Imported Fire Ant Eradication Program [NRIFAEP], National Electric Ant Eradication Program [NEAEP], African big-headed ant, and Argentine ant programs). Most successful eradications in the world have been in areas of infestation less than 1ha, and the largest eradication in the last decade has been 41ha. In comparison, the four tramp ant projects aiming for eradication evaluated here ranged from 76ha to >36,000ha when the area of infestation was first estimated. The goal of the yellow crazy ant programs is regional containment (Arnhem Land) and supercolony suppression (Christmas Island).

Management and control of tramp ants lies at the heart of all six programs and is where most of the resources are directed. For all programs except for the yellow crazy ant on Christmas Island, surveillance is done to detect infestations following public reports, tracing activities, or proactive identification of high risk areas. If ants are found, closely spaced lures (NEAEP, African big-headed ant, Argentine ant programs), odour detection dogs (NRIFAEP, NEAEP) or visual searches (yellow crazy ant Arnhem Land program) are used to delimit the infestation. NRIFAEP has recently implemented remote sensing as its primary coarse-scale surveillance method. On Christmas Island, a biennial Island-Wide Survey and follow-up bounding using a card count method is used to identify supercolony locations and delimit their boundaries.

Each program relies on toxic baits to treat the ants, with the type of bait and the number of treatments varying among programs from one planned treatment (African big-headed ant, Argentine ant), to three treatments (yellow crazy ant in Arnhem Land) to six treatments (NRIFAEP, NEAEP). In all five of these, follow-up treatments are done for persistent infestations. On Christmas Island, yellow crazy ants were aerially baited 2002, 2009, and 2012. The development of a biological control program to control the scale insects that yellow crazy ants rely on to achieve supercolony status is underway and if successful, would eliminate the need for further aerial baiting for yellow crazy ants on Christmas Island.

All of the programs are making progress toward attaining their tramp ant abatement goals. As of the end of 2011-12, in the NRIFAEP, a total of 1488 sites, covering 13,555 hectares have had their infested site status removed, and the number of colonies found at new detections is decreasing. Genetic analyses indicate there are unlikely to be undetected populations, and genetic diversity is declining, possibly with fitness consequences. In the NEAEP, pest-free status has been achieved at four areas covering 14.4ha and two more infestations (16ha) are due to have their final post-treatment surveys in 2012-13, with a further 13 scheduled for 2013-14. There are no sites where electric ants are still seen. The yellow crazy ant in Arnhem Land program had achieved local eradication at 21 sites up to end of CfOC funding period. Another 600ha were treated last month and it is anticipated that the program is on track to achieve regional containment in five years. On Christmas Island, aerial baiting can suppress supercolonies for about two years, but a potential biological control agent for the scale insect that plays a key role in fuelling yellow crazy ant supercolony formation has been identified in Malaysia, and steps are underway to obtain approval for its introduction. On Lord Howe Island, correct identification of the African big-headed ants reduced the area infested from 200ha to approximately 20ha, and the last 6ha are scheduled for treatment in early 2013. On Norfolk Island, 11 zones of infestation have received at least one treatment, including the difficult to access steep cliff faces. Argentine ants appear to have been eliminated from three sites.

For all but the program on Christmas Island, following treatment, surveillance must be done for a sufficient time period after the last treatment (NEAEP: 18 months; NRIFAEP, yellow crazy ants in Arnhem Land, African big-headed ants: 2 years; Argentine ants: 3 years) to be able to declare a site to be free of the target tramp ant. In all cases, the CfOC funding period evaluated here has ended or will end before eradication or regional containment is achieved.

Impacts on biodiversity

All programs have recognized that native invertebrate communities, especially ants, are the component of biodiversity most likely adversely affected by tramp ants and by baits applied to control tramp ants. The four longest running programs (NRIFAEP, NEAEP, and the yellow crazy ant programs) have documented some effects of the target tramp ant on invertebrates at the project site. Documented effects range from changes in the native ant fauna (NRIFAEP, NEAEP, yellow crazy ants in Arnhem Land), changes in the community composition of other ground invertebrates (NEAEP, yellow crazy ants in Arnhem Land), and marked population declines of Red land crabs, increases in scale insect populations, and associated ecosystem-level changes (yellow crazy ants on Christmas Island).

The programs have generally been poor at documenting species recovery following tramp ant abatement, with just three programs (yellow crazy ants on Christmas Island and in Arnhem Land, and the red imported fire ant in Queensland) documenting some recovery following tramp ant control. On Christmas Island, aerial baiting of yellow crazy ant supercolonies appears to have halted the decline of Red land crabs, and their numbers may be increasing, though it is too early to tell whether this reversal will translate to recovery of the forest. Both the NRIFAEP and yellow crazy ant in Arnhem Land program have documented some recovery of native ant species following baiting for the tramp ant. All programs are likely achieving some recovery of invertebrate taxa following tramp ant abatement, but only Christmas Island has dedicated funds to monitor biodiversity.

Other native species that are potentially at risk from tramp acts have been identified in various assessment processes, including during development of Tramp Ant Threat Abatement Plan; in the process of listing tamp ants as key threatening processes, and in the process for listing species as threatened under the EPBC Act; in formulation of species recovery plans; and in the formative stages of the programs themselves. Nonetheless, in all but one program (yellow crazy ant on Christmas Island) there has been no investment in monitoring occupancy or trends in populations in any native species identified as potentially vulnerable to the tramp ants. In this review we highlight that risk assessment should not be seen as an end in itself. A principal reason for risk assessment is to guide further action, either in developing control protocols to minimise the identified risks; to develop monitoring programs so as to be able to robustly report on levels of realised non-target impacts; or both. The program on Christmas Island is exemplary in demonstrating such a link between risk assessment and monitoring.

In each of these programs the infestation site is within or closely adjacent to areas designated of high conservation value by State and/or Commonwealth governments, and by international conventions and agreements because of outstanding biodiversity and other natural features of international significance. It is clear that unabated, the red imported fire ant, electric ant, yellow crazy ant, African big-headed ant, and Argentine ant will adversely affect many endemic or native taxa. We developed a rapid risk assessment approach and accordingly assessed risks in the bioregion in which the respective programs were embedded, focusing principally on species and subspecies listed under the EPBC Act, but additionally included species/subspecies recognized as high priority in the bioregion, and species/subspecies that are common, characteristic or otherwise iconic elements of the regions' fauna. Our assessment for sample of fauna indicates:

- Red imported fire ants in southeast Queensland: Assessment included 123 native taxa, with most species/subspecies in the bioregion predicted to be affected to some degree, and effects sufficiently severe to cause population declines in ~45% of birds, ~38% of mammals, ~69% of reptiles and ~95% of amphibians.
- Electric ants in Wet Tropics Bioregion. Assessment included 198 native taxa, with~87% of the species/subspecies predicted to suffer some level of impact, and effects sufficiently severe to cause population declines in ~18% of birds, 25% of mammals, 14% of reptiles, and 24% of amphibians.

- Yellow crazy ants in Arnhem Coast Bioregion of Northern Territory. Assessment included 78 native taxa, with~97% of birds, ~41% of mammals and ~96% of reptiles assessed predicted to suffer some level of impact, and effects sufficiently severe to cause population declines in ~34% of birds, ~35% of mammals, and ~9% of reptiles.
- Yellow crazy ants on Christmas Island. Assessment included 49 native taxa, ~94% of species/subspecies predicted to be affected to some degree, with effects sufficiently severe to cause population declines in ~33% of birds, all 3 mammals, ~60% of reptiles and ~27% of crabs.
- African big-head ants on Lord Howe Island Group. Assessment included 33 vertebrate and 8 invertebrate taxa, with effects sufficiently severe to cause population declines in ~31% of birds, the single mammal, and 33% of reptiles. Of the eight threatened invertebrates assessed, four or 50% are predicted to suffer population declines.
- Argentine ants on Norfolk Island Group. Assessment included 33 birds, 1 mammal, 6 reptiles and 5 invertebrates, with effects predicted to be sufficiently severe to cause population declines predicted in ~6% of birds, the single mammal, and 2 of 6 reptiles. Of the 5 threatened invertebrates assessed, all are predicted to suffer population declines.

Most programs have not adequately tested for effects on non-target species, and have assumed that the impact of the tramp ant on other species will far outweigh any effect of the toxic bait. The preliminary analysis of native ant recovery in the red imported fire ant program indicates that for some taxa, this is not true. In contrast, the monitoring of native ants in Arnhem Land suggests no effect of the bait, and preliminary results on Lord Howe Island also indicate that the bait is not adversely affecting non-target ground invertebrates. The yellow crazy ant program on Christmas Island has the best track record of investigating non-target effects of the baiting regime, and may also have the most vulnerable native fauna.

We outline a framework from which a minimum core set of measurements might be developed to assess and report on tramp ant impacts on biodiversity in Australian terrestrial ecosystems. It is recommended that this framework be developed further within a consultative process with stakeholders.

Community awareness

The primary goals of community engagement activities, for all but the Christmas Island program, are to prevent further inadvertent spread of the tramp ants and to educate and motivate the public to detect and report infestations. The need for raising community awareness and public surveillance for infestations is greatest in the four programs aiming for eradication. The two largest of these programs (NRIFAEP, NEAEP) have budgets and staff for community engagement activities, as well as a legal mandate to impose movement controls on high risk materials. They also receive feedback via a formal annual household survey. Both of these programs have achieved high level of public awareness of the tramp ant and have benefitted substantially from public reporting of new infestations. For NRIFAEP, ~70% of new infestations have been reported by the public. The two smaller eradication programs (African big-headed ant, Argentine ant) both utilize their island's informal networks and close-knit communities to raise awareness of the tramp ant and control efforts, and to encourage reporting of suspect ants. The YCA program in Arnhem Land has trained at least 20 indigenous people in yellow crazy ant identification, chemical application, and general knowledge of the impacts of the ant, and has also worked with Pacific Alumina to develop its capacity to manage the ant on the minesite lease. On Christmas Island, community engagement activities are done to garner and maintain community support for control efforts and for Christmas Island National Park and conservation activities generally.

Conclusions

Achieving eradication or abatement of tramp ants at the scale that these programs are attempting is a long-term process, requiring a sustained, dedicated effort, and lots of trial and error along the way. Unless and until long-term management solutions are achieved (e.g., complete eradication, regional containment, or sustained biological control), the legacy of these programs will always be threatened by discontinuous or insufficient funding.

Some key lessons that should be gleaned from the collective experience of these programs are

- an early response to infestations is needed
- infestations are almost always larger in area than initially anticipated
- insufficient funds and a lack of contingency plans will hamper progress
- investment in research and development can improve program efficiency
- community engagement is a worthwhile investment
- multiple treatment rounds and extremely effective post-treatment surveillance is required to confidently declare eradication has been achieved

All programs need to ensure there is sufficient institutional memory for the program to continue should key personnel become unavailable. The longest running programs need to publish their results and methodologies in peer-reviewed scientific journals.

In our review, we observed that often stretched financial and labour resources mean monitoring of outcomes for the environment, including biodiversity, were neglected in favour of delivery of controls and monitoring to confirm pest numbers are reduced. Nonetheless, it should be borne in mind that pest control is only a means to an end. Being able to track and report on higher-level outcomes – the realised economic, social and environmental benefits accruing from the program – is not only an integral part of adaptive management feed-back loops upon which operational activities can be honed, but is also central to engendering ongoing support from the public and funding agencies. There are ample opportunities in which biodiversity impact assessment and monitoring can occur within the context of abatement programs, and in a robust scientific manner. More fully resourcing programs and setting program outcomes and milestones that specify the investigation of biodiversity impacts, would increase the likelihood that biodiversity is monitored and biodiversity outcomes reported alongside progress to achieving eradication, suppression or containment.

In all cases, these tramp ants have high potential to adversely affect biodiversity at infestation sites and adjoining areas should these abatement programs fail. The high potential for the five tramp ant species targeted by these programs to wreak havoc on local biodiversity makes their management highly appropriate. Our assessment is that the red imported fire ant, electric ant, yellow crazy ant, African big-headed ant, and Argentine ant are of such significance that abatement programs at all infestation sites justify ongoing resourcing.

The six objectives articulated in Tramp Ant Threat Abatement Plan remain highly relevant to tramp ant abatement:

- Increase science-based knowledge and expertise, incorporate Indigenous traditional ecological knowledge, quantify impacts, and improve access to information for priority tramp ant species
- Prevent entry and spread of tramp ants by increasing diagnostic capacity, offshore surveillance, inspection, treatment, and national and state and territory surveillance
- Prepare for rapid response to tramp ant incursions and spread through risk assessment of tramp ant species and pathways of introduction, and development of contingency plans
- Enhance emergency response to tramp ant incursions by improving reporting and response rates, and by developing tools for response and follow-up
- Build stewardship by engaging, educating, and informing the Australian community about the impacts of invasive tramp ants and effective means of response
- Coordinate Australian Government, state and territory government, and local management activities in Australia and the region.

Implementation of the Plan, signed by the Minister of Environment and Heritage in June 2006, would enable a national, coordinated, and more proactive approach to addressing tramp ant incursions.

Other tramp ants and opportunities for future abatement programs

In comparison to ten other tramp ant species in Australia, the five ant species currently the subject of some abatement clearly represent the highest threat to biodiversity values. Of the ten other tramp ant species reviewed, only *Solenopsis geminata* (on Ashmore Reef), and possibly *Tetramorium bicarinatum* (on Northeast Herald Cay) have documented adverse ecological effects in Australia. Of known tramp ant infestations in Australia, the stand-out opportunity for management that will potentially yield the greatest benefit to biodiversity is the yellow crazy infestation of the Wet Tropics World Heritage Area in Queensland.

1. INTRODUCTION

Ants are among the most ubiquitous and numerous insects in the world. Approximately 25,000 species are thought to exist, though only little more than half have been described[1]. At least 150 ant species have been introduced to new regions beyond their native range with human help[2]. These so called tramp ants are often associated with humans and thrive in disturbed habitats. Invasive ants are the small subset of tramp ants that are able to establish and spread in undisturbed habitats[3]. The IUCN list of 100 of the world's worst invasive species includes all five of the ant species[4] that are the subject of this evaluation. Because their environmental effects and the means by which they are managed are dependent on their biology, we summarize some of their basic characteristics in the table below (Table 1.1).

Tramp ants generally have several life history traits in common[3, 5, 6]. Their nests have multiple queens (polygyny) and workers of the same species can move among nests without encountering intraspecific aggression (unicoloniality). An extremely dense or vast area of unicolonial nests is termed a supercolony[6]. Queens reproduce within the nest and start a new nest by walking a few meters with a few workers and brood (budding). Long-distance dispersal is predominantly human-mediated and is facilitated by the ability to nest in a variety of materials (e.g., pot plants, timber, machinery, commercial products)[7]. Electric ants and red imported fire ants, both of which originate from seasonally flooded regions, are capable of creating a raft of interconnected workers around the queens and brood, or can cling to floating vegetation, and thereby survive and disperse when floods commence[3].

The red imported fire ant has a more complex social structure than most other tramp ants, occurring in either a polygyne or a monogyne form[3]. The social form affects the colony density and mode of dispersal. Monogyne colonies have a single queen and workers that will aggressively defend the colony from fire ants of other colonies. Monogyne queens found new nests primarily after nuptial flights. In Australia, average dispersal distance is 500m for monogynes, and 1-50m for polygynes[8]. In contrast, polygyne colonies can have several hundred queens, and workers can move among neighboring nests. Queens from polygyne colonies can undergo short nuptial flights, but generally found new nests by budding[6]. Polygyne colonies are more stable and occur at a much higher density than monogyne colonies, reaching 1635 colonies per hectare in Texas[8].

Table 1.1 Native range, size, and features that affect management for the five invasive ant species*

	Red imported fire ant	Electric or little fire ant	Yellow crazy ant	African big-headed ant	Argentine ant
Scientific name	*Solenopsis invicta*	*Wasmannia auropunctata*	*Anoplolepis gracilipes*	*Pheidole megacephala*	*Linepithema humile*
Native range	South America	South America	Africa or Asia	Africa	South America
Known distribution in Australia	SE Queensland	Cairns region	Christmas Island, northeast Arnhem Land, Cairns region and other parts of Qld, incursions elsewhere	Widespread	widespread
Location of program(s)	SE Queensland	Cairns region	Christmas Island, northeast Arnhem Land	Lord Howe Island	Norfolk Island
Appearance	Polymorphic, 2-6mm, coppery brown	Monomorphic, 1-1.5mm, golden brown, slow moving	Monomorphic 4-5mm, yellow-brown, erratic	Dimorphic, 2mm (minors) 3.5mm (majors) major workers have distinctively large heads; light brown	Monomorphic, 3mm, brown
Features affecting management	Nests in mounds; has 2 social forms; seasonal activity	Clonal and sexual reproduction, enters houses, very small, forages in canopy	Reaches very high densities (supercolonies), apparent dependence on honeydew, forages in canopy	Easily confused with some native *Pheidole* or other ants; seasonal activity	Foraging in canopy; seasonal activity
Dispersal	Nuptial flights, budding, humans, rafting	Budding, humans, rafting	Budding, humans, some reports of nuptial flights on Christmas Island[9]	Budding, humans	Budding, humans
Indicative rate of natural spread[3]	10-40m/year for polygyne form in Texas	170-500m/year in Galapagos[10]	37-402m/year in Seychelles	15m/year in northern Australia	15-270m/year in northern California

*See each program for further discussion and references

2. MANAGEMENT AND CONTROL

Killing ants is unlike killing other pest insects. The division of labor in ant colonies means that after mating and founding their nest, reproductive females (queens) remain safely within the nests whereas the non-reproductive workers forage for food and interact with the environment. Only a small fraction of workers are foraging at any one time. To be an effective means of controlling ants then, a chemical bait must be non-repellent at the product concentration, have a delayed action of at least 24 hours to enable food sharing throughout the colony before ants begin to die, and be fatal to the target ants at concentrations as little as 1/100th of the original dose[11]. If the queens are not affected, it is likely the colony will recover, regardless of how many workers have died.

The six tramp ant management programs to which Caring for Our Country (CfOC) has contributed project funding and under review here, are very ambitious compared to successful eradications internationally. Table 2.1 summarizes the size and other features of the treatment operations of the six tramp ant programs in Australia. These are discussed in detail in Sections 2.1-2.6. Most successful eradications in the world have been in areas of infestation less than 1ha, and the largest eradication in the last decade has been 41ha[12]. Consequently, Australia is at the forefront of developing methodologies to implement eradication attempts on large scales and has made considerable progress.

Management and control of tramp ants lies at the heart of all six programs and is where most of the resources are directed. The protocol required to control and eradicate invasive ants is (adapted and generalised from the National Electric Ant Eradication Program Operational Plan[13]):

- Locate all infestations (ongoing)
- Delimitation of all detections to determine the extent of the infestation
- Definition of a restricted area around infestation and appropriate buffer
- Implementation of movement controls to prevent further spread outside the restricted area
- Application of chemical control treatments
- Monitoring activities following completion of treatment to assess treatment efficacy
- Confirmation of no further infestation and proof of freedom with two clear passes of surveillance at an appropriate intensity and duration after the last treatment to provide confidence that eradication has been achieved.

Many of the programs utilize the same active ingredients in the toxic baits employed for ant control, summarized here for ease of comparison (Table 2.2). Ant toxins currently in use can be classified into three categories: metabolic inhibitors (or “stomach” poisons), neurotoxins, and insect growth regulators (IGRs), or more recently renamed insect growth disruptors (IGDs)[14, 15] (to avoid confusion we retain use of IGR). Metabolic inhibitors, such as hydramethylnon, kill all workers and reproductive ants it comes into contact with, generally within two to three days[15]. Neurotoxins, such as fipronil, disrupt the normal functioning of the nervous system and provide rapid kill of contacted insects[16]. IGRs, such as pyriproxyfen and methoprene, mimic juvenile insect hormones and disrupt development of queen ovarian tissues[14, 15]. They can take several weeks before reductions in populations are observed[15].

The programs and CfOC projects within these vary significantly in their scope due to differences in the biology of the target tramp ants, and the extent and location of the infestations. We review each of the CfOC projects within the context of the programs. Where possible, we illustrate our points with maps and figure; these are of varying quality and format.

For each CfOC project we

1. identify treatment methods used in CfOC tramp ant projects to reduce the impact of tramp ants,
2. assess the success of these different methods, recognizing that most of these CfOC funded projects are parts of larger programs and it is difficult to separate out achievements that occur only during the CfOC funded period, and
3. provide practical on-ground advice for future management to improve the effectiveness of projects to reduce the impact of tramp ants on biodiversity, based on the data available at the time of writing. Several programs were at a pivotal stage when we finalized our report.

Table 2.1 Summary of treatment operations for the six tramp ant programs*

	RIFA[17-19]	EA[10, 13, 20]	YCA-NT[21]	YCA-CI[21-24]	ABHA[25-27]	AA[28-33]
First detected	2001	2006	1975	1915-1934; first supercolony 1989	2003, likely there since 1993	2000; confirmed in 2005
Estimated Initial infestation	>36,000 ha (2001)	76ha (Aug 2006)	450ha (2002)	Widespread;~200ha supercolonies by 1998, 2500 ha by 2003	120ha, but revised to 20ha following correct ant identification	>76ha (2010)
Program goal	Eradication	Eradication	Regional containment	Supercolony suppression	Eradication	Eradication
First treatment	21 March 2001	August 2006	2001	2000	2008	2006
CfOC funding years in this evaluation	2008-09, 2009-10	2008-09, 2009-10, 2010-11	2008-09	2011-15	2011-13	2010-12
Chemical control method	Direct injection of mounds with fipronil; initially 6 treatment rounds of broadcast S-methoprene and/or pyriproxyfen	6 applications of hydramethylnon; S-methoprene used near water	3 treatments each 3 months apart of either fipronil, pyriproxyfen or hydramethylnon	Biennial aerial spread of either fipronil, pyriproxyfen, or S-methoprene depending on proximity to water	Single application hydramethylnon, persistent infestations to be re-treated	Single application of fipronil paste or spray with follow-up treatment as necessary
Treated Buffer zone	Initially, at least 500m, now 50m	50m	100m	None	20m	50m
Detection & delimitation methods	Visual detection of mounds, odour detection dogs, remote sensing, trace forward and back	Peanut butter & hotdog lures, odour detection dog; gutter, pitfall, canopy traps; trace forward and back	Visual searches	Island wide survey conducted biennially	Public reports, trace forward and back	Public reports, trace forward and back, survey with lures

* RIFA= red imported fire ant; EA= electric ant, YCA-NT= yellow crazy ant-Arnhem Land, YCA-CI= yellow crazy ant-Christmas Island, ABHA= African big-headed ant, AA= Argentine ant

Table 2.2 Active ingredients in chemical control, their mode of action, and the programs that use them

Chemical	Mode of action	Programs using*					
		RIFA	EA	YCA-NT	YCA-CI	ABHA	AA
fipronil	Broad use, slow acting poison, kills by both contact and ingestion, works by disrupting the normal function of the central nervous system in insects[16]	X		X	X		X
S-methoprene	Insect growth regulator/disruptor, a juvenile hormone analogue, it interferes with molting, egg-laying, and egg-hatching. Breaking the reproductive cycle results in colony starvation as workers die and are not replaced[34]	X	X		X		
pyriproxyfen	Insect growth regulator/disruptor, a juvenile hormone analogue that disrupts egg production and brood care by overloading the hormonal system of the ants[35]. Breaking the reproductive cycle results in colony starvation as workers die and are not replaced.	X		X	X		
hydramethylnon	a metabolic inhibitor, causes lethargy within 24 hours and mortality in 72-96 hours[36]	X	X	X		X	
indoxacarb	Kills by binding to sodium channels thereby impairing nerve function and causing feeding cessation and death. The toxin is a metabolite of indoxacarb that is not activated until the carrier is ingested and regurgitated by larvae in the nest[36].	X					
chlorpyrifos	Interferes with acetylcholinesterase, an enzyme necessary for nervous system function; fatal by contact or ingestion[37]		X				

* RIFA= red imported fire ant; EA= electric ant, YCA-NT= yellow crazy ant-Arnhem Land, YCA-CI= yellow crazy ant-Christmas Island, ABHA= African big-headed ant, AA= Argentine ant

2.1 Red imported fire ants in Queensland

Red imported fire ants, *Solenopsis invicta*, were discovered on the Fisherman Islands in the Port of Brisbane February 2001. By the end of February, an in principle agreement was reached between all State and the Commonwealth governments to eradicate the infestation, and the first treatment was applied on the 21st of March 2001[8]. A second population in the suburb of Wacol in the greater Brisbane area was also discovered in 2001. A third population in Yarwun, Gladstone, approximately 500km north of Brisbane, was detected in 2006[8, 38]. The three populations are genetically distinct and represent three separate incursions. The Port of Brisbane population consisted of predominantly monogyne colonies and the Yarwun population consisted exclusively of monogyne colonies, whereas the greater Brisbane population was found to be a mix of monogyne and polygyne colonies[38]. Red imported fire ants are thought to have been in Queensland for 15 years before detection[39].

The National Red Imported Fire Ant Eradication Program (NRIFAEP) is a national cost-share program. It received part of its funding from CfOC in 2008-09 ($2.181 million[40]) and 2009-10 ($7.5 million[41]) financial years. The three CfOC Project Objects applicable to 2009-10 funding were[41]:

1. Reduction in red imported fire ant nests in the southeast Queensland Restricted Area to move the species closer to eradication;
2. Development and application of a remote sensing pilot project to detect red imported fire ants in non-urban and rural areas; and
3. Production of a report by an independent review panel examining the National Red Imported Fire Ant Eradication program, providing an assessment of technical feasibility of eradication.

We discuss these three targets in the context of the treatment and detection methods, their success, and advice for future management below. We focus on activities and results during periods of CfOC funding from 2008-2010, but provide data that were available for other years for context.

2.1.1 Treatment methods

Controlling and managing fire ant infestations requires early detection of colonies, destruction of colonies and treatment of areas around colonies, and prevention of new colonies outside the limit of natural dispersal [38].

Detection

NRIFAEP has employed a mixture of structured surveillance methods (Table 2.3) as well as passive surveillance via community engagement (see Section 4.1). Structured surveillance is conducted to detect new colonies as well as to verify that colonies have been eliminated following treatment (post-treatment validation). Canine surveillance was trialed in 2006 and the first dog, “Aka,” was validated in 2007[18]. Two more dogs were validated in May 2008[18]. Currently several dogs are operational. Trained odour detection dogs are sensitive enough to detect a single ant[42].

Table 2.3 Structured surveillance methods employed by NRIFAEP[38]

Technique	Description	Delivery	Use situation	Estimated sensitivity	Indicative work rate/day/unit
Visual surveillance	Team members form a line with pre-set spacing depending on terrain and conduct survey sweep across land to be surveyed, repeating as necessary	Field teams	Detection, response to public reports, pre-disturbance inspections	80%	10ha/team of 10 people
Traps and lures	Pitfall traps in a grid pattern; not currently used	Field teams	Detection and verification	N/A	N/A
Canine surveillance	Trained odour detection dogs with handlers, regularly validated	Canine unit	Detection and verification	Near 100%	6ha (one handler, 2 dogs)
Remote sensing	Aerial photographing of the landscape with high definition visual, near infrared and thermal cameras to detect mounds	Helicopter	Detection and verification	N/A	>750ha/day/ aircraft

The total area that undergoes structured surveillance each year varies greatly depending on program needs and budget limitations. Table 2.4 summarizes the structured surveillance conducted in the first ten years of the program. It is important to note that for 2001-2010, the Structured Surveillance Completed column indicate only to the areas that were known at the outset of the financial year and do not include any additional infestations discovered and surveyed (e.g., following a report by the public)[43]. For 2010-11 and 2011-12, only the total number of hectares surveyed was available. The number of colonies detected is provided for general comparison only, as it is difficult to distinguish colonies in polygyne populations. Nonetheless, it is clear from the table that new infestations have continued to be detected, and at least since 2005, surveillance activities have been consistently underfunded. According to the 2009 Response Plan [8], priority is given to responding to public reports, pre-disturbance inspections, and high risk areas around infestations in urban, rural, and peri-urban areas. Figure 2.1 shows the areas surveyed in 2008-09 and 2009-10.

Post-treatment monitoring protocol

In 2008-09, the endorsed post-treatment validation protocol was to visit sites two weeks after nest injection and if no further ants were detected to visit again in two weeks and to place in ground lure traps for five to seven days[8]. Currently, infested areas are revisited a minimum of eight weeks after direct nest injection and surveillance is performed within 50m of the infested site.

Table 2.4 Summary of structured surveillance required, budgeted, and completed by NRIFAEP 2001-2012[8, 44]

	Surveillance area (ha) required at beginning of year	Surveillance area (ha) within budget	Structured surveillance completed (ha)[a]	Colonies detected	
				Inlier	Outlier
2001-02	33,583	24,698	12,326	384	205
2002-03	36,701	39,631	29,423	479	267
2003-04	27,945	5,773	522	71	118
2004-05	16,176	57,870	55,260	35	80
2005-06	60,742	62,211	48,394	201	115
2006-07	13,617	7,470	5,925	530	69
2007-08	9,659	5,832	4,961	434	120
2008-09[b]	10,524	3,288	2,769	493	63
2009-10[b]	12,004	7,000[c]	3632	>4800	1237
2010-11			17,614	2480[d]	
2011-12			16,117	879[d]	

[a]For years 2001-02 to 2009-10 indicates hectares surveyed out of the original planned at the outset of the year, for 2010-11 and 2011-12 indicates all surveillance conducted.
[b]CfOC funding year
[c] includes 1400 ha of trials and validation for remote sensing
[d] inlier or outlier not specified

Remote sensing

The need to improve detection capabilities if eradication is to be feasible was a key finding of the most recent Technical Review[45, 46]. Remote sensing is the use of aerial imagery to detect red imported fire ant colonies. It has three main components: capturing imagery, analyzing the imagery to detect fire ant mounds, and providing information to field staff to allow treatment[47]. The method utilizes multispectral (RGB and near infrared) and thermal images and finds mounds on the basis of the lower vegetation cover on, and higher temperature of, fire ant mounds relative to the surrounding area. The aim of remote sensing is to reduce the costs of surveillance, allow surveillance over larger areas, and increase the likelihood of detecting colonies in non-urban areas[41]. The need for better detection methods was recognized in the 2003 Operational Review, and remote sensing was specifically suggested in the 2005 Operational Review[8]. Investigation of remote sensing by NRIFAEP began in July 2008, and a phased trial commenced in 2009[42]. Remote sensing of red imported fire ants in the U.S. has achieved detection success rates of 80% and it is thought that detection rates as low as 20-40% would still result in a large increase in the probability of eradication in southeast Brisbane[38]. See Section 2.1 for recent developments.

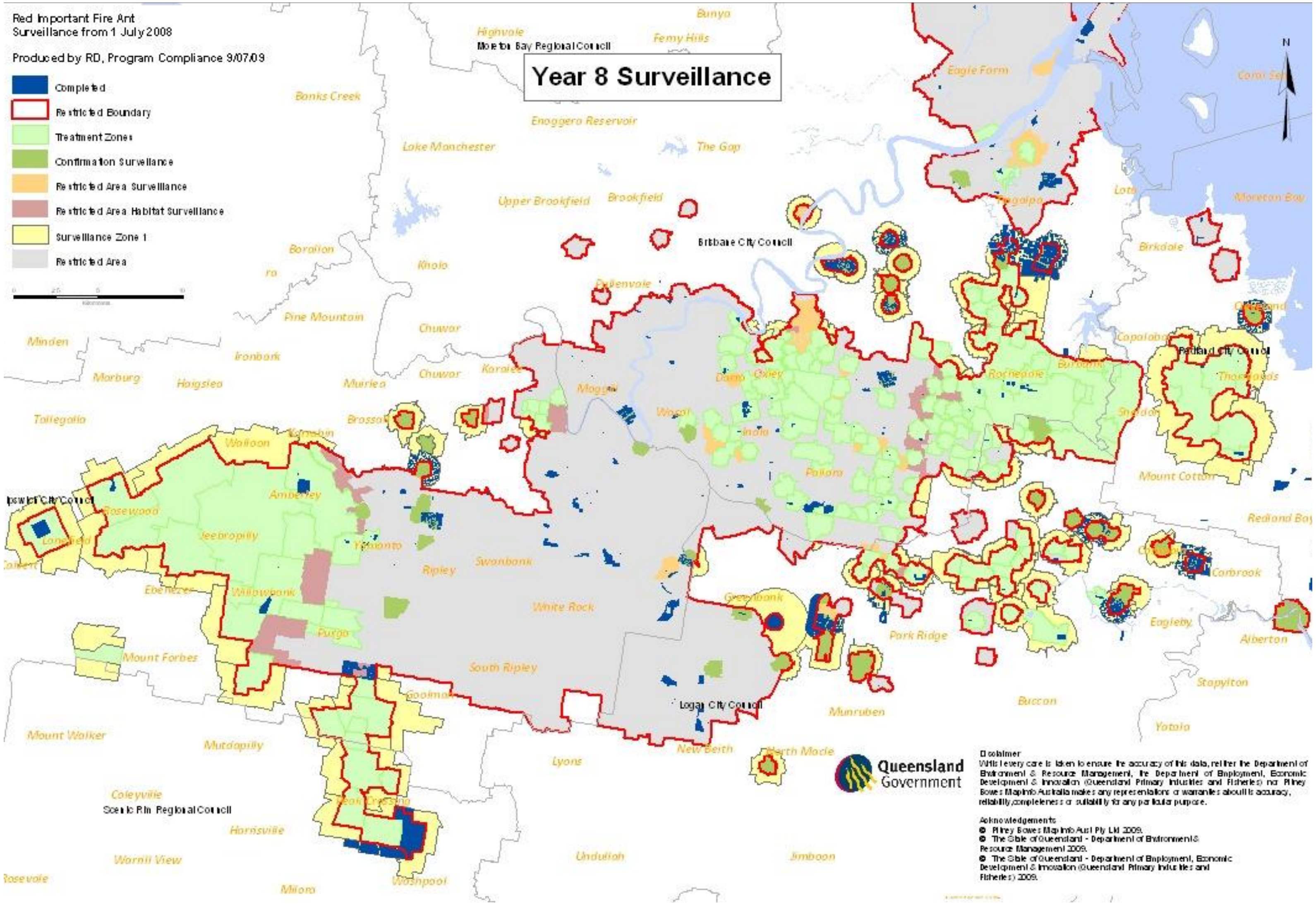


Figure 2.1A Surveillance conducted by NRIFAEP in 2008-09

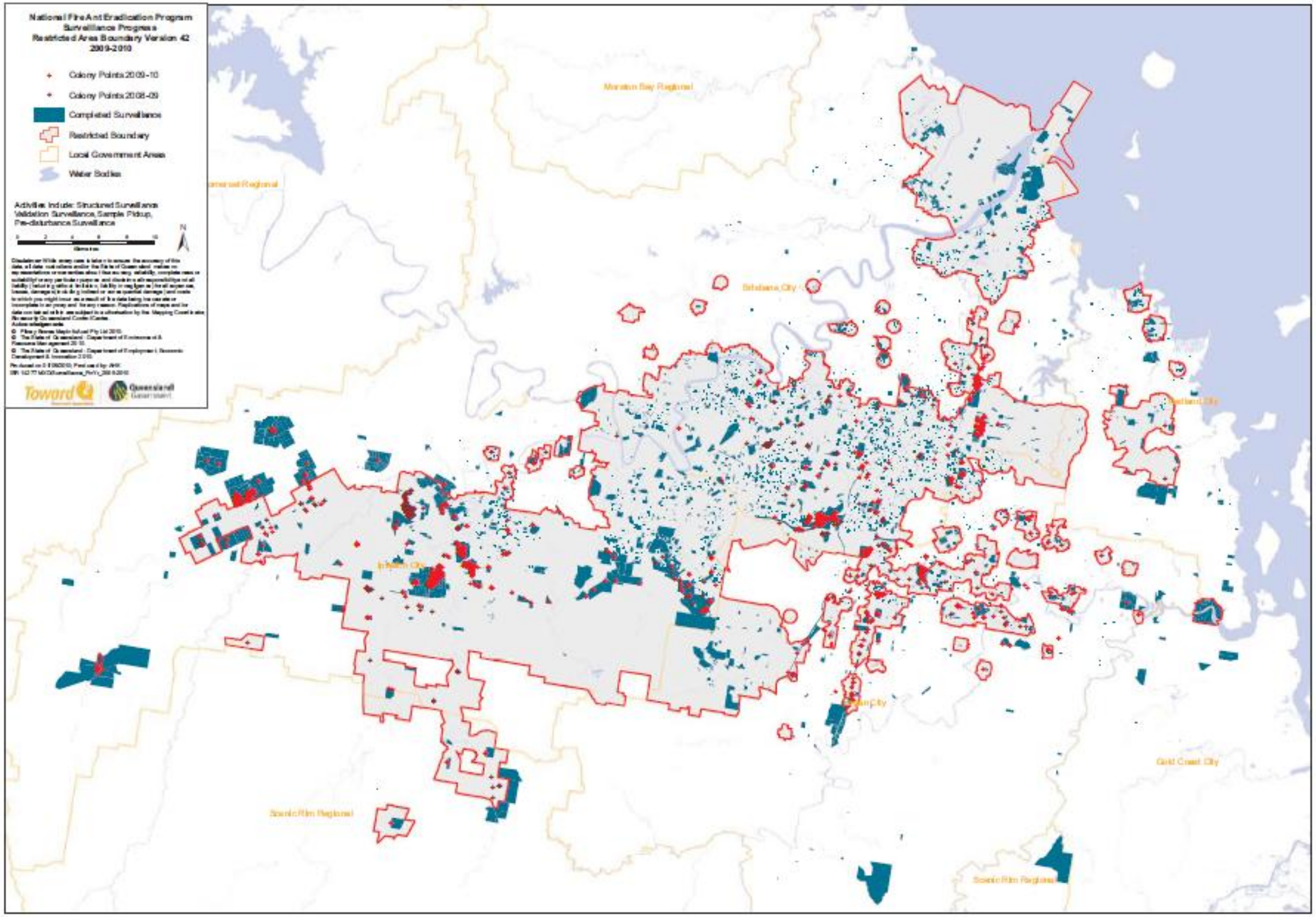


Figure 2.1B Surveillance conducted by NRIFAEP in 2009-10

Treatment and containment

Chemical control

The types of chemicals used, the situation in which they are used, and their presumed effectiveness are summarized in Table 2.5. The ideal effective toxic bait for use on red imported fire ants will provide delayed toxicity (<15% mortality after 1 day), be non-repellent, be easily formulated with carriers that are attractive to the ants, and be environmentally acceptable[36]. Treatment activities are most effective when the ants are active and therefore occur when ground temperatures reach a minimum of 20^{o}C, usually September-early May[18].

Efficacy trials for indoxacarb commenced in 2009-10 and continued to 2010-11. Results ranged from 82-100% reduction in fire ants with one treatment over 30-90 days[48]. Indoxacarb-associated mortality exceeds 15% after 24 hours, but the low toxicity for the first eight hours may be sufficient time for distribution through the colony[36]. It has been found to perform best against monogyne populations on bare sandy soils and worst against polygyne populations in grassy habitat in clay soils[48]. Indoxacarb has a similar efficacy as hydramethylnon and is being used as an alternative to hydramethylnon[48, 49].

Table 2.5 Use of chemical controls by NRIFAEP and their effectiveness[36, 38, 42]

Chemical	Where used by NRIFAEP	Efficacy
Fipronil	Direct nest injection of liquid formulation	"near 100%" when injected into nests in the NRIFAEP
S-methoprene	Broadcast as bait granules up to the edge of waterways	In U.S. trials, 66-98% efficacy over 4-8 months; varies with environmental factors, reinvasion can be a problem
Pyriproxyfen	Broadcast as bait granules ≥ 8m from waterways	In trials elsewhere, 86.9-100% over 2-9 months; considered more effective than S-methoprene
Hydramethylnon	Broadcast as bait granules around mounds	In trials elsewhere, lethargic within a few hours, death within 72 hours; 78-99% mortality in 2-21 weeks
Indoxacarb	As an alternative to hydramethylnon, commenced in 2011-12	In Brisbane trials, 82-100% effective, best on monogyne populations in sandy soils

The endorsed treatment protocol in 2008-09 was[8]:

- direct injection of nests with 25-40 liters of diluted fipronil (2.5ml/100 liters) in a liquid form, and application of a corn grit bait impregnated with hydramethylnon in the surrounding area
- six broadcast bait treatments with insect growth regulators (IGRs), over at least two years within a 500m radius of the infestation, to be increased if the perceived risk of spread is high. S-methoprene can be used up to the edge of waterways and pyriproxyfen within 8m of waterways. Pyriproxyfen is preferred because it is more stable and achieves a greater knockdown[43]. Broadcast baiting is conducted aerially, where possible, otherwise by all-terrain vehicle or on foot.

- prophylactic broadcast bait treatment in areas presenting a high risk of fire ant establishment and spread (terminal waste streams, landfill sites, bulk soil deposits)

The treatment protocol has been modified over the years of the program to incorporate new knowledge of the biology of the ant, most effectively utilize program resources, and take advantage of new bait products. Analysis of the population structure of over 3000 colonies has revealed that only 14% of colonies have both male and female alates (reproductive ants)[50]. Furthermore, 99% of nuptial flights are shorter than 2km, therefore a colony that is more than 2km away from another colony is unlikely to be able to reproduce[43]. With this knowledge, the buffer around single-nest infestations has been reduced from 500m to 50m[43].

In 2008-09, the discovery of multiple infested sites at Amberley stretched already inadequate resources even further, and resulted in National Tramp Ant Committee (NTAC) and Tramp Ant Scientific Advisory Panel (TASAP) defining the year as a 'hold year' and consenting to reduce the number of treatment passes to two from three[18]. By November 2009, treatment priorities were to continue with direct nest injection with fipronil applied to 20m around the nest, and IGR application 20-50m around the nest, followed by a second IGR treatment out to 50m from the infested site at least 8 weeks later[8]. Areas surrounding all detections would receive at least one broadcast bait treatment, but not more than two in a 12 month period. High risk areas or areas with a large number of colonies within a 2km radius would be treated with a large buffer. Prophylactic treatment of terminal waste streams and areas surround dense infestations would also continue [8].

At present, low levels of infestation get a single treatment. Higher density infestations are managed on a case by case basis and receive multiple treatments[42, 43].

The numbers of hectares needing treatment, budgeted for treatment, and actually treated are summarized in Table 2.6. It should be noted that for 2001-2010, the Treated Area column corresponds only to areas that were known about at the beginning of the financial year and do not include additional areas that were discovered and treated in the year[43]. For 2010-11 and 2011-12, only the total area treated was reported. As with surveillance progress shown above, it is clear from the table that since at least 2005, the program has not been adequately funded to enable the required level of treatment. The areas treated in 2008-09 and 2009-10 are shown in Figure 2.2.

Movement controls

Prevention of human-assisted dispersal of red imported fire ants is key to containing the pest. NRIFAEP employs phytosanitary measures, including quarantine of infested properties, as well as implementation of movement controls in the Restricted Area and for high risk materials under Queensland's *Plant Protection Act 1989* and *Plant Protection Regulation 2002*[38]. The Restricted Area is periodically updated to reflect new detections and areas where the ant has been eliminated (see Table 2.6). As of 17 December 2012, the boundaries of the Restricted Area follow suburb boundaries, and suburbs are classed as either high risk (red zone), or low risk (orange zone) (Figure 2.3). Previously, the Restricted Area was defined by areas of infestations and risk, but this proved cumbersome to update, implement, and communicate to the public.

Table 2.6 Summary of Restricted Area and Treatment Areas of the NRIFAEP 2001-2012[8, 44]

	Restricted Area (ha)	Treatment area (ha) required at beginning of year	Treatment area (ha) within budget	Treated Area (ha)
2001-02	31,415	125,576	126,316	85,348
2002-03	37,301	111,828	151,402	135,563
2003-04	49,827	149,729	291,036	226,268
2004-05	69,375	196,216	102,024	100,232
2005-06	71,743	87,548	15,483	11,561
2006-07	81,053	45,635	31,087	29,842
2007-08	86,205	53,731	40,989	39,343
2008-09[2]	92,908	82,102	40,880	40,296
2009-10[2]	94,819	93,405	40,000	37,220
2010-11	98,608			82,606
2011-12	120,714[3]			73,525

[1] For years 2001-02 to 2009-10 indicates areas treated of those planned for treatment at the outset of the year, for 2010-11 and 2011-12 indicates all treatment conducted
[2]CfOC funding years
[3] As defined on 16 Dec 2011[48]

Movement controls apply to both residents living in, and commercial enterprises operating in, the Restricted Area. Residents can use the Restricted Area Search Engine or check the map (Figure 2.3) on the Queensland DAFF website to see if their property occurs in the Restricted Area. If it does, they may move up to one cubic meter of soil or a high risk item without an inspector's approval only if they believe the item does not have fire ants and they complete a Fire Ant Declaration form[51]. The form must be kept on file for one year at the location to which the item(s) have been transferred. Under the Plant Protection Regulation 2002, high risk items are defined as[51]:

- red imported fire ants
- soil or anything with soil attached (e.g., a plant that has soil on its roots or turf)
- waste material, other than soil, that comes from the ground or is manufactured from material that comes from the ground (e.g., material extracted from the ground as part of building construction or kiln dust)
- waste bio-solids that are a product of processing or manufacturing an animal, a plant or anything that comes from an animal or plant (e.g., solid waste from a sewerage treatment plant or solid waste produced by processing an animal at an abattoir)
- a container used for growing, harvesting, moving, packing or storing that contains soil or has soil attached (e.g., beehive, bin, carton, case, crate, pallet or pot)
- baled hay or straw
- an appliance used to disturb soil or for moving any of the above items
- anything associated with a person's commercial activity that an inspector decides may spread fire ants. Once the inspector notifies the person of this decision, the item is deemed high-risk.

Commercial enterprises whose work practice presents a potential pathway for spreading fire ants need to implement approved risk mitigation in the form of an Approved Risk Management Plan (ARMP). At the end of 2008-09, 3234 businesses had ARMPs[18], and this grew to 3570 in 2009-10[44]. As of the end of 2011-12, 3895 businesses have them[48]. The majority of these are service providers and are not based within the Restricted Area and identifying them has proved challenging[8]. The Plan includes sections on methods to increase the early detection of fire ants, treatment for fire ants and of high risk items, staff training, and site inspections[52].

Movement of more than one cubic meter of soil requires an inspector's approval, and Biosecurity Queensland inspectors conduct random inspections and audits of businesses within restricted areas to check for compliance. Failure to comply with movement controls can result in penalties for residents and commercial enterprises [51, 52]. In 2008-09, 532 compliance activities were conducted, and 87% of businesses were found to be compliant[18]. Since July 2009, there has been an increased focus on compliance. There was a doubling in the number of inspectors working on compliance in 2009-10[44]. Table 2.7 summarizes the number of detected offenses, their nature, and the status for 2009-12. In February 2011, a fine was imposed for the first time. The business had illegally moved 388 tonnes of soil out of a fire ant restricted area. Although no fire ants were spread, the court indicated that it was important to send a strong message about the seriousness of the breach, and the $12,500 fine would have been higher if the breach had resulted in spread of fire ants[42].

Table 2.7 Summary of compliance investigations by NRIFAEP 2009-2012[42, 44, 48]

	Number of suspected offenses	Nature of offense			Warning or fine imposed
		Move high risk material	Disturb soil without approval	Other	
2009-10	15	12	2	1	1
2010-11	15	12	2	1	1
2011-12	5	4	1	0	0

2.1.2 Success of methods

Eradication

Several tracing events over the years have revealed spread via pot plants and other materials to other areas, but the ants were detected and eradicated before they had established[8].

The major success of the NRIFAEP has been the eradication of two of the initial incursions of red imported fire ants. The Yarwun population near, Gladstone, which was discovered in 2006, encompassed 14 known colonies with the possibility of up to 100 based on genetic analyses. Over 1084 hectares were treated[53]. Mounds were directly injected with fipronil, and a hydramethylnon-impregnated bait was applied in areas of heavy infestation. Seven rounds of an IGR (either S-methoprene and/or pyriproxyfen) were applied as prophylactic treatment to a buffer extending at least 500m around infested areas, and extending to more than one kilometer over 18 months. Treatment commenced on 10 May 2006, 13 days after initial detection, and the final round of treatment was applied 22 November 2007. Pest free verification surveillance was undertaken from 25 May-17 June 2009[53]. Yarwun officially achieved pest free status in November 2010.

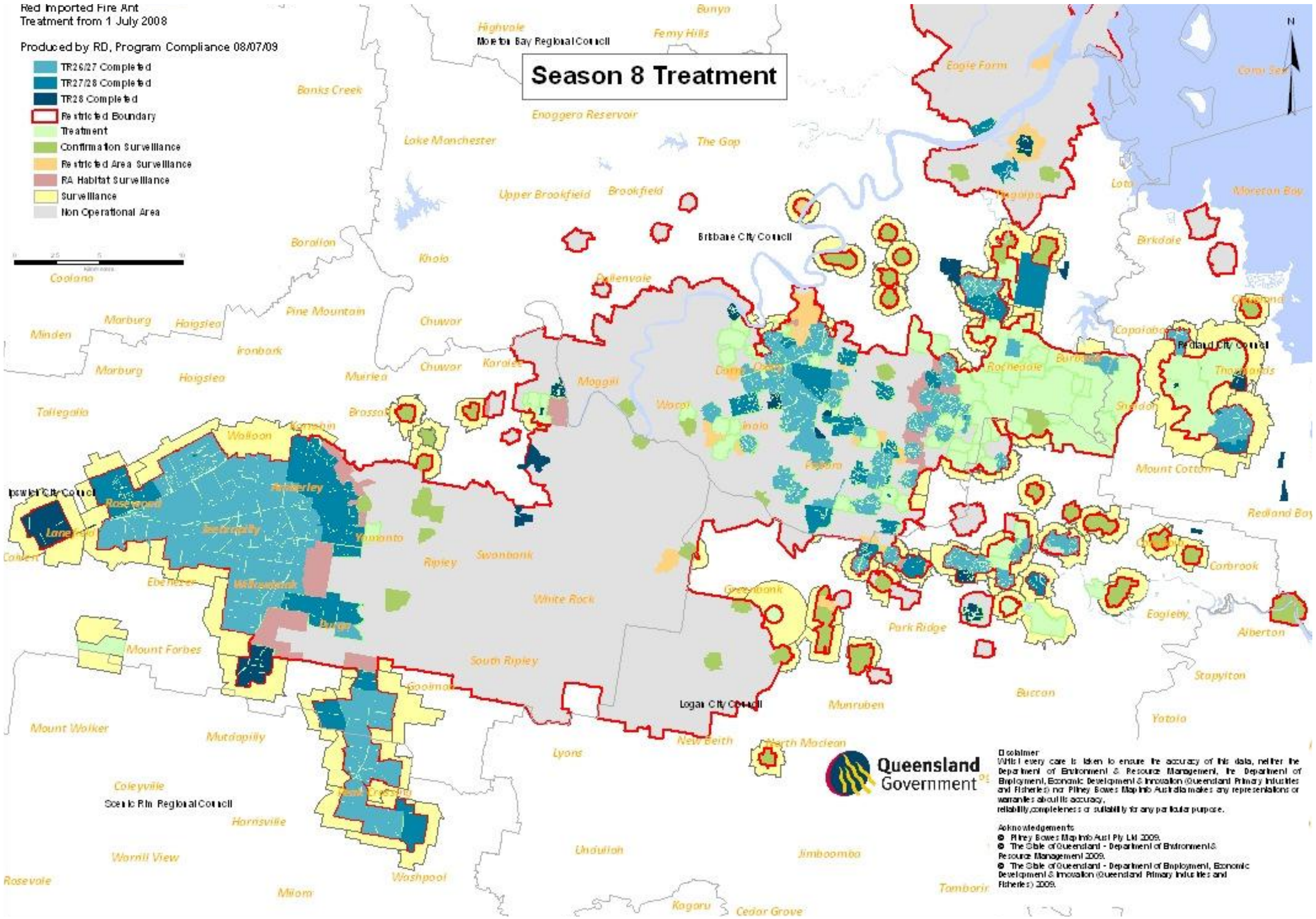


Figure 2.2A Area treated by NRIFAEP in 2008-09

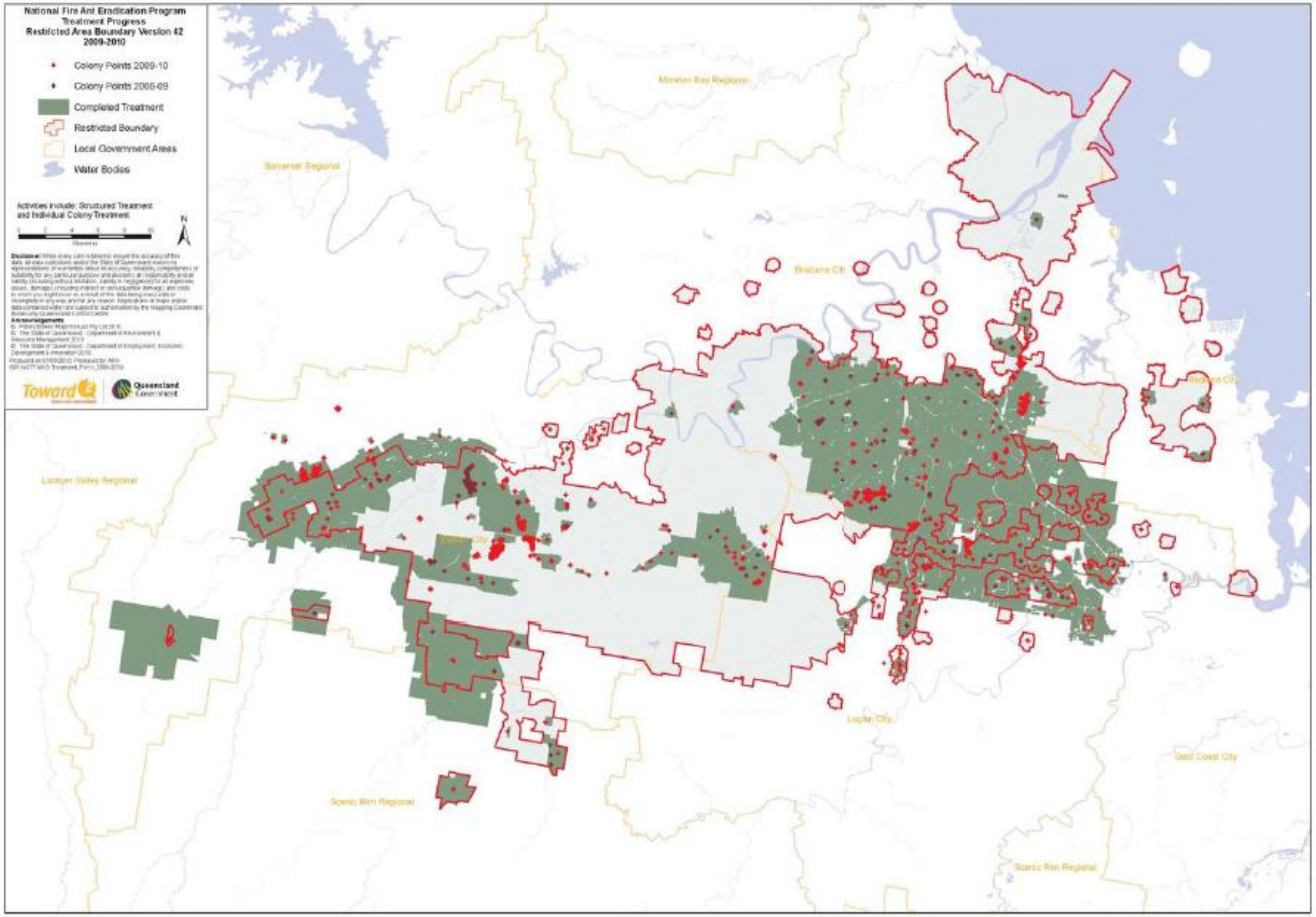


Figure 2.2B Area treated by NRIFAEP in 2009-10

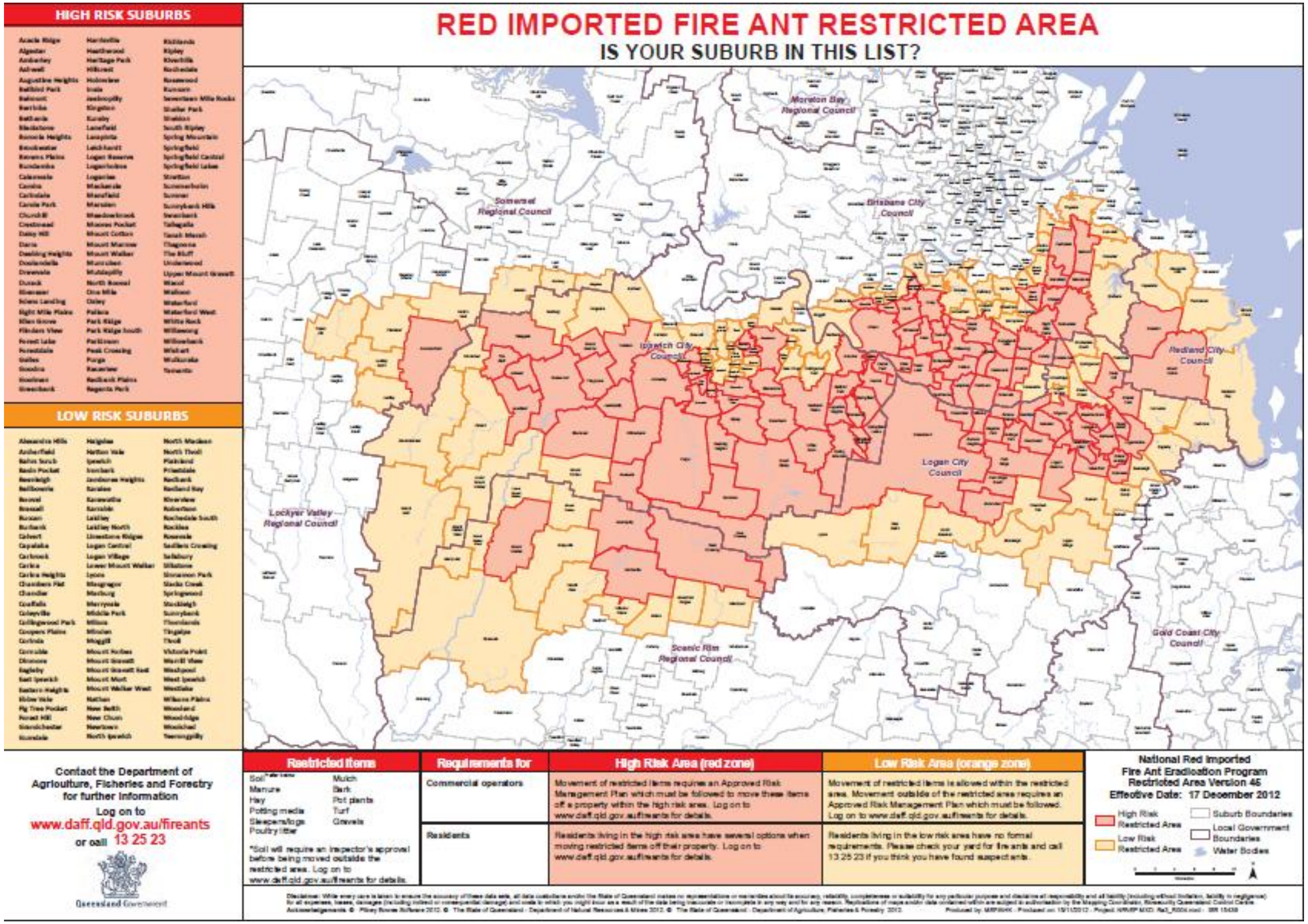


Figure 2.3 NRIFAEP Restricted Area as of 17 December 2012

The initial infestation at the Port of Brisbane, Fisherman Islands has also been considered eradicated. This population, which was detected in 2001 and consisted of 12,367ha, 130 infested sites, and 470 known colonies, was eliminated by 2005. However, fire ants have now re-infested the area, most likely from the wider-Brisbane populations[46].

Based on increases in the Restricted Area, it appears the third population in greater Brisbane has not been successfully contained. The number of hectares in the Restricted Area has increased every year since the eradication effort commenced (see Table 2.6). The detection of the Amberley infestation in July 2007 added 7500 hectares to the Restricted Area[8] and reduced the number of treatment rounds that were feasible in that year and 2008-09[8, 18]. Detections of several very dense populations amounting to over 4800 colonies in another six suburbs in the last quarter of 2009-10 also required a significant shift in program resources[44] and case management of hundreds of hectares[42].

Baiting is effective in reducing infestations. After the first season of treatment 75% of infested sites are found to be fire ant free, and after three seasons 99.5% of sites lack fire ants[47]. The primary problem has been detecting the infestations.

The 2009 Scientific Review of NRIFAEP found that eradication of red imported fire ants in southeast Brisbane was not considered feasible with the current means of detection and treatment[46]. The review recommended that for at least the next 18-24 months NRIFAEP focus on containment, rather than eradication, while alternative surveillance and treatment options are developed[46]. The review panel also found that with hindsight, since at least 2004-05, the program has not been on a clear trajectory to achieve eradication[46].

However, in the past two years, there have been some notable achievements and promising trends. The drop in the number of newly infested suburbs discovered each year from 21 to 12 to 3 over each of the last three financial years, respectively, is attributed to the prophylactic treatment buffer applied on the western fringe of the infestation in previous years[42 48]. Also, by the end of 2011-12, a total of 1488 sites, covering 13,555 hectares have had their infested site status removed[48]. Also encouraging is that the number of colonies found at new detections is decreasing, indicating earlier detection. In 2009-10, seven sites had more than 100 colonies and two sites had more than 500[42]. In 2010-11, two sites had more than 100 colonies, and 62% of newly detected infestations had only one colony. In the last quarter of 2011-12, 74% of newly detected sites had a single colony and none had more than 11[48].

The results of genetic analyses have also yielded some optimism that eradication is still achievable. In November 2011, a Scientific Advisory Panel met to critique the program's approach and interpretation of the molecular genetics data that have been collected. The Panel concluded[48] that there is lower genetic diversity in the Australian population than has been observed in other countries, and that the genetic diversity has been decreasing over time. About 75% of newly detected colonies can be traced back to known colonies, indicating that there are unlikely to be undetected populations. There is strong evidence of inbreeding, which suggests that the program is disrupting mating. The reduced genetic variation may result in reduced adaptability and biological fitness.

Research of persistent infestations and bait efficacy

A 2010 investigation of sites with 'persistent' infestations of red imported fire ants[54] found that of 2282 treated sites, 175 had red imported fire ants after one year. Of these, 97 were persistent, 51 had been re-infested, and 27 were indeterminate. Analysis by land use revealed that 81% of the 175 sites were subject to some form of regular disturbance (earth moving, tillage, or vegetation maintenance). Analysis by time revealed that 92 of the 97 persistent sites and 20 of the 27 indeterminate sites had been treated in 2001-2003 when the treatment regime was in flux. Of the five persistent sites that were treated after 2003, one was a sports oval, and one was disturbed bushland, and three were market gardens. There are three main theories as to why chemical control may be less effective on market gardens: constant watering of the crops destroys the bait before it is retrieved by the ants, constant disturbance associated with regular tilling affects ant foraging, and regular chemical use on the crops affects foraging, or may repel ants[44]. Since genetic analyses indicate that it is new colonies that are being detected rather than the same colonies persisting[44], it is likely that the regular disturbance of the soil is facilitating fire ant establishment[54]. In 2009, 303 of the 433 new infestations were on disturbed sites and in 2010, 106 of 136 new infestations were associated with disturbance. NRIFAEP staff hypothesize that red imported fire ant colonization of new sites in Queensland is strongly associated with site disturbance[54].

With this knowledge, program staff have identified market gardens and disturbed land in the Restricted Area as being at high risk of red imported fire ant establishment. Areas with disturbed soil within the Restricted Area (e.g., new housing developments) are now proactively treated twice a year[43]. As of the end of 2011-12[48], 124 of 400 identified current or former market gardens had been surveyed and 16 of them, covering 13ha, were found to be infested. Nine of these had been previously infested. All infested market garden sites receive standard direct nest injection and post-treatment validation 12 weeks later[48].

Trials to determine the efficacy of treatments has been ongoing. An analysis of results[42] from 70 sites has revealed that an average of 3.3-4.3 treatment rounds over 8.5 -11.0 months was required before the fire ant population was eliminated at sites that only received broadcast bait treatment. These results were not different than sites that had both direct nest injection and broadcast treatment (average of 4.0-4.8 treatment rounds over 8.3-10.0 to achieve 100% reduction).

Remote Sensing

When remote sensing was initially investigated, technical limitations of image capture and data storage and processing limited the utility of the method. Reinvestigation of remote sensing began in July 2008 and a trial was conducted in September 2009. The trial involved capturing imagery from 2033ha in areas of known fire ant mounds and testing manual and automated detection of mounds from the images[44, 47]. Analysis of a subset of the data resulted in a 30% detection rate and only the largest mounds were detected. It was also noted that the existing systems would not meet all the criteria required to achieve a 60% detection rate of mounds greater than 30cm in diameter from a height of 400 feet.

Existing image capture systems would not be able to meet this criterion so an open tender process was needed. After a number of delays due to the complexity of the development, the new remote sensing camera system arrived in Australia in September 2011 and aerial surveillance began within days[47, 55]. Active surveillance was conducted on 5200ha in several suburbs, and 1800ha were flown over known infestations for which there were also ground-truth data. More image capture was completed in the U.S. so that appropriate testing of manual analysis and algorithmic software could be completed. Preliminary results were that 82% of mounds were visible in the RGB and NIR images and 60% were visible in all three images (RGB, NIR, thermal). For mounds larger than 30cm, 90% of mounds were visible in RGB and NIR bands and 67% were visible in all three[55]. Following these developments, goals for 2011-12 were to deploy remote sensing technology for active surveillance, automate detection of fire ant mounds in areas of unknown infestation, continue improving automation based on new detections, and to limit false positives and negatives[55].

In May to September 2012, 51,000ha in southeast Queensland were imaged with remote sensing cameras. The result was the detection of five new colonies that were distributed over 3000ha, some 10km from the nearest known infestation. An additional three colonies were found during follow-up on-ground surveys[43]. The exercise has also revealed the best times and conditions for achieving good temperature differentials between the mounds and surrounding areas[47, 48]. Work to develop the algorithm to automate detection of mounds from the images was delayed nearly a year due to strict Queensland Government procurement requirements. In the meantime, NRIFAEP has had to rely on manual analysis of imagery, which is still slower than be ideal[47]. However, even with current capability the method offers significant cost savings. The 100,000ha of surveillance scheduled for 2012-13 would cost $32 million with field staff, but using remote sensing it will cost $7.225 million, a saving of $24.775 million[47].

High detection rates appear to have been achieved. The latest algorithm tested detected over 80% of all fire ant mounds. However, the number of false positives is an issue, with an overall average of 170 points per hectare. With manual analysis, this is brought down to 2.1 points per hectare, and further reduction should be possible with refinement of the algorithm[47].

The Queensland government has used success with remote sensing as justification to eliminate 45 jobs from the NRIFAEP[56] and cut its additional funding for fire ant eradication by more than half.

2.1.3 Advice for Future management

The NRIFAEP has undergone several reviews since its inception. Scientific reviews were conducted in 2002, 2004, 2006, and 2009. Operational reviews were conducted in 2003, 2005, and 2006. These all resulted in several recommendations to improve the efficiency of the program and increase the likelihood of eradication being achieved. Many of these have been implemented[8].

With the 24 month holding pattern declared in January 2010 reaching its end, a Technical Forum of national and scientific experts convened in February 2012 to review developments in detection and eradication. The Forum found[57] that the program has continued to suppress fire ants, and that the remote sensing and community surveillance will enable the program to know within three years whether the infestation has been fully delimited. Further, spread simulation modelling over the next year will give an estimated time and level of confidence for achieving eradication. The Forum recommended that the National Management Group endorse the Fire Ant Future Program 2012-2015[50] (hereafter Future Program) and set dates in December 2012 to reconvene to review progress on remote sensing and other technical developments[57]. The Future Program clearly states that with the latest advances in technology, "eradication of fire ants in southeast Queensland remains an achievable objective."

As of the time of writing this report, we are not aware of the outcome of the December 2012 Technical Review. We anticipate based on the Future Program[50] that the focus of the next three years will be on delineation using remote sensing technology. Approximately 150,000ha will be remotely surveyed each year. Treatment will focus on high risk areas, such as where soil is disturbed, and infested sites as they are detected. Eradication of fire ant in remaining areas of infestation after the three year delineation is expected to take another five to ten years.

Considering the recent success with remote sensing, the very high benefit to cost ratio, and the rapid spread and consequent economic and environmental impact of the ant in the United States, we would support a return to eradication as the objective of the program. This time, however, the eradication plan should include specific criteria for triggering a formal review of the program goals. Drawing on those used in the National Electric Ant Eradication Program (see Section 2.2), these might include:

- the additional detection of red imported fire ant infestation means that eradication by a specified time point is no longer feasible, or
- where delivery of the protocol exceeds the proposed indicative budget for the program, or
- where other program milestones are not being achieved, or
- where additional detections are made and the colonies detected are not related to any known infestations.

Adequate contingency funding should also be sought (and given) in the event of unforeseen circumstances (e.g., damage to the remote sensing cameras) so that they do not have drastic effects on program schedules and outcomes. Further 'hold' years where treatment is less thorough or frequent than in proven protocols will decrease the likelihood of eradication success in the desired time frame.

If eradication is abandoned, a containment-oriented program (as opposed to just suppression) would require defining boundaries outside of which red imported fire ants would not be tolerated. We would urge that vulnerable flora and fauna be considered in defining these areas (see Section 3.4 for a risk assessment of vulnerable species in the bioregion).

Regardless of whether eradication or containment is the way forward, we advise that funds be requested or allocated to enable a comprehensive analysis of the Fire Ant Information System and other data collected since the inception of the program and publication of findings in peer-reviewed scientific journals. The 2010-2011 Annual Report[42] indicates several lines of research that could inform management practices and lead to publishable results. Some of the lines of inquiry that should either continue or begin to be investigated with the data include:

- the effect of different site and environmental conditions on chemical control methods.
- the effect of fire ant and its chemical control on non-target species at the treated sites.
- the interplay between social form, and population and colony structure and how they are related to persistence and spread
- the consequence of reduced genetic variation for biological fitness[48]

- the role of disturbance in nest establishment and persistence. For example, is it a paucity of native ants, physical turnover of the soil, or another factor that facilitates fire ant establishment?

We also recommend that the impact of the program on local biodiversity be explicitly and rigorously assessed. The implicit assumptions of the program are that:

- eliminating the ant is protecting biodiversity, and
- the means of eliminating the ant (chemical treatments) are less damaging to biodiversity in the long-term than the ant.

These may very well end up being valid assumptions. But as noted in Section 3.4, investigations of the effects of the red imported fire ant on Australian flora and fauna to date are few and lacking in rigour. Providing quantitative evidence to validate these assumptions will help to justify the continued management of the ant and the expenditure of resources. It appears that the program already has some data with which to test these assumptions. The 2010-11 Annual Report[42] indicates that of ants collected from 60 infested sites some genera were affected by the bait but not the fire ants, some were affected by the fire ants but not the bait, some were affected by both bait and fire ants, and some were affected by neither. The publication appears to be a work in progress[58]. These samples need to be identified to species and quantitative analyses should be conducted as soon as possible to rule out the possibility, however small, that chemical treatments to control red imported fire ants are doing more harm to the native ant assemblage than the ant itself. If these ants were collected with pitfall traps, then the other taxa captured should similarly be identified and their abundance and richness analyzed for effects of baits and fire ants (see Section 5.2).

We note that there may be a reluctance to spend time and resources on such analyses when they may not directly or immediately lead to improvements in the program or increase the likelihood of eradication. However, the program has had significant success in partnering with scientists and other experts to develop the remote sensing technology[47], model the spread of the red imported fire ant[59], conduct a cost-benefit analysis of eradication[60], and investigate the value of community engagement[61]. The program should seek partnerships with scientists to investigate the effects of the program on biodiversity. The existing FAIS database represents a valuable resource that would likely be of interest to invasive ant experts. Sharing these and other collected data could expedite their analysis and application of their findings at little or no cost to the program.

We lastly urge program staff to ensure that there is sufficient ‘institutional memory’ of the history of the program, the development of its protocols, and its successes and failures to ensure that program capacity is retained should there be a turnover in key personnel.

2.2 Electric ants in Queensland

Electric ants (*Wasmannia auropunctata*), also sometimes known as little fire ants (Table 1.1), were confirmed to be present at Smithfield, north of Cairns, on 11 May 2006. They are thought to have been present in Australia for three to four years before they were detected [10]. The Consultative Committee for Emergency Plant Pests agreed a national response was required to address the threat posed by the ants on 18 May 2006 and scoping began in June[62] , and the first treatment was applied in August 2006[63]. A formal application for a national cost-sharing program to run for four years was made only in April 2007, after the response required had been fully scoped[64]. In 2006-07, and 2007-08, delineations of the infestation, and treatment and surveillance of high risk and other areas, were conducted[62].

Genetic analyses indicate that all infestations known to date have arisen from the one incursion[65]. The ant has a slow rate of natural expansion. With the exception of three infestations that were the result of movement by water, all infestations have been the result of human-assisted movement[63]. Smithfield remains the most likely first point of infestation[65].

Caring for Our Country contributed to the national cost-share program in the 2008-09 ($704,911), 2009-10 ($728,500), and 2010-11 ($471,042) financial years[66]. The Caring for Our Country Project Objects applicable to this funding were[67]:

1. to reduce the impact of the ant via treatment of known infestations, detections of new infestations with surveys and tracing activities, and confirmation of treatment surveillance of treated areas, as well as research and development regarding food preference, traps, odour detection, influence of scale insects, and genetic techniques for tracing infestations, and
2. to improve the knowledge and skills of land managers and increase community knowledge and skills (discussed in section 4.2).

In the discussion of the treatment and detection methods, their success, and advice for future management below, we focus on activities and results during periods of CfOC funding from 2008-2011, but provide data that were available for other years for context.

2.2.1 Treatment methods

Detection

As with the NRIFAEP, NEAEP relies on several methods of surveillance. The terminology used has changed over the course of the program but the purpose has remained the same: to detect new areas of infestation, to delineate new infestations, and to verify eradication following treatment. Passive surveillance to detect new infestations is done by the public and is facilitated by raising community awareness (see Section 4.2).

Electric ants are extremely small and single workers are easily missed in visual inspections. NEAEP structured surveillance utilizes several traps and lures to attract electric ants (Table 2.8) where they can be collected and identified with the aid of a microscope in a laboratory[37]. In 2011-12, development of a PCR diagnostic test was completed, allowing for large numbers of samples to be processed accurately and efficiently[65].

Table 2.8 Lures and traps used for surveillance in the NEAEP[10]

	Description	Placement	Time to collection
Peanut butter lures	Ice block stick with peanut butter	In a grid on ground	60 minutes
Hotdog sausage lure	A skewer speared through a slide of hotdog sausage	Spiked in the ground in a grid	60 minutes
Peanut butter lured pitfall traps	A centrifuge vial with peanut butter	Buried to the lid and left in the ground	3-7 days
Gutter traps	A lure fixed to a rod that has been covered in the sticky substance Tanglefoot®	In the gutter of building roofs	1-3 days
In-house traps	Small vial containing white oil and a suspended food source (lure)	Fixed to secluded areas of the house	1-3 days
Canopy traps	External plastic pipe with an internal rod smeared with Tanglefoot and a lure	Suspended from trees	3-7 days

The program identifies areas to undergo surveillance by tracing infestations forward to other potential infestations and back to their sources, and by identifying high risk sites and suburbs. High risk sites include transfer stations, landfills, and illegal dumping sites. Suburbs are deemed high risk on the basis of their proximity to previous infestations, the existence of new developments, and their geographic connectivity to infested suburbs via topography, population interactions and movement, and target industries. Analysis of infestations showed that since 2006, all but one infestation had been present along footpaths[66]. In April 2011, proactive footpath surveillance commenced in high risk suburbs. Footpath surveillance is logistically easier than searching backyards because no permission is needed for access. In addition to detecting ants, it increases public awareness of the program and provides an opportunity to deliver electric ant information directly to residents[65]. Footpath surveillance has been completed in 12 suburbs and has begun in another 15 suburbs[65].

Two post-treatment validation surveillance rounds are conducted at each site, at least nine months apart and at least nine months after all treatments have been applied[37]. Proof of freedom from the pest is confirmed if no electric ants are found in either round of post-treatment validation[13]. Prior to 2010, validation was done with the use of food lures (peanut butter or hot dog) placed on a 5m x 5m grid[13]. From February 2010, the program employed a trained odour detection dog, Ofira, for post-treatment validation[37]. The dog proved to be 100% sensitive, as well as being much faster than detection with lures. In April 2012, the dog was diagnosed with a degenerative condition and post-validation surveillance was suspended for the latter half of 2011-12. Another dog, Quest, is being trained and will become operational during 2013[65]. The odour detection dog also assists with delineation and high risk surveillance, and industry compliance inspections.

Comparison of surveillance efforts over the years of the program is hampered by the changes in terminology since 2008-09, but the number of hectares surveyed has generally necessarily increased. In 2008-09 "Active Surveillance" was conducted over 33.96ha on 80 sites. This apparently included high risk surveillance, structured surveillance, and target surveillance for compliance and public call outs[68]. "Confirmation Surveillance" was conducted on 74ha across 251 sites to determine the effectiveness of the treatment program[68]. In 2009-10, surveillance occurred at 315 sites beyond known infested areas[20]. By 2010-11, surveillance was divided into post-treatment validation surveillance and non-scheduled surveillance, which included tracing surveillance, delineation of new detections, regular surveillance of high risk sites, and general surveillance of sites beyond deemed infestation areas[66]. In 2010-11, 915ha were surveyed, of which 729ha were non-scheduled[66], and in 2011-12, 1099ha were surveyed, of which 1093ha were non-scheduled[65]. As noted above, no post-treatment validation surveys occurred in the latter half of 2011-12 due to the unavailability of the odour detection dog. Table 2.9 shows the number of new infestations detected each year. Figure 2.4 shows the known electric ant infestations in 2008-09, and Figure 2.5 shows new detections for 2009-10 and 2010-11 in comparison to previous years.

Table 2.9 Summary of new infestations and area treated by NEAEP by year

Financial year	New infestations	Area of new infestations (ha)	Area treated (ha)	Infested area at year end (ha)
May 2006[62]	1	60		
2008-09*[20]	4	29.7	100	110.7
2009-10*[20]	3	11.6	214	120.6
2010-11*[66]	13	62.7	868	183.8
2011-12[65]	3	13.95	797	193.7

*CfOC funding years

Containment and treatment

Chemical control

Three different kinds of treatment protocols are carried out under the program: structured treatment of infested areas, prophylactic treatment of sites considered at risk of becoming infested (waste transfer stations), and treatment to mitigate the risk of spread (e.g., treatment of green waste bins)[65]. Structured treatment occurs on known infested areas and a 50m buffer. Six treatments of hydramethylnon (7.3g/kg) in a corn grit, soy oil matrix (Campaign®) are applied over a two year period[37]. In areas within 8m of water, S-methoprene (5g/kg) is used in place of hydramethylnon. Initially this was also a corn grit in soy oil carrier formulation (Engage®). In February 2011, approval was granted to use Engage+®, which has 5% protein added to the bait carrier to improve attractiveness[66]. These baits are typically spread with a hand-held fertilizer spreader, though mechanical blowers are used to distribute bait in dense vegetation. Chlorpyrifos, which comes in liquid form, is used for prophylactic treatment of pot plants. Campaign® or Engage+® is used for treatment to mitigate the risk of spread[63]. The total number of hectares treated each year for the last three years is summarized in Table 2.9 (above).

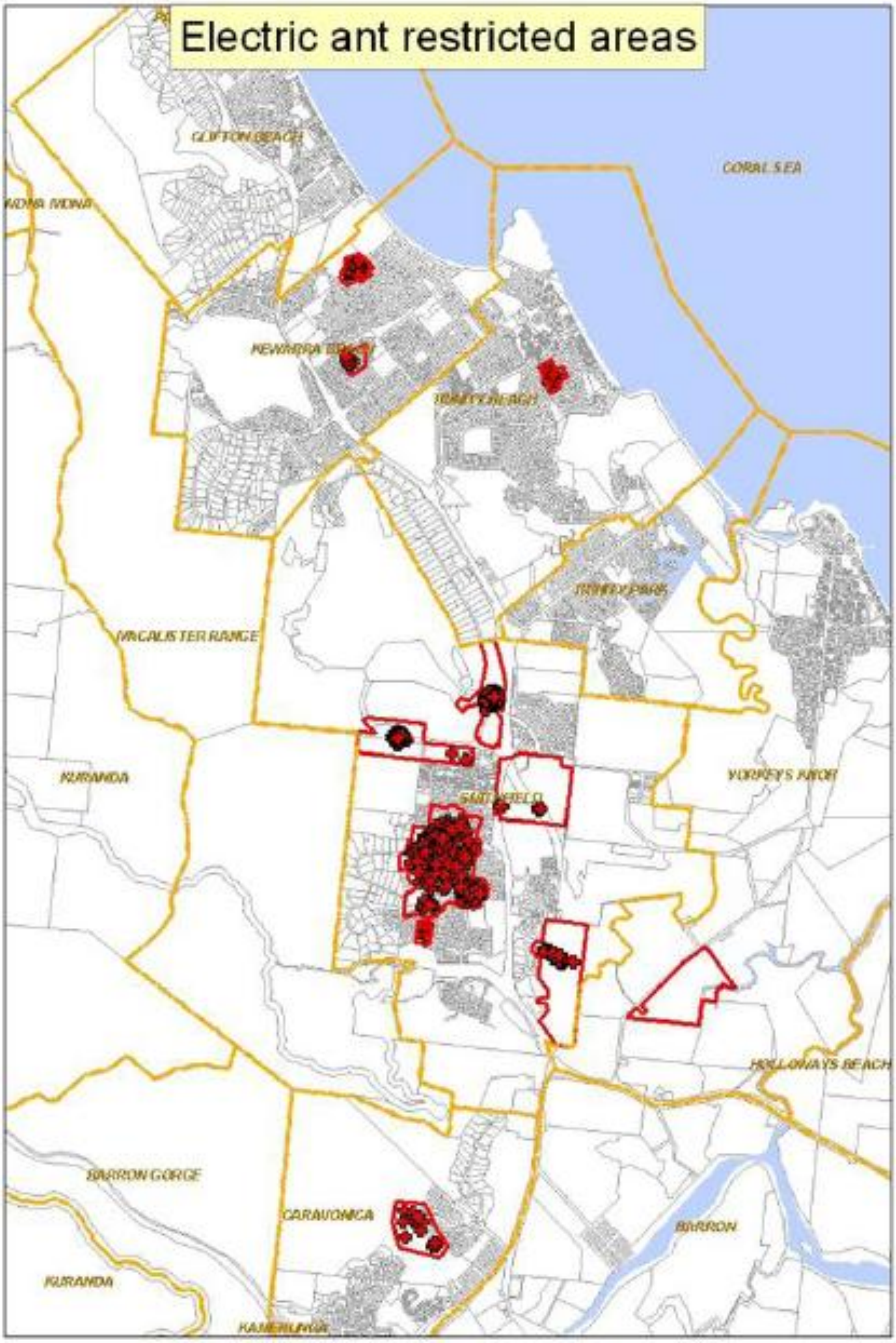


Figure 2.4 Known electric ant infestations and corresponding restricted areas in 2008-09

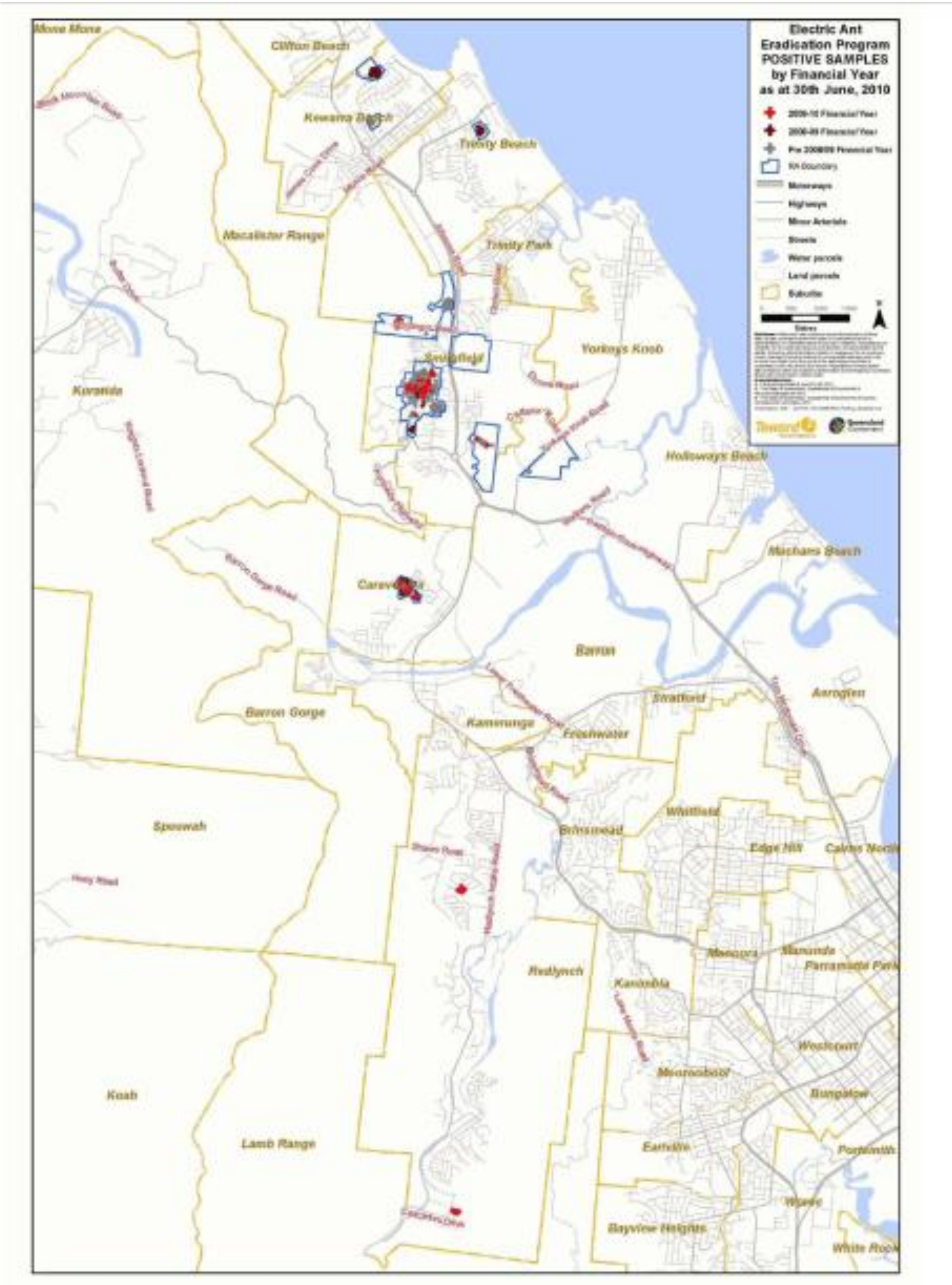


Figure 2.5A Electric ant detections for 2009-10 in comparison to detections made in previous financial years

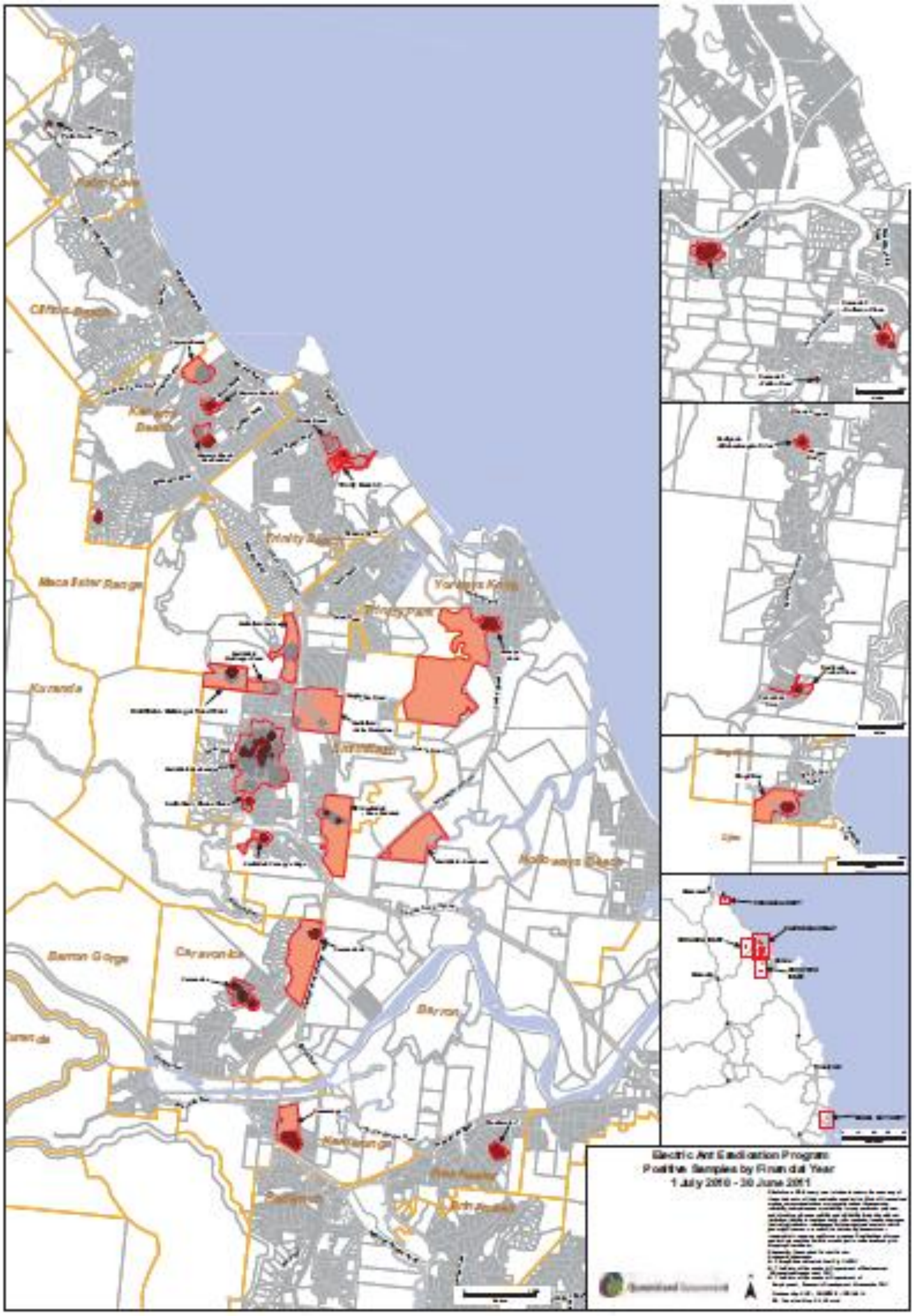


Figure 2.5B Electric ant detections for 2010-11 in comparison to detections made in previous financial years

Infestations detected prior to establishment don't receive as much treatment[65]. Infestations that are under a year old (as determined by tracing), or that are less than 1ha in extent are considered pre-establishment infestations. These infestations receive three rounds of treatment, though up to six treatment rounds are applied if necessary[63].

Movement controls

Legislative power to quarantine and impose movement controls to prevent the spread of electric ants applies under the *Plant Protection Act 1989* [69]. In the NEAEP, a restricted area is defined as 50m beyond the last infestation[13]. The restricted areas as of 2008-09 are shown in Figure 2.4. High risk materials cannot be moved from restricted areas without an inspector's approval. High risk materials include[69]:

- Plant and plant related items (cuttings, garden waste)
- Soil and anything with soil attached
- Waste material, building wastes and other material extracted from the ground
- Containers such as bee hives, bins, crates, pallets, pots and garden sleepers
- Mulch, baled hay, straw
- Equipment used for disturbing soil or in construction

Garden waste can be moved without an inspection to one of the four specified Transfer Stations and placed in a special area for electric ant movement control[69]. Residents can check the maps of all movement control areas are available on the Department of Agriculture, Forestry, and Fisheries website[69].

Industry compliance is monitored via inspections. Operational staff are all appointed as Inspectors under the *Plant Protection Act 1989*[37]. Inspectors identify and contact high risk businesses and conduct inspections to confirm compliance with movement controls. Compliance monitoring staff survey skip bins, soil, plants, building equipment and other high risk materials. In addition to a range of industry types (tree lopping, gardening, wholesale nursery, building and construction, real estate, etc.), garage sales, and plant sales sold at school events are also targeted for awareness raising campaigns and inspection[37]. The number of inspections conducted has varied greatly across program years with 48 being conducted in 2008-09[68], 294 being conducted in 2009-10[20] , 47 in 2010-11[66], and 41 in 2011-12[65]. More recently, the program is working with businesses in electric ant areas to develop Voluntary Risk Management Plans (VRMPs) as part of a voluntary process under the NEAEP, rather than under legislative requirements which exist for the NRIFAEP[63].

2.2.2 Success of methods

Detection

NEAEP feels like they are getting ahead of the invasion because the rate of detection is slowing and new infestations are being detected before they fully establish. The success appears to be attributable to tracing efforts and proactive footpath surveillance. At least 12 of the 29 infestations and two pre-establishment detections made to date were due to pot plant movements, and many of these were traced after talking to residents[65]. Electric ants make use of concrete and other smooth surfaces, such as footpaths, as dispersal routes, and these linear features can facilitate spread.

Footpath surveillance led to the detection of four new infestations and one interception between April 2011 and June 2012[65].

Available data indicate near 100% compliance with phytosanitary measures to prevent inadvertent movement of the ants. The only reported breach was in October 2011 when soil was being moved from a property inside the movement restriction boundary to one outside. The soil did not have electric ants and the owner of the soil was given an official warning[65].

The program has also been successful in identifying microsatellite loci[68] leading to the ability to determine relatedness of different colonies, and therefore that all have come from a single infestation

Eradication

Confirmation surveillance conducted early in the program gave confidence that six rounds of treatment would eliminate electric ants (Table 2.10). The monitoring was done on 31 sites in four different habitat types: rainforest, disturbed, sclerophyll, and residential. Post-treatment surveillance occurred one month after treatment[63, 68].

Table 2.10 Results of post-treatment monitoring for electric ants to document the effectiveness of treatment[68]

Post-treatment round	Monitoring date	% reduction using ground lure averages	% reduction using tree lures
1	Sep 2006	75.65	79.67
2	Dec 2006	99.83	99.99
3 pre treatment	July 2007	94.14	97.15
3 post treatment	Sep 2007	100	100
4	Nov 2007	100	100
5	Jan 2008	100	100
6	Sep 2008	100	100

Though new infestations are still being detected and the total infested area has increased each year, this is in part due to the three and a half year minimum time frame to conduct all six treatments and two rounds of post-surveillance treatment. As of June 2012, NEAEP had achieved pest-free status at four areas covering 14.4ha. Two more infestations (16ha) are due to have their final post-treatment surveys in 2012-13, and a further 13 will have theirs in 2013-14. Table 2.11 shows the number of treatments and status of each infestation, and when they were declared pest free or will be eligible to meet that status if no more electric ants are found.

NEAEP has investigated the likely reasons for the persistent remnant infestations at six sites and found two primary reasons: inadequate application of bait, or application of bait that was not attractive to ants[65]. Inadequate application of bait has occurred at some sites that have steep terrain and heavy vegetation (Smithfield Residential, Caravonica). It is anticipated that improved sensitivity of GPS units and the use of bait stations will enable improved bait distribution in the future[65]. Chemical sensitivity of a resident (in Smithfield Residential[66]) and the presence of a dangerous dog (Smithfield Nimba Close, Redlynch-Michelangelo Drive[65])also precluded full bait application. These

Table 2.11 Summary of size, date of detection, and current status of electric ant infestations[65]

Site	Area (ha)	Date of detection	# treatments completed	Status	Eligible for Pest free status
1. Smithfield Residential	65.6	11 May 2006	6 + 3 additional for persistent remnant	Persistent infestation due to steep terrain and dense vegetation	2014-15
2. Smithfield North	4.8	8 June 2006	6	Pest free June 2012	
3. Smithfield Cane Paddock	4.8	21 June 2006	9	Persistent infestation due to original treatment with Engage®	2014-15
4. Smithfield Palm Plantation	2.4	3 July 2006	6	Pest free June 2012	
5. Smithfield-McGregor Rd	3.4	2 August 2006	6	Pest free June 2012	
6. Smithfield McGregor Rd West	1.9	5 December 2006	6 + 2 additional for persistent remnant	Persistent remnant infestation due to original treatment with Engage®; no ants detected 2011-12	2014-15
7. Kewarra Beach Residential	4.4	5 February 2007	6	Pest free June 2012	
8. Smithfield-Nimba Close	3.6	3 December 2008	11	Incomplete bait coverage because of vicious dog	2013-14
9. Kewarra Beach 2	11.2	6 January 2009	6	Validation delayed because of unavailability of canine team	2012-13
10. Caravonica	11.9	22 April 2009	6 +1 additional for persistent remnant	Persistent remnant infestation due to steep terrain and original treatment with Engage®	2014-15
11. Trinity Beach	5.0	11 May 2009	6	Round 1 of validation due before 30 June 2013	2014-15
12. Redlynch-Michelangelo Dr	4.8	16 May 2010	5	Treatment due to finish end of 2012-13	2012-13
13. Redlynch-Frond Close	7.6	28 May 2010	6	Treatment finished; validation to begin 2012-13	2013-14
14. Bingil Bay	4.7	2 August 2010	5	Last treatment due 2012-13	2013-14

Table 2.11 continued

Site	Area (ha)	Date of detection	# treatments completed	Status	Eligible for Pest free status
15. Yorkeys Knob	6.1	24 August 2010	6	Treatment finished; validation to begin 2012-13	2013-14
16. Kewarra Beach 3	4.4	18 November 2010	4	Treatment due to finish 2012-13	2013-14
17. Caravonica 2	2.6	3 December 2010	6	Treatment finished, validation to begin 2012-13	2013-14
18. Smithfield-Canopy's Edge	2.0	24 December 2010	5	Treatment due to finish 2012-13	2013-14
19. Kuranda 2	12.8	25 December 2010	4	Treatment due to finish 2012-13	2013-14
20. Kamerunga	6.5	11 January 2011	5	Treatment due to finish 2012-13	2013-14
21. Trinity Beach 2	1.7	21 January 2011	6	Treatment finished, validation to begin 2012-13	2013-14
22. Kuranda 3	4.0	8 February 2011	5	Treatment due to finish 2012-13	2013-14
23. Craiglie/Port Douglas	4.2	14 March 2011/5 April 2011	5	Treatment due to finish 2012-13	2013-14
24. Freshwater	4.4	7 April 2011	5	Treatment due to finish 2012-13	2013-14
25. Kewarra Beach 4	3.6	16 June 2011	3	Treatment due to finish end of 2012-13	2014-15
26. Kewarra Beach 5	8.4	27 June 2011	3	Treatment due to finish end of 2012-13	2014-15
27. Trinity Beach 3	1	27 September 2011	3	Treatment due to finish end of 2012-13	2014-15
28. Brinsmead	4.7	14 December 2011	2	Treatment due to finish end of 2012-13	2014-15
29. Brinsmead 2	8.25	22 February 2012	1	Treatment due to finish end of 2012-13	2014-15

problems have been resolved. Sites that include or are near water (Smithfield Cane Paddock, McGregor Road West, Caravonica) most likely have persistent infestations because they were treated with S-methoprene in the form of Engage®, which had poor uptake by the ants. This problem was noticed in 2009[66]. These sites are being re-treated with Engage +®, which was approved in February 2011[65].

Although the program has a poor track record of publishing its scientific findings, the conclusions have informed protocols[63]. The food preference trials revealed Don's Skinless hotdogs to be the most attractive lure tested; further tests showed that they attracted twice as many electric ants as any other types of hotdogs, and measurements of foraging trails revealed how far apart lures should be placed. Observations of electric ant activity periodicity led to the practice of applying bait late in the afternoon to take advantage of a peak in foraging activity and lowered risk of the bait breaking down in sunlight before it is consumed.

NEAEP has four critical review points for triggering a formal review of the status of the program. These are[65]:

- The additional detection of electric ant infestation means that eradication by 2014-15 is no longer achievable, or
- Where the delivery of the eradication protocol exceeds the proposed indicative budget for the program, or
- Where other program milestones are not being achieved, or
- Where additional detections are made and the colonies detected are not related to any known infestations

As of June 2012, these points have not been breached and the program is considered to be on track to achieve eradication[65].

2.2.3 Advice for future management

NEAEP underwent an on-site Technical Review in November 2010 that concluded that eradication remains technically feasible and is highly worthwhile and cost-effective[64]. Most of the problems indicated have been addressed (e.g., improving the attractiveness of the S-methoprene bait, and setting criteria for eradication). Some issues remain, however. In our points below we echo and expand on some of the recommendations of the review. We recognize, however, that as with NRIFAEP, the activities conducted by NEAEP are constrained by its budget and that detecting and treating infestations must remain the highest priority tasks.

- Continue to closely monitor the effect of treatments and keep sufficient records to be able to investigate the reasons for any treatment failures

  To date, persistence has been attributed to inadequate bait distribution or poor bait uptake. The latter appears to have been solved with a new bait formulation and GPS units with better sensitivity. The ultimate success of the program will depend on eradication of the ant from all sites, even within the densest vegetation.

- Identify areas with high biodiversity values (e.g., Wet Tropics World Heritage Area [WTWHA]) near infestation sites) and regularly proactively survey these areas for electric ants. Identify key entry points into these areas (car parks, picnic areas, known illegal dumping spots). Also train managers to identify electric ants.

In Section 3.4.5 we identify a number of faunal elements that may be affected by electric ants in the WTWHA and may usefully be the subjects on monitoring.

- Continue investigating new bait options and methods of applications (e.g., indoxacarb gels and splatter treatment).

  Though electric ants in the canopy apparently come down to forage under certain conditions[63], treatment may be more efficient if it is applied in the canopy. For example, perhaps the canopy traps designed for surveillance can be modified to hold bait.

- Publish results in peer-reviewed journals

  Publication of the scientific achievements of the program would yield expert opinion on the science in the form of peer review of the manuscripts, would make the data and techniques broadly available to other electric ant management programs, would give the program international recognition, and may lead to further productive collaborations. The program has several findings that would advance global knowledge of electric ant biology and management and merit publication, including:

  - Environmental impact assessment, especially if it is accompanied by a follow-up study
  - Food preference trials
  - The design of canopy, gutter, and other traps
  - Bait efficacy
  - Diurnal and nocturnal activity levels and foraging behaviour

- Conduct basic research on electric ant reproductive biology in the Cairns environment

  Other programs (NRIFAEP, yellow crazy ant programs) have benefitted from investigating the reproductive biology of the ant in the local environment. These findings have made treatment application more efficient. Electric ants are known to have an unusual means of reproduction, which may contribute to its ecological dominance[70]

- Further liaising with other environmental bodies, academic institutions

  The review noted that there is "… little evidence that environmental agencies are fully engaged in supporting the program." Recently some progress has been made in liaising with the Wet Tropics Management Authority (WTMA) and Conservation Volunteers Australia, though this seems to have been initiated by WTMA.

- Consider developing an Electric Ant Volunteer program

  Volunteers might visit schools or neighbourhood community groups, or provide information at community events. Seek advice from the NRIFAEP, which has Fire Ant Volunteers.

- Consider collecting 'negative' data from households as well, as is being done with NRIFAEP now. Rather than ask residents to report if they have found EA, have them put out lures and report no findings (recognizing that electric ants are very hard to detect).

- Ensure that there is sufficient institutional memory for the program to continue should key personnel (e.g., Gary Morton) leave the program.

2.3 Yellow crazy ants in Arnhem Land

Yellow crazy ants (*Anoplolepis gracilipes*) were discovered on mainland Australia at a bauxite mine on the Gove Peninsula in 1975. In 1990, yellow crazy ants were found at Balkpalkbuy, about 100km from Nhulunbuy[21]. In 1999, a small-scale investigation by the Northern Territory Conservation Commission to determine the extent of the invasion found 12 infested sites. Following a small promising trial with a fipronil-based ant bait (Presto®), a more detailed scoping study to assess the possibility of eradicating the ant was funded by the Indigenous Land Corporation and conducted by CSIRO in 2002. The 2002 study found 63 out of approximately 550 locations with the ant and estimated that 100 infestations existed totaling up to 450ha [21, 71].

Though eradication was considered feasible, no state or federal government department considered that it had primary responsibility or local infrastructure to conduct an eradication program. In 2003-04, a multi-agency collaboration led by the Dhimurru Land Management Aboriginal Corporation with on-ground support from CSIRO and input from Alcan Gove, Northern Land Council, Northern Territory Parks and Wildlife Commission, Indigenous Land Corporation, and Department of Environment and Heritage formed and developed a plan based on protocols of yellow crazy ant control on Christmas Island. However, it soon became clear that the ant was more widespread than initially anticipated, particularly on the Alcan Gove mine site. Alcan Gove became a major funder of the effort with other financial and in-kind contributions from The National Heritage Trust (Northern Territory and Regional), Indigenous Land Corporation, and Northern Territory Government[21].

The program had some successes achieving local eradication at several sites, but it became clear by 2007 that regional eradication of the ant was not feasible[71]. The focus has shifted to eradication from the Gove Peninsula and containment within a more isolated region to prevent further spread[72]. The project was funded by Caring for Our Country ($250,000) in the 2008-09 transitional year as a critical continuity project[73]. A further $747,000 was provided by other parties. The Caring for Our Country Project Objectives and associated activities were[73]:

1. finalize the post-treatment assessments of eight yellow crazy ant infestations in northeast Arnhem Land treated prior to 2008 to declare eradication success at these locations with detailed post-treatment assessments;
2. assess the appropriateness and effectiveness of containment and eradication efforts to date by contracting an expert on tramp ant biology and management;
3. enable Rio-Tinto Alcan Environmental staff to conduct independent but complementary ant management on its mining lease by providing training in yellow crazy ant identification, infestation mapping, and treatment;
4. commence the mapping and treatment required to contain yellow crazy ants in an area that greatly reduces the risk of its spread across northern Australia by assessing at least 1000 new point locations and treating five specified sites.

2.3.1 Treatment methods

Once it became clear that yellow crazy ant could not be eradicated from the region, focus shifted to local eradication of the ant from areas with highest human contact. Figure 2.6 shows the areas from which the program is attempting to eradicate yellow crazy ants.

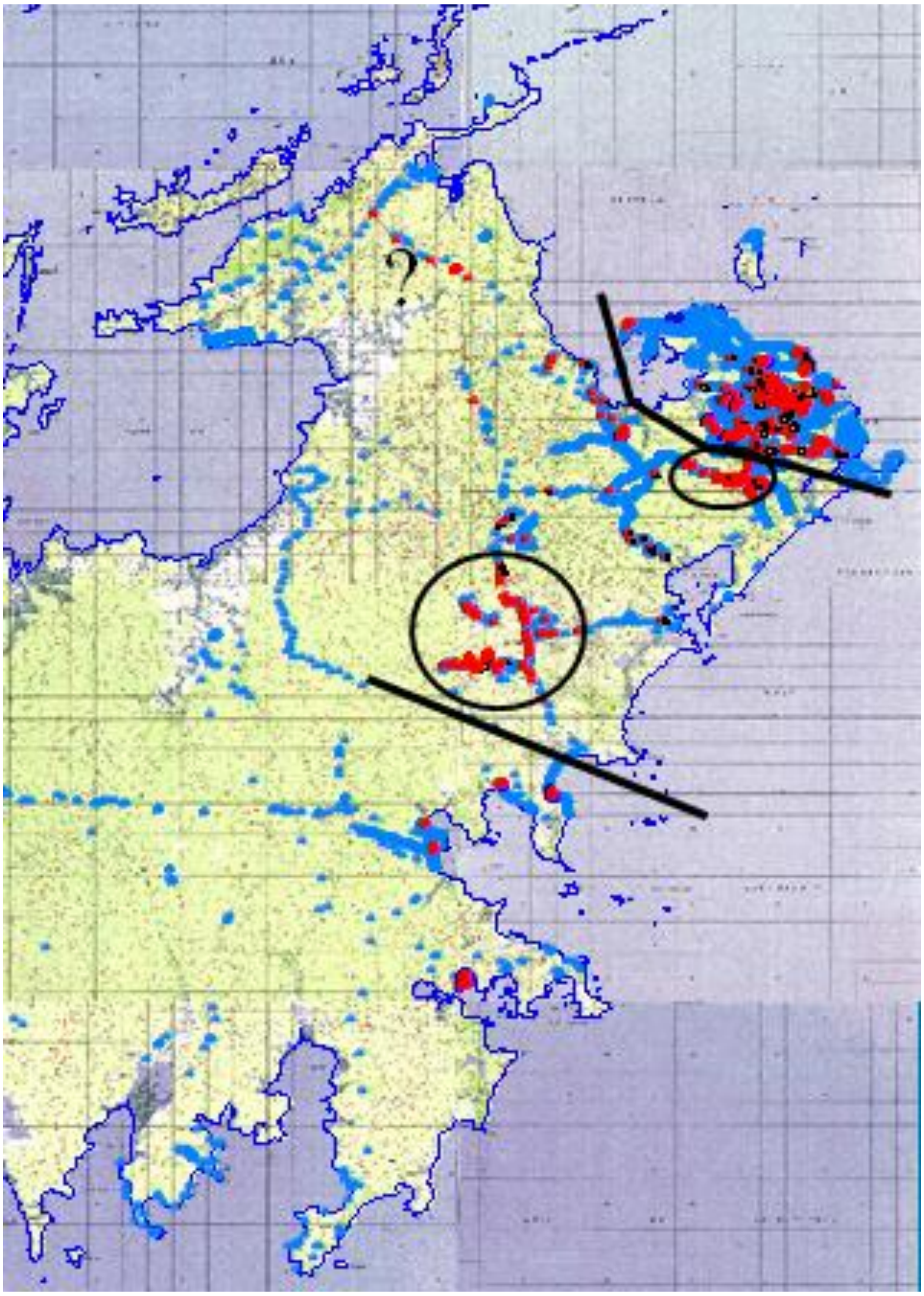


Figure 2.6 Map of containment lines for yellow crazy ants in northeast Arnhem Land, NT The goal of the program is to eliminate yellow crazy ants from the Gove Peninsula (northeast of the upper line) and from southwest of the lower line. Red dots indicate infested areas; blue dots indicate absence of yellow crazy ants in surveys. The circles indicate the areas to which the ant will be regionally contained.

Detection

The program has two surveillance protocols: Infestation Detection and Infestation Extent[74]. Yellow crazy ants are detected via visual searches in the morning (6am-10am) and late afternoon (3pm-6pm) when temperatures are favorable for foraging. At each point being searched, a minimum of four microsites (rock, tree base) within 15m is assessed for at least five seconds per microsite. The searcher walks continuously through the landscape and records presence or absence of yellow crazy ant every 15m in a handheld GPS unit. If no ants are found and the location is along a road, then points are assessed every 50m. Otherwise, the entire site (e.g., campground) is searched.

If yellow crazy ants are discovered, the infestation boundary is assessed by a team of at least three people. The team forms a line, with at least 15m in between each individual. The team walks in one direction and continuously surveys microsites until no yellow crazy ants have been found by any member for at least 100m. If there are other known points of infestation nearby, indicating an infestation is larger than 2ha, when the first boundary is found the team re-aligns so that it is perpendicular to the infestation, with one person walking within the infestation and the others outside, confirming the absence of the ant. The team continues readjusting its direction so that eventually it has walked in a circle back to the location where the first boundary was identified. If the infestation is smaller than 2ha, the team starts at a known infestation point and then walks in parallel lines out from the infestation until at least 100m is surveyed with no crazy ant detections.

The Infestation Detection protocol further details the locations in which ant surveillance should occur. Searches for infestations were and continue to be conducted in the following locations[74]:

- Point locations reported by the public, even if they have been inspected previously
- All point locations where vehicles are likely to have stopped in the last 70 years (camping areas, hunting areas, houses, etc.)
- All infrastructure and machinery encountered
- Point locations at the edges of roads, with more traveled roads being inspected at shorter intervals (50m vs. 100m or 1km)
- Entire road edges within the rehabilitation areas of the Gove mine site and any other locations with a high probability of infestation that are accessible by foot
- Other locations opportunistically visited by staff and project collaborators

In 2008-09, in the year of CfOC funding, 954 locations were assessed for the presence of crazy ant (Figure 2.7). No new crazy ant sites were found.

Post-treatment assessments are done with visual searches and attractive baits (lures). Visual inspections are done as per the Infestation Detection protocol described above. Teaspoon-sized tuna or cat food lures are placed at a density that is greater than the measured nest density at the site and not less than one lure per four square meters[75]. The lures are left for 15 minutes and then inspected for yellow crazy ants. It takes a team of ten people a full day to do a post-treatment assessment in a 2000 m^2 area[71]. Eradication is declared when post-treatment monitoring conducted at least two years following the triple treatment protocol reveals no yellow crazy ants[75]. Because post-treatment assessments are very labor-intensive, and because project staff are confident of the effects of the treatment and are aiming for containment, rather than eradication, post-treatment assessments are no longer done over large areas[71].

For the eight sites at which post-treatment assessments were conducted in 2008-09 as per the contract with CfOC, 6282 tuna lures were used and 10 person-hours of visual searches were conducted[76].

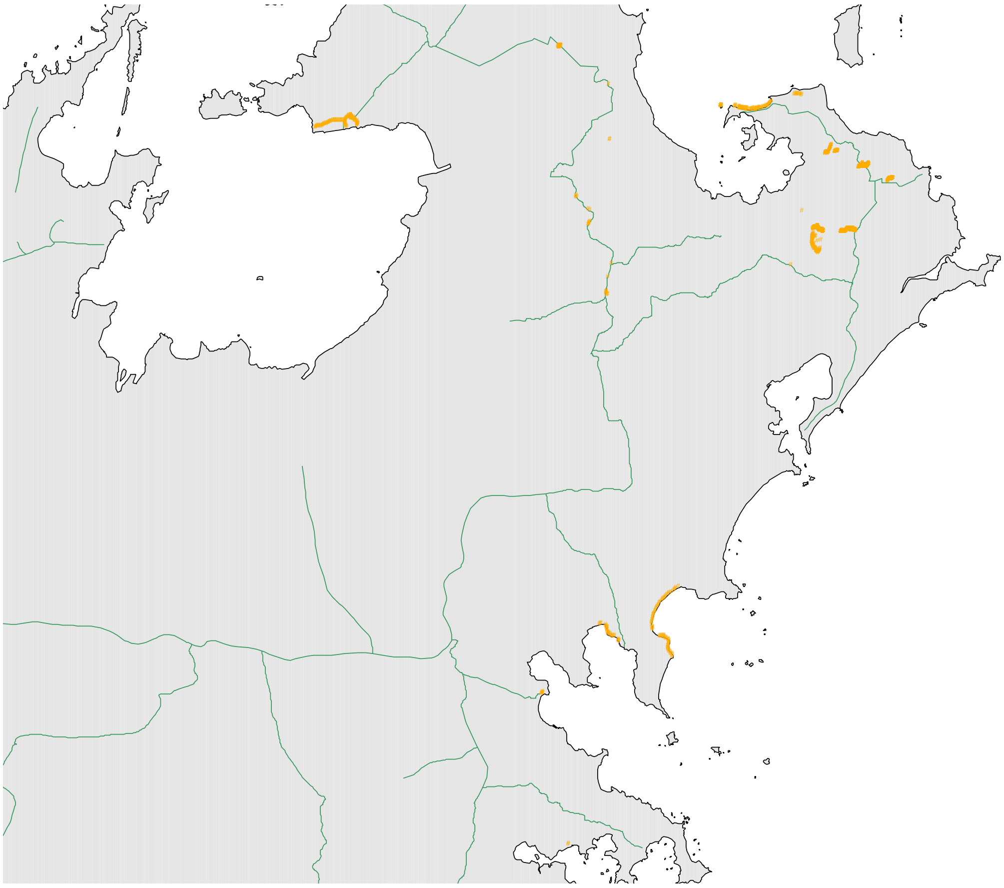


Figure 2.7 The 954 locations assessed for yellow crazy ant presence or absence (orange dots) in Arnhem Land, NT

Containment and treatment

Chemical control

The chemical control protocols used to control yellow crazy ants in the Northern Territory are based on results from Christmas Island, from documented local successes and failures, as well as knowledge of the biology of the ant. According to the treatment protocol[75], bait (0.01g/kg fipronil[77] in a fish meal matrix [formerly Presto®, now AntOff®]) is applied via helicopter over infested areas and a 100m buffer zone at a rate of 10kg/ha[75]. Early on in the program, application rates of 2.5, 5, and 10kg/ha were tested and the highest application rate always gave the best response[71]. Within 20m of open water, treatment is applied with hand-held applicators. Where possible, all areas to be treated are burnt at least one week prior to treatment. Bait is applied in the afternoons and not less than four hours before forecast rain, or within 24 hours after rain[75]. To be successful, the first round of baiting has to occur in December, after the burning season (September-November), and after the ants have finished their sexual reproduction (August-November). The second round occurs in March or April and the third in July or August. Some combination of the fipronil-based bait, hydramethylnon (Campaign®) or pyriproxyfen (Distance Plus®) in a corn grit carrier, are used for the triple treatment[71].

The combination of products used apparently does not affect success, as long as three treatments are applied and they occur in the months specified[71]. To avoid bait shyness, it is also best to apply a bait with a different carrier than was used in the previous baiting round. Presto®/Ant-Off® achieves a 99.9% knockdown and Campaign® achieves 80%. Distance Plus® achieves approximately 50% knockdown within three months, but effects continue for several months[71].

Though the fipronil-based bait is most effective and cheapest of the three baits, it usually comes in a form too wet for dispersal by helicopter. The drying process is laborious and time consuming. Improvements made in the bait formulation may obviate the need for drying, and will be evaluated in the baiting that commences in December 2012[71].

In 2008-09, in the year of CfOC funding, 14 previously mapped sites covering 333ha underwent a triple treatment, and an additional eight sites were fully mapped for treatment[76].

Movement controls

The management program has no legal mandate to implement movement controls and therefore relies on raising community awareness to prevent inadvertent transport of the ant. Part of this is achieved by training and employment of indigenous rangers who take their knowledge back to their homeland[78]. Other community engagement efforts have also been employed and are described in Section 4.3.

2.3.2 Success of methods

Of the eight sites at which post-treatment assessments were conducted in 2008-09, in the year of CfOC funding, five infestations were declared locally eradicated (Figure 2.8), and three had persistent infestations[76]. The sites where ants persisted were among the first sites treated and the persistence was likely due to only one treatment being applied. One of the sites received a second treatment a year after the first. The other two sites received three treatments in 2009/10, but only received their first treatment in June, when all other sites were getting a second treatment. Experience with these sites confirmed the necessity of the triple treatment protocol with appropriate timing of bait application[71].

From 2003-2009, management of yellow crazy ants in the Northern Territory achieved local eradication at 21 sites covering 246 hectares[73] (Figure 2.9). To achieve this, 8127 locations in the region were assessed for the presence or absence of yellow crazy ants, 238,454 assessments were made to accurately map 35 infestations and 221,624 tuna lures were used to assess crazy ant eradication.

2.3.3 Advice for future management

Another round of baiting for yellow crazy ants in Arnhem Land commenced in December 2012, funded by CfOC and by the Biodiversity Fund[71]. This round will cover the largest area yet, 600ha, of which approximately half is on Gove Peninsula, and half is southwest of the Balkpalkbuy infestation (see Figure 2.6 above). Regional containment continues to be the goal and it is anticipated this will be achieved within 5-7 years[71]. Genetic analyses have shown that the current infestation is likely all from one a single invasion event[79], which is remarkable considering the incursion occurred at least 37 years ago. Given the slow natural rate of spread and low likelihood of additional incursions, if eradication is achieved on the Gove Peninsula and the southwest population, yellow crazy ants will be regionally contained for several decades.

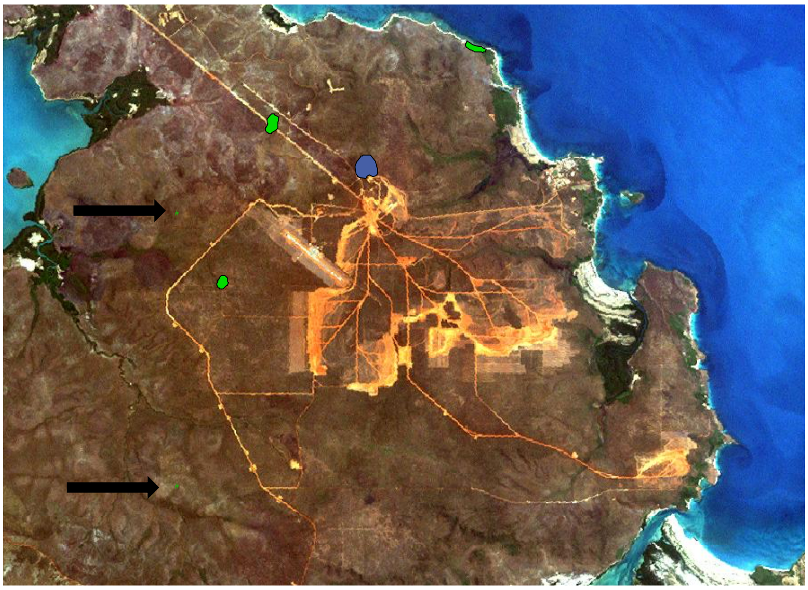


Figure 2.8 Five sites where the yellow crazy ant has been locally eradicated, and one site where it was persistent as of 2008-09 in Arnhem Land, NT. The two smallest eradication sites are denoted by the arrows. The two persistent sites not shown are to the southwest.

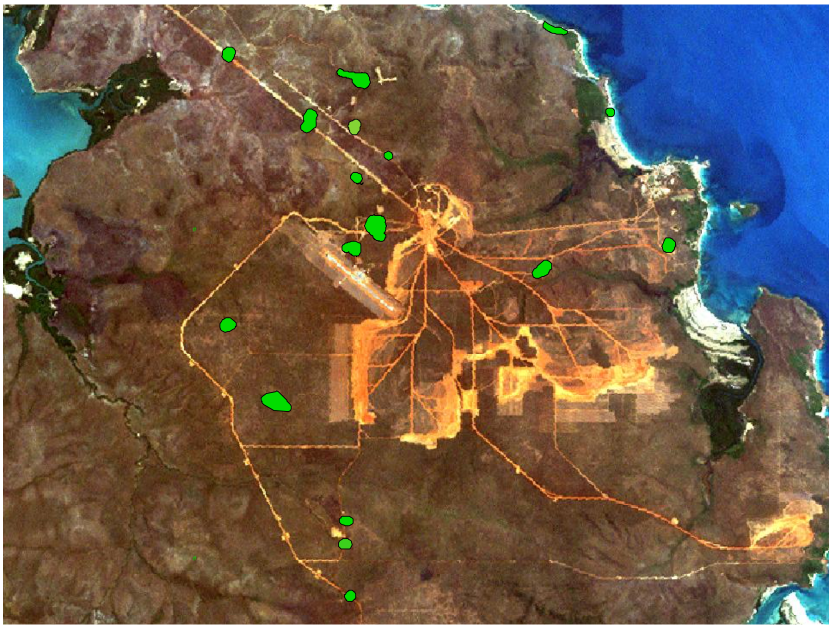


Figure 2.9 Nineteen sites where the yellow crazy ant has been locally eradicated Arnhem Land, NT from 2003-2009. Two additional sites where local eradication has been achieved are to the southwest (not shown).

The effectiveness of the treatment is evidenced by the local eradications achieved to date. Research related to the program has also led to the publication of several peer-reviewed scientific journal articles. To assure continued program success and maximize protect ion of biodiversity, we advise:

- More research be conducted on potential local non-target effects of fipronil at the rates and frequency at which it is applied in the region

Because it is aiming for local eradication rather than suppression of yellow crazy ants, this program applies fipronil at two and a half times the rate applied on Christmas Island (10kg/ha compared to 4kg/ha) and applies it up to three times per year. It is unclear, however, whether the yellow crazy ant density in Arnhem Land is high enough for bait monopolization to occur. Arnhem Land does not have the iconic crabs that Christmas Island does, but nonetheless the Gove Peninsula and north-east Arnhem coast is considered to have "International Significance" as a Site of Conservation Significance because of its biodiversity[80]. With expected knock-down of 99.9% after the first application, it is less likely that bait monopolization by yellow crazy ants occurs during subsequent treatments.

To date, research conducted on non-target effects is limited to pitfall traps, which capture ground-dwelling arthropods. Fipronil is highly toxic to bees at exposures as low as 0.1ng/bee[81]. Effects on bees or other flying or phytophagous insects would not have been measured with pitfall traps. We recognize that any risk to other invertebrates needs to be considered in the context of the risk posed by yellow crazy ants. However, since a combination of any of the three bait types (fipronil as Presto® or AntOff®; hydramethylnon as Campaign®; pyriproxyfen as Distance Plus®) appears to be equally effective at eliminating yellow crazy ants when applied at the right times of year[71], it would be useful to test whether non-target effects of the different bait type are also similar. Collection of the appropriate data will ensure that management decisions can be made that also result in the fewest and least severe non-target effects.

In the absence of such data, a precautionary approach should be considered in locations of known extant Gove crow butterfly populations (see Figure 3.7).

- Seek independent evaluation of the program

This is the only one of the four large programs that has not had independent oversight, most likely because it has received no sustained committed funding. Peer-reviewed publication is a form of independent review, and we note that several publications have arisen from the work on yellow crazy ants in Arnhem Land. However, the treatment methodology and the results of the ecological monitoring have not been independently reviewed or published, nor has the overall program.

- Investigate natural decline in yellow crazy ant populations

Some of the yellow crazy ant populations appear to have died back on their own[71], a phenomenon that has also been observed on Christmas Island (see section 2.4) and on Tokelau[82]. Given the expansive database of infestations in the Gove Peninsula from earlier years in the program, funds should be sought to enable a comprehensive re-sampling to determine how common this phenomenon is and to attempt to elucidate a mechanism for it (e.g., differences in environmental conditions or resources at the sites).

- Ensure that there is an institutional memory of the program.

Much of the program's success appears to be attributable to Dr. Ben Hoffmann of CSIRO-Darwin. Dhimurru should ensure that there is a mechanism in place to maintain the knowledge and data that Dr Hoffmann has gained during the years of the management effort should he leave the region or CSIRO.

2.4 Yellow crazy ants on Christmas Island

Yellow crazy ants have been present on Christmas Island since at least 1935. Genetic analyses indicate that two separate invasion events have occurred[83]. The ants did not become a pest until they started forming supercolonies in the 1980s, and they were first recognized as a major threat to the island's ecosystems in 1998 [24, 84]. Their dramatic population increase is thought to be related to their association with the Lac scale, *Tachardina aurantiaca*[85]. The ant tends this sap-sucking insect for its carbohydrate-rich honeydew. With few, if any, natural enemies of Lac scale on the island and the removal of honeydew by ants, scale and yellow crazy ant populations can reach extremely high numbers. An area is deemed to be within a supercolony when 37 ants cross a 10cm x 10cm quadrat of a 20cm x 20cm white card. At this abundance, yellow crazy ants begin to kill Red land crabs[86].

Caring for Our Country funds ($3.2 million) have been awarded for 2011-15. The funding does not specify targets, aims, or activities that must be completed[86-88]. Nor are there any MERI or other traditional reports required. Rather, Christmas Island National Park (CINP) staff report to and take guidance from the Crazy Ant Scientific Advisory Panel (CASAP), which meets via teleconference every six months. The implicit goal of the program is to protect the biodiversity of Christmas Island from yellow crazy ants.

2.4.1 Treatment methods

The yellow crazy ant management program on Christmas Island is primarily focused on reducing yellow crazy ant abundance below supercolony status.

Detection

Substantial effort is put into carefully delineating supercolonies via the Island Wide Survey (IWS) and follow-up ground-truthing. The IWS has been described in a background document produced by CINP staff[84]. The IWS is based on a grid of 1024 waypoints spread across the island (including rainforest, built environment, and areas cleared for phosphate mining) on a grid of 365.7m x 365.7m intervals (Figure 2.10). This interval coincides with an existing network of overgrown 'drill-lines' bulldozed across much of the island plateau in the 1960s for phosphate exploration. Drill-lines are crucial because they provided ready access for field crews conducting the survey. The IWS also depends on the Christmas Island GIS system. Each waypoint is offset into undisturbed forest and field crews used hand-held GPS units to locate them. The island wide survey has been conducted in some form biennially since 2001. The survey allows the CINP staff to[84]:

- Determine the island-wide status of supercolony formation by yellow crazy ants on a regular basis
- Establish the distribution and magnitude of associated impacts (e.g., crab burrow densities)
- Obtain spatial and temporal information upon which to base decisions about where to target ant control operations and to monitor their effectiveness
- Obtain additional information useful for estimation of total control effort and resources needed for management of the invasion
- Provide a basis for modelling the spread, dynamics, and impact of yellow crazy ants on an island-wide spatial scale, including identification of environmental correlates with ant invasion using the Christmas Island Geographical Information System (CIGIS)

- Survey for a number of extra species whose life histories are such that they are amenable to surveying by the IWS (e.g., land birds, Abbott's booby, specific weed and native plant species).

Surveys take place in the dry season (April/May-early November) to the extent possible. It takes a team of ~9 staff 4 months to complete the field component of IWS[86]. The number of waypoints examined each survey depends on access and mining activities and has varied from 877 (2007) to 988 (2005)[89] (Table 2.12). Data collection methods have also been refined over the years. Currently, at each waypoint a specific protocol is followed for the collection of crazy ant abundance and Red land crab burrow size and density. Surveyors also record the presence of specific other fauna and native and non-native plants[84]. Since 2009, surveyors also note the presence of focal plant and animal species and whether they are in or out of a supercolony while they are in transit in between waypoints. In this context, project staff are directed to identify supercolonies as areas with[84]:

- High crazy ant abundance on the ground and as 'trunk traffic' on trees
- Large numbers of ant nests, typically at the base of trees and in rotten logs
- Ant-infested Red land crab burrows
- Dead or absent land crabs
- Relatively high amounts of leaf litter
- Relatively high numbers of seedlings
- Relatively high numbers of scale insects
- Excessive sooty mould
- Giant African land snails
- Relatively low diversity of other invertebrates, particularly other ants

In 2009, repeat surveying of a subset of waypoints was introduced to test the detectability of surveyed species and the repeatability of data collection. In 2011, 103 of the 933 IWS waypoints were surveyed a second time, and 50 of these were surveyed a third time[89]. The 2011 survey took 75 days to complete.

More precise delineation, or bounding, of supercolonies takes another several weeks and occurs in the months prior to aerial baiting. Results of the 2011 IWS indicated that supercolonies covered 598ha on the island[90]. The July 2012 bounding revealed that supercolonies covered approximately 1107ha[90] (Figure 2.11). Some of this increase is due to the more accurate 2012 bounding. But it is also thought that the ants spread during the long hot dry season[86].

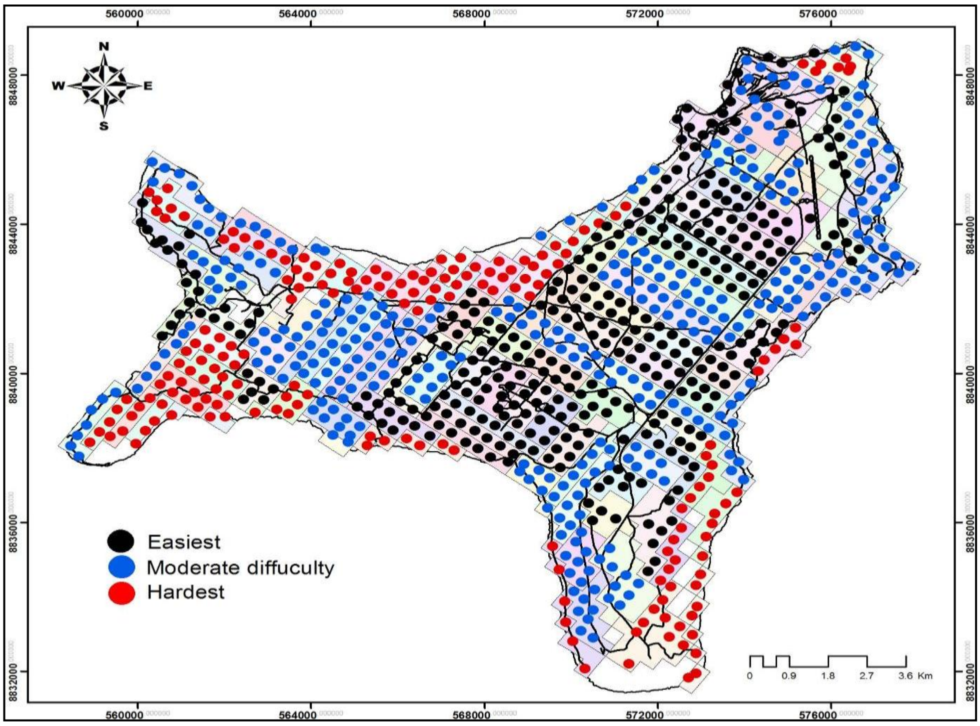


Figure 2.10 Island Wide Survey waypoints on Christmas Island coded by level of difficulty in accessing

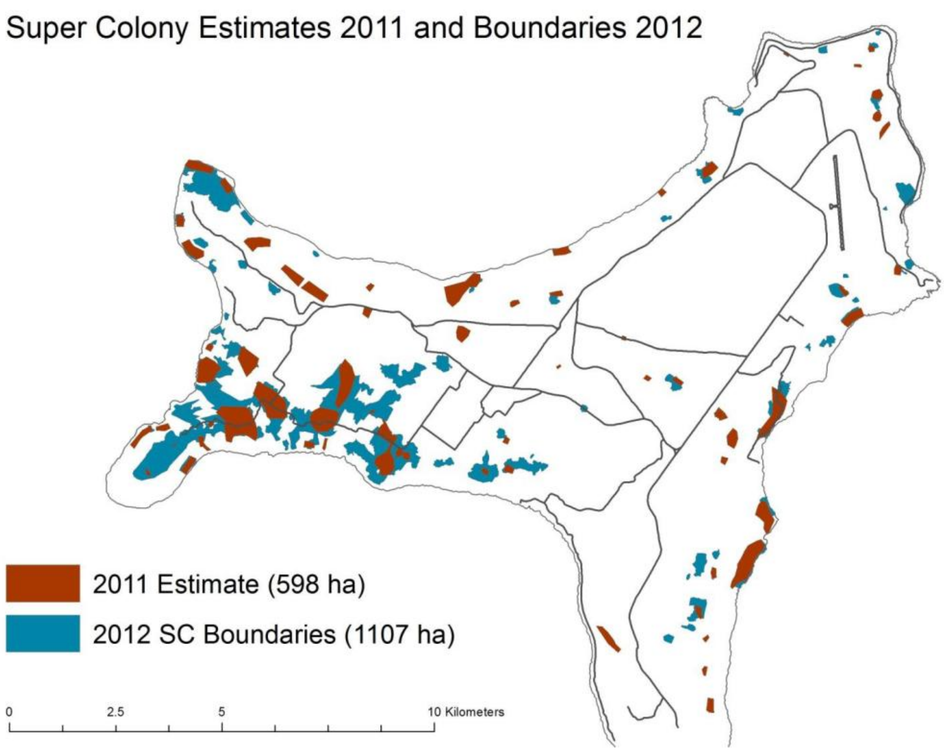


Figure 2.11 Supercolony boundary estimates from the 2011 Island Wide Survey and from 2012 bounding

Table 2.12 A summary of yellow crazy ant data collected for all Island Wide Survey years[85, 86, 89]

Year	Total waypoints	Number of supercolonies	Average supercolony size (ha)	Ant Abundance				
				Supercolony (≥ 38 ants)	Medium (20-37 ants)	Low (1-19 ants)	Present but not on card	None
2001	972	22	107	19% (188)	3% (30)	11% (110)	6% (62)	60% (582)
2003	988	40	4.96	3% (30)	2% (19)	14% (143)	15% (147)	66% (649)
2005	980	16	9.69	5% (47)	4% (36)	22% (215)	21% (209)	48% (473)
2007[*]	877	33	5.84	8% (71)	5% (43)	24% (214)	8% (74)	54% (475)
2009	893	73	10.7	10% (92)	4% (40)	26% (233)	14% (123)	45% (405)
2011	933	67	8.9	7% (69)	4% (35)	26% (247)	18% (170)	44% (412)

[*]Does not include 103 waypoints on the mine site that had previously been included and where yellow crazy ants are present but not in sufficient densities to cross the card.

Treatment

Chemical control

Aerial baiting by helicopter (helibaiting) has taken place in 2002, 2009 and 2012. Hand-baiting occurred 2000-2008[85]. In 2012, 1084 hectares were baited with 80 hours of flight time[86, 90]. The helicopter flies 40m above the canopy and relies on the careful delineation of supercolonies and GIS positioning for accurate dispersal of bait. Helibaiting is accurate to within 10-20m, with pilots accounting for drift at the boundaries of supercolonies[86]. Table 2.13 summarizes the three baits used.

Table 2.13 The three baits used during the 2012 helibaiting campaign on Christmas Island[90]

Product and concentration	Where used on Christmas Island	Application rate (kg/ha)	Area treated (ha)
Fipronil (AntOff®) (0.01g/kg)	>200m from waterways and >100m from town	4.38	834
Pyriproxyfen (5g/kg)	80-200m from waterways	4.26	141
S-methoprene (5g/kg)	20-80m from waterways	4.17	87

The IGRs (pyriproxyfen and S-methoprene) were trialed previously on Christmas Island with limited success[90]. If they had not been used in 2012, none of the areas within 20-200m of water bodies would have been treated[86].

Time and cost constraints meant that eight sites comprising 30 hectares were not treated. Sites are prioritized for baiting on the basis of where Red land crabs are most affected.

Before commencement of aerial baiting, Robber crabs are lured away from areas to be baited with a mixture of chicken feed and shrimp paste. See Section 3.6 for a discussion of the efficacy of this process.

Biological control research

The biological control research is not funded by CfOC funds, but rather through research grants via La Trobe University. However, if successful, biological control will fundamentally change the methods of managing yellow crazy ants on Christmas Island. The basic concept is that yellow crazy ants reach supercolony status because of the availability of honeydew from scale insects[91]. It is estimated that up to 70% of the honeydew is provided by the Lac scale[91]. If the Lac scale can be controlled, then yellow crazy ants will not have access to high levels of honeydew and will also decline in number. One part of the research is to demonstrate the ‘proof of concept’ and involves manipulating honeydew availability and monitoring yellow crazy ant response. The other part of the research is finding suitable biological control agents from sites in Asia that affect Lac scale on the same host tree species, and result in population control of the scale in the presence of yellow crazy ants[91].

2.4.2 Success of methods

Surveying

The IWS is a labor-intensive undertaking and it is remarkable that CINP staff have been able to complete it with biennial frequency. The enormous utility of the IWS in addressing operational questions is illustrated by the rigour in which yellow crazy ant supercolonies are identified and mapped for targeting by baiting programs[22], and in understanding trends in various elements of the native and invasive biota (e.g., [22, 92-94]).

Advances in GPS and GIS technology, and refinement of the survey data collection methods have increased the amount of data taken with relatively minimal extra effort. Data from replicate surveying have not yet been formally analyzed. A preliminary analysis indicates that some measurements differ more than others. It may be difficult to determine whether differences are due to the team recording the data, or to changes that may have taken place at the site in the 6-15 days in between measurements.

Supercolony suppression

The success of the methods needs to be considered both at the scale of individual supercolonies, as well as at the scale of the island as a whole, and in the context of Red land crab population recovery. Initial results of the 2011 helibaiting with fipronil show 60-99% decline in ant activity at card counts over 11 weeks[90] (Figure 2.12). Results from sites treated with the IGRs are more variable. Six of the sites appear to have some reduced ant activity, but activity levels at another supercolony (186) have increased under both types of IGR treatment (Figure 2.13). In both cases, some of the comparison non-baited sites also declined (Figures 2.12 and 2.13). One possible reason for the less-than-expected decline after IGR treatment is that the baiting was conducted in September rather than in August as originally planned (due to logistical delays). In September, new queens are in the pupal stage and therefore would be unaffected by the IGRs[95].

Results of the 2009 helibaiting with fipronil showed suppression of eight of nine monitored supercolonies over 107 weeks (Figure 2.14). The ninth supercolony (148) was at its pre-bait abundance at 78 weeks post-baiting and continued to increase. This site had a high component of secondary vegetation and was drier, which may affect the abundance of scale insects and yellow crazy ants[86]. Four supercolonies that were not baited were also monitored for comparison. These also declined, but over a longer time period (Figure 2.15).

In the last ten years, the number of supercolonies has increased, however. Table 2.12 (above) summarizes the number of supercolonies and the number of waypoints by ant abundance category for IWS estimates 2001-2011. From 2001 to 2009 the number of supercolonies tripled. Future surveys will reveal whether the change from 73 to 67 supercolonies from 2009 to 2011 represents a real trend downwards. Disturbingly, however, an average of 76 ± 56 waypoints are newly infested each survey[89], and fewer than half of the waypoints have been completely free of yellow crazy ants in the last two surveys.

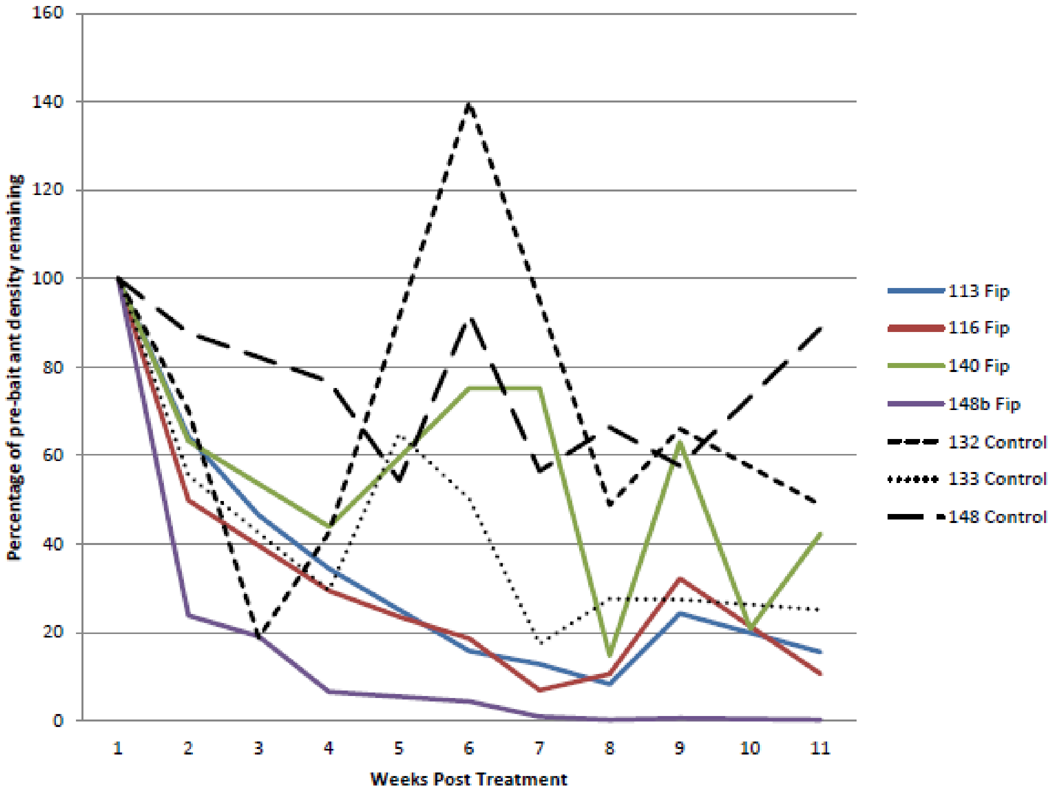


Figure 2.12 Yellow crazy ant activity (card counts) as a percentage of pre-bait activity for four fipronil treated and three non-treated sites on Christmas Island for 11 weeks following the 2012 helibaiting[90]

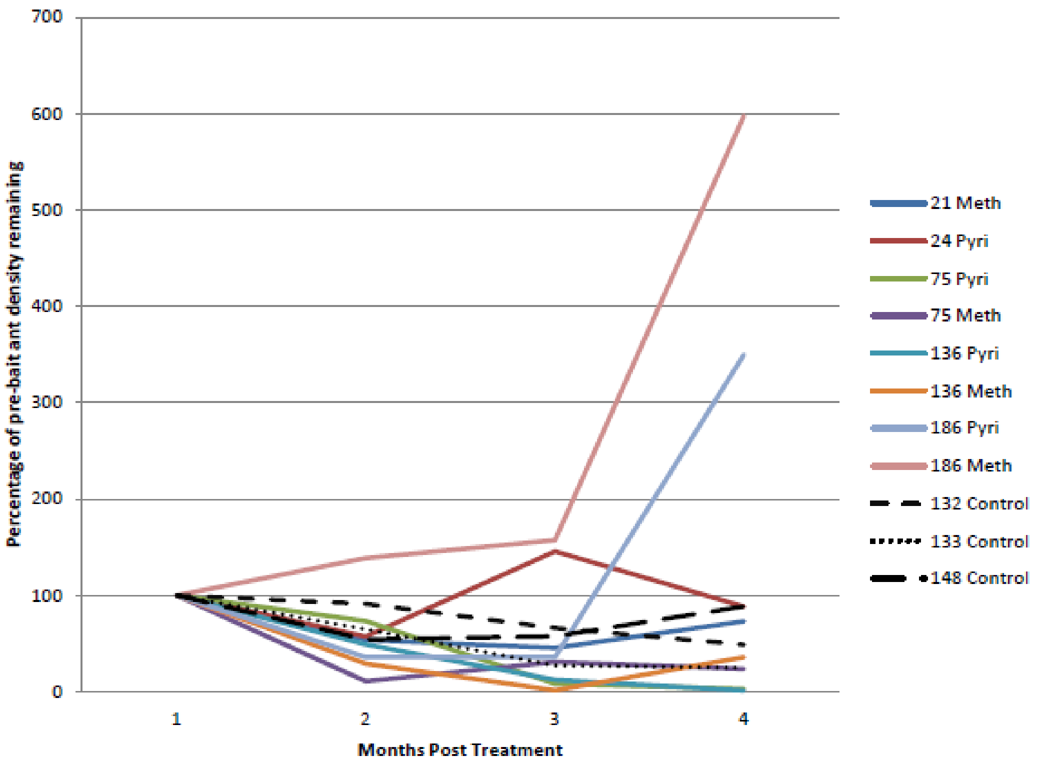


Figure 2.13 Yellow crazy ant activity (card counts) as a percentage of pre-bait activity for four S-methoprene, and four pyriproxyfen treated sites and three non-treated sites on Christmas Island for 11 weeks following the 2012 helibaiting[90]

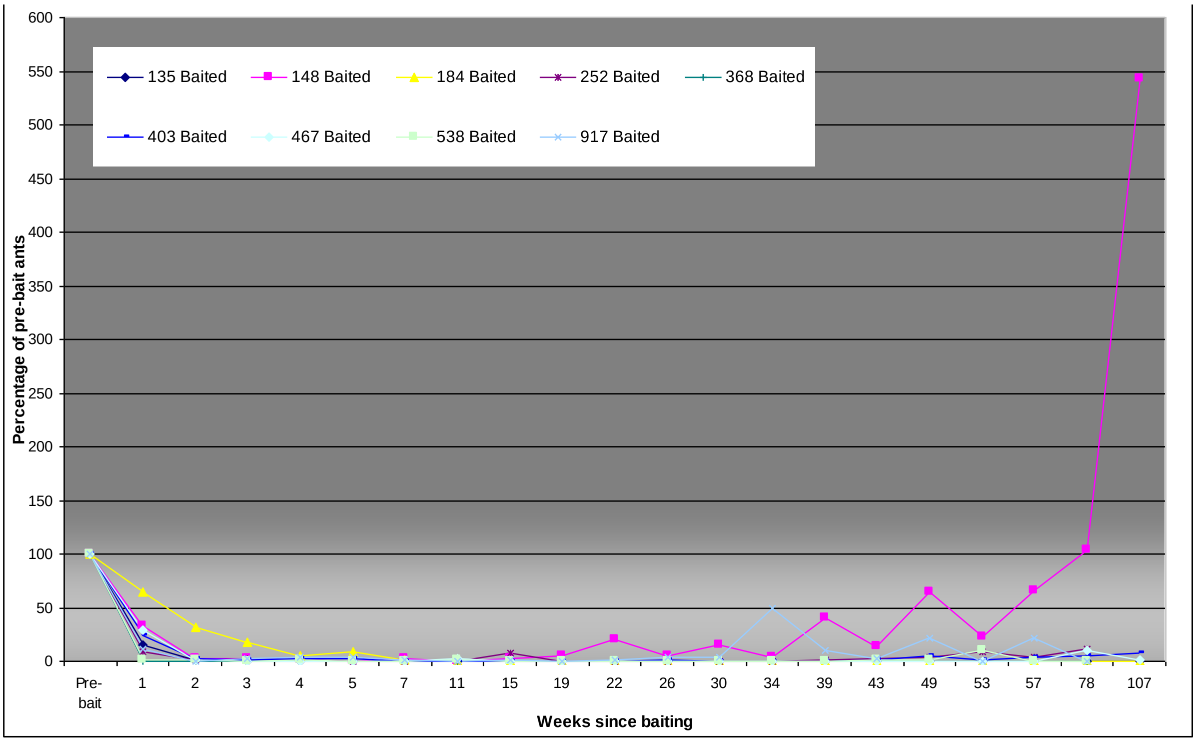


Figure 2.14 Yellow crazy ant activity (card counts) as a percentage of pre-bait activity at eight fipronil baited sites for 107 weeks following 2009 aerial baiting[96] on Christmas Island

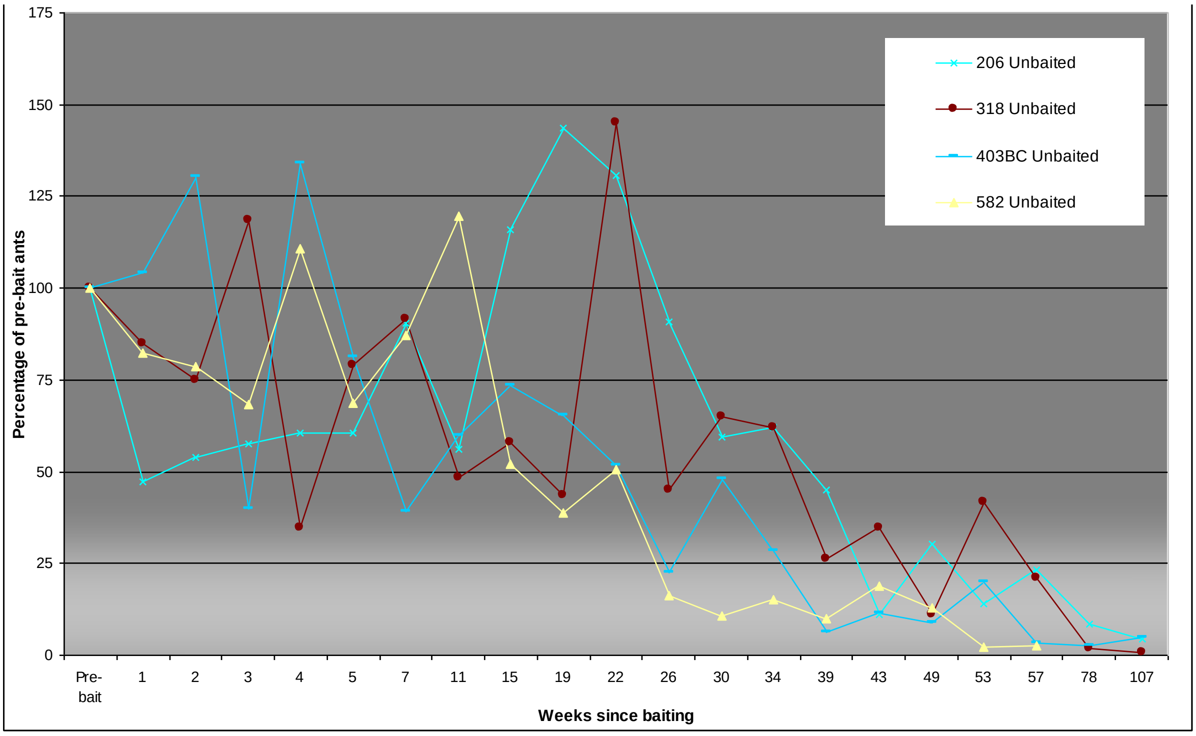


Figure 2.15 Yellow crazy ant activity (card counts) as a percentage of pre-bait activity at four non-treated sites for 107 weeks following 2009 aerial baiting[96] on Christmas Island

Biological control

The results of several experiments clearly indicate that yellow crazy ants benefit from carbohydrates. Yellow crazy ants that were denied access to honeydew resources rapidly declined in abundance[91]. Within four weeks, foraging on the forest floor fell four-fold. Another set of experiments revealed that when sugar availability is elevated, reproductive output increases, death rates of workers decline, foraging tempo quickens, and interspecific aggression intensifies[91].

The search for natural enemies of scale insects that produce honeydew on Christmas Island was also productive. Research into potential biological control agents for the Lac scale revealed[91] that the scale is attacked by a parasitoid wasp, *Tachardiaephagus somervillei* (Encyrtidae) across a 1900km range in peninsular Malaysia and Malaysian Borneo. *T. somervillei* causes high rates of parasitism even in the presence of tending ants, and can be reared under laboratory conditions. Surveying scale insects on Christmas Island further revealed the presence of two parasitoids of soft scale insects (Coccidae). Their effects are currently limited by their low dispersal ability. They may also be affected by the fipronil bait[95].

2.4.3 Advice for future management

The yellow crazy ant program on Christmas Island is gearing up for a major change in its approach to managing the ant. At the 12 December 2012 meeting, CASAP fully endorsed proceeding with plans to obtain permission to import biological control agents from Asia to attack the Lac scale insect. CASAP further agreed to proceed with rearing and releasing the soft scale parasitoids already present on Christmas Island. These decisions were made following a review of the data supporting the proof of concept, as well as discussion of the relative risks of the biological control approach. Successful establishment of the parasitoids and consequent decline in scale insects should eventually allow the yellow crazy ant management program to operate more as an integrated pest management program that has the potential to eventually become self-sustaining, rather than a biennial toxic baiting regime.

CASAP has identified several steps that will need to be taken before *T. somervillei* can be released on Christmas Island. These primarily involve identifying the government body from which permission must be granted to introduce the non-native insect, and following the processes to obtain permission.

However, it will likely still be some time before the biological control program can be implemented. As has been identified by CASAP and CINP[95], in the meantime, it will be necessary to develop a methodology for either indirectly or directly measuring scale abundance so that effects of the biological control agents can be monitored. It will also be necessary to figure out if this additional surveillance should be done as part of the IWS, or as a separate exercise.

The collective expertise of CASAP and CINP ensures that the implementation of the biological control program will be well thought out. Having reviewed the data provided to CASAP regarding the biological control agents and their effects in Malaysia, we advise:

- Further consideration of the density and behavior of yellow crazy ants in the Malaysian context compared to the Christmas Island context.

The summary provided to CASAP[91] indicates that in Malaysia *T. somervillei* can parasitize *T. aurantiaca* in the presence of tending ants. It does not mention the density of these ants, which would have to be lower than on Christmas Island for the logic of the whole exercise to be supported. Moreover, since Malaysian yellow crazy ants most likely have decreased access to carbohydrates, they are likely to be less aggressive than Christmas Island yellow crazy ants, as suggested by the program's finding that providing sugar increases yellow crazy ant aggression[91].

- To avoid interference by yellow crazy ants when the biological control agents are released on Christmas Island, some means of reducing the potential for yellow crazy ants to interfere with the agents may need to be employed (e.g., tree barriers).

  Care will need to be taken to ensure that the mechanism used does not preclude the ability to draw conclusions on the effectiveness of the biological control agents to reduce both the scale and yellow crazy ant populations.

The program has benefitted greatly from the research and scientific input of scientists and students at La Trobe and Monash Universities. Research related to the program has also led to the publication of several peer-reviewed scientific journal articles. To assure continued program success and maximize protect ion of biodiversity, we further advise that:

- Natural declines of yellow crazy ant populations continue to be investigated.

  Data from the 2009 helibaiting show four unbaited supercolonies that declined to a small fraction of their 2009 abundance over 107 weeks (Figure 2.15). Unexplained declines have also been observed in Arnhem Land and have been documented on Tokelau[82]. Identifying a mechanism of natural population decline might yield another tool for management.

- Research continue for potential treatment options in areas with lower yellow crazy ant density.

  To date, the focus of the treatment program has been on suppressing yellow crazy ants to below supercolony status. However, yellow crazy ants at densities below those constituting supercolony status are also thought to have adverse effects, particularly on other invertebrates[86]. Bait applications are limited to supercolonies because supercolonies are the treatment priority, and because yellow crazy ants in a supercolony are more likely to monopolize the bait, thereby preventing its consumption by Robber crabs and other non-target species. Given the documented effects of fipronil on invertebrates, other treatment methods for areas with low density yellow crazy ants should continue to be sought. We note that this is slated for 2013-14[86], and recommend that remains a priority.

- Research on the dynamics of supercolony formation, size, and distribution be started or continue

Several questions would be worth answering. For example: why are supercolonies becoming smaller? Are they forming more quickly? Are there environmental correlates with supercolony formation or boundaries? Do the two different haplotypes have different rates of supercolony formation?

A plan (and if possible, accompanying budget) be drawn up for appropriate rigorous data analysis and publication of several sets of data collected in the IWS and from treatment exercises.

- Analyse the resurveyed waypoints for significant differences between surveys teams.

- The entire running of the program as presently configured, and conclusions about its success, rely on data collected in the IWS. Therefore, it behooves CINP staff to ensure the data collected are as accurate and complete as possible. Resurvey of waypoints within a particular IWS provides a mechanism for checking repeatability of the data collected. The results of resurveys would be more indicative of any differences in data collection methods or accuracy by the teams if the teams were not aware which sites would be resurveyed or the previous survey results. We recognize that a 'blind' resurveying has not been implemented for logistical reasons, but we suggest that for a subset of sites this might be achievable. It will also be necessary to determine which values are likely to have changed in the time between sampling, and which should be similar. For those that are not expected to have changed in the days between initial and repeat samplings, a maximum allowable difference between values should be set, with retraining and/or review of procedures for cases that exceed the threshold.

2.5 African big-headed ants on Lord Howe Island

The *Draft Work Plan to Guide the Eradication of the African Big-headed Ant from Lord Howe Island*[27] (hereafter, Draft Plan) describes the history of African big-headed ant (*Pheidole megacephala*) on the island. According to the Plan, the ants were most likely introduced to Lord Howe Island in 1993 in building materials transported from mainland Australia, but were only recognized as a problem in 2003. Some field assessments and bait trials were conducted in 2005-06. By October 2006, when a survey was conducted as part of a treatment plan, it was thought that at least 120ha were infested. Due to delays in acquiring the bait, treatment did not occur until February 2008. Infestations continued to be reported around the settlement that year, however, both in treated and in untreated locations. By January 2010, surveys mapped the infestation area as 220ha, covering almost the entire residential area of the island. Opportunistic surveys and treatment were carried out in 2010, and in January 2011, most of the areas mapped as containing the ant were treated.

Caring for Our Country funds ($414,263) were awarded for June 2011-June 2013 for five activities to meet the target of addressing identified key threats to the natural values of the Lord Howe Island World Heritage area. One of these five activities (receiving $195,000 of the funds) is to implement a strategy to eradicate African big-headed ant infestations from Lord Howe Island over two years[97]. The activity is to include purchasing bait and engaging an ant eradication specialist to train Lord Howe Island Board (LHIB) staff. Progress to date has been limited by the delay in availability of CfOC funds to February 2012 and the inability to effectively delimit and treat ant populations in the winter months. We report here on progress to date, including the development of the eradication plan, focusing on the period from which CfOC funding began, but also drawing on previous work as context where relevant.

2.5.1 Treatment methods

The ant eradication specialist, Dr. Ben Hoffmann of CSIRO, visited Lord Howe Island in March 2012, and commenced training LHIB staff and developing of priorities for treatment of African big-headed ant[98].

Detection

During initial surveying and staff training in March 2012, it was realized that LHIB staff had been misidentifying the target ant. A widespread, possibly native *Pheidole* species was being mistaken for *Pheidole megacephala*, the African big-headed ant[27]. Dr. Hoffmann provided an identification card with the name, distinguishing features, and samples of African big-headed ants and the four most common ants on the island to facilitate correct identification. From February 2012, when CfOC funding commenced, to late 2012, 105ha have been surveyed[99] (Figure 2.16). Correct identification revealed that the infestation was confined to the ‘settlement’, and covering an area of 18-20 ha[99,100], instead of the anticipated ~200ha[100].

Surveys to detect and delimit the ant infestation on the island comprise a coarse-scale rapid assessment followed by fine scale infestation mapping. All assessments need to be undertaken during dry conditions at temperatures that do not exceed 30°C, and are ideally 24-30°C to correspond with ant activity levels[27]. Rapid assessment is done at sites in which the ant has been recorded previously or that are predicted to be suitable for infestation, and involves visual searches, and use of meat lures (dog food) placed at 10m intervals. At sites where African big-headed ants are found, meat lures are placed in a grid at 3-5m intervals to more finely delimit the infestation. The Draft Plan[27] had indicated that 5-10m spacing for the fine delimitation and 50m spacing for the rapid assessment would be sufficient, but these were changed to allow detection of isolated infestations[99]. The grid extends outward until no African big-headed ants have been detected for ≥ 20m radius. Presence and absence of African big-headed ants are recorded on GPS units for ease of mapping later. Figure 2.17 shows an example map of an area that has undergone fine scale assessment for African big-headed ants.

No post-treatment surveys have been conducted to date, but the proposed approach is to use a combination of rapid and fine scale survey methods at least three to four months after treatment[27, 99].

Containment and treatment

Chemical control

A granular bait of 7.3 g/kg hydramethylnon in a corn grit and soybean oil matrix (Amdro®) is used to control African big-headed ants on Lord Howe Island. It is applied at the manufacturers recommended rate of 2.5 kg/ha or 5g/20m^2 with the use of a hand-held spreader[27]. LHIB staff applying the bait walk in parallel lines 3m apart over the area to be treated. The treatment area is the area of infestation plus a 20m buffer on all sides. Adequate coverage and spacing is confirmed with the use of GPS units[99]. The plan is for one application applied under suitable conditions to be sufficient to achieve eradication; however, persistent infestations will be re-treated. Buildings within a known infestation area are treated with Amdro® in an Ant Cafe®, which is a means of containing the bait so that it lasts longer and is not accessible to other animals such as pets.

Movement control

Measures to prevent dispersal and reinvasion have been identified in the Draft Plan[27]. Nine known source points have been identified including the Waste Management Facility (WMF). Staff at WMF have been trained in African big-headed ant identification and check the facilities quarterly for the ants. If the ants are found, they are traced back to their source[100]. The *New South Wales Plant Diseases Act 1924* lists African big-headed ant as a declared pest species and allows for an inspector to serve notice on a landowner to prevent its spread[27]. At the island level there are import restrictions, with neither raw nor second-hand timber is allowed in, gravel has to be certified, and vehicles need to be cleaned[100].

2.5.2 Success of methods

The delay in finalizing the CfOC contract (to Feb 2012) meant that opportunities for treatment during the summer months of 2011-2012 were significantly reduced[27]. Fresh surveys with correct identification of the ant led to increased LHIB staff morale and a significantly reduced area to be treated. As of late December 2012, 14ha comprising 14 sites and 16 known source points have been treated. Post-treatment surveillance needs to be done during suitable weather conditions (not winter) and at least three months after treatment, and therefore it is too soon to know how effective treatment has been.

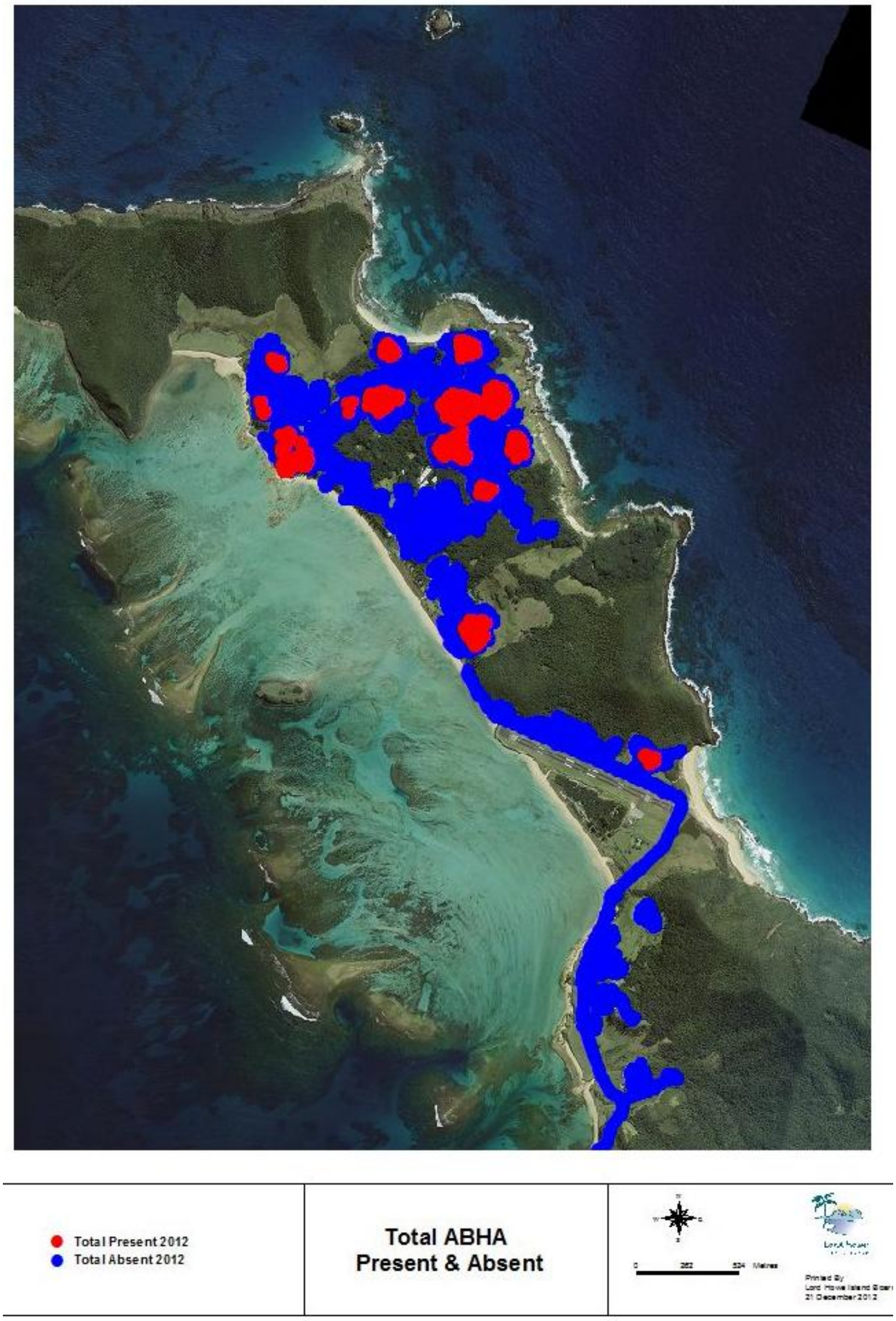


Figure 2.16 Area on Lord Howe Island surveyed for African big-headed ants in 2012

One known source point of 6ha still needs to be treated. Treatment of this property has been hampered by uncooperative occupants. It was necessary for Hank Bower, the LHIB appointed inspector, to apply for a Certificate of Authority under section 13 of the *NSW Plant Diseases Act 1924* to enter and search the property for African big-headed ant[100, 101]. The matter appears to have been resolved and treatment is scheduled for early 2013[99].

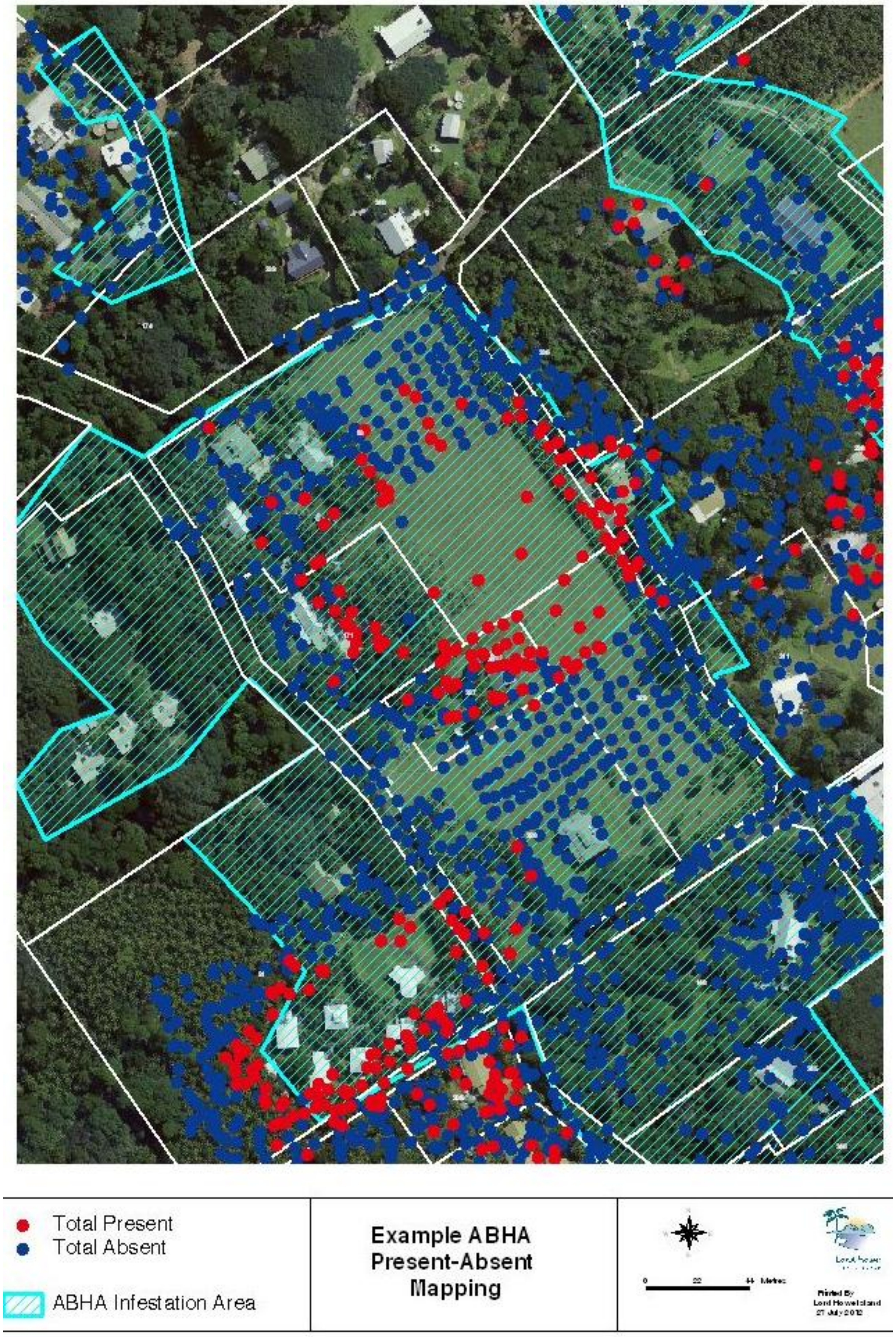


Figure 2.17 Fine scale mapping of an African big-headed ant infestation on Lord Howe Island

2.5.3 Advice for future management

The Draft Plan[27] identified many lessons learned from the 2005-2010 treatment efforts:

1. lack of expert advice in training and identification of African big-headed ant, distribution mapping, and post- treatment survey methods

2. inadequate planning
3. deficiencies in surveying, monitoring, and treatment methodology
4. lack of skilled supervisors
5. missing treatment windows due to wet weather
6. insufficient long-term funding to enable follow-up surveys and treatments until eradication is achieved

The current effort appears to have addressed the first four of these with the engagement of an experienced ant eradication specialist (Dr Ben Hoffmann), the development of an Eradication Plan that takes previous short-comings into account, and the use of high resolution GPS technology interfaced with GIS mapping capabilities. The fifth problem was again encountered in this round with the delay in provision of funds by CfOC, which significantly shortened the time to conduct surveillance and treatment before the onset of winter. We are not aware of the reason for the delay, but anticipate that now that the funding agreement is in place, the remainder of the program can be carried out as planned.

It will not be possible to document that eradication has been achieved by the time CfOC funding concludes on 30 June 2013. The Draft Plan protocol for declaring an area pest-free requires that surveys occur annually until no African big-headed ants are found for two consecutive years[27]. If the treatment schedule goes according to plan, the earliest eradication could be documented would be in early 2015, two years after the last treatment is applied. This assumes that there are no persistent infestations. We therefore advise that LHIB identify funding sources now for follow-up treatment and surveys after 30 June 2013. Alternatively, or in addition, the savings that must have been realized when the extent of African big-headed ant infestation was found to be ~10% of what was initially anticipated should be requested to be carried over to 2013-14 and allocated to follow-up surveys and treatment.

To maximize program efficiency and build capacity for the future, we further advise project staff:

- Perform a simple analysis of the cost of applying another round of bait as compared to doing surveillance three months after the initial treatment.

  A single bait application had success in Northern Territory rainforest[102]. However, Lord Howe has a different physical and climatic environment, and a history of poor results from a single treatment[27]. As eradication is the aim, a more aggressive approach with a second precautionary treatment might be warranted, especially given the small area of infestation. Detection of 100% of surviving colonies three months after baiting seems unlikely.

- Attempt to determine the cause of previous African big-headed ant persistence.

  Utilize any data collected and discuss treatment practices with staff present during the 2006-2010 surveillance and treatment efforts. Such data might elucidate whether eradication failed because there was inadequate bait coverage, bait was applied during poor conditions, site attributes prevent bait dispersal or uptake, re-infestation occurred from an adjoining undetected infestation (poor delimitation), or another reason. For the current treatment efforts, as much information as possible should be retained in a database (e.g., areas treated, vegetation type, measure of ant abundance, weather conditions during treatment) to support any future eradication efforts.

- Follow-up on the identity and ecological role of the "other *Pheidole*" that was mistaken for the African big-headed ant.

  The factsheet[103] on the African big-headed ant that has been produced by LHIB indicates that this "other *Pheidole*" it is a native species, but its identity and origin remain uncertain[71, 100]. Given that the limited data collected to date indicate this *Pheidole* is spreading rapidly, its potential ecological impacts and origin should be investigated. It will be useful to know whether earlier failures of treatment directed against African big-headed ant were due in part to the wrong ant being treated.

- Keep voucher specimens of ants observed in surveys.

  Maintaining a collection of labelled specimens will help to avoid any future confusion about ant species identity and will enable a more rapid detection of any new ant species that may invade. If there are not resources to maintain a properly curated collection, specimens can be kept ethanol to avoid decomposition, but specimens should be identified dry.

- Regularly refresh staff abilities to distinguish the ant species on the island.

  This could be accomplished with periodic review of the voucher specimens and will help ensure that capacity is retained to recognize and rapidly deal with any future incursions.

- Implement regular surveying of areas of the island of highest biodiversity value for African big-headed ants and other non-native ants.

  Proactive surveillance will enable early detection and treatment of any infestations to these locales.

- Identify and document actual and potential threats to biodiversity posed by the African big-headed ant.

  The Draft Plan suggests that successful eradication will lead to "rapid ecological recovery" [27] but it is not clear what this recovery is, as the infestation is currently largely restricted to the settlement.

- Ensure that communication with residents includes information on how to avoid inadvertent spread of African big-headed ants.

  African big-headed ants can be dispersed inadvertently with the movement of pot plants, gardening materials, soil, refuse, and other materials. The 'African big-headed Ant Eradication Fact Sheet[103] does not explain to residents how moving these materials may result in the spread of the ant. Future communications (e.g., newspaper articles) should include this information.

- Ensure program legacy and institutional memory by documenting the entire management process.

2.6 Argentine ants on Norfolk Island

The presence of the Argentine ant (*Linepithema humile*) on Norfolk Island was confirmed in 2005 and subsequent modeling suggested it had probably been there since at least 2000[30]. An island wide survey in 2006 indicated that the infestation was limited to two properties on the western part of the island and some control measures were implemented on these properties[104]. By mid-2007, Argentine ants were confirmed at the Waste Management Centre; they were thought to have been transported there in waste materials from the western infestation[30]. Since the Centre is a central waste drop off point for all island residents and is also the source of mulch that had been sold to residents all over the island, with this detection it was recognized that the risk Norfolk Island's environment had increased exponentially[104].

The Norfolk Island Administration (NIA) sought expert advice from Peter Davis from Western Australia and Viv Van Dyke of FBA Consulting in New Zealand. By the time of their visit in May 2008, the initial infestation on the western side of the island was at least 63.5ha and the Waste Management Centre infestation was 12ha[30]. The maritime climate of the island is ideal for the ants, and it is thought that even without human assistance the western infestation was expanding by 25-30ha per year in 2008[30]. Following the advice of the experts, the Administration of Norfolk Island agreed to attempt to eradicate the ant[104].

Following an approval to utilize the toxic bait product and advice in relation to an EPBC Referral, FBA Consulting was commissioned to undertake an initial detection and treatment program[104]. Approximately 20% of the funding came from the National Heritage Trust. Surveillance and ant treatment took place over a one week period in late November 2008, and by November 2009 it was estimated that "92% of eradication had been achieved" [104]. According to the 2011 Strategic Plan written by FBA Consulting, the effort then stalled due to lack of funds[32].

Caring for Our Country funds ($157,000) were awarded to NIA for 2010-2012 to continue towards the goal of eradicating Argentine ants from the island. The specific activities that are required in the funding deed all mention surveying and baiting for Argentine ants, though the metrics of achievement are more aligned with broader CfOC goals than with Argentine ant eradication[105]:

1. to increase by at least 3455 hectares (the size of Norfolk Island), the area of native habitat and vegetation that is managed to reduce critical threats to biodiversity and enhance the condition, connectivity, and resilience of habitats and landscapes
2. to increase by at least five new volunteers being recruited and retained in community groups involved in managing natural resources
3. to increase by six farmers on 12 properties over 40 hectares adopting activities that contribute to the ongoing conservation and protection of biodiversity.

2.6.1 Treatment methods

Detection

Delimiting the areas of infestation on the island had begun before CfOC funds were awarded and continued for the first several months of funding[106, 107]. By March 2011, the NIA primary field officer had established a database of all 151 properties where a risk of Argentine ant infestation had been identified[106]. Risk factors included previously known infestations, proximity to known infestations or at risk of from receiving goods from infestations, high volume material handling, easy public access, reported observations from land holders and the general public, and sites with mulch, vendor stalls, commercial growers, sellers of firewood, stock feed, or high risk staff[32, 108]. Based on risk factors, high risk sites were identified as[32]:

- Ocean tip site
- Wood suppliers
- Sawmills
- Fruit, plant, and vegetable traders from known infestation sites
- Hospital
- Rental car depots
- Nurseries
- Airport and cargo jetties

By 30 June 2011, the database had increased to 156 properties and all known infested areas had been identified and mapped[107]. Of the 156 properties, 63 had received mulch from the Waste Management Centre, of which three were infested. An additional 68 of the 156 properties also had various levels of infestation[109, 110]. An owner's or occupant's substantial contact with an infested property (e.g., employment at an infested site) was identified as another means of spread[110].

Exploratory and delimiting surveillance are both accomplished with skilled searching based on knowledge of the ant's behavior as well as with use of lures[32, 110]. Exploratory surveillance is conducted in response to reports of suspected or confirmed Argentine ant activity, and in areas at risk of infestation. Delimiting an infestation is done by searching for the ants in 50m increments away from the known infestation until no Argentine ant activity is found. A lure consisting of peanut butter and salad oil is placed in a 60mm clear plastic pot (pottle) and left out for two hours in 20-25°C dry weather[32, 110]. At least four pottles are placed out for each 100m ^{2} area. Ant samples are collected and sent to FBA Consulting for identification. Sometimes the results require additional samples to be taken in order completely delineate the infestation before baiting can commence. This process has proved more time consuming than anticipated[106].

The island has been divided into 11 zones as described in Table 2.14 and shown in Figure 2.18.

Containment and treatment

Chemical control

The eradication effort on Norfolk Island uses fipronil-based toxic bait in either paste, or spray form. Xtinguish® comes in a paste form and contains 0.1g/kg fipronil in an egg and fruit pulp matrix, and is applied at 6kg/ha with builders' silicone guns[110]. Xtinguish® was developed by the Department of Agriculture in Western Australia, but was commercialized in New Zealand by Bait Technology/Flybusters[30]. It is imported from FBA Consulting in New Zealand. In 2011, the bait price increased by $4.00 per tube. To offset the increase, it was necessary to have the bait shipped by sea rather than by airfreight. This necessitated even more advance and precise planning to ensure that the correct amount was ordered and that it arrived in time[111]. The spray form is a 4ml/l solution of Termidor® with one cup of sugar added. It is applied with hand pressurized two liter spray bottles.

Table 2.14 Zones of Argentine ant infestation on Norfolk Island[110]

Zone	Total infested area (ha)[1]	Description
1	131.948	Located along western coastline, 19 privately held portions and Crown Land Headstone Reserve including waste burning area. Private lands are mostly farm or grazing lands but include display gardens/ tourist maze, organic farm, Historic church and graveyard, large tourist show attraction, approximately 1.5ha wetlands and 2km of steep cliff face
2	22.240	One public reserve known as Hundred Acre Reserve. A mostly heavily wooded area with walking trails and picnic areas
3	15.130	One residence & grazing property. Located SW of airport main runway and east of Zone 1
4	7.492	Residential properties and commercial palm growing operation. Located in SW sector of the island
5	50.790	Private grazing land and industrial area of airport - airport terminal, power generation facility, waste management & recycling facility sewage treatment plant & fire drill area, dense vegetation and creek / wetlands
6	19.940	Comprises tourist accommodation property, grazing land, bushland and three residences, borders Norfolk Island National Park and also Norfolk Island Botanic Gardens
7	10.530	Hospital, shops, bushland, residential and light industrial workshops
8	8.10	Tourist accommodation, residential and steep terrain bushland
9	28.9	One public reserve, known as Ball Bay Reserve, includes Bulk fuel storage depot, cattle stock pen and steep terrain bushland.
10	22.58	One public reserve known as Cascade Reserve, Jetty, Creek, steep terrain grazing land, steep terrain bushland
11	3.4714	Two chimneys, several residential properties

[1] the total area infested with Argentine ants within the zone

Care is taken in application to minimize the risk of waterway contamination[110] NIA staff also avoid placing or spraying bait in flowers and near bee hives to avoid contact with foraging bees. For treatment of cliff faces, Xtinguish® is applied to coarse gravel and dispersed from the top of the cliff into the thick vegetation below. The use of 'drop lines' consisting of 100m weighted fishing lines with small bottles of non-toxic attractant will be trialed in autumn 2013. These will be placed in conjunction with the volunteer Rescue Squad as a training exercise[110]. The aim is to attract Argentine ants to the top or bottom of the cliff where they may be sprayed en masse.

Infested sites are treated on dry warm days from spring to early summer and from late autumn to early winter. Xtinguish® dries out after 2-4 days, and would dry even faster if applied in very dry hot times of year. In late autumn or early winter masses of Argentine ants are sprayed with the Termidor® solution as they begin to shelter in structures and tree root buttresses[110]. Sites are treated once unless Argentine ants are detected in post-treatment monitoring, which occurs at least two months after treatment. If further treatment is needed it needs to be at least three months after the previous treatment to avoid bait shyness[110]. Some sites have been baited three times. Monitoring has so far been limited to accessible areas.

Termidor® is used to treat infested items prior to their being moved[112].

Baiting was scheduled to commence in February 2011, but was postponed to April 2011 due to a delay in the arrival of the bait[106]. As of June 2011, 90% of known infestations had been baited with Xtinguish®. The two month delay meant that areas of infestation had expanded beyond what was planned and the baiting took longer to complete[107]. Baiting recommenced in October 2011, when the weather became warmer. By November 2011, all known infestations had been baited, including the two kilometers of cliff face on the western coast[29]. Additional baiting was conducted in autumn 2012 to treat newly discovered re-infestations and to re-treat persistent infestations[29]. In July 2012, the infestation in zone 11 was discovered. It was immediately delimited and treated, but a follow-up visit indicated another area of infestation approximately 160m away. This infestation was treated in November 2012.

Figure 2.18 Zones of Argentine ant infestation on Norfolk Island. Zone 11 was discovered in July 2012 and maps have yet to be updated. The approximate location of zone 11 is indicated with the red circle.

Movement controls

The 2011 Strategic Plan noted that the closure of dispersal pathways is one of the key activities that has been neglected[32]. The document did not specify any pathways, or a plan for closing them however. The sale of mulch to residents all over the island certainly facilitated spread and this was stopped in April 2007. NIA is attempting to privatize the management of green waste so that the operation can be removed from the Waste Management Center and the high risk of infestation[110].

With the local culture of sharing a wide-range of items, such as garden plants and machinery, the movement of vegetation and other goods, and the community collection of firewood were recognized as dispersal pathways by the NIA. Rather than take a hard-nosed approach, which probably would not have worked, the program has relied on raising community awareness (see Section 4.6) to keep the community strongly supportive of the eradication effort[110].

2.6.2 Success of methods

A quantitative measure in Argentine ant decline has been difficult to define because of the varying conditions between properties and infestations[110]. Based on visual inspections, good knockdown has been achieved[113] and other ants are returning[110]. Because the protocol being followed requires three years of monitoring before eradication can be declared, none of the sites have yet been declared free of Argentine ants. However, three sites, Norfolk Island Botanic Gardens, Collins Head Road, and Cascade Reserve, in zones 6, 8, and 10 respectively, appear to be currently clear of Argentine ants[110].

2.6.3 Advice for future management

NIA has recently been successful in obtaining additional CfOC funds to eradicate Argentine ants from Norfolk Island. This is a positive development for continuing progress towards eradication. To ensure that the program has the greatest chance of success, we advise:

- The effect of the fipronil spray on ant behavior be investigated immediately

The spray must be dilute enough that Argentine ants survive and return to the nest to spread the poison to the queens and brood, but it also must be strong enough that it eventually kills the ants. If the spray is acting as a contact poison, it is highly likely that queens and brood will survive and eradication will not be achieved. The return of other ants is not sufficient proof that the method is effective. Remnant colonies might not be detected for a year or more. In the absence of confidence that the workers are able to survive long enough to spread the toxicant throughout the nest, it would be better to employ the slower-acting, but proven-effective Xstinguish®.

- Implement regular surveying of areas of the island of highest biodiversity value for Argentine ants

Proactive surveillance will enable early detection and treatment of any infestations at these locales.

- Perform a simple analysis of the cost of applying another round or more of bait as compared to doing surveillance three months after the initial treatment.

As shown by the November 2008 baiting exercise on the island, eradication is unlikely to be achieved with a single application of bait. It might be more cost-effective and would help with bait purchase planning to plan to treat each infestation at least three times at the outset, regardless of the observed outcome of the first treatment. Ideally, a proper investigation of the number of treatments required to achieve eradication would be conducted (e.g., as has been done in the NEAEP).

- Development of a labelled reference collection of all ant species on the island

Sending samples offshore for identification is time consuming and costly. If resources are not available for a properly curated collection, then a collection of labelled specimens preserved in ethanol could be maintained. Ideally, a simple key or list of distinguishing features would be developed for distinguishing ant species. This would also build capacity to detect any future incursions.

- Staff abilities to distinguish the ant species on the island be regularly refreshed

This could be accomplished with periodic review of the voucher specimens and will help ensure that capacity is retained to recognize and rapidly deal with any future incursions.

- The source of the toxic bait should not also be the sole provider of strategic advice.

There is the potential for conflict of interest with the same entity providing these two services. Some independent evaluation needs to be incorporated into the project.

- Capitalize on the close-knit population and public support for the program by asking every resident to actively check his/her property

Given the recent (July 2012) detection of a large (3-4 properties), and therefore old infestation, by a resident, it may useful to actively ask residents to check their properties for Argentine ants, rather than relying on reports once they reach nuisance abundance. Consider setting a designated "Check for Argies Day", with appropriate build-up in the local newspaper and by word of mouth. Step-by-step instructions could be provided in the newspaper, along with photos and distinguishing features of the ants most likely to be confused with Argentine ants. Simple steps may for residents might include checking all fruit and vegetable crops for trails, or placing out a protein lure (e.g., tuna fish, cat food, meat or fish scraps) for an hour and checking to see what is attracted.

- Continue investigating means of bait application in difficult to access areas

The use of drop lines to detect Argentine ants in areas with steep cliff is an innovative approach. In addition to using the drop lines to detect the ants, investigation should be done to see if the lines may also be a means of distributing toxic bait evenly over the area. Also, since Argentine ants forage in the canopy, some investigation should be done to see if the ants are returning to the ground to forage or to determine if placement of bait in the canopy is needed.

- Specify strategic terms of reference for any future consultant contracts

The April 2011 Strategic Plan[32] is in many places a generic discussion of procedures and options for management activities rather than a plan with specific protocols to follow. Future consultant contracts should specify clear Terms of Reference that proscribe best courses of action specifically for Norfolk Island based on available information.

- Ensure program legacy and institutional by documenting the entire management process.

3. IMPACTS ON BIODIVERISTY

3.1 General observations pertaining to all six projects

Tramp ants are managed for their actual or potential economic, social, and environmental impacts. Caring for Our Country provides funds to address the threats tramp ants pose to biodiversity. In this introductory section, we provide some context for our evaluation of the tramp ant abatement projects in Sections 3.3 to 3.8 below. In Section 3.1.1 we summarise the context in which CfOC awards funds and the general expectation for evaluation against target outcomes. In Section 3.1.2 we summarise the goals and proposed performance measures of the *Threat abatement plan to reduce the impacts of tramp ants on biodiversity in Australia and its territories* (TAP). In Section 3.1.3 we discuss approaches to assessment of impacts on biodiversity, and in particular highlight the different contextual settings of incursion response, non-target effects of applied pesticides and other operational activities, and ecological release of native biodiversity and ecosystem processes. Lastly, in Section 3.1.4 we discuss approaches to assessment of future risks to biodiversity posed by tramp ants, including an outline of the approach to risk assessment adopted in this review to identify species that may be priority for more comprehensive risk assessment and monitoring.

3.1.1 Caring for Our Country evaluation context

The tramp ant projects are funded by CfOC within the strategic outcome national priority area BIODIVERSITY AND NATURAL ICONS. The two five-year outcome targets are relevant:

- By 2013, Caring for our Country will increase, by at least one million hectares, the area of native habitat and vegetation that is managed to reduce critical threats to biodiversity and to enhance the condition, connectivity and resilience of habitats and landscapes. This is additional to the 125 million hectares that is to be protected within the National Reserve System.
- By 2013, Caring for our Country will reduce the impact of invasive species, including tramp ants ....in at least one priority area.

As part of its funding agreements, CfOC generally requires projects to[114]:

- Collect or develop sufficient baseline data and information at the start in order to provide a reference point for monitoring any changes or progress as a result of the funded Activity;
- Monitor the performance of funded Activity in relation to the CfOC Outcomes and Targets and provide Performance (Monitoring and Evaluation) Reports.
- Ensure all monitoring and evaluation activities relating to the funded Activity are consistent with the principles outlined in the Australian Government Natural Resources Management Monitoring and Evaluation Reporting and Improvement Framework available at http://www.nrm.gov.au/publications/frameworks/men-framework.html
- Ensure adequate resources are applied to fulfil the monitoring and evaluation requirements

The situation is complex in respect to monitoring and evaluation of tramp ant projects. In some cases, the outcome of CfOC funding being evaluated in this report is part of a larger program that has been ongoing for several years (e.g., RIFA, EA, YCA-CI, YCA-NT), and reporting requirements have shifted over the years. The requirement to document project performance through Monitoring and

Evaluation Reporting and Improvement (MERI) plans (Table 3.1) began in the 2009-10 financial year. More recently developed management efforts funded by CfOC (Lord Howe, Norfolk Island) have been subjected to the MERI approach since their inception.

It should be noted, however, that contract schedules, in which specific tasks and/or milestones are listed, do not specifically address the requirement for assessment of biodiversity impacts. The MERI Plan approach, with its focus on operational performance, is deficient in this regard.

Evaluation within the context of MERI plans is based on Key Evaluation Questions (KEQs), which are the high-level questions that the project needs to answer about its impact, effectiveness, appropriateness and efficiency. KEQs are also explicit questions to be answered for the purposes of reporting or improvement.

KEQs are addressed through evidence from various sources, such as:

- Commissioned studies (evaluations, research, benefit-cost analysis, performance story reports, etc.)
- Reviews of existing data and project management strategies and processes
- Mandatory project progress reports

There is the expectation that not all evaluations will require specially commissioned studies.

Table 3.1 Caring for Our Country guideline to MERI reporting for projects >$80,000[114]

MERI component	Information resources
MERI planning	
A MERI plan with a rigorous program logic with documented assumptions and evidence of causal links, including links to Caring for our Country targets and five-year outcomes, and an outline of how the following MERI requirements will be met.	Guides to MERI planning and developing a program logic are available at the Caring for our Country website (http://www.nrm.gov.au/index.html) under monitoring and evaluation.
Monitoring	
» Track and report expenditure » Measure delivery of project immediate outcomes » Collect baseline data » Measure progress towards project intermediate and longer-term outcomes, including Caring for our Country targets and five-year outcomes » Determine mechanisms for measuring post-project impact where relevant » Any other project-specific monitoring requirements identified through theme MERI plans (4.2.1)	» Measures (standard immediate outcomes; intermediate (five-year) outcomes) (Appendix 1) » Theme program logics (to be identified as part of individual theme MERI plans developed by the Australian Government) (4.2.1)
Evaluation	
» Establish mechanisms for evaluation of project » Evaluate project outcomes (with respect to appropriateness, efficiency, effectiveness, impact, legacy and lessons learned) and contribution to Caring for our Country targets and five-year outcomes	Project MERI planning (3.2.1)
Reporting	
» Interim progress report including a project expenditure summary » Yearly progress report including an end-of-year financial report » Final project report including a financial acquittal of all project funds	» Project financial reporting (3.3) and template (Appendix 2) » Project progress and final report (3.4) and template (Appendix 2)
Improvement	
Establish, and report on implementation of, mechanisms for improvement of project during its delivery	Project MERI planning (3.2.1)

3.1.2 Tramp Ant Threat Abatement Plan

As a goal, the *Threat abatement plan to reduce the impacts of tramp ants on biodiversity in Australia and its territories* (TAP)[115] focuses on:

- minimising the impact of invasive tramp ants on biodiversity in Australia and its territories by protecting threatened native species and ecological communities; and
- preventing further species and ecological communities from becoming threatened.

TAP proposed that performance would be measured, in part, by:

- a decreased rate of tramp ant incursions into Australia and its territories; and
- a reduction in the incidence and magnitude of impacts arising from established tramp ants on Australian native species and ecological communities.

The TAP explicitly addresses impacts of tramp ants under Objective 1 of its six objective approaches (Table 3.2).

Table 3.2 Actions and performance indicators relating to assessment of impacts of tramp ants as outlined in the Tramp Ant Threat Abatement Plan[115]

Action group	Actions	Performance indicators (the extent to which the following are in place)
Objective 1 Increase science-based knowledge and expertise, incorporate Native traditional ecological knowledge, quantify impacts, and improve access to information for priority tramp ant species		
1.3 Assess tramp ant impacts in Australia and its territories (High priority, Short term)	1.3.1 Quantify direct and indirect impacts (and mechanisms of impact) of priority tramp ants, focusing on biodiversity but where appropriate including other environmental, economic, health and cultural impacts.	Peer-reviewed publications and reports documenting impacts for priority tramp ants established in Australia or its territories as a basis for risk assessment and establishing priorities for management response.
	1.3.2 Review known impacts of all tramp ant species of concern, especially those species emerging as threats.	Reports on potential impacts for species of concern that are not yet established in Australia or its territories as a basis for risk assessment and establishing priorities for management response.
	1.3.3 Commission an economic assessment of environmental/human health/social costs of priority tramp ants.	An economic assessment of the broad direct and indirect costs of tramp ants to Australian society.

3.1.3 Approaches to biodiversity impact assessment in incursion response situations

There are three principle mechanisms by which tramp ant programs affect biodiversity:

- Prevention of tramp ant incursion into and impacts in areas important to native biodiversity
- Non-target effects of applied pesticides and other actions to manage tramp ants, including collateral accidental effects of increased vehicular and human traffic, and further spread of weeds and pests during those control operations
- Ecological release of native biodiversity and ecosystem processes from tramp ant impacts

Each of these mechanisms is relevant to the tramp ant programs addressed in this review, and each program's performance is assessed accordingly.

Prevention of tramp ant incursion and impacts on biodiversity

All CfOC funded tramp ant programs function to prevent incursion into areas important to native biodiversity, albeit the approach and rigor to *a priori* identification of those important areas has varied greatly among programs. Prevention of incursions into areas and minimising impacts on biodiversity is primarily effected by containment and suppression or eradication of known tramp ant infestations. All programs operate within the context of national and state biosecurity strategies to prevent incursions across country and state borders. Some programs include development of strategies and plans for incursion management at regional scales.

The proximity of incursions to areas of high biodiversity significance should translate to the urgency and vigour to which containment and eradication activities are undertaken. Prevention of spread into areas of high biodiversity significance will ultimately be more cost-effective than attempts to eradicate once established. Further, eradication of tramp ants does not necessary mean full restoration of affected ecosystems if species extinctions have occurred.

Non-target effects of applied pesticides and other actions

The application of insecticides to control tramp ants is not without risk. All of the chemical control methods used have potential to affect non-target species. In the main, the baits used in ant control (active ingredients and formulations) have been through rigorous registration processes and as such their toxicology and fate in soils and waters are well known. The risks may be mitigated by

- Rapid breakdown of the active ingredient of unconsumed bait under certain environmental conditions,
- Application of baits attractive to the target species,
- Application of baits where and when the target species is more likely to monopolize the bait, and
- Adherence to specifications on the product label for application rate and use near waterways

Ideally, a before-after-control-impact (BACI) experimental design[116], or involving a replicated comparison of infested and non-infested sites, should be used for investigation of non-target effects of tramp ant control.

Ecological release of native biodiversity and ecosystem processes

Restoration of native biodiversity, and of ecosystem processes dominated by native biodiversity, may occur following severe reduction or eradication of tramp ants. Such ecological release is inherently long-term. It is reasonable to expect that the degree to which native communities and ecosystem processes are restored, relative to those operating prior to tramp ant invasions, will vary with the length of time tramp ant has been present at the site and the severity of disruption of native biodiversity and ecosystem processes. Furthermore, the spatial scale at which ecological release occurs may be larger than the area freed from the tramp ant, if the site is important to native species that have part of their life cycle elsewhere.

Given the generally long-term nature of ecological release, and the short-term nature of CfOC funding, it may be unreasonable to expect programs to generate conclusive evidence for restoration of biodiversity and ecosystem processes. However, it is not unreasonable that programs establish a monitoring protocol, collect baseline data, build stakeholder support and community participation, and build a case for ongoing federal or state government financial support to ensure that, as a legacy of CfOC funding, the benefits of tramp ant eradications are fully documented.

3.1.4 Approach to assessment of future risks to biodiversity

There have been several previous reviews of the impact of particular tramp ants on native floras and faunas in regions to which tramp ants have invaded (e.g.,[3, 117-122]). A comprehensive review is therefore not repeated here.

Risk assessments of invasive species often necessarily rely on documented effects from elsewhere in the species' introduced range. Care must be taken to ensure the ecological context is also similar with regard to abiotic and biotic factors that affect tramp ant behavior and interactions. It is generally recognised that impacts of tramp ants on native biota are most apparent under circumstances where the tramp ants are able to attain high population densities[3, 117]. The abundance of tramp ants can vary tremendously, and studies do not always provide information to enable a comparison of density across locales. Consideration of the functional roles of the tramp ant relative to that of native ants is also key.

An additional challenge is the proper interpretation of changes in abundance of native species that might occur in the short term following tramp ant establishment. Changes in the abundance in one or more life stages, relative to non-infested reference sites is commonly interpreted and extrapolated to suggest that the tramp ant is adverse to the native species in question. In most cases, those are the best data available. However, it should be noted that marked changes in mortality in a particular part of the life cycle may have no real impact on the population trend of the animal or plant if variation in that stage is not critical to population regulation[117, 123]. A tramp ant that alters the abundance of one or more natural enemies may, for example, have profound effects on the temporal stability of abundance in a native herbivore whose populations are naturally primarily regulated by top-down trophic interactions. Conversely, such changes in natural enemy abundance due to tramp ants will have little impact for an herbivore whose populations are primarily regulated by bottom-up processes such as food abundance and quality. Moreover, the intergenerational trend in the abundance of a particular life stage may, in animal groups such as insects and *r*-selected vertebrates, be entirely regulated by population processes acting on other life stages in other strata at the site, or indeed at other sites. Proper elucidation of tramp ant effects on species can only be achieved by appropriate comparative or manipulative experiments coupled with monitoring spanning a number of generations of the species perceived to be at risk.

In assessing future risks to biodiversity in newly invaded regions, such information on population-level outcomes in almost invariably absent – that is simply the nature of risk assessment. Nonetheless, there remains a need to consider how population processes might be perturbed and how intergenerational population trends might change in the presence of the tramp ant. Figure 3.1 provides two examples of how understanding of the interplay between tramp ants and native species life strategies can guide estimates of likely population-level outcomes in risk assessment.

In the approach utilized in this report, we also highlight the need to take into consideration the importance in the national context of the populations being affected by tramp ants. In this framework, relatively small reductions in population levels or in geographic range of critically endangered native species are viewed as having greater impact than corresponding changes in population levels or range in species of lesser threat status. Figure 3.1C provides a simple framework for extrapolating mechanisms of tramp ant impacts to probable population-level or range size outcomes in native species based on their current conservation status.

Approach to risk assessment adopted in this review

Taking the above discussion into account, in assessing risks for native species as a result of tramp ant establishment and spread, we scored the following five factors:

- Assessment of the national importance or significance of the population(s) likely to co-occur with and be affected by the invasive species;
- Estimate of the extent of geographic overlap of the native and invasive species (inclusive of recognition that significance of this geographic overlap may vary spatially);
- Estimate of the extent to which the local niche of the native and invasive species overlap, and given this, to what extent these species will interact directly (predation, competition for resources) or indirectly (as a consequence of changes in community-level species assemblages and ecosystem-level modification of nutrient regimes, polarity in bottom-up vs. top-down regulation, etc.);
- Assessment of likely effects of local interactions with the invader on key processes that determine local intrinsic growth rate of the native species, namely
    - breeding success, and
    - food acquisition through effects on foraging success and food resources.

An example of the embodiment of these factors into a figure for a hypothetical native species is shown in Figure 3.2.

This is an inexact science. Robust risk assessment has high dependence on good information on both the invader and the native species, but most current information is anecdotal and qualitative. Often the biology of the native species is poorly known - in the case of threatened species due in large part to rarity and low population densities being barriers to robust observation. A large body of scientific literature is becoming available on the invasion ecology of tramp ants, but the predictive power remains coarse, both spatially and ecologically. Quantitative niche modelling is a powerful tool for assessment of risk at macro-scales, and new theory and modelling methods are beginning to address biotic interactions and niche dimensions at landscape to local scales. Interactions between a native species and an invader are novel events in the respective species' evolutionary history and the outcomes are highly unpredictable. Prior outcomes of interactions with the invasive species in other invaded regions can provide a guide to the types and strengths of impacts, given some knowledge of the biological traits of the native species that might lend to vulnerability and some understanding of the functional characteristics of the invaded ecosystem. However, as noted above, extrapolation from one biogeographic region to another is to be treated with some caution.

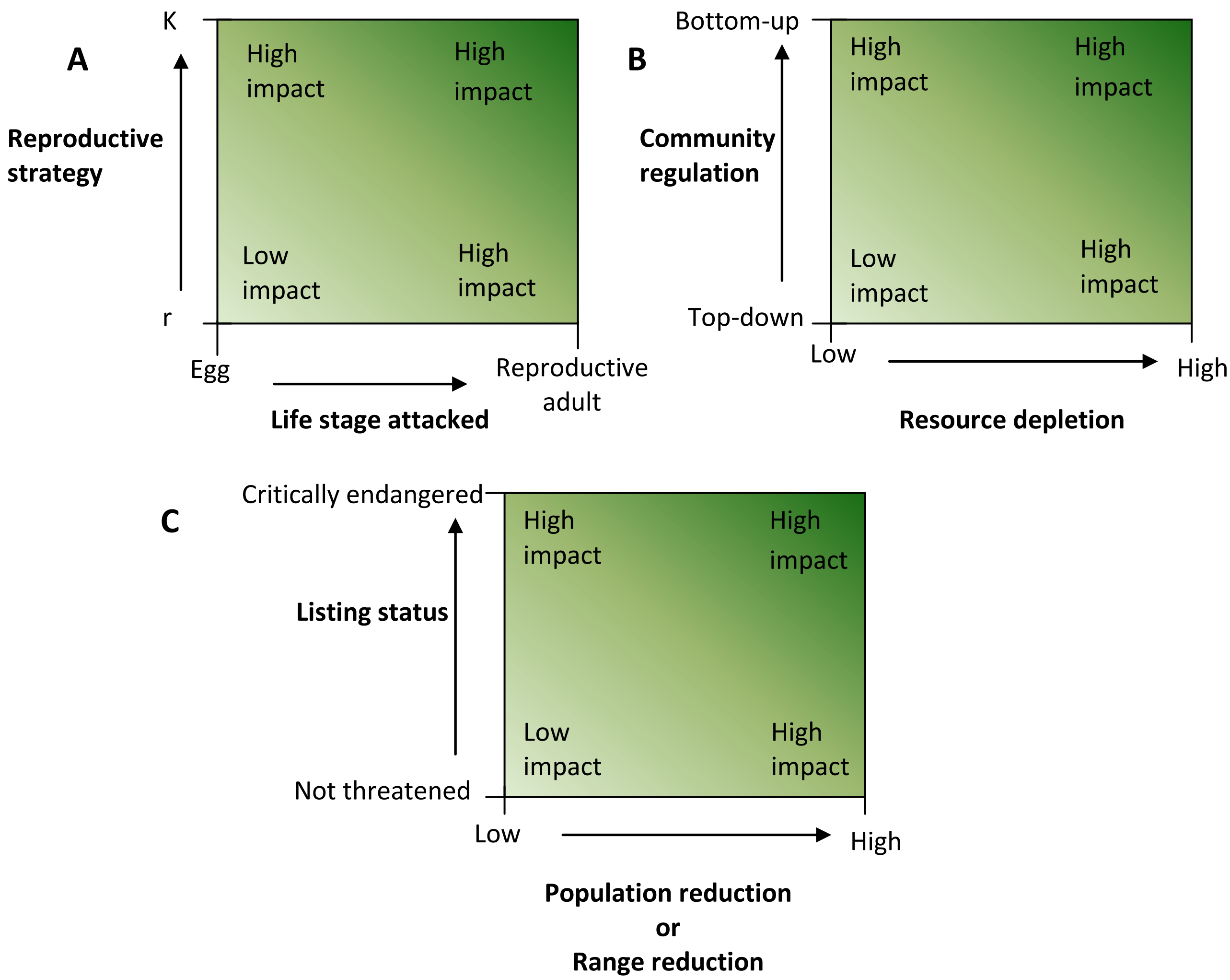


Figure 3.1 Illustration of simple frameworks that may guide extrapolating mechanisms of tramp ant impacts to probable population-level outcomes in native species. The green block represents the response surface, being a continuum from low impact in the left bottom corner to high impact in the other corners. Outcomes for the native species as affected by the interplay between **A)** the life stage predated by the tramp ant and the reproductive strategy of the species attacked, **B)** the level of resource depletion by the tramp ant and the top-down verse bottom-up regulatory setting of the native species utilizing those resources, and **C)** the level of population-level reduction or range reduction effected by the tramp ant (directly or indirectly) and the current conservation status (e.g., EPBC Act Listing Status) of the native species.

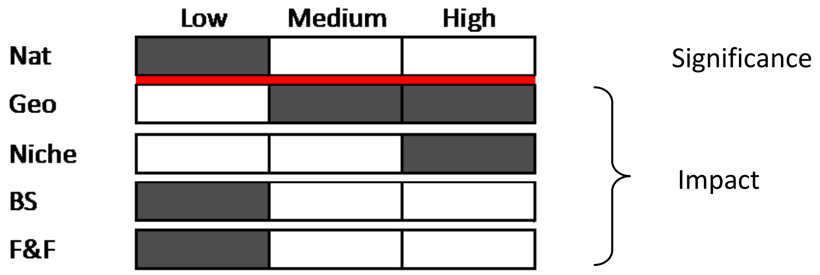


Figure 3.2 Example of a simple block chart used to summarise assessments of potential significance and level of impacts of a tramp ant on a native species within a particular bioregion. Nat: *National importance or significance* of the regional population(s) under consideration. This takes into account the current geographic range of the species relative to the extent of the bioregion as a whole; the threat status (e.g., EPBC Act Listing Status) of the species; and how threatening processes may vary spatially. Nat is an index of the irreplaceability value of the population(s) within the bioregion. An 'Endangered' species endemic to the bioregion would be afforded a higher risk category than an 'Endangered' species distributed across several bioregions, and the latter afforded a higher risk category than a species of lower threat status and/or more widely distributed. **Geo**: Extent of *geographic range overlap* with the tramp ant within the Bioregion (terrestrial/non-marine component of range only). This addresses broad (landscape scale) patterns of likely co-occurrence of the native species and the tramp ant based on macro-environment and habitat preferences. For warmth-loving tramp ants, it is recognized that their population density and impacts will diminish along the elevational transition to upland/montane environments. A native species that is likely to co-occur with the tramp ant across a large part of the bioregion would be afforded a higher risk category than a species with more limited co-occurrence. **Niche**: Extent and intensity of likely *local scale, microhabitat co-occurrence* with the tramp ant, taking into account degree of competition for or required co-sharing of physical resources such as shelter, nest sites, substrate or vegetation strata, and food sources. Additionally, it takes into account the likely local suitability for the tramp ant and thus its colony density. **BS**: The extent to which *breeding success* (inter-generational maintenance of population density) is likely to be directly or indirectly reduced by the tramp ant, taking into account likelihood of mortality in the reproductive population through predation; disruption in pollination, mating, nest/den building and occupancy; vulnerability and likely survival rate of eggs/hatchlings/juveniles; in case of insects, vulnerability and likely survival rate of pupae, newly emergent adults, or resting/diapausing stages; and in plants seed destruction and disrupted dispersal. **F&F**: The extent to which *foraging* is disrupted, extent to which *food resources* are likely to be reduced directly or indirectly by the tramp ant, and extent to which feeding on tramp ants leads to poisoning and mortality, taking into account the degree of reduction in food acquisition due to change in foraging behaviour enforced by predator-avoidance type phenomena, food resource monopolisation by the tramp ant through superior search efficacy, and/or increased rarity of the food resource itself.

The outcome of interactions between the native and invasive species will vary over geographic space. In conservation biology it is well recognised that threatening processes vary geographically within a native species' range (e.g.,[124, 125]). And, both prior range contractions and fragmentation, and prior reductions in population densities, have strong ongoing influence on viability of residual populations[126] and is a fundamental tenant of conservation genetics. The emergence of novel biotic interactions as occur with establishment of an invasive species, can acerbate existing threatening processes, and indeed instigate new threatening processes.

In light of the uncertainties, the above five factors were simply scored as low, medium or high and illustrated as block charts for easy qualitative comparison among the native species assessed (see Appendices). Two categories were scored within a single factor in cases where the level of uncertainty was especially high, either in fundamental aspects of the native species' ecology, or in the nature and/or extent of probable impacts by the tramp ant. These assessments were made in the light of thorough, but not exhaustive, review of available scientific literature and online resources. The available information was generally narrative and qualitative. The assessments are intended as a comparative guide, allowing initial prioritisation and gap identification. Ultimately, decisions on operational priorities should be made subject to further species-level expert advice.

Native species across the full spectrum of current conservation status – e.g. not threatened, and 'Vulnerable' to 'Critically Endangered' *sensu* EPBC Act Listing Status – may be vulnerable to tramp ants, with potentially severe impacts on populations at sites invaded by the tramp ants. However, the consequences at the species level may be much greater when the native species is subject to other threatening processes.

3.2 Review of project activities and outcomes related to impacts on biodiversity

In the discussion below, for each project, we

1. Identify what the tramp ant impacts are on biodiversity at the project site,
2. Identify the monitoring and evaluation tools used in the projects to measure impacts on biodiversity,
3. Identify the monitoring and evaluation outcomes from the project (both impacts from tramp ants and /or post recovery of species),
4. Discuss other biodiversity impacts that may be occurring from tramp ants at the project sites, and
5. Identify the future risks to biodiversity at the project site if the tramp ants are not contained.

Then, addressing the projects collectively, we

6. Identify other monitoring and evaluation tools to collect biodiversity data on the tramp ant impacts on biodiversity, and
7. Provide practical on-ground advice from the projects and our own knowledge that could improve the project design to enhance biodiversity outcomes.

In addressing these questions, 'project site' was here defined as the place and extent of the tramp ant infestation currently the focus of funded operational activities. 'future risks to biodiversity if the tramp ants are not contained' were assessed for the bioregion (as a whole) (*sensu* Interim Biogeographic Regionalisation for Australia[127] in which the 'project site' is embedded, namely SE Queensland Bioregion, Wet Tropics Bioregion, Arnhem Coast Bioregion, Christmas Island, Lord Howe Island Group, and Norfolk Island Group for red imported fire ant, electric ant, yellow crazy ant-NT, yellow crazy ant-CI, African big-headed ant and Argentine ant, respectively.

Table 3.3 summarizes project investment in assessing biodiversity outcomes, emphasising that during period of CfOC funding.

Table 3.3 Program investment in assessment of biodiversity impacts at the project site, with emphasis on activities during the term of CfOC funding[1]

	RIFA	EA	YCA-NT	YCA-CI	ABHA	AA
Years reviewed	2008-10	2008-11	2008-09	2011-15	2011-13	2010-12
Specified as project milestone or task	No	No	No	No	No	No
Dedicated budget	No	No	No	Yes	No	No
Dedicated personnel	No, general Scientific Services support only	No, general Scientific Services support only	No	No	No	No
Commissioned or other studies during CfOC funding	Several; none during term of CfOC funding	None during term of CfOC funding	None; B. Hoffmann, CSIRO, included in program team to provide advice and undertake research, assessments and monitoring.	Numerous planned or in progress, includes non-target effects of baiting; environmental fate of applied pesticides; investigation of biological control	B. Hoffmann, CSIRO to undertake post-treatment non-target effects and recovery monitoring	Flybusters developed a strategic plan for control operations and identify ants
Prevention of tramp ant spread or effects on biodiversity	Eradication not yet achieved. Program currently researching spread models, genetics, and remote sensing to enhance program's ability to detect and eradicate ants	Eradication not yet achieved, but believed to be technically feasible and highly cost effective	Local eradication achieved for 21 sites; aiming for regional containment, which will aid in the prevention of its spread through all of northern Australia	Published scientific studies relating to effects prior to current CfOC funding. Ongoing monitoring of native species and ecosystem properties through Island-wide-survey and other methods.	Early in project life cycle; eradication not yet achieved, but considered technically feasible. Data analysis and report pending	Early in project life cycle; eradication not yet achieved, but considered technically feasible.

Table 3.3 continued

	RIFA	EA	YCA-NT	YCA-CI	ABHA	AA
Investigation of non-target effects of applied pesticides and other actions	Mention of monitoring of non-target effects of alternate baits formulations, but no other details made available	Studied early in program life, but none during term of CfOC funding	Effects of fipronil baiting on native ants	Effects of fipronil on robber crabs are high; attempts to mitigate risk by luring robber crabs away of unknown success	Early in project life cycle; B. Hoffmann, CSIRO commissioned to evaluate efficacy of treatments. Data analysis and report pending	Not studied
Ecological release of native biodiversity and ecosystem processes	Unpublished abstract on reversal of decline of some native ants, further details pending	Reputed biodiversity impact assessments after several rounds of treatment, but neither data nor report was made available	Assessments of recovery of native ants, following baiting with fipronil	Early in CfOC funded project life cycle	Early in project life cycle	Early in project life cycle
Monitoring of native species of conservation concern and identified as at risk from tramp ant impacts	Numerous native species identified as potentially at risk, including a number known to be resident at the program site. No monitoring of these or other native species undertaken.	Moth butterfly, Apollo jewel butterfly and Southern cassowary identified as potentially at risk. No monitoring of these or other native species undertaken.	Gove Crow Butterfly identified as potentially at risk. No monitoring of this or other native species undertaken.	Numerous native species identified as potentially at risk. Monitoring of trends in several of these species ongoing through Island-wide-survey and other methods.	Several native species identified as at risk, including Lord Howe placostylus within or near the project site. Monitoring of trends in several native species undertaken, but not specifically in relation to the tramp ant.	No assessment of species at risk. Monitoring of trends in several native species undertaken, but not specifically in relation to the tramp ant.

[1] RIFA= red imported fire ant; EA= electric ant, YCA-NT= yellow crazy ant-Arnhem Land, YCA-CI= yellow crazy ant-Christmas Island, ABHA= African big-headed ant, AA= Argentine ant

3.3 Red imported fire ants in Queensland

3.3.1 Tramp ant impacts on biodiversity at the project site

NRIFAEP has relied largely on known economic and ecological consequences of red imported fire ant invasion elsewhere as rationale for developing and continuing the program. Earlier in the program (2001-2003; before CfOC funding), several preliminary assessments were made of species at risk from red imported fire ants within the Brisbane infestation site (Table 3.4). These assessments were cursory and neglected the majority of species known to be resident at the site. Main foci of the assessments were native ant species, other soil and litter invertebrates, frogs, and skinks, including effects of the bait on non-target ants. Two of these assessments[128, 129] allude to earlier assessments of biodiversity impacts, but we have found no evidence of scientific publications or scientific data to indicate that thorough investigations of red imported fire ant impacts within the area of infestation in SE Queensland have been undertaken.

Table 3.4 Summary of documented potential effects of the red imported fire ant on native fauna at the project site in SE Queensland

Taxa studied	Monitoring methods	Impact
Native ants[129, 130]	Infested vs. non-infested site comparison. Pitfall trapping, visual search, observations at baits[129, 130]	Reduced richness and abundance[130] (not statistically analysed)
Litter fauna[128-132]	Pitfall trapping, visual search, observation at baits[129, 130,3]	Reduced abundance[130] (not statistically analysed)
Eastern Grass Skink (*Lampropholis delicata*)[130]	Infested vs. non-infested site comparison. Visual search	Reduced (not statistically analysed)
Burrowing skink (*Ophioscincus ophioscincus*)[130]	Infested vs. non-infested site comparison. Visual search	Reduced (not statistically analysed)
Crow (*Corvus* sp.)[129]	Infested vs. non-infested site comparison. Tuna baits.	Reduced occurrence at baits (result not published and not statistically analysed)
Magpie (*Gymnorhina tibicen*)[129]	Infested vs. non-infested site comparison. Tuna baits.	Reduced occurrence at baits (result not published and not statistically analysed)

The only ‘controlled’ investigation of the impact of the red imported fire ant on biodiversity in southeast Queensland is that of Natrass and Vanderwoude[130], but it is only semi-quantitative and has a flawed design. These authors compared invertebrates at one infested site and one reference site with a combination of sampling methods. They found 12 ant species, 45 other invertebrates and 4 vertebrates at the invaded site, and 23 ant species, 79 other invertebrates, and 2 vertebrates at the reference site and concluded that native ants and other invertebrates were affected by red imported fire ants, but vertebrates were not. However, the non-infested site in this study was dominated by the African big -headed ant, *Pheidole megacephala*, which is well-known to have significant detrimental effects on other invertebrates (see Section 3.7). Unless all of SE Queensland’s areas of high biodiversity value are dominated by African big-headed ant, which is not the case, the comparison between these two sites is not a valid indicator of the effects of red imported fire ant on local biodiversity. Yet, results of the study have been cited as supportive evidence for detrimental effects of red imported fire ant in Queensland[38, 128, 129], and therefore to support the implicit assumption that removing red imported fire ants from the region will benefit biodiversity.

A manuscript is currently being drafted with an analysis of pitfall trap samples collected in earlier years of the program[49]. An abstract of that draft manuscript was made available to this review team[58], but full details are neither available nor yet peer-reviewed. Sampling of 60 sites for an average of three years with pitfall traps demonstrated decline in red imported fire ant abundance to undetectable levels within 12 months with baiting. Associated with the decline in red imported fire ants, abundance in five native ant genera increased over time (*Iridomyrmex*, *Paratrechina*, *Rhytidoponera*, *Ochetellus*, *Notonchus*), four exhibited no change (*Cardiocondyla*, *Polyrhachis*, *Tapinoma*, *Tetramorium*) and one genus (*Pheidole*) significantly declined over time. The decline in *Pheidole* was attributed to the baiting regime directed towards red imported fire ant eradication. It is unclear as to which years this monitoring program covers. The identification of ants to generic level provides only a very coarse measure of red imported fire ant effects on native ant richness. Significant differences may have occurred among ant species within genera, but these effects would be overlooked with identifications at the generic level. Further analyses of the data, focusing on species-level effects, are reportedly in progress[42].

From the analyses of the data from these 60 monitoring sites, NRIFAEP[42] has concluded:

> "...The results suggest that the effects of the baiting program and of fire ant presence on native ant populations may have been less severe than was anticipated."

To enable sound advice, in February 2012 the TACC convened a technical forum to assess research, development and epidemiological analysis being undertaken by NRIFAEP that were to form the basis for ongoing eradication efforts. Among various recommendations, the Forum recognised the need to better understand the interrelationships between red imported fire ant infestation, baiting treatments and native ants[48].

3.3.2 Monitoring and evaluation tools used in the program to measure impacts on biodiversity

The January-March 2010 Quarterly Situation Report[133] and 2009-10 Draft Final Annual CfOC Report[134] mention ongoing pitfall trapping, but details have not been made available to this review team. Other than the manuscript in preparation described above, and for which the dates of monitoring are unclear, we are not aware of any monitoring or evaluation tools being used to measure impacts on biodiversity in the 2008-2010 CfOC funding years.

3.3.3 Monitoring and evaluation outcomes (both impacts from tramp ants and/or post recovery of species)

The contract with CfOC includes a requirement for a MERI Plan by which NRIFAEP is to report on monitoring and evaluation in respect to program and CfOC targets and five-year outcomes. The project MERI Plan[135] (see Table 5 of the Plan) sets out data sources and measures to address key evaluation questions. The MERI Plan makes no mention of monitoring or evaluation of impacts on biodiversity. The MERI Plan focuses on eradication of red imported fire ants as the mechanism for delivery on CfOC targets and outcomes, but specifically identifies monitoring and evaluation activities neither directed at documenting tramp ant impacts nor documenting benefits to biodiversity of fire ant control. There is an implicit, probably valid assumption that eradication of the red imported fire ant, if successful, will deliver benefits to biodiversity, but there is no emphasis on quantifying impacts of red imported fire ant on biodiversity in SE Queensland, or on their recovery once fire ants are removed, to establish that this link is real or significant.

We are not aware of any other monitoring or evaluation efforts that explicitly pertain to biodiversity outcomes relevant to CfOC targets and outcomes.

3.3.4 Other biodiversity impacts that may be occurring from tramp ants at the project site

Beyond a few species and species groups listed in Table 3.4, there has been no previously systematic attempt to identity what native species might be at risk from red imported fire ants at the SE Queensland project site.

Brisbane city and its environs are known to be biologically rich. Most of these species have wider occurrences in the SE Queensland Bioregion, and accordingly potential red imported fire ant impacts are discussed in section 3.3.5 below.

3.3.5 Future risks to biodiversity if the tramp ants are not contained

In this section we focus on potential for the tramp ant to affect the conservation status of native species.

Mechanisms of potential red imported fire ant impacts

The red imported fire ant is one of the most thoroughly studied tramp ant species. There have been several previous reviews of red imported fire ant impacts in invaded ecosystems (e.g., [3, 117, 121, 122]). Accordingly a full review is not presented here.

Red imported fire ants affect other species through several processes. We summarize the salient points, relevant to risk assessment, from these reviews and other recent work:

Predation on animals

Red imported fire ant is well known as an effective predator of a wide range of species, encompassing birds, mammals, reptiles, amphibians, and invertebrates.

- Many reptiles, amphibians and invertebrates produce eggs with thin shells that are vulnerable to penetration by red imported fire ants.
- Birds and some reptiles and invertebrates produce eggs that are impermeable to red imported fire ant predation. However, an entry is gained as the young starts to pip. Mortality is high in these circumstances.
- Vertebrate immature stages in nests and dens are often defenceless due to low mobility and/or lack of high body cover by fur, feathers, scales, or of harden skin, and consequently are highly vulnerable to predation.
- Red imported fire ants are especially attracted to prey with mucous or similarly moist body surfaces.

- Resting stages in the life cycle are vulnerable due to lack of mobility. This includes resting stages below the soil surface.
- The stinging ability of the red imported fire ant is purported to be a key feature of its ability to directly attack vertebrates.

Predation on seeds

- The red imported fire ant is an effective seed predator.

Behavioural displacement

Avoidance of areas with high red imported fire ant densities

- Nesting and den building attempts, roosting, and general foraging by birds, mammals, reptiles and amphibians can be aborted due to aggressive behaviour by the ants and monopoly of sites
- Displacement to less favourable sites can have consequences for fitness, including lower growth rates, lower reproductive output, higher predation and parasitism.

Disruption of native myrmecophilous associations

- Native ants can be displaced, with consequent effects on species of insects and plants tended by those native ants.

Competition for food

The red imported fire ant has high search efficacy and thus high rates of discovery of food items, leading to monopoly of food resources. Consequences for other species include:

- Direct competition with bird, mammal, reptile, amphibian and invertebrate species which overlap in diet and are active in the same habitat space.
- Indirect competition with bird, mammal, reptile, amphibian and invertebrate species that may suffer reduced food availability due red imported fire ants reducing prey or host abundances through direct competition or predation.
- Red imported fire ants simplify invertebrate communities, with potential negative effects on native species that utilize invertebrates as food.

Toxicity

Red imported fire ant venom consists primarily of alkaloids with haemolytic, cytotoxic, and necrotic properties quite unlike that of any other Australian Hymenoptera species.

- Ingestion of red imported fire ants can lead to toxicity and mortality in many vertebrates (birds, mammals, reptiles, amphibians, fishes).

Indirect ecosystem-level effects

- Displacement of ants that provide functional roles not taken over by red imported fire ants, leading to shifts in ecosystem properties and ecosystem functioning.

- Foraging for nectar can lead to displacement of other invertebrate flower visitors, including pollinators, leading to reduced reproductive fitness in some plant species. The red imported fire ant has not been reported to be a regular visitor to flowers and therefore may have minimal impact on these processes.
- Invasive ant interactions with honeydew-producing hemipterans can lead to outbreaks of these sap-sucking insects and in turn influence plant fitness and vegetation composition. Ants may increase hemipteran populations by removing honeydew that contributes to the growth of sooty mould, moving nymphs to better sites, and deterring parasites and predators. Honeydew may play a key role in the success of red imported fire ants in the U.S.[136]
- Ant invasions generally have negative consequences for plants that rely on ants for seed dispersal (myrmecochory). Invasive ants are typically poor seed dispersers due to smaller body size relative to specialist native seed-dispersing ants. Reduced seed dispersal can influence recruitment success and lead to shifts in vegetation composition.
- The red imported fire ant has been termed a 'ecosystem engineer' for the influence that its mound-building has on surrounding habitat – including increased aeration and infiltration, altered soil pH, increased levels of available phosphorus and potassium, lower surface soil bulk density, reductions in organic matter, and greater fungal abundance coupled with lower species richness and diversity. However, the importance of these changes are dependent on red imported fire ant colony densities, and the degree to which soil modification activities of red imported fire ants differ from that of displaced native ants.

Prior risk assessments

Assessment of the potential effects of Red imported fire ant on biodiversity in Queensland date back to 2002-2003, long before CfOC funding was provided. Early in the program, Greenland[129] provided a review of the flora and fauna of the SE Queensland Bioregion at risk from the red imported fire ant, although the coverage of invertebrates was cursory. Although not comprehensive, the work of Moloney and Vanderwoude[128, 131] attempted to indicated risks if the red imported fire ant was not contained and spread to its full potential across the continent.

These assessments and other information were included in the determination and listing of red imported fire ant as a key threatening process on 2 April 2003[137]. The species identified as potentially at risk from red imported fire ants in the above assessments are listed in Appendix 1. Subsequent documents such as TAP background document[132] and the NEBRA Response Plan[38], relied heavily on this material as little new information on red imported fire ant impacts on biodiversity under Australian conditions had become available. A total of 99 species, resident in the SE Queensland Bioregion, have previously been identified as potentially at risk from red imported fire ant.

To our knowledge, these early assessments have not been acted upon. For example, despite 34 EPBC listed animal taxa being identified as potentially at risk from the red imported fire ant, and known to occur within the SE Queensland Bioregion – many within the current infestation area, there have been attempts neither by the program team nor by relevant government and state departments to monitor outcomes for these taxa.

A re-assessment of potential impacts of red imported fire ants

We assessed risks in the SE Queensland Bioregion (note, the bioregion extends into NE NSW), focusing principally on listed species, but additionally included species recognized as high priority in the bioregion, and species that are common, characteristic or otherwise iconic elements of the regions' fauna. These assessments are summarized numerically in Table 3.5, and detailed in narrative in Appendix 1.

Despite being listed previously as at risk from red imported fire ant[128, 129, 131, 132], the following taxa are here excluded from further consideration due to absence from the SE Queensland Bioregion: Apollo Jewel butterfly (*Hypochrysops apollo apollo*); Bathurst copper butterfly (*Paralucia spinifera*); Buff-breasted button-quail (*Turnex olivei*); Coastal sheathtail bat (*Taphozous australis*); Common wombat(*Vombatus ursinus ursinus*); Faint-striped blind snake (*Ramphotyphlops broomi*); Ghost bat (*Macroderma gigas*); Golden-shouldered parrot (*Psephotus chrysopterygius*); Golden-tailed gecko (*Strophurus taenicauda*); Gouldian finch (*Erythrura trichroa*); Malleefowl (*Leipoa ocellata*); Mallee emu-wren (*Stipiturus mallee*); Night parrot (*Pezoporus occidentalis*); Noisy scrub-bird (*Atrichornis clamosus*); Partridge pigeon (western) (*Geophaps smithii blaauwi*); Partridge pigeon (eastern) (*Geophaps smithii smithii*); Plains-wanderer (*Pedionomus torquatus*); Red-tailed tropicbird (*Phaethon rubricauda*); Robust burrowing snake (*Simoselaps warro*); Rough frog (*Cyclorana verrucosa*); Slender-billed thornbill (western) (*Acanthiza iredalei iredalei*); Southern emu-wren (Eyre Peninsula) (*Stipiturus malachurus parimeda*); Southern emu-wren (Fleurieu Peninsula)/Mount Lofty southern emu-wren (*Stipiturus malachurus intermedius*); Thick-billed grasswren (eastern) (*Amytornis textilis modestus*); Thick-billed grasswren (Gawler Ranges) (*Amytornis textilis myall*); Thick-billed grasswren (western) (*Amytornis textilis textiles*); Western ground parrot (*Pezoporus wallicus flaviventris*); Western whipbird (*Psophodes nigrogularis*); Western whipbird (western heath) (*Psophodes nigrogularis nigrogularis*); White rumped swiftlet (*Collocalia spodiopygius*). Additionally, the Lewin's rail (*Lewinia pectoralis clelandi*), Southern platypus frog (*Rheobatrachus silus*), and Southern day frog (*Taudactylus diurnus*) are also excluded as they are presumed extinct.

We assessed a total of 123 species for potential risk from red imported fire ants, comprising 47 birds, 16 mammals, 32 reptiles, 19 amphibians, 4 freshwater fishes, and 5 invertebrates. The assessments provided here are intended as a more-or-less representative sample from the very species-rich animal fauna of the SE Queensland Bioregion, but cannot be considered comprehensive.

The species assessed encompassed the full spectrum of conservation status, with several listed by the Commonwealth under the EPBC Act, others listed at the state level, while further species are currently not considered threatened. In general, listing under the EPBC Act was a poor predictor of how the species was scored for likely impact of the red imported fire ant. Among the 123 native species assessed, all but two reptile species (Hawksbill turtle, *Eretmochelys imbricata*; Leathery turtle, *Dermochelys coriacea*) were considered likely to be affected by red imported fire ants within the SE Queensland Bioregion. These assessments lead us to conclude that the impacts of red imported fire ants are potentially far reaching in respect to breadth of animal species affected, with potential to restructure entire animal communities across the Bioregion if not contained.

Table 3.5 Numeric summary of rapid assessments for risk from the red imported fire ant for a sample of fauna in the SE Queensland Bioregion

Taxonomic Group	Species or subspecies	EPBC Act listing status	Significance[1]	Impact[2]	Geo[3]	Niche[4]	BS[5]	F&F[6]
Bird	Albert's lyrebird (*Menura alberti*)	Not listed	3	2	1	2	2	2
Bird	Azure kingfisher (*Ceyx azurea*)	Not listed	1	1	1	1.5	1.5	0
Bird	Australian brush-turkey (*Alectura lathami*)	Not listed	1	2	2	2	2	2
Bird	Beach stone-curlew (*Esacus neglectus*)	Not listed	1	1.5	1	1.5	2.5	1
Bird	Black bittern (Australasian) (*Ixobrychus flavicolllis australis*)	Not listed	1	1	2	1	1	1
Bird	Black-breasted button-quail (*Turnix melanogaster*)	V	3	2.5	3	3	2.5	2
Bird	Black chinned honeyeater (*Melithreptus gularis gularis*)	Not listed	1	1	1	1	1	1
Bird	Black-throated finch (southern) (*Poephila cincta cincta*)	E	3	1	2.5	2	1	1
Bird	Buff-banded rail (*Gallirallus phillippensis*)	Not listed	1	2	3	2.5	1.5	1.5
Bird	Bush stone-curlew (*Burhinus grallarius*)	Not listed	2	2	2	2	2	2
Bird	Cotton pygmy-goose (*Nettapus coromandelianus*)	Not listed	2	1	1	1	1	1
Bird	Coxen's fig-parrot (*Cyclopsitta diophthalma coxeni*)	E	2.5	1	1	1	1	1
Bird	Eastern bristlebird (*Dasyornis brachypterus*)	E	2	1	1	2	2	2
Bird	Eastern curlew (*Numenius madagascariensis*)	Not listed	1	1	1	1	0	1
Bird	Emerald ground-dove (*Chalcophaps indica chrysochlora*)	Not listed	1	2	3	3	1.5	1
Bird	Freckled duck (*Stictonetta naevosa*)	Not listed	1	1	1	1.5	0	1
Bird	Glossy black-cockatoo (*Calyptorhynchus lathami*)	Not listed	1	1	2	1	1	1
Bird	Grey fantail (*Rhipidura albiscapa alisteri*)	Not listed	1	2	3	2.5	1.5	2
Bird	Grey goshawk (*Accipiter novaehollandiae*)	Not listed	1	1	2.5	2	1	1
Bird	Ground parrot (*Pezoporus wallicus wallicus*)	Not listed	1	2	2	2	2	1
Bird	Freckled duck (*Stictonetta naevosa*)	Not listed	1	1	1	1	1	1
Bird	Little tern (*Sterna albifrons*)	Not listed	1	1.5	1	2	2	1
Bird	Major Mitchell's cockatoo (*Cacatua leadbeateri*)	Not listed	1	1	0	1.5	1	1
Bird	Masked lapwing (*Vanellus miles*)	Not listed	1	2	1.5	2	2	1.5
Bird	Olive whistler (*Pachycephala olivacea*)	Not listed	1	1	1	1	1	1

Table 3.5 continued

Taxonomic Group	Species or subspecies	EPBC Act listing status	Significance[1]	Impact[2]	Geo[3]	Niche[4]	BS[5]	F&F[6]
Bird	Painted honeyeater (*Grantiella picta*)	Not listed	1	1	2	1	1	1
Bird	Painted snipe (*Rostratula benghalensis*)	Not listed	1	1	1	1	1.5	1
Bird	Powerful owl (*Ninox strenua*)	Not listed	1	1	2	1	1	1
Bird	Plumed frogmouth (*Podargus ocellatus plumiferus*)	Not listed	3	1.5	2	1	1	1.5
Bird	Rainbow bee-eater (*Merops ornatus*)	Not listed	1	2	1.5	1.5	1.5	1.5
Bird	Red-browed treecreeper (*Climacteris erythrops*)	Not listed	1	1	2	1	1	1.5
Bird	Red goshawk (*Erythrotriorchis radiatus*)	V	1	1	2	1	1	1
Bird	Regent's honeyeater (*Anthochaera phrygia*)	E	1.5	1	2	1	1	1
Bird	Rufous scrub-bird (*Atrichornis rufescens*)	Not listed	3	2	1.5	1.5	1.5	1.5
Bird	Sacred kingfisher (*Todiramphus sanctus*)	Not listed	1	1.5	1.5	1.5	1.5	1
Bird	Shining bronze-cuckoo (*Chrysococcyx lucidus*)	Not listed	1	1.5	2.5	2	1.5	1.5
Bird	Silver-eye (*Zosterops lateralis*)	Not listed	1	1	2.5	2	1.5	1.5
Bird	Sooty owl (*Tyto tenebricosa*)	Not listed	1	1	1	1	1	1
Bird	Sooty Oystercatcher (northern) (*Haematopus fuliginosus opthalmicus*)	Not listed	1	1	1	1	1.5	1
Bird	Southern emu-wren (*Stipiturus malachurus malachurus*)	Not listed	1	2	1.5	1.5	1.5	1.5
Bird	Square-tailed kite (*Lophoictinia isura*)	Not listed	1	1	1.5	1	1	1
Bird	Squatter pigeon (*Geophaps scripta scripta*)	V	2	2	2	3	1.5	1.5
Bird	Star finch (eastern)(*Neochmia ruficauda ruficauda*)	E	2	2	3	3	2	1.5
Bird	Superb lyrebird (*Menura novaehollandiae*)	Not listed	1	1.5	1	1.5	1.5	1.5
Bird	Swift parrot (*Lathamus discolor*)	E	1	1	1	1	0	1.5
Bird	Turquoise parrot (*Neophema pulchella*)	Not listed	1	2	1.5	1.5	1.5	1
Bird	White-faced heron (*Ardea novaehollandiae*)	Not listed	1	1	1.5	2	1	1
Mammal	Brown antechinus (*Antechinus stuartii*)	Not listed	2	1	1	1	1	1
Mammal	Brush-tailed rock-wallaby (*Petrogale penicillata*)	V	1	1	1.5	1.5	1	1
Mammal	Duck-billed platypus (*Ornithorhynchus anatinus*)	Not listed	1	1	1.5	1	1	0
Mammal	Eastern long-eared bat (*Nyctophilus timoriensis*)	V	1	1	1.5	1	1	1.5
Mammal	False water-rat (*Xeromys myoides*)	V	1	1	1.5	1.5	1	1

Table 3.5 continued

Taxonomic Group	Species or subspecies	EPBC Act listing status	Significance[1]	Impact[2]	Geo[3]	Niche[4]	BS[5]	F&F[6]
Mammal	Golden-tipped bat (*Kerivoula papuensis*)	Not listed	1	1	1.5	1.5	1	1
Mammal	Grey-headed flying-fox (*Pteropus poliocephalus*)	V	1.5	1	2	1	1	1
Mammal	Hasting River mouse (*Pseudomys oralis*)	E	3	1.5	1	1.5	1.5	1
Mammal	Koala (*Phascolarctos cinereus*)	Not listed	2	1.5	2	1.5	1	1.5
Mammal	Large-eared pied bat (*Chalinolobus dwyeri*)	V	2	1	1	1	1	1.5
Mammal	Little pied bat (*Chalinolobus picatus*)	Not listed	1	1.5	2	1.5	1	1.5
Mammal	Long-nosed potoroo (*Potorous tridactylus tridactylus*)	V	1	1.5	2	2	1	1.5
Mammal	Red-legged pademelon (*Thylogale stigmatica*)	Not listed	1	1	2.5	2.5	1	1
Mammal	Semon’s leaf-nosed bat (*Hipposideros semoni*)	E	1	1	1	1	1	1.5
Mammal	Short-beaked echidna (*Tachyglossus aculeatus*)	Not listed	1	2	2.5	2.5	1.5	1.5
Mammal	Spotted-tailed quoll (SE mainland population) (*Dasyurus maculatus maculatus*)	E	2	1.5	1	2	1	1.5
Reptile	Brigalow scaly-foot(*Paradelma orientalis*)	V	1	1.5	1	2.5	1.5	1.5
Reptile	Brisbane short-necked turtle (*Emydura macquarii signata*)	V	3	2.5	2	2	1.5	0
Reptile	Bunya Mountains sunskink(*Lampropholis colossus*)	Not listed	3	1.5	1	2	1.5	1.5
Reptile	Burrowing skink (*Ophioscincus ophioscincus*)	Not listed	2.5	1.5	3	2.5	2	2
Reptile	Collared delma (*Delma torquata*)	V	3	2	2	2.5	1.5	2
Reptile	Common death adder (*Acanthophis antarcticus*)	Not listed	1	2	2	2.5	1	1.5
Reptile	Cooloola blind snake(*Ramphotyphlops silvia*)	Not listed	3	2.5	2.5	2.5	2	2
Reptile	Cooloola snake-skink (*Ophioscincus cooloolensis*)	Not listed	3	2.5	2	2.5	2	2
Reptile	Dunmall’s snake(*Furina dunmalli*)	V	2	2	3	2.5	2	2
Reptile	Dwarf crowned snake (*Cacophis krefftii*)	Not listed	1.5	2	2	2	2	2
Reptile	Eastern grass skink (*Lampropholis delicata*)	Not listed	1	2	3	3	2	2
Reptile	Elf skink (*Eroticoscincus graciloides*)	Not listed	3	2	2	2	1.5	2
Reptile	Green snake (*Dendrelaphis punctulata*)	Not listed	1	1	2	2	1	1
Reptile	Green turtle (*Chelonia mydas*)	V	1	1	0	1	1	0
Reptile	Grey snake (*Heriaspis damelii*)	Not listed	1	1	1.5	1.5	1.5	1
Reptile	Gully skink (*Saproscincus spectabilis*)	Not listed	3	2	1	1.5	1.5	2

Table 3.5 continued

Taxonomic Group	Species or subspecies	EPBC Act listing status	Significance[1]	Impact[2]	Geo[3]	Niche[4]	BS[5]	F&F[6]
Reptile	Flatback turtle (*Natator depressus*)	V	1	1	1	1.5	1	0
Reptile	Hawksbill turtle(*Eretmochelys imbricata*)	V	1	0	0	1	1	0
Reptile	Leathery turtle (*Dermochelys coriacea*)	E	1	0	0	1	1	0
Reptile	Loggerhead turtle (*Caretta caretta*)	E	1.5	1	0	1.5	1	0
Reptile	Major skink (*Bellatorias frerei*) [*Egernia frerei*]	Not listed	2	1.5	2.5	2.5	1.5	1.5
Reptile	Mary River turtle (*Elusor macrurus*)	E	3	2	2.5	2	1.5	0
Reptile	Nangur spiny skink (*Nangura spinosa*)	CE	3	2	2.5	3	1.5	2.5
Reptile	Pale-flecked garden sunskink (*Lampropholis guichenoti*)	Not listed	1	2	3	3	2	2
Reptile	Rainforest cool-skink (*Cautula zia*)	Not listed	2	1	1	1	1	1
Reptile	Ringed thin-tailed gecko (*Phyllurus caudiannulatus*)	Not listed	3	2	1.5	1.5	1	1.5
Reptile	Rose's shadeskink (*Saproscincus rosei*)	Not listed	3	1	1	1.5	1	2
Reptile	Saw-shelled turtle (*Myuchelys latisternum*)	Not listed	1	1.5	1.5	1	1	1.5
Reptile	Short-limbed snake-skink(*Ophioscincus truncatus*)	Not listed	3	2	2	2	1.5	2.5
Reptile	Stephens' banded snake (*Hoplocephalus stephensi*)	Not listed	2	1	1.5	1	1	1
Reptile	Three-toed snake-tooth skink (*Coeranoscincus reticulatus*)	V	3	2	1.5	1.5	1	1.5
Reptile	Yakka skink (*Egernia rugosa*)	V	1	2	1.5	2.5	1.5	1.5
Amphibian	Australian marsupial frog (*Assa darlingtoni*)	Not listed	3	1.5	1	2	2.5	2.5
Amphibian	Black-soled frog (*Lechriodus fletcheri*)	Not listed	3	2	1.5	2	1	2.5
Amphibian	Brown broodfrog (*Pseudophryne major*)	Not listed	2	2	2.5	2	1	2.5
Amphibian	Cascade tree frog (*Litoria pearsoniana*)	V	3	1.5	1	2	1	2
Amphibian	Cooloola sedgefrog (*Litoria cooloolensis*)	Not listed	3	2	3	1.5	0	1.5
Amphibian	Eastern dwarf tree frog (*Litoria fallax*)	Not listed	1	1.5	3	1.5	0	1.5
Amphibian	Green-thighed frog (*Litoria brevipalmata*)	Not listed	3	2	1.5	1.5	1	2
Amphibian	Kroombit tinker frog (*Taudactylus pleione*)	CE	3	1.5	1	1.5	1.5	2
Amphibian	Loveridge's mountain frog (*Philoria loveridgei*)	Not listed	3	1.5	1	1.5	1.5	2
Amphibian	Masked mountain frog (*Philoria kundagungan*)	Not listed	3	1.5	1	1.5	1.5	2
Amphibian	Ornate burrowing frog (*Platyplectrum ornatum*)	Not listed	1	1.5	1.5	1.5	0	1.5
Amphibian	Striped rocket frog (*Litoria nasuta*)	Not listed	1	1.5	1.5	1.5	0	1.5

Table 3.5 continued

Taxonomic Group	Species or subspecies	EPBC Act listing status	Significance[1]	Impact[2]	Geo[3]	Niche[4]	BS[5]	F&F[6]
Amphibian	Fleay's barred-frog (*Mixophyes fleayi*)	E	3	1.5	2	1.5	0	1.5
Amphibian	Giant barred-frog (*Mixophyes iterates*)	E	2	2	2	2	1.5	2
Amphibian	Great barred-frog (*Mixophyes fasciolatus*)	Not listed	2	1.5	1	1.5	1.5	2
Amphibian	Superb collared frog (*Cyclorana brevipes*)	Not listed	1	1.5	1	1.5	0	1.5
Amphibian	Tusked Frog (*Adelotus brevis*)	Not listed	2	1.5	1	1.5	1	2
Amphibian	Wallum froglet (*Crinia tinnula*)	Not listed	3	2	3	2.5	1	2
Amphibian	Wallum rocket frog (*Litoria freycineti*)	Not listed	2	1	3	1.5	1	2
FW fish	Australian bass (*Macquaria novemaculeata*)	Not listed	1	1	2	0	1	1
FW fish	Honey blue-eye (*Pseudomugil mellis*)	V	3	1	2.5	0	1	1
FW fish	Oxleyan pygmy perch (*Nannoperca oxleyana*)	E	3	1	2.5	0	1	1
FW fish	Rainbow fish (*Rhadinocentrus ornatus*)	Not listed	3	1	2.5	0	1	1
Invertebrate	Australian fritillary (*Argyreus hyperbius inconstans*)	Not listed	2	2.5	3	2.5	2.5	0
Invertebrate	Illidge's ant-blue (*Acrodipsas illidgei*)	Not listed	3	2.5	2.5	2	2.5	2.5
Invertebrate	Pale imperial hairstreak (*Jalmenus eubulus*)	Not listed	2	1.5	1	2	2.5	1
Invertebrate	Richmond birdwing (*Ornithoptera richmondia*)	Not listed	2	1.5	1	1.5	2	1
Invertebrate	Satin opal (*Nesolycaena albosericea*)	Not listed	3	2.5	3	2.5	2.5	1

[1]Significance = Importance of populations within the Bioregion to the species' security, taking into account the species' conservation status and range size. Low, medium and high translated to numeric 1-3 scale.

[2]Impact = Assessment of likely importance of the tramp ant to persistence of the species within the Bioregion, taking into account Geo, Niche and effects of the tramp ant of breeding success, foraging and food resources. Nil, low, medium and high translated to numeric 0-3 scale. High impact implies the conservation status of the species may change, requiring re-assessment of their respective listed status.

[3]Geo = Extent of likely geographic overlap of the animal species and tramp ant within the Bioregion. Nil, low, medium and high translated to numeric 0-3 scale. Note that species without occurrence in the Bioregion were excluded from the assessments.

[4]Niche = Extent of likely niche overlap of the animal species and tramp ant. Nil, low, medium and high translated to numeric 0-3 scale.

[5]BS = Extent to which breeding success is likely reduced directly or indirectly by the tramp ant. Nil, low, medium and high translated to numeric 0-3 scale.

[6]F&F = Extent to which *foraging* is disrupted, extent to which *food resources* are likely to be reduced directly or indirectly by the tramp ant. Nil, low, medium and high translated to numeric 0-3 scale.

Among birds, ground dwelling species that feed predominately on invertebrates were identified as at greatest risk, with direct exposure to predation by red imported fire ants (especially young in the nest), and foraging disrupted through likely reductions in invertebrate prey resources and displacement through avoidance behaviour. Among the birds assessed, the following were identified of most concern: Albert's lyrebird (*Menura alberti*), Black-breasted button-quail (*Turnix melanogaster*), Black-breasted button-quail (*Turnix melanogaster*), Australian brush-turkey (*Alectura lathami*), Bush stone-curlew (*Burhinus grallarius*) and Masked lapwing (*Vanellus miles*). These species had previously been identified as potentially at risk[128, 129, 132].

A number of additional bird species scored highly for likely adverse effects of red imported fire ants on either breeding or foraging, including Beach stone-curlew (*Esacus neglectus*), Eastern bristlebird (*Dasyornis brachypterus*), Grey fantail (*Rhipidura albiscapa alisteri*), Ground parrot (*Pezoporus wallicus wallicus*), Little tern (*Sterna albifrons*), and Star finch (eastern) (*Neochmia ruficauda ruficauda*).

All but two of the 16 mammal species assessed have previously been considered potentially at risk from the ant. The Short-beaked echidna (*Tachyglossus aculeatus*) was identified as a mammal most likely affected by the tramp ant within the SE Queensland Bioregion. Short-beaked echidna young are likely highly vulnerable to red imported fire ants in nursery burrows, as are adults during hibernation and foraging on the ground. Abundance of their prey – comprising ants, termites and other invertebrates – is likely to be reduced. Given the importance of ants in its diet[138], the species may nonetheless benefit from increased ant abundance, if fire ants are palatable and nutritious and do not induce avoidance behaviour. Short-beaked echidna scored low for significance as the species is widely distributed in Australia (and New Guinea) and thus the Bioregion is not critical to its persistence.

The SE Queensland Bioregion mammals of highest ranking under the EPBC Act, namely Hasting River mouse (*Pseudomys oralis*), Semon's leaf-nosed bat (*Hipposideros semoni*) and Spotted-tailed quoll (SE mainland population) (*Dasyurus maculatus maculatus*) (all listed as 'Endangered'), scored low for red imported fire ant impact due to weak geographic and/or niche overlap and aspects of their ecology.

Reptiles and amphibians were identified as two animal groups highly at risk from red imported fire ants. Impact of the ant is potentially high given many reptiles and amphibians are vulnerable to predation (especially as pipping eggs and young), their invertebrate and small vertebrate prey is likely reduced by fire ant, and they often have strong geographic and niche overlap with the fire ant. Amphibians are also especially vulnerable because their moist body surfaces are highly attractive to the ant, and some species spawn in terrestrial sites readily accessible by foraging fire ants – e.g., Australian marsupial frog[139] (*Assa darlingtoni*); Giant barred-frog (*Mixophyes iteratus*)[140, 141]; Loveridge's mountain frog (*Philoria loveridgei*)[142]. The risk was identified as especially acute for Nangur spiny skink (*Nangura spinosa*) which is listed as 'Critically Endangered' under the EPBC Act. Kroombit tinker frog (*Taudactylus pleione*), also listed as 'Critically Endangered', is at lesser risk due to lower potential geographic and niche overlap with the red imported fire ant.

The absence of nesting within the SE Queensland Bioregion means Hawksbill turtle and Leathery turtle are not at risk. Potentially the pipping and hatchling stages are highly vulnerable to the ant.

Four freshwater fishes – Australian bass (*Macquaria novemaculeata*), Honey blue-eye (*Pseudomugil mellis*), Oxleyan pygmy perch (*Nannoperca oxleyana*) and Rainbow fish (*Rhadinocentrus ornatus*) – have previously been identified as at risk from red imported fire ants. Their vulnerability was related primarily related to toxicity that can occur when feeding on red imported fire ants rafting on the water surface, and reductions in the abundance of potential insect prey by fire ant activity in the surrounding the wetland habitat. The importance of these mechanisms of impact in the Australian context is not well understood, and our assessments suggest the risks to these fishes are minimal.

Thus, among vertebrates, red imported fire ants are likely to affect most species in the SE Queensland Bioregion, with effects sufficiently severe to cause population declines in ~45% of birds, ~38% of mammals, ~69% of reptiles and ~95% of amphibians.

Our analyses confirm previous risk assessments for four insect species – Australian fritillary (*Argyreus hyperbius inconstans*), Illidge's ant-blue (*Acrodipsas illidgei*), Pale imperial hairstreak (*Jalmenus eubulus*), and Richmond birdwing (*Ornithoptera richmondia*). Each of these butterflies are specialists that have potential for medium to high geographic and niche overlap with the ant, have life stages highly vulnerable to predation by the ant, and in the case of Illidge's ant-blue and Pale imperial hairstreak have obligate associations with native ants that are likely displaced by fire ants.

An additional specialist butterfly, the Satin opal (*Nesolycaena albosericea*), can be added to this list of at-risk species. This butterfly is associated with *Boronia* in eucalypt woodlands and banksia heathlands, thus has high potential geographic overlap with red imported fire ants, which is likely to predate immature stages and thus exacerbate decline due to loss of habitat.

The other 95% - Taxa neglected in existing assessments

Earlier assessments, and those made here, neglect the majority of invertebrate species potentially at risk from red imported fire ants.

Taxa that are vulnerable to habitat disturbance by nature of their geographic range size and/or ecology, such as short range endemics (SRE) and other narrow range taxa, also have been largely omitted. Often the lack of knowledge about SRE taxa precludes their consideration for listing as threatened or endangered. Many of the species listed as Data Deficient are also short-range endemics.

Harvey[143] suggested a nominal range of less than 10,000 km^2 as a working definition of short-range endemism. Several life history features characteristic of SREs, including poor powers of dispersal, ecological confinement to discontinuous or rare habitats, slow growth and low fecundity, make them vulnerable to changes in their habitats.

It is beyond the resources of the present review to identify all native species that are potentially at risk from the red imported fire ant.

The displacement of native ants is the most commonly documented effect of ant invasions[3, 117]. Invasive ants frequently break the discovery-dominance trade-off that is thought to be important in regulating native ant communities[144-146], in that they both discover food resources more quickly and recruit to food in higher numbers than their native competitors (e.g.,[6, 147]). The limited results to date for red imported fire ants in Australia are consistent with this phenomenon[130]. Nonetheless, Lach and Hooper-Bùi[117] reviewed recent studies that challenge the view that red imported fire ants, at least the monogyne form, has long-term detrimental effects on native ant assemblages. King and Tschinkel[148] and Morrison and Porter[149] report a positive correlation between monogyne red imported fire ants and the abundance of other ants, and Morrison and Porter[149] also found a positive correlation between monogyne red imported fire ant density and ant species richness. These findings suggest that the same abiotic and biotic factors control monogyne red imported fire ant and native ant populations[149], although further studies are needed to partition out site factors such as disturbance history from the direct competitive effects of red imported fire ants[117].

The preliminary results of the pitfall trap sampling done by NRIFAEP[58] suggests that at least some native ants are able to coexist with red imported fire ant for a number of years and are able to increase their numbers when red imported fire ant densities are reduced by control efforts. Work internationally indicates that native ants can coexist with invasive ants when they utilize different resources[150, 151], use the same resources at different times[150, 152], or have potent chemical defences[3]. The opportunities for native ants to persist and coexist are higher when the invader is not numerically dominant[153] such as occurs at the margin of its abiotic tolerance[154].

While it is widely acknowledged that tramp ants displace/reduce abundance of native ants, we have not considered risks posed on ants endemic to the areas infested by tramp ants simply because there is presently little information on range limits of native ant species and their vulnerability to extinction. While displacement/reduction in numbers does not necessarily mean local extinction, it is evident that risks to native ant species should be considered alongside risks to other fauna. Native ants are the group in the native fauna most directly and intimately affected by red imported fire ants.

That the current assessment of risks posed by red imported fire ant is not comprehensive is readily illustrated by consideration of just one invertebrate group – land snails. Short-range endemic (range <~10,000km^2), ground-dwelling species would constitute that component of the land snail fauna potentially at most risk from red imported fire ants. A perusal of Stanisic et al.[155], the most recent and most comprehensive catalogue of eastern Australian land snails available, indicates at least 80 species that should be provisionally considered as at risk from red imported fire ants (see Appendix 2). If other classes of range restricted taxa were to be included (e.g., those in which the SE Queensland Bioregion is vital to persistence), and/or if taxa living arboreally in the lower vegetation tiers also considered vulnerable, then numerous additional land snails should be considered at risk from red imported fire ants in the SE Queensland Bioregion.

There is a need to systematically assess risks in other groups of invertebrates. This will require expert knowledge of these groups and properly designed experiments or drawing on knowledge of effects observed elsewhere the red imported fire ant has invaded.

3.4 Electric ants in Queensland

3.4.1 Tramp ant impacts on biodiversity at the project site

Royer[156] conducted a baseline impact assessment to document the effects of electric ants on ground-dwelling and arboreal native ants, invertebrates, and vertebrates in the Cairns area (summarized in Table 3.6). She found much lower native ant richness and abundance in sclerophyll, rainforest, and residential sites, where electric ants account for nearly 100% of the ground ant fauna in infested areas. Three genera common in non-infested sites were completely absent from infested sites, and another two genera were highly reduced compared to their abundance in non-infested sites. Native arboreal ants were under-represented in infested sites, with 56% (sclerophyll), 62% (rainforest), and 99% (residential) decline in native species representation compared to non-infested sites in the same habitat type.

The reported analyses of other invertebrates collected in pitfall traps did not highlight any detrimental effects of electric ants. Invertebrate abundance in infested sites was higher than in non-infested sites due to the higher numbers of Collembola (springtails) captured. As their common name suggests, springtails are able to use their tails to spring away from would-be predators. They may be thriving in an environment saturated with electric ants because their competitors may have largely been displaced. However, an analysis without collembolans showed no significant difference in invertebrate abundance between infested and non-infested sites. Ordinal richness of invertebrates did not vary significantly either.

Although this is the most comprehensive, indeed, only, baseline environmental impact report we have come across for the six programs, we cannot place too much confidence in the reported lack of effects on the invertebrate community. Pitfall traps are a standard method for collecting samples of ground-dwelling invertebrates. Most studies that want to capture more than ants utilize a trap diameter of at least 25mm, and up to 70mm if a broad range of invertebrates is being sought. This study used a trap diameter of 15mm (see in next section). It is also unclear whether the lids were kept on the traps for the entire three day sampling period with the assumption that the fauna would fall into the trap by walking through the 5mm and 2mm holes mentioned in the report. If so, this is a very unorthodox way of using pitfall traps, and would effectively greatly reduce the number of specimens captured. Indeed, the number of invertebrates captured seems to be on quite low. We recognize that identification of invertebrates is extremely laborious and requires specialist knowledge to get beyond order-level classification. However, identification to order only allows a very coarse measure of richness, and there may be significant differences missed at the species, genera, or even family levels. A look at the raw data in the Appendix reveals a higher number of Acari (mites) in infested sites, which we found to be statistically significantly different (76 vs. 39, $p=0.040$, M-W U test) and a trend toward a higher number of Coleoptera larvae in infested sites (18 vs. 0, $p=0.09$, M-W U test). These results were not mentioned in the report. Higher numbers of some taxa in infested sites is not an indication that electric ants are benefitting biodiversity, rather that there are likely significant changes in the composition and functioning of the community taking place as a result of the myriad types of interactions indirectly or directly affected by the ant.

Counts of vertebrates in the baseline survey showed no significant trends between the electric ant-infested sites (sclerophyll: 5 birds, 0 reptiles; rainforest: 19 birds, 7 reptiles; residential: 4 birds, 3 reptiles) and non-infested sites (sclerophyll: 7 birds, 2 reptiles; rainforest: 15 birds, 8 reptiles; residential: 0 birds, 3 reptiles). Although surveys identified a variety of birds, reptiles and amphibians across the sites, with a total count of only 73 animals sighted at 30 sites during the noontime surveys, caution must be used when interpreting the results. Also, with the lack of resolution at the species level, some effects may not have been apparent. Vertebrate species interact with the environment at much larger ranges than most invertebrates. Sampling was conducted along a single 24m transect at each site, but no details were provided in the report about the extent of electric ant infestation at sites. If the infested area was small relative to the area utilized by the vertebrate of interest, then effects of the ant may be small or non-existent.

Table 3.6 Summary of documented effects of the electric ant at the project site near Cairns, Queensland[156]

Taxa studied	Monitoring methods	Impact
Invertebrates		
Native ants	Replicated comparison of infested and non-infested sites across 4 habitat types	Average 88% lower abundance in native ants at infested sites (result supported by statistical analyses)
Ground invertebrates	Replicated comparison of infested and non-infested sites across 4 habitat types	Higher abundance of Collembola[2] and Acari at infested sites; likely significant change in community composition and function
Birds		
Total counts (species unspecified**)**	Replicated comparison of infested and non-infested sites across 4 habitat types.	No difference in abundance between infested and non-infested areas (result supported by statistical analyses), but overall counts low
Reptiles		
Total counts (species unspecified)	Replicated comparison of infested and non-infested sites across 4 habitat types.	No difference in abundance between infested and non-infested areas (result supported by statistical analyses), but overall counts low
Amphibians		
Total counts (species unspecified)	Replicated comparison of infested and non-infested sites across 4 habitat types.	No difference in abundance between infested and non-infested areas (result supported by statistical analyses), but overall counts low

3.4.2 Monitoring and evaluation tools used in the program to measure impacts on biodiversity

The environmental impact assessment conducted by Royer (discussed above), sampled native ants, other invertebrates, and vertebrates. Five replicate infested and non-infested sites were compared for each of four habitat types: residential, rainforest, sclerophyll, and “disturbed” (cleared lots awaiting construction). Infested sites all had electric ants and had not yet been treated. The location of these sites was limited to a degree by availability of habitat types in each zone, and Royer gives no indication that a quantitative approach (e.g., environmental stratification, or random assignment) was used to allocate sites to replicates. The data analyses evidently did not account for possible block effects. All infested and non-infested sites were within close proximity of each other, except for two rainforest sites whose location was determined by availability of rainforest habitat in the treatment buffer zone.

The baseline sample collection was conducted in August - the middle of the dry season, several months after first discovery and probably within 3-4 years of electric ant establishment.

At each site Royer set a 24m transect with multiple sampling points per transect. Sampling methods used at each site were: ground luring, tree luring; pitfall trapping and vertebrate counts. These sampling methods are described as:

- Ground luring (for ground dwelling ants). Eight hotdog skewers were placed 3 metres apart along the transect for 40 minutes. Ants and invertebrates found on the hotdog after this time period were collected into 70% ethanol.
- Tree luring (for arboreal ants). Single hotdog pieces were pinned on five tree trunks at a height of approximately 1.5m for 40 minutes. All ants and invertebrates on the hotdog after this time period were collected into 70% ethanol.
- Pitfall trapping (for ground dwelling invertebrates, including ants). Eight unbaited pitfall traps (plastic tubes with 15mm internal diameter with two rows of 5mm holes near the lid and one row of 2mm holes halfway down) partly filled with propylene glycol were placed 3 metres apart along the transect. Traps were left out for 3 days.
- Vertebrate counts. 3 points 8 metres apart along the transect were visually surveyed for 10 minutes each. All vertebrates seen in a 10m 180˚radius were recorded.

The report stated that environmental monitoring would continue throughout the life of the eradication effort, but we have not seen evidence that a monitoring program was put into place.

3.4.3 Monitoring and evaluation outcomes (both impacts from tramp ants and/or post recovery of species)

There has been no additional effort to evaluate effects of the electric ant or its management on biodiversity. NEAEP has documented reductions in electric ant populations following treatment (see Section 2.2), but these have not been accompanied by any quantitative assessment of ecological recovery.

Ecological impact assessments with clear strategies and performance measures were originally envisioned for the program. The Queensland Electric Ant Program Plan[62] had two objectives relating to the measuring and reporting of the ecological effects of the treatment program, a strategy statement that included conducting pre- and post-treatment monitoring, and a monitoring performance measure. However, these goals were not part of the contract with CfOC[67] and as a consequence have not been a priority for NEAEP staff[49,63,64].

We have not found evidence of any evaluation of non-target effects of the insecticide or of ecosystem recovery following treatment conducted by NEAEP.

The contract with CfOC includes a requirement for a MERI Plan by which NEAEP is to report on monitoring and evaluation in respect to program and CfOC targets and five-year outcomes. In relation to biodiversity, the project MERI Plan[158] states "The goal of the National Electric Ant Eradication Program (NEAEP) is to eradicate electric ants from Australia" as a contribution to CfOC outcome target "Reduce the impacts of invasive species". The MERI Plan sets out data sources and measures to address key evaluation questions. The MERI Plan makes no mention of monitoring or evaluation of project impacts on biodiversity. The MERI Plan focuses on eradication of electric ants as the mechanism for delivery on CfOC targets and outcomes, but specifically identifies monitoring and evaluation activities directed neither at documenting electric ant impacts nor documenting benefits to biodiversity of electric ant control. There is an implicit, likely valid, assumption that eradication of electric ants, if successful, will deliver benefits to biodiversity, but no emphasis on quantifying impacts of electric ants on biodiversity in Queensland, or the recovery of any affected taxa following removal of the ant, to establish this link.

3.4.4 Other biodiversity impacts that may be occurring from tramp ants at the project site

The NEAEP is a strategic investment, with eradication of electric ant at the project site critical to protecting natural heritage values of international significance in the adjoining Wet Tropics World Heritage Area (WTWHA).

Nonetheless, there has been very limited assessment of the potential impact of electric ant in the Queensland Wet Tropics Bioregion. In addition to native ants, the only elements of biodiversity that to-date have been identified specifically as at risk are Apollo jewel butterfly (*Hypochrysops apollo apollo*)[62, 156], Moth butterfly (*Liphyra brassolis*)[156] and Southern cassowary (*Casuarius casuarius*)[10,37]. These species have wide occurrences in the Queensland Wet Tropics Bioregion, and accordingly potential electric ant impacts are discussed in section 3.4.5 below.

3.4.5 Future risks to biodiversity if the tramp ants are not contained

In this section we focus on potential for the tramp ant to affect the conservation status of native species.

Mechanisms of potential electric ant impacts

There have been several previous reviews of electric ant impacts in invaded ecosystems internationally (e.g.,[117, 119, 120, 159]). Accordingly a full review is not presented here.

Electric ant is a generalist feeder, occurring in a wide range of habitat types – disturbed urban settlements and agricultural fields through to undisturbed closed forest. It feeds 24 hours a day in most weather conditions. Nests are found on the ground and in trees, and colonies are highly mobile and will relocate if disturbed. Foraging occurs on the ground and into the canopy of shrublands and forests.

Electric ants affect other species through several processes. We draw on recent reviews and other scientific publications in summarizing the salient points relevant to risk assessment:

Predation on animals

- Well known as an effective predator of a wide range of invertebrate species, tending to population declines.

- Electric ants attain numerical dominance of ant communities in disturbed habitat in its native range and in disturbed to undisturbed habitats in its invaded range. Workers are highly aggressive to other ant species and in some locations where they have invaded, they are able to exclude other ant species completely and dominate an area. In their native range they do not defend territories, but recruit to and defend food resources close to their nest.
- Birds and reptiles and some invertebrates produce eggs that are impermeable to electric ant predation. However, an entry is gained as the young starts to pip. Mortality is potentially high in these circumstances but the evidence for effects at the population level is weak.
- Vertebrate immature stages in nests and dens are often defenceless due to low mobility and/or lack of high body cover by fur, feathers, scales, or of harden skin, and consequently are potentially vulnerable to electric ant predation.
- Do not sting en masse like red imported fire ants. Consequently, there are few reports of direct predation on larger mobile animals. Nonetheless, electric ants can stress vertebrates. There are increasing records of corneal cloudiness and blindness in vertebrates due to stinging in the eyes. This can lead to mortality.
- Effects on amphibians poorly studied.

Predation on seeds

- Seeds are often a minor component of the diet.

Dependence on carbohydrate sources

- Electric ants will actively source carbohydrate-rich nutrient sources such as plant nectar or honeydew. Electric ants form close associations with phytophagous bugs in order to acquire honeydew produced by these insects, and with plants with extrafloral nectaries.

Behavioural displacement

- Animals exhibit avoidance of areas with high electric ant densities.
- Nesting and den building attempts, roosting, and general foraging by birds, mammals, reptiles and amphibians can be aborted due to aggressive behaviour by the ants and monopoly of sites.
- Displacement to less favourable sites can have consequences for fitness, including lower growth rates, lower reproductive output, higher predation and parasitism.

Disruption of native myrmecophilous associations

- Native ants can be displaced, with consequent effects on species of insects and plants tended by those native ants.

Competition for food

The electric ant has high search efficacy and thus high rates of discovery of food items, leading to monopoly of food resources. Consequences for other species include:

- Direct competition with bird, mammal, reptile, amphibian and invertebrate species that overlap in diet and are active in the same habitat space.

- Apparent competition with bird, mammal, reptile, amphibian and invertebrate species that may suffer reduced food availability due the electric ant reducing invertebrate and small vertebrate prey or host abundances through direct competition or predation.
- Electric ants simplify invertebrate communities, with potential negative effects on native species that utilize invertebrates as food.

Indirect ecosystem-level effects

- Displacement of ants that provide functional roles not taken over by electric ants, leading to shifts in ecosystem properties and ecosystem functioning.
- Foraging for nectar can lead to displacement of other invertebrate flower visitors, including pollinators, leading to reduced reproductive fitness in some plant species, and in turn leading to shifts in vegetation composition. Impact most important in pollen-limited, arthropod-pollinated plants.
- A large proportion of diet is from nectar by tending extrafloral nectaries, and honeydew by tending including aphids, mealybugs, scales, psyllids, and whiteflies. Interactions with hemipterans can lead to outbreaks of these sap-sucking insects and in turn influencing plant fitness and vegetation composition. Electric ants may increase hemipteran populations by removing honeydew that contributes to the growth of sooty mould, moving nymphs to better sites, and deterring parasites and predators.
- Electric ant typically a poor seed disperser due to smaller body size relative to specialist native seed-dispersing ants. Reduced seed dispersal can influence recruitment success and lead to shifts in vegetation composition.

Prior risk assessments

As discussed above, Royer[156] made an assessment of risks to native ants, and myrmecophilous associations, based on observations at electric ant-infested and non-infested sites in Cairns. Of native ant genera abundant at non-infested sites, *Oecophylla, Iridomyrmex, Tetramorium* were found to be absent from the ground at infested sites. Other genera were highly reduced numbers – *Pheidole* and *Pheidologeton* on the ground; *Oecophylla* in trees.

Significant differences may have occurred among ant species within genera at the project site, but these effects would be overlooked with identifications at the generic level. The genera *Pheidole*, *Iridomyrmex* and *Tetramorium* are specious in Australia[160] and Royer's samples likely involved multiple species in each case. African big-headed ant (*Pheidole megacephala*) is present in the Wet Tropics, but it is unclear if the *Pheidole* in Royer's samples included this tramp species. *Pheidologeton* is confined in Australia to northeast Queensland, inclusive of the Wet Tropics, where it is represented by a single species, *Pheidologeton affinis*[160]. This species occurs also widely in Asia[161]. The longer term fate of the native ant species in the presence of electric ant is not known.

As noted by Royer[156], the weaver ant *Oecophylla smaragdina* is the only representative of this genus in Australia. This arboreal-nesting species is found widely and commonly in India and SE Asia through to Australia and thus of little conservation concern at the global scale. In northern Australia the species maintains a dominant role within native ant communities[162-164] by aggressive colony defense and monopolization of resources. Therefore its absence would likely have cascading effects on many ecosystem processes.

Among other faunal elements, as noted in Section 3.4.4, the Apollo jewel butterfly (*Hypochrysops apollo apollo*)[156], Moth butterfly (*Liphyra brassolis*)[156] and Southern cassowary (*Casuarius casuarius*)[37] have previously been identified as species of the Wet Tropics that are potentially at risk from electric ants. Larvae of the Apollo jewel butterfly live within *Myrmecodia* epiphytes (Rubiaceae) on various coastal trees, particularly *Melaleuca viridifolia*, where they are associated with the native ant *Iridomyrmex cordatus*. The nature of the myrmecophilous relationship is presently not well understood but in other lycaenid-ant relationships, the ant protects the larvae from predation. Following an earlier assessment by Moloney and Vanderwoude[128], Royer[156] concluded that displacement of *Iridomyrmex* by electric ants is likely to lead to reduced recruitment of these butterflies and thus place further stress on populations of this rare butterfly.

The Moth butterfly feeds on the brood of *O. smaragdina* in the nest[165]. Royer concludes[156] that, as *O. smaragdina* was totally absent from samples taken from the ground and highly reduced in samples taken arboreally when electric ants were present, an associated decline in the butterfly has also likely occurred.

The Southern cassowary is an endangered species restricted to Cape York Peninsula and the Wet Tropics. It's high reliance on fruit from rainforest trees and its ground nesting habits could make it susceptible to electric ants[10, 37].

To our knowledge, no monitoring of Moth butterfly, Apollo jewel butterfly, or Southern cassowary has been undertaken to confirm these assessments.

There have been no recent assessments of the biodiversity values at risk from electric ants in the Wet Tropics Bioregion. The Tramp Ant Consultative Committee coordinated a review of the NEAEP in November 2010. The technical review[64] concluded that eradication remained technically feasible and continued investment is worthwhile given:

> "…potential for electric ants to cause very significant, <u>but unquantified</u>, environmental and social impacts should electric ants be allowed to spread without control" [our emphasis]

A re-assessment of potential impacts of electric ants

The enormous biological diversity of the Wet Tropics Bioregion is a significant barrier to obtaining an unbiased assessment of risk posed by electric ants to flora and fauna. A great many species are so poorly known – including many undescribed – so as to forego their inclusion in risk assessment. In the present review we assessed risks in the Wet Tropics Bioregion, focusing principally on EPBC listed species, but additionally included species recognized as high priority in the bioregion (i.e. listed in Schedules 1-4 of the Nature Conservation (Wildlife) Regulation) and species that are common, characteristic or otherwise iconic elements of the regions' fauna and flora (e.g., [166]).

The assessments provided here are intended as a more-or-less representative sample from the very species-rich animal fauna of the Wet Tropics, but cannot be considered comprehensive. These rapid assessments are summarized numerically in Table 3.7, and detailed in narrative in Appendix 3. It should be emphasised that these assessments were undertaken within the constraints of poor knowledge of the impacts of electric ants on vertebrates. There have to date been few studies that have examined population-level effects of electric ants on birds, mammals, reptiles and amphibians. Nonetheless, there is sufficient information to imply impacts will not be insignificant. The assessments provide a provisional ranking of native species for impact from electric ants, and thus a useful starting point for prioritization among native species for more comprehensive impact assessments and monitoring within the Wet Tropics Bioregion, but should be used to compare impacts among different tramp ant species with great caution.

We assessed a total of 198 species or subspecies for potential risk from electric ants, comprising 80 birds (8 EPBC listed); 44 mammals (10); 36 reptiles (7); 33 amphibians (8); and 5 invertebrates (0). The taxa assessed encompassed the full spectrum of conservation status, with several listed by the Commonwealth under the EPBC Act as indicated, others listed at the state level, while further taxa are currently not considered threatened, or at least are not yet subject to a formal listing process.

Among the 198 native taxa assessed, all but Great crested grebe (*Podiceps cristatus australis*) were identified as having life strategies and morphological traits that indicate some level of vulnerability to electric ants directly or via modification of ecological conditions. Herald petrel (*Pterodroma heraldica*) (EPBC listed as ‘Critically Endangered’), Red-tailed tropicbird (*Phaethon rubricauda*), Green turtle (*Chelonia mydas*) (‘Vulnerable’), Leathery turtle (*Dermochelys coriacea*) (‘Endangered’), Loggerhead turtle (*Caretta caretta*) (‘Endangered’) occur within the Bioregion but are considered not likely affected due to absence of breeding and/or terrestrial feeding in areas likely invaded by electric ants should they not be contained. Many Wet Tropic species/subspecies were identified with traits and lifestyles that would make them potentially vulnerable to electric ants, but will not overlap geographically with the tramp ant by way of being restricted to cool montane rainforests unfavourable to the tropical ant, namely Atherton scrubwren (*Sericornis keri*), Golden bowerbird (*Prionodura newtoniana*), Masked white-tailed rat (*Uromys hadrourus*), White-footed dunnart (northern population) (*Sminthopsis leucopus*), Yellow-bellied glider (Wet Tropics) (*Petaurus australis*) (‘Vulnerable’), Bartle Frere barsided skink (*Eulamprus frerei*), Bartle Frere cool-skink (*Bartleia jigurru*), Thornton Peak calyptotis (*Calyptotis thorntonensis*), Bellenden Ker nurseryfrog (*Cophixalus neglectus*), Buzzing nurseryfrog (*Cophixalus bombiens*), Carbine barred frog (*Mixophyes carbinensis*), Dainty nurseryfrog (*Cophixalus exiguus*), Little waterfall frog (*Litoria lorica*) (‘Critically Endangered), Magnificent brood frog (*Pseudophryne covacevichae*) (‘Vulnerable’), Mountain mistfrog (*Litoria nyakalensis*) (‘Critically Endangered), Mountain nurseryfrog (*Cophixalus monticola*), Rattling nurseryfrog (*Cophixalus hosmeri*), Tapping nurseryfrog (*Cophixalus concinnus*), and Tinkling frog (*Taudactylus rheophilus*) (‘Endangered’).

Our assessments thus indicate 172 or 87% of the 198 species/subspecies assessed are likely to suffer some level of impact from electric ant should it not be contained and spread through the Wet Tropics Bioregion. Forty three or 22% of the assessed taxa are considered at particular risk. While it is acknowledged that these rapid assessments are sensitive to the poor quality of the information available on electric ant impacts, these assessments lead us to conclude that the impacts of electric ants are potentially far reaching in respect to breadth of animal species and subspecies affected, with potential to modify animal communities across the Bioregion if not contained. High impact implies the conservation status of the taxa may change over time in the presence of the electric ant, requiring re-assessment of their respective Commonwealth and State listing status.

Birds

Among the Wet Tropics land birds assessed, 14 taxa were identified as mostly likely affected by the electric ant should it not be contained, namely Black-chinned honeyeater(*Melithreptus gularis*), Buff-breasted button-quail (*Turnix olivii*) (‘Endangered’), Bush stone-curlew (*Burhinus grallarius*), Eastern whipbird (*Psophodes olivaceus lateralis*), Grey-crowned babbler (eastern) (*Pomatostomus temporalis temporalis*) Grey fantails (*Rhipidura albiscapa alisteri* and *Rhipidura fuliginosa frerei*), Macleay's honeyeater (*Xanthotis macleayana*), Masked lapwing (*Vanellus miles*), Northern logrunner (*Orthonyx spaldingii*), Rainbow bee-eater (*Merops ornatus*), Red-backed button-quail (Australian) (*Turnix maculosa melanota*), Squatter pigeon (*Geophaps scripta scripta*) and Star finch (eastern) (*Neochmia ruficauda ruficauda*). These birds commonly include invertebrates and often small vertebrates and/or nectar as large components of their diet and thus are vulnerable to direct competition with electric ants or to depleted or restructured food resources. They variously have other traits that make them vulnerable to predation or disruption by electric ants such as small body size and ground nesting and/or foraging.

For the migratory seabird, Little tern (*Sterna albifrons*), nesting attempts and fledgling success are likely disrupted by electric ants occurring at coastal breeding sites.

Being mobile, it is possible that many affected native species will be displaced in avoidance responses to electric ant activities.

Despite being previously identified as potentially affected by electric ants[10, 37], our assessment is that the Southern cassowary (*Casuarius casuarius*) (‘Endangered’) is not especially at risk.

Mammals

Of 44 mammals assessed, 11 species/subspecies (25%) were identified as likely affected by the electric ant in the event that it is not contained and spreads through the Wet Tropics Bioregion, namely Common dunnart (N Qld) (*Sminthopsis murina tatei*), Mahogany glider (*Petaurus gracilis*) (‘Endangered’), Musky rat-kangaroo (*Hypsiprymnodon moschatus*), Northern brown bandicoot (*Isoodon macrourus*), Northern quoll (*Dasyurus hallucatus*) (‘Endangered’), Short-beaked echidna (*Tachyglossus aculeatus*), Southern brown bandicoot (Cape York) (*Isoodon obesulus peninsulae*), Squirrel glider (*Petaurus norfolcensis*), Striped possum (*Dactylopsila trivirgata*), Sugar glider (*Petaurus breviceps*), and Tube-nosed insect bat (*Murina florium*). These taxa possess small body size, vulnerable/defenceless young, and preponderance of invertebrates and often nectar in their diet.

Reptiles

Among reptiles, Faint-striped blind snake (*Ramphotyphlops broomi*) was identified at risk, but the level of impact is ambiguous. Occurring in leaf litter and rotting logs, this species is thought to have a lifestyle similar to other typhlopids in its semi-fossorial habit and feeds on earthworms as well as eggs and larvae of ants and termites. It has a high likelihood of microhabitat overlap with electric ants, including entry into the ant’s nests. The tramp ant is unlikely to accept nest intrusion, but it is unclear whether the tough body scales and other external adaptations for burrowing provide Faint-striped blind snake with an effective defence against attack from electric ants. The extent to which decreased abundance of native invertebrate prey reduced by electric ants may possibly be off-set by overall increase in ant abundance is unknown.

Other reptiles identified as likely affected if the electric ant is not contained include Black Mountain gecko (*Nactus galgajuga*), Black Mountain rainbow-skink (*Liburnascincus scirtetis*), Northern red-throated skink (*Carlia rubrigularis*) and Pale-flecked garden sunskink (*Lampropholis guichenoti*). These species are potentially vulnerable to predation by electric ants, especially in their juvenile stages, and are vulnerable to changes in compositional structure and abundance of invertebrate prey likely wrought by electric ants. These assessments should be qualified however, as these effects of food resources may possibly off-set by increased ant abundance where electric ant attains high densities. It would need to be demonstrated that electric ants are as palatable and provide the same nutrition as ants normally in the reptilian diet, a condition that has not been met following other ant invasions (e.g., [167]).

Amphibians

Eight of the 33 (24%) Wet Tropics frogs assessed were identified as most likely affected if the electric ant is not contained, namely Black Mountain boulderfrog (*Cophixalus saxatilis*), Common mistfrog (*Litoria rheocola*) ('Endangered'), Creaking nurseryfrog (*Cophixalus infacetus*), Eastern dwarf tree frog (*Litoria fallax*), Lace-eyed tree frog (*Nyctimystes dayi*), Northern barred frog (*Mixophyes schevilli*), Northern stoney creek frog (*Litoria jungguy*), and Peeping whistlefrog (*Austrochaperina fryi*). All frogs that overlap geographically with the tramp ant are likely to suffer effects of changes in food resources wrought by electric ant simplifying invertebrate communities and reducing overall invertebrate abundance. However, the extent to which frogs may benefit from any increased ant abundance is not well understood. Black Mountain boulderfrog, Creaking nurseryfrog, Northern barred frog and Peeping whistlefrog oviposit in moist leaf litter and thus their eggs, and the direct-developing young, are vulnerable to predation by electric ants.

In our assessments, we treated adult frogs as largely free from the predatory attentions of electric ants. As mentioned above, the predatory activity of electric ants on amphibians has not been adequately studied. Our assessments may thus underestimate risk to Wet Tropics species if all non-aquatic life stages of frogs are vulnerable to predation by electric ants.

Invertebrates

Green tree ants, or weaver ants (*Oecophylla smaragdina*), are known to be affected by electric ants in Queensland (see above) and thus provide a useful calibration of our rapid risk assessments. We scored the impact of electric ants on green tree ants medium to high.

Table 3.7 Numeric summary of rapid assessments for risk from electric ants for a sample of fauna in the Wet Tropics Bioregion

Taxon	Species or subspecies	EPBC Act listing status	Significance	Impact	Geo	Niche	BS	F&F
Bird	Atherton scrubwren (*Sericornis keri*)	Not listed	3	0	0	3	1	1.5
Bird	Azure kingfisher (*Ceyx azurea*)	Not listed	1	1	2	1.5	1	1
Bird	Australian brush-turkey (*Alectura lathami*)	Not listed	1	1	2	2	1	1
Bird	Australian king parrot (northern) (*Alisterus scapularis minor*)	Not listed	3	1	1	1.5	1	1
Bird	Beach stone-curlew (*Esacus neglectus*)	Not listed	1	1	1	1.5	1	1
Bird	Black bittern (Australasian) (*Ixobrychus flavicolllis australis*)	Not listed	1	1	2	1	1	1
Bird	Black-chinned honeyeater (*Melithreptus gularis*)	Not listed	1	1.5	2	1.5	1	1.5
Bird	Black-faced woodswallow (Cape York) (*Artamus cinereus normani*)	Not listed	1.5	1	1	1.5	1	1
Bird	Black-necked stork (*Ephippiorhynchus asiaticus australis*)	Not listed	1	1	1	1	0	1
Bird	Black-throated finch (southern) (*Poephila cincta cincta*)	E	1	1	2	1	1	1
Bird	Blue-faced parrotfinch (*Erythrura trichroa*)	Not listed	1	1	2	2	1.5	1
Bird	Boobook owl (*Ninox novaeseelandiae lurida*)	Not listed	2	1	2	2	1	2
Bird	Bower's shrike-thrush (*Colluricincla boweri*)	Not listed	3	1	1	3	1	1.5
Bird	Brown gerygone (*Gerygone mouki mouki*)	Not listed	3	1	1	2	1	1.5
Bird	Bridled honeyeater (*Lichenostomus frenatus*)	Not listed	3	1	1	3	1	2
Bird	Brown treecreeper (Cape York) (*Climacteris picumnus melanotus*)	Not listed	2	1	1.5	3	1	1.5
Bird	Buff-banded rail (*Gallirallus phillippensis*)	Not listed	1	1	1	2.5	1	1.5
Bird	Buff-breasted button-quail (*Turnix olivii*)	E	2	1.5	2.5	3	1	1.5
Bird	Bush stone-curlew (*Burhinus grallarius*)	Not listed	2	1.5	2	2	1	1.5
Bird	Cotton pygmy-goose (*Nettapus coromandelianus*)	Not listed	2	1	1	1	1	0
Bird	Crimson finch (*Neochmia phaeton phaeton*)	Not listed	1	1	1.5	2	1	1.5
Bird	Double-eyed fig parrot (*Cyclopsitta diophthalma macleayana*)	Not listed	3	1	2	2	1	1.5
Bird	Eastern curlew (*Numenius madagascariensis*)	Not listed	1	1	1	1	0	1
Bird	Eastern whipbird (*Psophodes olivaceus lateralis*)	Not listed	3	2	2	2.5	1	2
Bird	Emerald ground-dove (*Chalcophaps indica chrysochlora*)	Not listed	1	1	3	3	1	1
Bird	Emu (mainland) (*Dromaius novaehollandiae novaehollandiae*)	Not listed	1	1	1.5	2	1	1

Table 3.7 continued

Taxon	Species or subspecies	EPBC Act listing status	Significance	Impact	Geo	Niche	BS	F&F
Bird	Fern wren (*Oreoscopus gutturalis*)	Not listed	3	1	1	2.5	1	2.5
Bird	Freckled duck (*Stictonetta naevosa*)	Not listed	1	1	1	1.5	0	1
Bird	Glossy black-cockatoo (*Calyptorhynchus lathami*)	Not listed	1	1	2	1	1	1
Bird	Golden bowerbird (*Prionodura newtoniana*)	Not listed	3	0	0	2.5	1	2
Bird	Gouldian finch (*Erythrura gouldiae*)	E	1	1	1	2.5	1	1
Bird	Grass owl (eastern) (*Tyto capensis longimembris*)	Not listed	1	1	1	3	1	0
Bird	Great-billed heron (*Ardea sumatrana*)	Not listed	1	1	1	1.5	0	1
Bird	Great crested grebe (*Podiceps cristatus australis*)	Not listed	1	0	1.5	1	0	0
Bird	Grey-crowned babbler (E) (*Pomatostomus temporalis temporalis*)	Not listed	1	1.5	2	3	1.5	2
Bird	Grey fantail (*Rhipidura albiscapa alisteri*)	Not listed	1	1.5	3	2.5	1	2
Bird	Grey fantail (*Rhipidura fuliginosa frerei*)	Not listed	3	1.5	2.5	3	1	1.5
Bird	Grey goshawk (*Accipiter novaehollandiae*)	Not listed	1	1	2.5	2	0	1
Bird	Grey-headed robin (*Heteromyias cinereifrons*)	Not listed	3	1	1	2	1	1
Bird	Ground parrot (*Pezoporus wallicus wallicus*)	Not listed	1	1	2	2	1	1
Bird	Herald petrel (*Pterodroma heraldica*)	CE	1	0	0	1	0	0
Bird	Latham's snipe (*Gallinago hardwickii*)	Not listed	1	1	1	1	0	1
Bird	Lesser sooty owl (*Tyto multipunctata*)	Not listed	3	1	2	2.5	1	0
Bird	Lewin's rail (eastern) (*Rallus pectoralis pectoralis*)	Not listed	1	1	2	2	1	1
Bird	Little bittern (Australasian) (*Ixobrychus minutus dubius*)	Not listed	1	1	2	2	1	1
Bird	Little tern (*Sterna albifrons*)	Not listed	1	1.5	1	2	2	0
Bird	Macleay's honeyeater (*Xanthotis macleayana*)	Not listed	3	1.5	2	2.5	1.5	1.5
Bird	Magpie goose (*Anseranas semipalmata*)	Not listed	1	1	2	1.5	1	0
Bird	Masked lapwing (*Vanellus miles*)	Not listed	1	1.5	1.5	2	1	1.5
Bird	Masked owl (northern) (*Tyto novaehollandiae kimberli*)	V	1	1	2	2.5	1	0
Bird	Mountain thornbill (*Acanthiza katherina*)	Not listed	3	1	1	2	1	2
Bird	Northern logrunner (*Orthonyx spaldingii*)	Not listed	3	1.5	1	2	1.5	2
Bird	Orange-footed scrubfowl (E Qld) (*Megapodius reinwardt castanotus*)	Not listed	3	1	2	2	1	2

Table 3.7 continued

Taxon	Species or subspecies	EPBC Act listing status	Significance	Impact	Geo	Niche	BS	F&F
Bird	Painted honeyeater (*Grantiella picta*)	Not listed	1	1	2	1.5	1	1
Bird	Painted snipe (*Rostratula benghalensis australis*)	Not listed	1	1	1	1.5	1	0
Bird	Pale-yellow robin (*Tregellasia capito nana*)	Not listed	3	1	2	2.5	1	1
Bird	Pied currawong (*Strepera graculina*)	Not listed	1	1	3	2.5	1	1.5
Bird	Pied monarch (*Arses kaupi*)	Not listed	3	1	2.5	2.5	1	1
Bird	Radjah shelduck (Australian) (*Tadorna radjah rufitergum*)	Not listed	1	1	1.5	1.5	1	1
Bird	Rainbow bee-eater (*Merops ornatus*)	Not listed	1	1.5	2.5	2.5	1	1.5
Bird	Red-backed button-quail (Australian) (*Turnix maculosa melanota*)	Not listed	1	1.5	3	2.5	1.5	1.5
Bird	Red goshawk (*Erythrotriorchis radiatus*)	V	1	1	2.5	3	1	1
Bird	Red-tailed tropicbird (*Phaethon rubricauda*)	Not listed	1	0	1	1	0	0
Bird	Rufous owl (southern subspecies) (*Ninox rufa queenslandica*)	Not listed	2.5	1	2	1.5	0	1
Bird	Sacred kingfisher (*Todiramphus sanctus*)	Not listed	1	1	1.5	1.5	1	1
Bird	Sarus crane (Australian) (*Grus antigone gillae*)	Not listed	2	1	1.5	2.5	1	1
Bird	Satin bowerbird (*Ptilonorhynchus violaceus minor*)	Not listed	2	1	1.5	2.5	1	1
Bird	Silver-eye (*Zosterops lateralis*)	Not listed	1	1	2.5	2	1	1
Bird	Sooty owl (*Tyto tenebricosa*)	Not listed	1	1	1	1	1	1
Bird	Sooty Oystercatcher (N) (*Haematopus fuliginosus opthalmicus*)	Not listed	1	1	1	1	1	0
Bird	Southern cassowary (*Casuarius casuarius*)	E	2.5	1	2.5	2	1	1
Bird	Spotted catbird (*Ailuroedus melanotis maculosus*)	Not listed	1	1	2.5	2	1	1
Bird	Square-tailed kite (*Lophoictinia isura*)	Not listed	1	1	1.5	1	1	1
Bird	Squatter pigeon (*Geophaps scripta scripta*)	V	2	1.5	2	3	1.5	1.5
Bird	Star finch (eastern) (*Neochmia ruficauda ruficauda*)	E	1.5	3	3	2	1.5	0
Bird	Tooth-billed catbird (*Scenopoeetes dentirostris*)	Not listed	2	1	1	2.5	1.5	1
Bird	Victoria's riflebird (*Ptiloris victoriae*)	Not listed	2	1	1	2.5	1	1
Bird	White-faced heron (*Ardea novaehollandiae*)	Not listed	1	1	1.5	2	1	1
Bird	white-rumped swiftlet (*Aerodramus spodiopygius*)	Not listed	1	1	1.5	2.5	1	1.5

Table 3.7 continued

Taxon	Species or subspecies	EPBC Act listing status	Significance	Impact	Geo	Niche	BS	F&F
Bird	Yellow-breasted boatbill (*Machaerirhynchus flaviventer secundus*)	Not listed	2	1	2.5	2.5	1	1.5
Mammal	Agile Wallaby (*Macropus agilis*)	Not listed	1	1	2	2	1	1
Mammal	Atherton antechinus (*Antechinus godmani*)	Not listed	3	1	1	3	1	1
Mammal	Bare-backed fruit bat (*Dobsonia moluccensis*)	Not listed	1	1	1.5	2.5	1	1
Mammal	Bare-rumped sheathtail bat (*Saccolaimus saccolaimus nudicluniatus*)	CE	1	1	1	2	1	1.5
Mammal	Bennett's tree-kangaroo (*Dendrolagus bennettianus*)	Not listed	1	1	1.5	2.5	1	1
Mammal	Black-footed tree-rat (*Mesembriomys gouldii*)	Not listed	2	1	2	2.5	1	1
Mammal	Coastal sheathtail bat (*Taphozous australis*)	Not listed	2	1	2.5	2.5	1	1
Mammal	Common dunnart (N Qld) (*Sminthopsis murina tatei*)	Not listed	3	1.5	2.5	2.5	1.5	1.5
Mammal	Daintree River ringtail possum (*Pseudochirulus cinereus*)	Not listed	3	1	1	2.5	1	1
Mammal	Diadem leaf-nosed bat (*Hipposideros diadema reginae*)	Not listed	2	1	1	1.5	0	1
Mammal	Duck-billed platypus (*Ornithorhynchus anatinus*)	Not listed	1	1	1.5	1	1	0
Mammal	Eastern tube-nosed bat (*Nyctimene robinsoni*)	Not listed	1	1	2.5	2.5	1	1
Mammal	False water-rat (*Xeromys myoides*)	V	1	1	1.5	1.5	1	1
Mammal	Ghost bat (*Macroderma gigas*)	Not listed	1.5	1	2	2	0	1
Mammal	Giant white-tailed rat (*Uromys caudimaculatus*)	Not listed	2	1	2	2.5	1	1
Mammal	Golden-tipped bat (*Kerivoula papuensis*)	Not listed	1	1	1.5	2	1.5	1.5
Mammal	Greater large-eared horseshoe bat (large form) (*Rhinolophus philippinensis*)	E	2	1	2	2.5	1	1
Mammal	Green ringtail possum (*Pseudochirops archeri*)	Not listed	3	1	1	2.5	1	1
Mammal	Herbert River ringtail possum (*Pseudochirulus herbertensis*)	Not listed	3	1	1	2.5	1	1
Mammal	Koala (*Phascolarctos cinereus*)	Not listed	2	1	2	1.5	1	1.5
Mammal	Lemuroid ringtail possum (*Hemibelideus lemuroids*)	Not listed	3	1	1	2.5	1	1
Mammal	Long-tailed pygmy-possum (*Cercartetus caudatus macrurus*)	Not listed	3	1	1	2.5	1	1
Mammal	Mahogany glider (*Petaurus gracilis*)	E	2	1.5	2.5	2.5	1	1.5
Mammal	Mareeba rock-wallaby (*Petrogale mareeba*)	Not listed	2	1	1.5	2	1	1

Table 3.7 continued

Taxon	Species or subspecies	EPBC Act listing status	Significance	Impact	Geo	Niche	BS	F&F
Mammal	Masked white-tailed rat (*Uromys hadrourus*)	Not listed	2.5	0	0	2	1	1
Mammal	Mount Claro rock-wallaby (*Petrogale sharmani*)	Not listed	3	1	1	2.5	1	1
Mammal	Musky rat-kangaroo (*Hypsiprymnodon moschatus*)	Not listed	3	1.5	1.5	2	1	1.5
Mammal	Northern bettong (*Bettongia tropica*)	E	3	1	1	2.5	1	1
Mammal	Northern brown bandicoot (*Isoodon macrourus*)	Not listed	1	1.5	2	2.5	1	1.5
Mammal	Northern quoll (*Dasyurus hallucatus*)	E	1	1.5	2	2.5	1	1.5
Mammal	Red-legged pademelon (*Thylogale stigmatica*)	Not listed	1	1	2.5	2.5	1	1
Mammal	Semon's leaf-nosed bat (*Hipposideros semoni*)	E	1	1	1	1	1	1.5
Mammal	Short-beaked echidna (*Tachyglossus aculeatus*)	Not listed	1	1.5	2.5	2.5	1.5	1.5
Mammal	Southern brown bandicoot (Cape York) (*Isoodon obesulus peninsulae*)	Not listed	2	1.5	2.5	3	1	1.5
Mammal	Spectacled flying-fox (*Pteropus conspicillatus*)	V	1	1	2.5	3	1	1
Mammal	Spectacled hare-wallaby (mainland) (*Lagorchestes conspicillatus leichardti*)	Not listed	1	1	1	1.5	1	1
Mammal	Spotted-tailed quoll (N Qld) (*Dasyurus maculates gracilis*)	E	1	1	2	2.5	1	1
Mammal	Squirrel glider (*Petaurus norfolcensis*)	Not listed	1	1.5	2	2.5	1.5	1.5
Mammal	Striped possum (*Dactylopsila trivirgata*)	Not listed	1	1.5	2	2.5	1.5	1.5
Mammal	Sugar glider (*Petaurus breviceps*)	Not listed	1	1.5	2	2.5	1.5	1.5
Mammal	Tube-nosed insect bat (*Murina florium*)	Not listed	1	1.5	2	2.5	1.5	1.5
Mammal	Water rat (*Hydromys chrysogaster*)	Not listed	1	1	2	1.5	1	1
Mammal	White-footed dunnart (N) (*Sminthopsis leucopus*)	Not listed	3	0	0	2.5	1	1
Mammal	Yellow-bellied glider (Wet Tropics) (*Petaurus australis*)	V	3	0	0	2.5	1	1
Reptile	Amethystine python (*Morelia amethistina*)	Not listed	1	1	2	2	1	1
Reptile	Atherton delma (*Delma mitella*)	V	1	1	1	2.5	1	1
Reptile	Barnard's snake (*Furina barnardi*)	Not listed	1	1	1	2.5	1	1
Reptile	Bartle Frere barsided skink (*Eulamprus frerei*)	Not listed	3	0	0	2.5	1	1
Reptile	Bartle Frere cool-skink (*Bartleia jigurru*)	Not listed	1	0	0	2.5	1	1
Reptile	Black Mountain gecko (*Nactus galgajuga*)	Not listed	3	1.5	2.5	2.5	1	1.5

Table 3.7 continued

Taxon	Species or subspecies	EPBC Act listing status	Significance	Impact	Geo	Niche	BS	F&F
Reptile	Black Mountain rainbow-skink (*Liburnascincus scirtetis*)	Not listed	3	1.5	2.5	2.5	1	1.5
Reptile	Boyds forest dragon (*Hypsilurus boydii*)	Not listed	3	1	2.5	2.5	1	1.5
Reptile	Brown tree snake (*Boiga irregularis*)	Not listed	1	1	2.5	2.5	1	1
Reptile	Carpet pythons (*Morelia spilota*)	Not listed	1	1	2.5	2.5	1	1
Reptile	Common death adder (*Acanthophis antarcticus*)	Not listed	1	1	2	2.5	1	1.5
Reptile	Estuarine crocodile (*Crocodylus porosus*)	Not listed	1	1	2.5	2	0	1
Reptile	Faint-striped blind snake (*Ramphotyphlops broomi*)	Not listed	3	1.5	2.5	2.5	2	2
Reptile	Freshwater crocodile (*Crocodylus johnstoni*)	Not listed	1	1	2.5	2	0	1
Reptile	Frilled lizard (*Chlamydosaurus kingii*)	Not listed	1	1	2	2	1	1
Reptile	Green snake (*Dendrelaphis punctulata*)	Not listed	1	1	2	2	1	1
Reptile	Green turtle (*Chelonia mydas*)	V	1	0	0	1	1	0
Reptile	Flatback turtle (*Natator depressus*)	V	1	1	1	1.5	1	0
Reptile	Hawksbill turtle (*Eretmochelys imbricata*)	V	1	1	1	1	1	0
Reptile	Leathery turtle (*Dermochelys coriacea*)	E	1	0	0	1	1	0
Reptile	Loggerhead turtle (*Caretta caretta*)	E	2	0	0	2	1	0
Reptile	Limbless snake-tooth skink (*Coeranoscincus frontalis*)	Not listed	3	1	2.5	2.5	1	1
Reptile	Major skink (*Bellatorias frerei*)	Not listed	2	1	2.5	2.5	1	1
Reptile	Northern leaf-tailed gecko (*Saltuarius cornutus*)	Not listed	3	1	1.5	3	1	1.5
Reptile	Northern red-throated skink (*Carlia rubrigularis*)	Not listed	3	1.5	2.5	3	1	1.5
Reptile	Northern tree snake (*Dendrelaphis calligastra*)	Not listed	3	1	3	2.5	1	1
Reptile	Pale-flecked garden sunskink (*Lampropholis guichenoti*)	Not listed	1	1.5	2	2.5	1	1.5
Reptile	Prickly forest skink (*Gnypetoscincus queenlandiae*)	Not listed	3	1	1.5	3	1	1
Reptile	Rainforest skink (*Eulamprus tigrinus*)	Not listed	3	1	1.5	3	1	1
Reptile	Ring-tailed gecko (*Cyrtodactylus louisiadensis*)	Not listed	1	1	2	2.5	1	1.5
Reptile	Rusty monitor (*Varanus semiremex*)	Not listed	1	1	1.5	2	0	1
Reptile	Saw-shelled turtle (*Myuchelys latisternum*)	Not listed	1	1	1.5	2	0	1
Reptile	Spotted python (*Liasis maculosus*)	Not listed	1	1	1.5	2	1	1
Reptile	Thornton Peak calyptotis (*Calyptotis thorntonensis*)	Not listed	3	0	0	2.5	1	1

Table 3.7 continued

Taxon	Species or subspecies	EPBC Act listing status	Significance	Impact	Geo	Niche	BS	F&F
Reptile	Water python (*Liasis fuscus*)	Not listed	1	1	1	2	0	1
Reptile	Yakka skink (*Egernia rugosa*)	V	1	1	2	2.5	1	1
Amphibian	Armoured mistfrog (*Litoria lorica*)	E	3	1	1	1.5	0	1
Amphibian	Australian wood frog (*Rana daemeli*)	Not listed	1	1	2	2	0	1.5
Amphibian	Bellenden Ker nurseryfrog (*Cophixalus neglectus*)	Not listed	3	0	0	2	0	1.5
Amphibian	Black Mountain boulderfrog (*Cophixalus saxatilis*)	Not listed	3	1.5	2	2	1	1.5
Amphibian	Buzzing nurseryfrog (*Cophixalus bombiens*)	Not listed	3	0	0	2	1	1.5
Amphibian	Carbine barred frog (*Mixophyes carbinensis*)	Not listed	3	0	0	1.5	0	1.5
Amphibian	Common green tree frog (*Litoria caerulea*)	Not listed	1	1	2	2	0	1.5
Amphibian	Common mistfrog (*Litoria rheocola*)	E	3	1.5	1.5	1.5	0	1.5
Amphibian	Creaking nurseryfrog (*Cophixalus infacetus*)	Not listed	3	1.5	1.5	1.5	1	1.5
Amphibian	Dainty nurseryfrog (*Cophixalus exiguus*)	Not listed	3	0	0	1.5	1	1.5
Amphibian	Dwarf rocket frog (*Litoria microbelos*)	Not listed	1	1	1.5	1.5	0	1.5
Amphibian	Eastern dwarf tree frog (*Litoria fallax*)	Not listed	1	1.5	3	1.5	0	1.5
Amphibian	Lace-eyed tree frog (*Nyctimystes dayi*)	E	3	1.5	1.5	1.5	0	1.5
Amphibian	Little waterfall frog (*Litoria lorica*)	CE	3	0	0	1.5	0	1.5
Amphibian	Magnificent brood frog (*Pseudophryne covacevichae*)	V	3	0	0	1.5	1	1.5
Amphibian	Marbled frog (*Limnodynastes convexiusculus*)	Not listed	1	1	1.5	1.5	0	1.5
Amphibian	Mottled barred frog (*Mixophyes coggeri*)	Not listed	2	1	1.5	1.5	0	1.5
Amphibian	Mountain mistfrog (*Litoria nyakalensis*)	CE	3	0	0	1.5	0	1.5
Amphibian	Mountain nurseryfrog (*Cophixalus monticola*)	Not listed	3	0	0	1.5	1	1.5
Amphibian	Northern barred frog (*Mixophyes schevilli*)	Not listed	2	1.5	1	1.5	1	1.5
Amphibian	Northern stoney creek frog (*Litoria jungguy*)	Not listed	3	1.5	1.5	1.5	0	1.5
Amphibian	Ornate burrowing frog (*Platyplectrum ornatum*)	Not listed	1	1	1.5	1.5	0	1.5
Amphibian	Peeping whistlefrog (*Austrochaperina fryi*)	Not listed	3	1.5	1	1.5	1	1.5
Amphibian	Rattling nurseryfrog (*Cophixalus hosmeri*)	Not listed	3	0	0	1.5	1	1.5
Amphibian	Robust whistlefrog (*Austrochaperina robusta*)	Not listed	3	1	1	1.5	1	1.5
Amphibian	Striped rocket frog (*Litoria nasuta*)	Not listed	1	1	1.5	1.5	0	1.5

Table 3.7 continued

Taxon	Species or subspecies	EPBC Act listing status	Significance	Impact	Geo	Niche	BS	F&F
Amphibian	Superb collared frog (*Cyclorana brevipes*)	Not listed	1	1	1	1.5	0	1.5
Amphibian	Tapping green-eyed frog (*Litoria genimaculata*)	Not listed	1	1	1	1.5	0	1.5
Amphibian	Tapping nurseryfrog (*Cophixalus concinnus*)	Not listed	3	0	0	1.5	1	1.5
Amphibian	Tinkling frog (*Taudactylus rheophilus*)	E	3	0	0	1.5	0	1.5
Amphibian	Waterfall frog (*Litoria nannotis*)	E	1	1	1	1	1	1.5
Amphibian	White-lipped tree frogs (*Litoria infrafrenata*)	Not listed	1	1	1	1.5	0	1.5
Amphibian	Whirring treefrog (N) (*Litoria revelata*)	Not listed	3	1	1	1.5	0	1.5
Invertebrate	Apollo jewel butterfly (*Hypochrysops apollo apollo*)	Not listed	1	2	2.5	2.5	2	2
Invertebrate	Australian beak butterfly (*Libythea geoffroy*)	Not listed	1	1.5	2.5	2.5	2	1
Invertebrate	Moth butterfly (*Liphyra brassolis*)	Not listed	1	2	2.5	2.5	2	1.5
Invertebrate	Purple dusk-flat (*Chaetocneme porphyropis*)	Not listed	1	2	2.5	2.5	2	1.5
Invertebrate	Weaver ant (Oecophylla smaragdina)	Not listed	1	2.5	3	3	2.5	1.5

[1]Significance = Importance of populations within the Bioregion to the species' security, taking into account the species' conservation status and range size. Low, medium and high translated to numeric 1-3 scale.

[2]Impact = Assessment of likely importance of the tramp ant to persistence of the species within the Bioregion, taking into account Geo, Niche and effects of the tramp ant of breeding success, foraging and food resources. Nil, low, medium and high translated to numeric 0-3 scale. High impact implies the conservation status of the species may change, requiring re-assessment of their respective listed status.

[3]Geo = Extent of likely geographic overlap of the animal species and tramp ant within the Bioregion. Nil, low, medium and high translated to numeric 0-3 scale. Note that species without occurrence in the Bioregion were excluded from the assessments.

[4]Niche = Extent of likely niche overlap of the animal species and tramp ant. Nil, low, medium and high translated to numeric 0-3 scale.

[5]BS = Extent to which breeding success is likely reduced directly or indirectly by the tramp ant. Nil, low, medium and high translated to numeric 0-3 scale.

[6]F&F = Extent to which *foraging* is disrupted, extent to which *food resources* are likely to be reduced directly or indirectly by the tramp ant. Nil, low, medium and high translated to numeric 0-3 scale.

Our assessments tend to confirm earlier views[156] that Apollo jewel butterfly and Moth butterfly are vulnerable to electric ants. Apollo jewel butterfly is likely highly vulnerable, especially in immature stages, to both direct predation and displacement of the native ant associate (*Iridomyrmex cordatus*) by electric ants. Sands[168] suggested that displacement of the ant in the bulbs of the food plant by the invasive African big-headed ant had contributed to the decline in abundance of the butterfly. However, there are doubts as to whether the native ants have an obligatory relationship with the larvae of the butterfly, since they may be occupying the same microhabitat as the butterfly without any direct interactions other than with the plant[169]. Nonetheless, African big-headed ants are known to be responsible for destroying the flowers and developing seeds of the epiphyte and may indirectly be responsible for declines in the abundance of the plant[169].

The Moth butterfly occurs in nests of ants, especially of green tree ants *Oecophylla smaragdina*, where the larvae are predatory on ant eggs and larvae. While both the butterfly and host ant are widespread in northern Australia, the association is vulnerable to displacement of *O. smaragdina* by electric ants, as noted above. Moth butterfly was assessed as likely affected by electric ant through displacement of native ant hosts and possibly by direct predation.

Australian beak butterfly (*Libythea geoffroy*) and Purple dusk-flat (*Chaetocneme porphyropis*) have not previously been assessed for risk from invasive ants. Both species have classical herbivorous associations with their respective host plants, *Celtis* spp. in Ulmaceae and various Lauraceae, respectively. Our assessment is that the immature stages of both species are likely affected as the eggs, larvae and pupae are vulnerable to predation by electric ants.

The other 95% - Taxa neglected in existing assessments

Earlier assessments, and those made here, neglect the majority of invertebrate species potentially at risk from electric ants.

There is a need to systematically assess risks in other groups of invertebrates. This will require expert knowledge of these groups and properly designed experiments or drawing on knowledge of effects observed elsewhere the electric ant has invaded.

It is well known that electric ants can assume numerical dominance of ant communities in invaded regions (e.g.,[3, 159, 170-175]). While displacement/reduction in numbers does not necessarily mean local extinction, it is evident that risks to native ant species should be considered alongside risks to other fauna. Native ants are the group in the native fauna most directly and intimately affected by electric ants. Presently there is insufficient knowledge of the distributional range of species of ants native to the Wet Tropics Bioregion, and their vulnerability to extinction, to make robust assessments of the likelihood that interactions with electric ant will to lead displacement and extinction.

3.5 Yellow crazy ants in Arnhem Land

3.5.1 Tramp ant impacts on biodiversity at the project site

The program team has conducted annual monitoring at many sites (the number of sites increases each year as the strategies change) since 2005, and some of this is ongoing[71]. The results of post-treatment monitoring of native ants are provided in section 3.5.3. Here we discuss data from two studies documenting impacts of yellow crazy ants on biodiversity in untreated sites (summarized in Table 3.8).

Hoffmann and Saul[176] set pitfall trap traps in paired yellow crazy ant-infested and non-infested sites in savannah woodland, dry vine thicket, and monsoon rainforest habitats in Arnhem Land in 2004. Native ant abundance (P = 0.021) and species richness (P = 0.019) were consistently lower in infested sites regardless of habitat (Figure 3.3), and yellow crazy ant abundance was negatively correlated with total native ant abundance. However, 62% (41 species) of all ant species found occurred in infested plots, and those that are smaller (<2.5mm) are less likely to be displaced. Thus the relative contribution of smaller ants is greater in infested plots[176]. No relationships were found between yellow crazy ant abundance and total abundance of other macro-invertebrates, or yellow crazy ant abundance and the abundance of individual macro-invertebrate orders (Figure 3.4). However, the identification of macro-invertebrates to ordinal level provides only a very coarse measure of community composition. Significant differences may have occurred among macro-invertebrate species within ordinal groups, but these effects would be overlooked with identifications at the ordinal level.

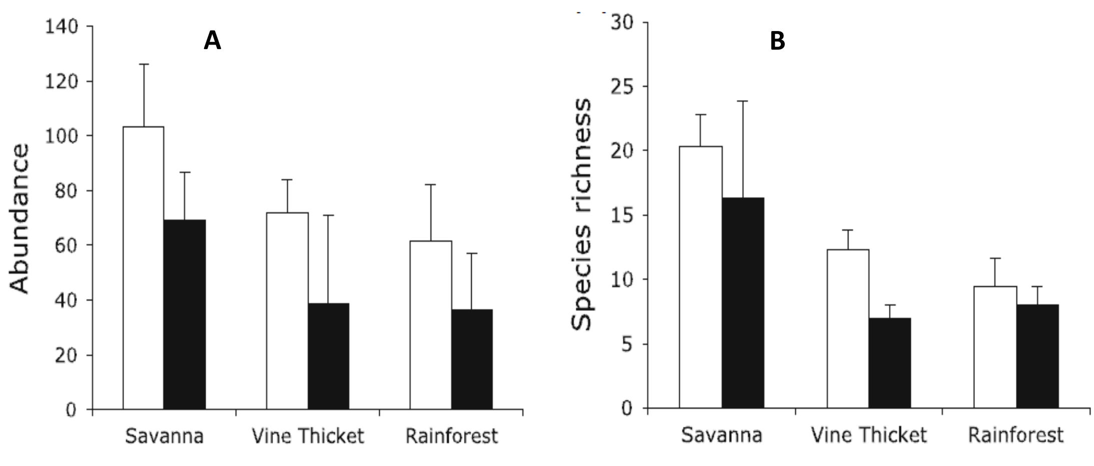


Figure 3.3 A) Mean abundance, and **B)** species richness of native ants in non-infested (white columns) and yellow crazy ant-infested (filled columns) plots in three habitats in Arnhem Land as measured by pitfall traps. (From Hoffmann & Saul[176])

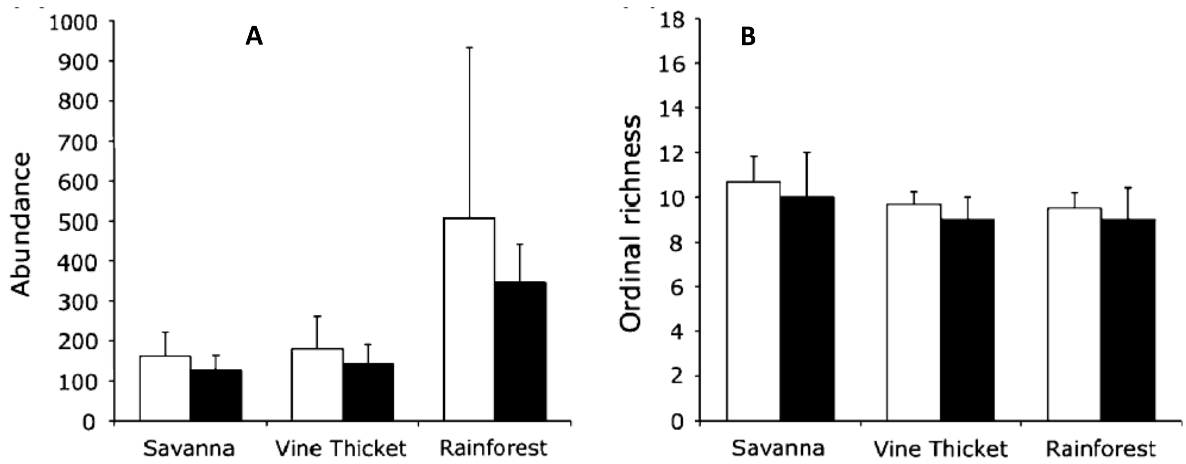


Figure 3.4 A) Mean abundance and **B)** species richness of native macro-invertebrates in non-infested (white columns) and yellow crazy ant-infested (filled columns) paired plots in three habitats in Arnhem Land as measured by pitfall trap catches. (From Hoffmann & Saul[176])

One of the large native ant species displaced by yellow crazy ants was the weaver or green tree ant, *Oecophylla smaragdina*[176]. The green tree ant is the only representative of this genus in Australia. This arboreal-nesting species is found widely and commonly in India and SE Asia through to Australia and thus of little conservation concern at the global scale. In northern Australia the species maintains a dominant role within native ant communities[162-164] by aggressive colony defense and monopolization of resources. Therefore its absence would likely have cascading effects on many ecosystem processes. Lach and Hoffmann[177] compared the plant defense services (protection from herbivory) provided by yellow crazy ants and green tree ants on acacia and eucalyptus trees with the use of a surrogate herbivore. Yellow crazy ants were more likely and quicker than green tree ants to discover the surrogate herbivore, were more thorough in their attacks, and recruited 3.4 – 4 times more workers to surrogate herbivores than were green tree ants. Discovery of surrogate herbivores by other predators did not vary significantly between trees in yellow crazy ant and green tree ant sites. However, the more aggressive and efficient foliar patrolling by yellow crazy ants does not translate to increased plant protection. Trees in yellow crazy ant sites had the same or higher herbivory than their counterparts in green tree ant sites.

Three other introduced ant species (*Monomorium floricola*, *Tetramorium simillimum* and *Paratrechina longicornis*) are known from the project site but at low abundance and not observed to be greatly affecting outcomes for biodiversity[176].

The nature of non-target effects of fipronil observed internationally has been reviewed by Tingle et al. and others[178-180]. The ecological monitoring of native ants in pitfall traps (see Sections 3.5.2 and 3.5.3) in sites pre- and post-treatment indicate no adverse effect of treatment on native ants. There has been no investigation of effects on other non-target taxa.

Table 3.8 Summary of documented effects of the yellow crazy ant and management treatments on native fauna at the project site in NE Arnhem Land

Taxa studied	Monitoring methods	Impacts
Invertebrates		
Ground-dwelling native ants[176, 181]	[181]In BACI experimental design, impact of one or two applications of fipronil bait studied by comparison of 13 infested sites and 9 non-infested sites over period 9 to 53 months post-treatment. Each site sampled with grid of 15 pitfall traps left out for 48 hours.	[181] Visual inspection of graphed means and ordination plots indicate an increase in native ant species abundance and possibly native ant species richness following treatment; and native ant species richness post-treatment and abundance within the range of untreated sites
	[176]Pitfall trapping in paired infested and non-infested sites in 3 habitat types.	[176]Native ant abundance (P = 0.021) and species richness (P = 0.019) were consistently lower in yellow crazy ant infested sites regardless of habitat.
Ground invertebrates[176]	Pitfall trapping in paired infested and non-infested sites in 3 habitat types.	Total abundance of invertebrates varied among habitat types. However, no differences in total abundance and ordinal richness were recorded between infested and non-infested sites.
Herbivory in trees[177]	Comparison of predation rates of a surrogate insect herbivore, and levels of herbivory, in acacia and eucalyptus trees infested with either yellow crazy ants or the native green tree ant.	Yellow crazy ants more efficient in discovery and recruiting to the surrogate herbivore than native green tree ants. However, levels of herbivory suffered by trees did not vary with ant identity.

3.5.2 Monitoring and evaluation tools used in the project to measure impacts on biodiversity

The program has employed a before-after-control-impact (BACI) design to test the effect of treatment on yellow crazy ants and non-target invertebrates[181] (results described in Section 3.5.3, Table 3.8). In 2005, 13 infested sites and 9 non-infested sites were each sampled with a 5 x 3 grid of 15 pitfall traps spaced 10m apart and left out for 48 hours[71, 181]. Sampling was conducted between August and November each year from 2005-2009, except for 2008. Post-treatment sampling was conducted 9 to 16 months after one or two applications of 0.01g/kg fipronil in a granular bait matrix applied at a rate of 10 kg/ ha[181].

The two studies described in Section 3.5.1([176, 177]) took place before 2008 and therefore were not part of the monitoring and evaluation tools used in the CfOC funded period. Their methods are well-described in the associated published manuscripts.

3.5.3 Monitoring and evaluation outcomes (both impacts from tramp ants and /or post recovery of species)

Monitoring outcomes

As described in 3.5.2, a BACI design experiment was conducted to evaluate recovery of native ants or non-target effects of treatment nine months after the application of the bait in 2005. Graphically there appears to be no discernible adverse effects of fipronil application on either species richness or abundance of native ants nine months after treatment (Figure 3.5), but the results should be formally statistically analyzed. Though native ant abundance has clearly increased (Figure 3.5B), it is not clear that native ant species richness has significantly improved from pre-treatment levels (Figure 3.5A) nine months after treatment. Three additional years of annual sampling (through to 2009) at a total of 31 sites[71] that have been treated either once or twice with fipronil, and comparison to non-infested sites that have not been treated has revealed that species richness and abundance are within the range of untreated sites within 9-16 months of treatment (Figure 3.6)[181].

Evaluation of outcomes

The management of yellow crazy ants in Arnhem Land commenced in 2004 (see Section 2.3) and thus encompasses a considerable amount of effort towards eradication of yellow crazy ants prior to CfOC funding in 2008-09. The program was identified in the 2008-09 transitional year as a critical continuity project under the Five Year Outcomes for Biodiversity and Natural Icons - Reduce the impact of invasive species - Invest in actions to eradicate tramp ants in at least one priority area. It should be noted, however, that this project commenced well before the advent of the CfOC five year business plan framework and associated target outcomes.

The objective during the period of CfOC funding (2008-09) was to finalise the post-treatment assessments of eight yellow crazy ant infestations in northeast Arnhem Land treated prior to 2008, in order to declare eradication success at these locations. The self-evaluation end report[73] highlights declaration of eradication at five sites as the achievement. Three sites were found to have persistent yellow crazy ant infestations and have been re-treated. Over the life of the program to 2009, local eradication of yellow crazy ants has been achieved at 21 sites within the Gove Peninsula, North East Arnhem Land priority area.

The Letter of Offer[72], and contract deed with CfOC[182] do not specifically require monitoring, evaluation, and reporting against CfOC targets and outcomes and there was no requirement for a MERI Plan. Accordingly, methodologies were not developed to demonstrate quantitatively that eradication of yellow crazy ant, if successful, would contribute to CfOC 2013 biodiversity and natural icons priority outcomes "....reduce critical threats to biodiversity and to enhance the condition, connectivity and resilience of habitats and landscapes" and "....reduce the impact of invasive species....". Since impacts of yellow crazy ants have been documented locally with appropriate sampling, it is accepted, however, that regional containment of yellow crazy ant, if successful, would indeed contribute to national outcomes.

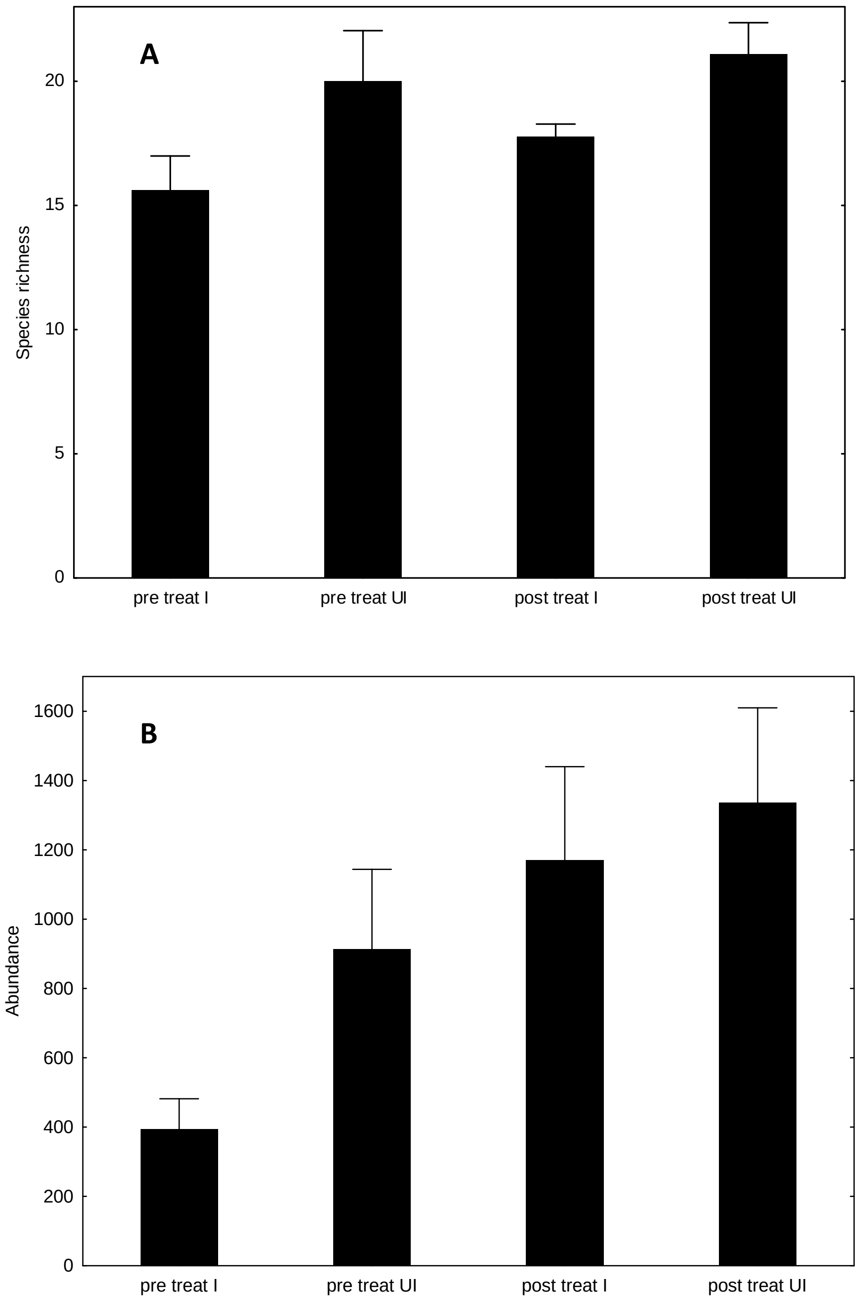


Figure 3.5 A) Mean species richness of native ants and **B)** mean abundance of native ants as determined from pitfall trap sampling in sites infested by yellow crazy ants (I) and non-infested control sites (UI) pre-treatment and 9 months post-treatment with 0.01% fipronil applied at 10kg/ha in Arnhem Land[181].

3.5.4 Other biodiversity impacts that may be occurring from tramp ants at the project site

The National Recovery Plan for the Gove Crow Butterfly[183], written in 2007, listed the yellow crazy ant as one of four potential threats to the endangered Gove crow butterfly (*Euploea alcathoe enastri*) via predation of the larval stages. At that time the butterfly was known from just seven discrete locations in the Arnhem Peninsula with no more than 10-15 adult individuals are usually sighted at each location[183]. The Plan suggests that protecting the butterfly will also protect the diverse habitat and other endemic invertebrate taxa that also likely occur in the region, and calls for a “survey, monitoring, and eradication program for yellow crazy ants at all sites”[183]. We are not aware of any monitoring program in place since 2007 to determine impacts of yellow crazy ant on the butterfly.

On the basis of more recent surveys, Braby[184] reviewed the species conservation status and concluded that it is stable and should be considered 'Near Threatened'. Of the four major habitat types in which Gove crow butterfly was detected, only mixed paperbark tall open forest with rainforest elements in the understorey and rainforest edge (i.e., the ecotone between evergreen monsoon vine-forest and eucalypt/paperbark woodland) comprise breeding habitats. These habitat patches were always associated with permanent creeks or perennial groundwater seepages or springs that form swamplands, usually along drainage lines or flood plains in coastal or near coastal lowland areas. Yellow crazy ants can occur in these habitats, but are not currently known to[71]. Yellow crazy ants, along with grassy weeds, were identified as a threat at the landscape level[184]

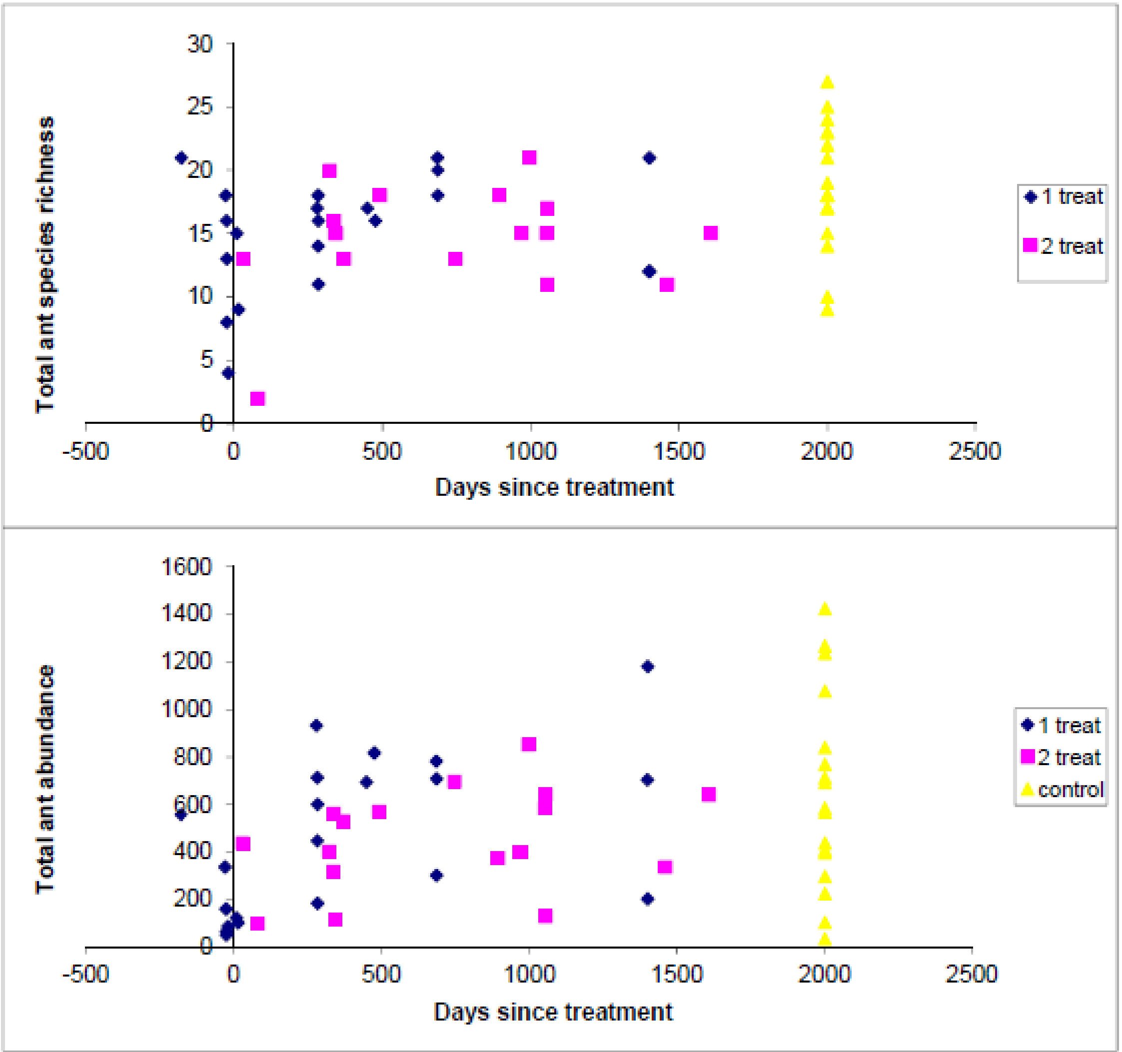


Figure 3.6 Time since treatment and A) species richness, and B) total ant abundance at sites treated with Presto ant bait (0.01g/kg applied at 10kg/ha) once (blue diamonds), twice (pink squares) and at untreated controls (yellow triangles)[181]

(Figure 3.7). Although Gove crow butterfly is a narrow-range endemic that is ecologically specialised, Braby[184] concluded there was no evidence of decline.

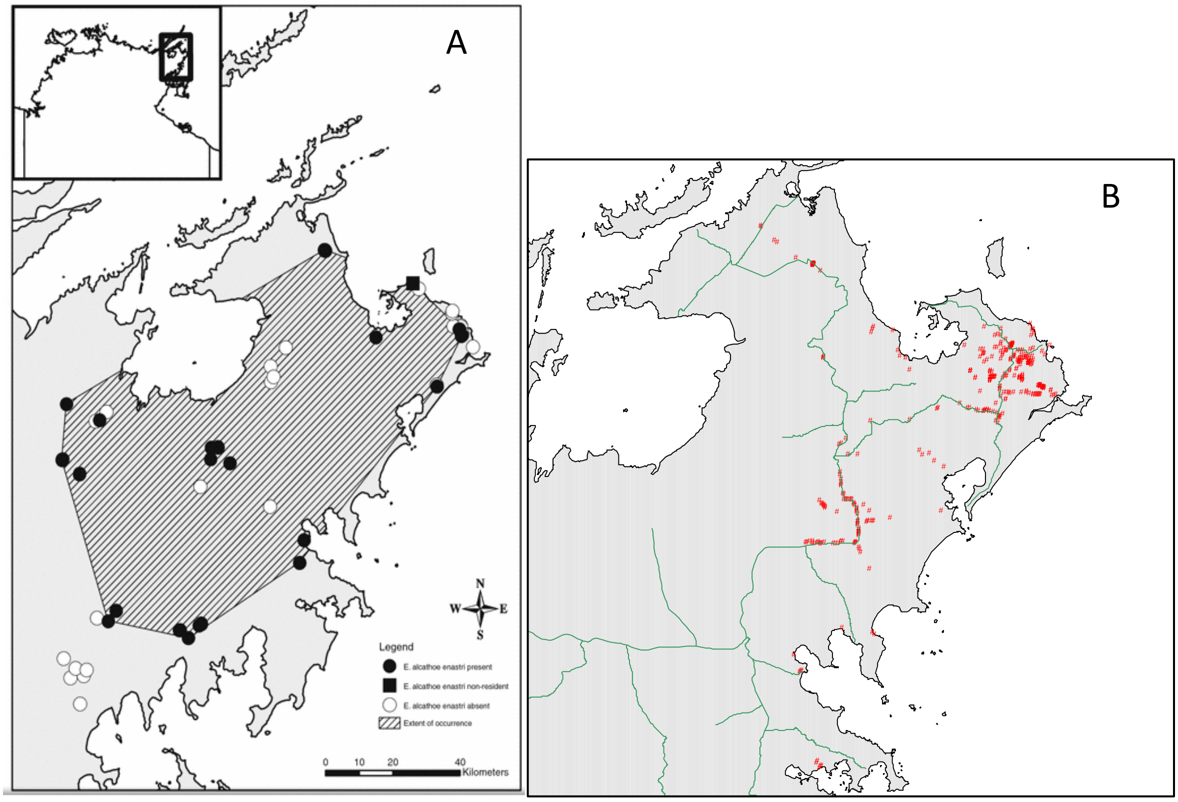


Figure 3.7 A) Distribution map of the Gove crow butterfly showing locations of extant populations (black points) on the Gove Peninsula in north-eastern Arnhem Land, NT[184] and **B)** known sites of yellow crazy ant infestation (red points) in north-east Arnhem Land for the period funded by CfOC[71]).

3.5.5 Future risks to biodiversity if the tramp ants are not contained

In this section we focus on potential for the tramp ant to affect the conservation status of native species.

Mechanisms of potential yellow crazy ant impacts

The yellow crazy ant is a generalist, occurring in a broad range of habitats, from open disturbed areas to natural closed forests. It favours moist, warm and shaded areas, but will tolerate very exposed and hot areas, including rocky slopes and beach dunes. The yellow crazy ant has very general nesting requirements, and can be found in trees, leaf litter, cracks and crevices, or underground. In Arnhem Land, the yellow crazy ants nests almost exclusively on the ground, but readily forages in trees. Its foraging is limited by high temperatures (>44˚C) and low humidity. In ideal conditions, foraging takes place in all hours, with peak activity occurring throughout the night, early morning and late afternoons. The ants forage individually, but will actively recruit to a food source.

There have been several previous reviews and other studies of yellow crazy ant impacts in invaded ecosystems (e.g., [3, 117, 185]). Accordingly a full review is not presented here.

Yellow crazy ants affect other species through several processes. We summarise the salient points, relevant to risk assessment, from published reviews and other literature:

Predation on animals

- The yellow crazy ant is a scavenging predator with a broad diet. It preys on a variety of litter and canopy fauna, from small isopods, myriapods, earthworms, molluscs, arachnids, and insects to land crabs, birds, small mammals, and small reptiles.
- Although they do not have a sting or strong mandibles, yellow crazy ants spray formic acid as a defence mechanism and to subdue their prey.
- Effects on amphibians poorly studied.

Dependence on carbohydrate sources

- Yellow crazy ants will actively source carbohydrate-rich nutrient sources such as plant nectar or honeydew.

Predation on seeds

- Yellow crazy ants are not known to be particularly effective seed predators.

Behavioural displacement

- Avoidance of areas with high yellow crazy ant densities by birds and mammals
- Disruption of bird nesting attempts and fledgling success
- Disruption of frugivory by birds
- Some tree-nesting birds appear to be able to coexist with yellow crazy ants, although there is a high degree of irritation

Disruption of native myrmecophilous associations

- Native ants can be displaced, with consequent effects on species of insects and plants tended by those native ants.

Competition for food

The yellow crazy ant has a high search efficacy at the colony level and thus high rates of discovery of food items, leading to monopoly of food resources. Consequences for other species include:

- Direct competition with bird, mammal, reptile, amphibian and invertebrate species that overlap in diet and are active in the same habitat space
- Indirect competition with bird, mammal, reptile, amphibian and invertebrate species that may suffer reduced food availability due yellow crazy ants reducing prey or host abundances through direct competition or predation

- Yellow crazy ants simplify invertebrate communities, with potential negative effects on native species that utilize invertebrates as food

Indirect ecosystem-level effects

- Displacement of ants that provide functional roles not taken over by yellow crazy ants, leading to shifts in ecosystem properties and ecosystem functioning
- Foraging for nectar can lead to displacement of other invertebrate flower visitors, including pollinators, leading to reduced reproductive fitness in some plant species, and in turn leading to shifts in vegetation composition. Impact most important in pollen-limited, arthropod-pollinated plants.
- Yellow crazy ant interactions with hemipterans can lead to outbreaks of these sap-sucking insects and in turn influence plant fitness and vegetation composition. Ants may increase hemipteran populations by removing honeydew that contributes to the growth of sooty mould, moving nymphs to better sites, and deterring parasites and predators.
- Ant invasions generally have negative consequences for plants that rely on ants for seed dispersal (myrmecochory). Invasive ants are typically poor seed dispersers due to smaller body size relative to specialist native seed-dispersing ants. This has not been tested for yellow crazy ants.
- Decreases fruit handling by birds and may erode seed dispersal, a key ecological function

Prior risk assessments

Modelling of the potential distribution using climate matching, suggests that the yellow crazy ant is capable of inhabiting most of northern and north-eastern Australia, from the Kimberley through Darwin, Cape York Peninsula, and down the eastern seaboard of Queensland into coastal and inland parts of northern New South Wales[186].

There has been very limited assessment of biodiversity values at risk from yellow crazy ants in Arnhem Land of the Northern Territory. Work to assess impacts on native ant communities and species at the project site is described above. Additionally there has been an earlier recognition of the yellow crazy ant as a threatening process in populations of Gove crow butterfly, also mentioned above.

The Dhimurru Draft Plan for Yellow Crazy Ant Management[21] makes limited assessment of biodiversity values at risk in Northern Territory, relying heavily on experiences on Christmas Island and other invaded regions to argue that all terrestrial ecosystems in northern regions of the Territory are at risk of ecological damage from this ant, and therefore all Listed species and communities in the region are at risk. Young et al.[187] also concluded that the yellow crazy ant is a serious threat to the invertebrate fauna of monsoon rainforests in northern Australia.

The yellow crazy ant was listed in 2005 as a key threatening process under the *Threatened Species Conservation Act* in Christmas Island[188] and New South Wales[80]. For Christmas Island, ten species were identified as currently or potentially threatened by yellow crazy ant, and another nine species were mentioned as being affected by yellow crazy ants (see Section 3.6.5). Of these species/subspecies, only Green turtle and Hawksbill turtle are known to occur in Northern Territory.

For New South Wales, species identified as potentially threatened by the presence of yellow crazy ant included ants such as *Rhytidoponera* spp., *Pheidole* spp., *Paratrechina* spp., the Eastern sedgefrog (*Litoria fallax*), the Eastern grass skink *Lampropholis delicata*, and Short-limbed snake-skink [as a burrowing skink](*Ophioscincus truncatus*). The mentioned ant genera are well represented in Northern Territory, but the species involved are likely to vary between the two regions [note many species formerly placed in *Paratrechina* are now assigned to genus *Nylanderia*]. The frog and lizards mentioned do not occur in Northern Territory.

A re-assessment of potential impacts of yellow crazy ant

We assessed risks in the Arnhem Coast Bioregion, focusing principally on listed species, but additionally included species recognized as high priority in the bioregion (e.g., [189, 190]) and species that are common, characteristic or otherwise iconic elements of the regions' fauna and flora (e.g., [191-194]. These rapid assessments are summarized numerically in Table 3.9, and detailed in narrative in Appendix 4.

We assessed a total of 78 species or subspecies for potential risk from the yellow crazy ant, comprising 32 birds (5 EPBC listed); 17 mammals (6); 23 reptiles (7); 4 amphibians (0); and 2 invertebrates (1). The taxa assessed encompassed the full spectrum of conservation status, with several listed by the Commonwealth under the EPBC Act as indicated, others listed at the state level, while further taxa are currently not considered threatened or at least not yet subject to a formal listing process.

The assessments provide a provisional ranking of native species for impact from yellow crazy ants, and thus a useful starting point for prioritization among native species for more comprehensive impact assessments and monitoring within the Arnhem Coast Bioregion.

Birds

Among our sample of birds, only Roseate tern (*Sterna dougallii*) was assessed as not being affected by yellow crazy ant should it not be contained and spread throughout the Coastal Arnhem Land Bioregion. Roseate terns will escape the attentions of crazy ants because although it occurs within the bioregion, this pelagic species does not to our knowledge nest on the Arnhem Land mainland. Thus our sample estimates ~97% of birds in the bioregion would be affected by yellow crazy ants in some way. Of the species/subspecies assessed, Australian bustard (*Ardeotis australis*), Bush stone-curlew (*Burhinus grallarius*), Chestnut-breasted button-quail (*Turnix castanotus*), Crested shrike-tit (N) (*Falcunculus frontatus whitei*) ('Vulnerable'), Rainbow bee-eater (*Merops ornatus*), Rainbow pitta (*Pitta iris*), Black-tailed treecreeper (*Climacteris melanurus*), Gouldian finch (*Erythrura gouldiae*) ('Endangered') and Masked lapwing (*Vanellus miles*) are considered most likely affected to a significant degree with foraging likely disrupted and their food resources (mostly invertebrates and small vertebrates) diminished by yellow crazy ants. Black-tailed treecreeper, Gouldian finch and Masked lapwing are also likely to suffer reduced reproductive output with crazy ants disrupting nest occupancy and fledgling success.

While primarily a granivore, Partridge pigeon (eastern) (*Geophaps smithii smithii*) ('Vulnerable') would similarly suffer disruption of foraging, reduced insect food resource, and, more particularly, disruption of its ground nesting habit. In our sample of birds, Partridge pigeon is most dependent on the Arnhem Coastal Bioregion, and degradation of habitat in the region by yellow crazy ants would require a re-assessment of its conservation status.

The estuarine feeding Little tern (*Sterna albifrons*) nests along the coast in the Arnhem Coastal Bioregion. Our assessment indicates the nesting would be disrupted if yellow crazy ant is not contained.

Mammals

All mammals in our sample are considered likely to be affected by the yellow crazy ant should it not be contained. For 7 species/subspecies (41%), the level of impact may be sufficient to undermine their conservation status within the Arnhem Coast Bioregion. In the case of the small-bodied Black-footed tree-rat (*Mesembriomys gouldii*), Brush-tailed rabbit-rat (*Conilurus penicillatus*) (Australia subspecies) ('Vulnerable'), Golden bandicoot (mainland) (*Isoodon auratus auratus*) ('Vulnerable'), Northern hopping-mouse (*Notomys aquilo*) ('Vulnerable') and Short-beaked echidna (*Tachyglossus aculeatus*), yellow crazy ants are likely to reduce reproductive output, disrupt foraging, and reduce availability or modify the composition of food resource (especially arthropods). For Short-beaked echidna in particular, these assessments must be qualified as ants are a regular diet item[195] and thus impacts may be off-set by increased prey abundance should yellow crazy ant sustain high densities. However, nothing is presently known of the acceptability of yellow crazy ant as a prey item for Short-beaked echidna and indeed for most animal species.

While the 'Endangered' Northern quoll (*Dasyurus hallucatus*) is an omnivore, invertebrates predominate in the diet[196, 197]. As such Northern quoll are vulnerable to the changes in invertebrate community structure and overall abundance that would be wrought by yellow crazy ants. Quolls also utilize nectar and small vertebrates, two additional resources that are likely affected by yellow crazy ants.

Reptiles

Among the 23 species assessed, all but Leathery turtle (*Dermochelys coriacea*) are likely to be affected by yellow crazy ants to some extent. However, only 2 (9%) of these assessed species are considered, by nature of their ecology, to likely be significantly affected by the yellow crazy ant should it fail to be contained and assume a wide distribution in the Arnhem Coast Bioregion. It should be noted, nonetheless, that many skinks – potentially at risk because of their small body size, oviparous reproduction and insectivorous feeding strategy – were not included in our assessments because of lack of information on many aspects of their biology and ecology.

The rather rare Chameleon dragon (*Chelosania brunnea*) is potentially vulnerable to the yellow crazy ant on several counts. With its preference for euculypt forests and woodlands, and activity on both the ground and arboreally, this lizard occupies habitat known to be favourable to yellow crazy ants in Arnhem Land. Thus there is likely to be considerable interaction with crazy ants during foraging and mating. The ground-burrow nesting habit exposes the pipping and juvenile stages to predation by the ants. Additionally, the insectivorous diet of Chameleon dragon comprises in large part green tree ants[198] which, as discussed above, are displaced by yellow crazy ants.

Arafura snake-eyed skink (*Cryptoblepharus gurrmul*) is a habitat specialist with a narrow range. It is presently known only from several small islands – Oxley, New Year and North Goulburn Islands – off the north-east Arnhem Land coast, and is thus vulnerable to disturbances[199] such as introduction of yellow crazy ants. Arafura snake-eyed skink occupies littoral habitats, including beach sands, rocks and coral rubble, and forages among rocks in the intertidal zone for invertebrates. It retreats to fringing supratidal vegetation when confronted by an incoming tide to shelter, forage, and to deposit its egg. During foraging in the littoral zone there is likely to be little interaction with crazy ants, but in the supralittoral zone the ants are likely to disrupt normal behaviour, predate the lizards (especially the pipping and juveniles), and compete for invertebrate prey.

Amphibians

The four frog species assessed were scored low for likely impact from yellow crazy ants, primarily because their aquatic breeding precludes predation on immature stages. However, these frogs are potentially affected by yellow crazy ants competing for invertebrate prey in their non-aquatic foraging grounds.

In our assessments, we treated adult frogs as vulnerable to the predatory attentions of yellow crazy ants. As mentioned above, the predatory activity of yellow crazy ants on amphibians has not been adequately studied. Our assessments may thus overestimate estimate risk to Arnhem Land species if non-aquatic life stages of frogs are not vulnerable to predation by yellow crazy ants.

Invertebrates

As noted by Royer[156], the green tree ant *Oecophylla smaragdina* is the only representative of the genus in Australia. In northern Australia the species maintains a dominant role within native ant communities[162-164] by aggressive colony defense and monopolization of resources. However, it is displaced by the yellow crazy ant[176]. Our assessment is that the green tree ant will be highly affected across the entire Arnhem Coast Bioregion if the yellow crazy ant is not contained.

Gove crow butterfly (*Euploea alcathoe enastri*) is a habitat specialist and as such is less widely distributed in the Arnhem Coast Bioregion than the green tree ant. Our assessment is that Gove crow butterfly is vulnerable to predation by yellow crazy ants, especially in its egg, larval and pupal stages, and thus is likely to be significantly affected should the tramp ant spread within the bioregion.

Table 3.9 Summary of rapid assessments for risk from yellow crazy ants for a sample of fauna in the Arnhem Coast Bioregion

Taxon	Species or subspecies	EPBC Act listing status	Significance	Impact	Geo	Niche	BS	F&F
Bird	Australian bustard (*Ardeotis australis*)	Not listed	1	1.5	2.5	2.5	1	1.5
Bird	Azure kingfisher (*Ceyx azurea*)	Not listed	1	1	2	1.5	1	1
Bird	Banded fruit dove (*Ptilinopus cinctus alligator*)	Not listed	1	1	1	2.5	1	1
Bird	Beach stone-curlew (*Esacus neglectus*)	Not listed	1	1	1	1.5	1.5	1
Bird	Black-tailed treecreeper (*Climacteris melanurus*)	Not listed	2	1.5	1	2.5	1.5	1.5
Bird	Black bittern (Australasian) (*Ixobrychus flavicolllis australis*)	Not listed	1	1	2	1.5	1.5	1
Bird	Bridled tern (*Onychoprion anaethetus*)	Not listed	1	1	0	2	1	0
Bird	Bush stone-curlew (*Burhinus grallarius*)	Not listed	1	1.5	2	2	1	1.5
Bird	Chestnut-breasted button-quail (*Turnix castanotus*)	Not listed	2	1.5	2	2.5	1	1.5
Bird	Crested shrike-tit (N) (*Falcunculus frontatus whitei*)	V	2	1.5	2	2.5	1	1.5
Bird	Eastern curlew (*Numenius madagascariensis*)	Not listed	1	1	1	1	0	1
Bird	Emu (mainland) (*Dromaius novaehollandiae novaehollandiae*)	Not listed	1	1	1.5	2	1	1
Bird	Grey goshawk (*Accipiter novaehollandiae*)	Not listed	1	1	2.5	2	1	1
Bird	Gouldian finch (*Erythrura gouldiae*)	E	1	1.5	2	2.5	1.5	1.5
Bird	Grass owl (E) (*Tyto capensis longimembris*)	Not listed	1	1	1.5	2.5	1	1
Bird	Great-billed heron (*Ardea sumatrana*)	Not listed	1	1	1	1.5	0	1
Bird	Hooded parrot (*Psephotus dissimilis*)	Not listed	3	1	1	2.5	1	1
Bird	Little tern (*Sterna albifrons*)	Not listed	1	1.5	1	2	2	0
Bird	Major Mitchell's cockatoo (*Cacatua leadbeateri*)	Not listed	1	1	1	1.5	1	1
Bird	Masked lapwing (*Vanellus miles*)	Not listed	1	2	1.5	2	2	1.5
Bird	Masked owl (*Tyto novaehollandiae kimberli*)	V	2	1	2.5	2	1	1
Bird	Painted honeyeater (*Grantiella picta*)	Not listed	1	1	2	1.5	1.5	1
Bird	Painted snipe (*Rostratula benghalensis*)	Not listed	1	1	1	1.5	1	0
Bird	Partridge pigeon (E) (*Geophaps smithii smithii*)	V	2.5	1.5	2.5	3	1.5	1
Bird	Rainbow bee-eater (*Merops ornatus*)	Not listed	1	2	2.5	2.5	1	1.5
Bird	Rainbow pitta (*Pitta iris*)	Not listed	2	1.5	2	2.5	1	1.5
Bird	Red goshawk (*Erythrotriorchis radiatus*)	V	1	1	2.5	3	1	1

Table 3.9 continued

Taxon	Species or subspecies	EPBC Act listing status	Significance	Impact	Geo	Niche	BS	F&F
Bird	Roseate terns (*Sterna dougallii*)	Not listed	1	0	0	1	1	0
Bird	Sacred kingfisher (*Todiramphus sanctus*)	Not listed	1	1	1.5	1.5	1	1
Bird	Square-tailed kite (*Lophoictinia isura*)	Not listed	1	1	1.5	1	1	1
Bird	Varied lorikeet (*Psitteuteles versicolor*)	Not listed	1	1	2.5	3	1	1
Bird	White-faced heron (*Ardea novaehollandiae*)	Not listed	1	1	1.5	2	1	1
Mammal	Agile Wallaby (*Macropus agilis*)	Not listed	1	1	2	2	1	1
Mammal	Arnhem sheathtail-bat (*Taphozous kapalgensis*)	Not listed	1.5	1	1	1.5	1	1
Mammal	Black-footed tree-rat (*Mesembriomys gouldii*)	Not listed	2	1.5	2	2.5	1.5	1.5
Mammal	Black wallaroo (*Macropus bernardus*)	Not listed	2	1	1.5	2.5	1	1
Mammal	Brush-tailed rabbit-rat (*Conilurus penicillatus*) (Australia subspecies)	V	2	1.5	2	2.5	1.5	1
Mammal	False water-rat (*Xeromys myoides*)	V	1	1	1	1	1	1
Mammal	Ghost bat (*Macroderma gigas*)	Not listed	1.5	1	2.5	2.5	0	1
Mammal	Golden bandicoot (mainland) (*Isoodon auratus auratus*)	V	3	1.5	2.5	2.5	1.5	1.5
Mammal	Nabarlek (*Petrogale concinna*)	Not listed	3	1	2.5	2.5	1	1
Mammal	Northern hopping-mouse (*Notomys aquilo*)	V	2.5	1.5	2	2	1.5	1.5
Mammal	Northern brush-tailed phascogale (*Phascogale pirata*)	V	3	1	2	2.5	1.5	1.5
Mammal	Northern quoll (*Dasyurus hallucatus*)	E	1	1.5	2	2.5	1	1.5
Mammal	Orange leaf-nosed bat (*Rhinonicteris aurantius*)	Not listed	1	1	2	2.5	0	1
Mammal	Pale field-rat (*Rattus tunneyi*)	Not listed	1	1	2	2.5	1	1
Mammal	Pygmy long-eared bat (*Nyctophilus walker*)	Not listed	1	1	2	2.5	1	1
Mammal	Short-beaked echidna (*Tachyglossus aculeatus*)	Not listed	1	2	2.5	2.5	1.5	1.5
Mammal	Spectacled hare-wallaby (mainland) (*Lagorchestes conspicillatus leichardti*)	Not listed	1	1	2	2	1	1
Reptile	Arnhem land skink (*Bellatorias obiri*)	E	3	1	1	1.5	1	1
Reptile	Arafura snake-eyed skink (*Cryptoblepharus gurrmul*)	Not listed	3	2	2.5	1.5	2	1.5
Reptile	Beach snake-eyed skink (*Cryptoblepharus litoralis*)	Not listed	1	1	2	1.5	1	1
Reptile	Brown tree snake (*Boiga irregularis*)	Not listed	1	1	2.5	2.5	1	1

Table 3.9 continued

Taxon	Species or subspecies	EPBC Act listing status	Significance	Impact	Geo	Niche	BS	F&F
Reptile	Carpet pythons (*Morelia spilota*)	Not listed	1	1	2.5	2.5	1	1
Reptile	Chameleon dragon (*Chelosania brunnea*)	Not listed	1.5	2	2	2.5	1.5	2.5
Reptile	Estuarine crocodile (*Crocodylus porosus*)	Not listed	1	1	2.5	1.5	0	1
Reptile	Green snake (*Dendrelaphis punctulata*)	Not listed	1	1	2	2	1	1
Reptile	Green turtle (*Chelonia mydas*)	V	1	1	1	1	1	0
Reptile	Flatback turtle (*Natator depressus*)	V	1	1	1	1.5	1	0
Reptile	Floodplain monitor (*Varanus panoptes*)	Not listed	1	1	1.5	2	1	1
Reptile	Hawksbill turtle (*Eretmochelys imbricata*)	V	1	1	1	1	1	0
Reptile	King brown snake (*Pseudechis australis*)	Not listed	1	1	1.5	1.5	1	1
Reptile	Leathery turtle (*Dermochelys coriacea*)	E	1	0	0	1	1	0
Reptile	Loggerhead turtle (*Caretta caretta*)	E	1.5	1	0	2	1	0
Reptile	Mertens' water monitor (*Varanus mertensi*)	Not listed	1	1	2	1	1	1
Reptile	Mitchell's water monitor (*Varanus mitchelli*)	Not listed	1	1	1.5	1.5	1	1
Reptile	Northern death adder (*Acanthophis praelongus*)	Not listed	1	1	2	2.5	1	1.5
Reptile	Northern ridge-tailed monitor (*Varanus primordius*)	Not listed	1	1	1	1.5	1	1
Reptile	Oenpelli python (*Morelia oenpelliensis*)	Not listed	2	1	1	1	0	1
Reptile	Olive ridley (*Lepidochelys olivacea*)	Not listed	1	1	1	1	1	1
Reptile	Pig-nosed turtle (*Carettochelys insculpta*)	Not listed	2	1	1	1	1	1
Reptile	Yellow-snouted gecko (*Lucasium occultum*)	E	3	1	0	1	1.5	1.5
Amphibian	Australian wood frog, Water frog (*Rana daemeli*)	Not listed	1	1	2	2	0	1.5
Amphibian	Marbled frog (*Limnodynastes convexiusculus*)	Not listed	1	1	1.5	1.5	0	1.5
Amphibian	Northern dwarf tree Frog (*Litoria bicolor*)	Not listed	1	1	3	1.5	0	1.5
Amphibian	Ornate burrowing frog (*Platyplectrum ornatum*)	Not listed	1	1	1.5	1.5	0	1.5
Invertebrate	Gove crow butterfly (*Euploea alcathoe enastri*)	E	3	2	2.5	2.5	2	1
Invertebrate	Weaver ant (*Oecophylla smaragdina*)	Not listed	1	2.5	3	3	2.5	1.5

[1]Significance = Importance of populations within the Bioregion to the species' security, taking into account the species' conservation status and range size. Low, medium and high translated to numeric 1-3 scale.

[2]Impact = Assessment of likely importance of the tramp ant to persistence of the species within the Bioregion, taking into account Geo, Niche and effects of the tramp ant of breeding success, foraging and food resources. Nil, low, medium and high translated to numeric 0-3 scale. High impact implies the conservation status of the species may change, requiring re-assessment of their respective listed status.

[3]Geo = Extent of likely geographic overlap of the animal species and tramp ant within the Bioregion. Nil, low, medium and high translated to numeric 0-3 scale. Note that species without occurrence in the Bioregion were excluded from the assessments.

[4]Niche = Extent of likely niche overlap of the animal species and tramp ant. Nil, low, medium and high translated to numeric 0-3 scale.

[5]BS = Extent to which breeding success is likely reduced directly or indirectly by the tramp ant. Nil, low, medium and high translated to numeric 0-3 scale.

[6]F&F = Extent to which *foraging* is disrupted, extent to which *food resources* are likely to be reduced directly or indirectly by the tramp ant. Nil, low, medium and high translated to numeric 0-3 scale.

3.6 Yellow crazy ants on Christmas Island

3.6.1 Tramp ant impacts on biodiversity at the project site

The yellow crazy ant was probably accidentally introduced to Christmas Island between 1915 and 1934, and the first supercolony was discovered in 1989[24]. O'Dowd et al.[24] predicted 10-fold yearly increases in extent of supercolonies. Before management was initiated, yellow crazy ant supercolonies occupied about 24.4% of island's rainforest[200] and infested about 25-30km^2 or ~30% of Christmas Island National Park[201].

Table 3.10 summarises the documented impacts of the yellow crazy ant on Christmas Island. Note that much of the work relating to yellow crazy ant on Christmas Island predates current funding by CfOC. Furthermore, some of the research, while highly relevant, was not funded directly from the Parks Australia. Indeed, the boundaries between research funded within the context of the abatement program and that undertaken independently and/or directed at other issues are not always clearly stated in the documents and thus not readily transparent to an outside observer.

Red land crabs

Red land crabs (*Gecarcoidea natalis*) are largely extirpated from areas infested by yellow crazy ant supercolonies[24], and it is estimated that one quarter to one third of the crabs had been killed by the late 1990s[202]. Yellow crazy ants spray formic acid into eyes, mouthparts and leg joints of Red land crabs, which become blind, paralysed, dehydrated, and succumb within 24-48 hours[85]. Crablings that emerge from the ocean must migrate inland to the forest floor of the island's Central Plateau, a route that for many young crabs passes through areas occupied by yellow crazy ants. Models of trends in Red land crab burrow densities (as a surrogate for crab numbers) across 811 sites included in the IWS from 2001 to 2009 indicate a strong negative relationship between burrow counts and yellow crazy ant density, and significant localised changes in burrow densities, suggesting a dynamic system[203, 204].

In the 1990's after the development of yellow crazy ant supercolonies, it was recognized that through displacement of the keystone species, the Red land crab, the yellow crazy ant was bringing about profound changes in biotic composition and functioning of the island's rainforest ecosystems. In the undisturbed rainforest, Red land crab was found to be the dominant forest floor consumer (e.g.,[24, 205-207]), clearing the forest floor of leaf litter and consuming most seeds and seedlings before they can become established. By digging burrows, they turn over and aerate the soil and promote water absorption. In the absence of the crabs, leaf litter is able to accumulate, seeds germinate, and a lush understorey develops, changing the character of the forest (e.g.,[24, 202, 205, 206, 208-211]).

As a legacy of yellow crazy ant supercolonies, 'ghosted forests' are presently a feature of the island. These ghosted forests are of two types - those from which yellow crazy ant supercolonies have been eliminated but in which Red land crab recovery has been limited, and forests in which there have been no yellow crazy ant supercolonies but from which Red land crabs have vacated due to death on migration through distant supercolonies and thus lack of recruitment. In ghosted forests of both derivations, significant changes in vegetation and soil structure are occurring (e.g., [212])(Table 3.10; Figure 3.8).

Table 3.10 Documented impacts of the yellow crazy ant on native fauna and flora and ecosystem properties at the Christmas Island project site

Taxa studied at site	Monitoring methods at site	Impact at site
Invertebrates		
Red land crab (*Gecarcoidea natalis*)[24, 202, 212, 213]	[212]Comparison of rainforest areas with ant supercolonies and those without (non-invaded, intact) and 'ghosted'. Active burrows of crab counted weekly over 4 months in a 50 × 6m transect for each plot.	[212]Burrow densities (a surrogate for crab abundance) higher in intact sites - no or few burrows at the yellow crazy ant-invaded and ghosted sites.
	[24]Crabs caged for 24 hrs at a supercolony site and a non-invaded, intact site.	[24]Higher mortality in crabs caged at supercolony site (57% vs. 0), but experiment not replicated and thus results not supported by statistical analyses.
	[24]Comparison of burrow occupancy in presence of yellow crazy ants at a supercolony site.	[24]Presence of live crabs in burrows depended on the absence of yellow crazy ants; live crabs never found in ant-occupied burrows; in the absence of ants 72% of sampled burrows were occupied by live crabs ($\chi 2 = 25.56$, $P < 0.001$, chi-square test).
	[213]Fifteen 0.25 ha plots in sites with and without yellow crazy ants. Active burrows counted in 100m x 4m belt transect in each plot.	[213]Burrow densities (no./m^2) were three-fold higher ($P = 0.008$) in non-invaded, intact sites compared to non-baited yellow crazy ant-invaded sites.
	[202]Six 1ha plots in yellow crazy ant-invaded forest sites were paired with 1ha non-invaded sites; paired plots within 200m of each other. Numbers of dead crabs and crab burrows counted in five 4m x 4m plots at each site.	[202]Density of crabs burrows lower (No./80m^2 2.3 vs. 95.7, $P = 0.001$) and of dead crabs (No./80m^2 52 vs. 0, $P = 0.007$) higher at invaded sites.
Ground-dwelling ant communities[24, 213]	[24]Comparison of yellow crazy ant supercolony sites and those without (non-invaded, intact), using sugar lures.	[24]Three-fold higher ant abundance at lures at supercolony sites, but yellow crazy ants dominated counts there. Differing community composition, with *Paratrechina* sp. A, *Odontomachus simillimus*, *Solenopsis geminata*, *Pheidole megacephala*, and *Monomorium* spp. only recorded in non-invaded sites, and *Pheidole megacephala* co-occurring with crazy ants at invaded sites.

Table 3.10 continued

Taxa studied at site	Monitoring methods at site	Impact at site
	[213]Fifteen 0.25 ha plots in sites with and without yellow crazy ants. Litter sampled in 0.25 m^2 quadrats until 1 kg of fine litter was collected and then invertebrates extracted by Winkler eclectors.	[213]GLM analyses (randomised block design with repeated measures) and community compositional patterns in Nonmetric multidimensional scaling (NMDS) ordinations combined with ANOSIM detected differences neither in abundance nor community structure. However, results expressed as density of invertebrates per gram of dry litter and thus did not account for litter mass differences between sites.
Ground invertebrates (excluding yellow crazy ants)[212 213]	[212]Comparison of rainforest areas with yellow crazy ant supercolonies and those without (non-invaded, intact) and 'ghosted'. Invertebrates >2mm body size extracted from litter in Winkler eclectors and quantified as numbers per square meter.	[212]Highest in ghosted sites and lowest in intact sites, consistent with standing litter mass (averaging 267, 291, and 354 invertebrates/kg litter at invaded, intact, and ghosted sites, respectively).
	[213]Fifteen 0.25 ha plots in sites with and without yellow crazy ants. Litter sampled in 0.25 m^2 quadrats until 1 kg of fine litter was collected and then invertebrates extracted by Winkler eclectors.	[213]GLM analyses (randomised block design with repeated measures) and community compositional patterns in Nonmetric multidimensional scaling (NMDS) ordinations combined with ANOSIM detected differences neither in abundance nor community structure at ordinal- and species-levels. However, results expressed as density of invertebrates per gram of dry litter and thus did not account for litter mass differences between sites.
Scale insects in canopy trees[202, 214-216]	[214, 215]BACI design, yellow crazy ant exclusion experiment.	[214, 215]Exclusion of crazy ants caused 100% decline in the density of scale insects in the canopies of 2 rainforest trees species within 12 months.
	[216]Sampled from 5 canopy tree species at 5 sites for yellow crazy ant-invaded and non-invaded, intact forests sites. Canopies 'fogged' with pyrethrum and falling insects collected in 5 0.5m^2 funnels.	[216]Large differences in Hemiptera abundance between treatments, with lowest numbers in canopies of non-invaded intact forest sites. Across treatments, abundances Hemiptera and ants (mainly yellow crazy ants) were highly correlated (r^2 = 0.58, P<0.001).

Table 3.10 continued

Taxa studied at site	Monitoring methods at site	Impact at site
	[202]Six 1ha plots in yellow crazy ant-invaded forest sites were paired with 1ha non-invaded sites; paired plots within 200m of each other. Scale insect abundance and sooty mould cover on leaves and stems removed from canopy for each of 5trees (>20 cm DBH) at each site. Scale insects were counted on a randomly chosen 20cm section of 5 shoots and on a randomly chosen, fully expanded leaf from each shoot. Sooty mould cover on these stems and leaves was rated as 0–20 (0), 21–40 (1), 41–60 (2),61–80 (3), or 81–100 (4) percentage cover.	[202]Density of scale insects was higher at yellow crazy ant-invaded sites (No./20cm stem 115 vs. 8, P= 0.008; No./leaf 122 vs. 7, P= 0.001). Sooty mould rating was similarly higher at invaded sites (Stem 2.2 vs. 0.4, P = 0.001; Leaf 2.0 vs. 0.2, P = 0.004).
Arthropods in canopy trees[216]	Sampled from 5 canopy tree species at 5 sites for yellow crazy ant-invaded and non-invaded, intact forests sites. Canopies 'fogged' with pyrethrum and falling insects collected in 5 0.5m^2 funnels.	Arthropod abundances (excluding yellow crazy ants and Hemiptera) not differing between treatments (P = 0.23), but sample sizes small.
Giant African land snail (*Achatina fulica*)[217]	Modelling of snail invasion of rainforest over 7 years based data from 750 IWS sites.	Probability of snail occurrence was facilitated 253-fold in presence of supercolonies, but impeded in intact forest where predaceous native Red land crabs remained abundant.
	Experimental suppression of yellow crazy ant supercolonies	Probability of snail invasion declined by allowing recolonisation by Red land crabs.
Birds		
Abbott's booby (*Papasula abbotti*)[94]	2009 census during biennial island-wide survey by looking and listening for each species for a minimum of 10 minutes at 889 points across the island.	Logistic regression model of probability of occurrence indicated widespread distribution on the island, with no evidence of a negative impact of high density yellow crazy ant supercolonies.
Christmas Island thrush (*Turdus poliocephalus erythropleurus*) **212 203, 216, 218**	[212]Point counts and observation of behaviour in yellow crazy ant-invaded (with supercolonies), non-invaded and 'ghosted' rainforest sites. Observations for 20 minutes at 2 points, repeated 20 times over 5 months.	[212]Nest-site location changed, and nest success and juvenile counts lower in invaded sites.

Table 3.10 continued

Taxa studied at site	Monitoring methods at site	Impact at site
	[218]Artificial fruiting displays and model fruits used to measure fruit handling by birds. Ten displays were attached to separate understorey plants at breast height and placed >25m apart within a 100m x 50m plot. One fruit survey was completed at each of 5 sites in October, November and January over 4 days.	[218]Of the 1151 model fruits that were handled (26% of all fruits presented), the handling rates were 2.2 and 2.4 times lower, and pecking rates 2.6 and 4.5 lower in yellow crazy ant-invaded sites than in intact and ghosted sites, respectively.
	[218]Yellow crazy ant exclusion from 10 displays at invaded sites by placing Tanglefoot bands at the base of each fruit display.	[218]Numbers of model and real fruits handled were 6.4 and 3.5 times higher, respectively, on yellow crazy ant-excluded displays than on displays accessible to ants.
	[216]Comparison of yellow crazy ant-invaded and non-invaded, intact forests sites. Diurnal observations for 20 minutes at 2 points per plot, repeated 11 times over 12 months.	[216]No significances between treatments.
	[203]2009 census during biennial island-wide survey by looking and listening for each species for a minimum of 10 minutes at 889 points across the island.	[203]Logistic regression model of probability of occurrence indicated widespread distribution on the island, no evidence of a negative impact of high density yellow crazy ant supercolonies.
Christmas Island emerald dove (*Chalcophaps indica natalis*)[203, 212, 216]	[212]Point counts and observation of behaviour in yellow crazy ant-invaded (with supercolonies), non-invaded and 'ghosted' rainforest. Observations for 20 minutes at 2 points, repeated 20 times over 5 months.	[212]Counts 9–14 times lower in invaded forest.
	[216]Comparison of yellow crazy ant-invaded and non-invaded, intact forests sites. Diurnal observations for 20 minutes at 2 points per plot, repeated 11 times over 12 months.	[216]No significances between treatments.
	[203]2009 census during biennial island-wide survey by looking and listening for each species for a minimum of 10 minutes at 889 points across the island.	[203]Logistic regression model of probability of occurrence indicated widespread distribution on the island, no evidence of a negative impact of high density yellow crazy ant supercolonies.
Christmas Island imperial-pigeon (*Ducula whartoni*)[203]	2009 census during biennial island-wide survey by looking and listening for each species for a minimum of 10 minutes at 889 points across the island.	Logistic regression model of probability of occurrence indicated widespread distribution on the island, no evidence of a negative impact of high density yellow crazy ant supercolonies.

Table 3.10 continued

Taxa studied at site	Monitoring methods at site	Impact at site
Christmas Island white-eye (*Zosterops natalis*)[203, 212, 216, 218]	[212]Point counts and observation of behaviour in yellow crazy ant-invaded (with supercolonies), non-invaded and 'ghosted' rainforest. Observations for 20 minutes at 2 points, repeated 20 times over 5 months.	[212]Counts and foraging success higher in invaded forest.
	[218]Artificial fruiting displays and model fruits used to measure fruit handling by birds. Ten displays were attached to separate understorey plants at breast height and placed >25m apart within a 100m x 50m plot. One fruit survey was completed at each of 5 sites in October, November and January over 4 days.	[218]Of the 1151 model fruits that were handled (26% of all fruits presented), the handling rates were 2.2 and 2.4 times lower, and pecking rates 2.6 and 3.5 lower, in yellow crazy-invaded sites than in intact and ghosted sites, respectively.
	[218]Yellow crazy ant exclusion from 10 displays at invaded sites by placing Tanglefoot bands at the base of each fruit display.	[218]Numbers of model and real fruits handled were 6.4 and 3.5 times higher, respectively, on yellow crazy ant-excluded displays than on displays accessible to ants.
	[216]Comparison of yellow crazy ant-invaded and non-invaded, intact forests sites. Diurnal observations for 20 minutes at 2 points per plot, repeated 11 times over 12 months.	[216]Fewer birds in non-invaded, intact forest sites (P = 0.041).
	[203]2009 census during biennial island-wide survey by looking and listening for each species for a minimum of 10 minutes at 889 points across the island.	[203]Logistic regression model of probability of occurrence indicated widespread distribution on the island, no evidence of a negative impact of high density yellow crazy ant supercolonies.
Reptiles		
Christmas Island gecko (*Lepidodactylus listeria*)[216]	Comparison of yellow crazy ant-invaded and non-invaded, intact forests sites. Nocturnal observations for 30 minutes at 2 points per plot, repeated 8 times over 12 months.	Lower abundance in yellow crazy ant-invaded sites than non-invaded, intact forest (approaching significance at P = 0.074-0.076).
Indirect impacts on ecosystem properties and processes		
Litter mass on forest floor[24, 202, 212, 213]	[24, 212]Comparison of rainforest areas with yellow crazy ant supercolonies and those without (non-invaded, intact) and 'ghosted'. All litter in 6 0.5-m^2 quadrats per plot dried at 70 ◦C for 48 h and weighed.	[24, 212]Highest in ghosted forest and lowest in non-invaded forest.

Table 3.10 Continued

Taxa studied at site	Monitoring methods at site	Impact at site
	[213]Fifteen 0.25 ha plots in sites with and without yellow crazy ants. Litter sampled from 0.25 m^2 quadrats.	[213]Litter mass/m^2 did not differ between treatments.
	[202]Six 1ha plots in yellow crazy ant-invaded forest sites were paired with 1ha non-invaded sites; paired plots within 200m of each other. Percentage litter cover estimated from presence/absence of leaf litter at each of 49 point intersections on a string grid 50cm x 50cm within each of 5 4m x 4m plots/site.	[202]Litter cover double at yellow crazy ant-invaded sites (87% vs. 43%, P = 0.006)
Seedling community composition[24, 202, 212]	[24, 212]Comparisons of yellow crazy ant-invaded supercolony sites paired with non-invaded, intact sites in each of six areas. Numbers, sizes (height in mm), and species identity of seedlings determined for 5 4m x 4m plots at each site.	[24, 212]Seedling densities were over 30 times greater in invaded sites than in non-invaded, intact sites (1375 /80 m^2 vs. 45 /80 m^2). Seedling species composition similarly differed: 17 species recorded overall in non-invaded, intact sites, with seedlings of *Barringtonia racemosa* (30%), *Inocarpus fagifer* (25%), and *Tristiropsis acutangula* (24%) dominant; 33 species in invaded sites, with *Arenga listeri* (18%), *Celtis timorensis* (14%), and *Pisonia umbellifera* (12%) most abundant, but no species dominant.
	[202]Six 1ha plots in yellow crazy ant-invaded forest sites were paired with 1ha non-invaded sites; paired plots within 200m of each other. Seedlings <200cm height counted in each of 5 4m x 4m plots/site.	[202]Seedling density 30-fold higher (No./80m^2 1376 vs. 45, P <0.001) and seedling species richness 3.5-fold higher at invaded sites (No./80m^2 22.2 vs. 6.3, P =0.002). Relative species composition of seedlings in understorey differed significantly between invaded and intact sites (ANOSIM P = 0.009).
Forest canopy condition[202]	Six 1ha plots in yellow crazy ant-invaded forest sites were paired with 1ha non-invaded sites; paired plots within 200m of each other. Canopy condition for each of 5 trees (>20 cm DBH) at each site estimated by collecting 30 shoots from each of 5 branches removed from the canopy. Presence or absence of canopy dieback in each tree was determined with binoculars.	Percentage of shoots with active growth lower at yellow crazy ant-invaded sites (73% vs. 96%, P = 0.024). Tree dieback higher at invaded sites, with 51% of trees showed evidence of dieback where yellow crazy ants were present; but just 18% of trees were affected at non-invaded sites ($\chi 2$ = 77.7, P < 0.0001).

Protection and restoration of Red land crab populations has been a prime motivation by CINP in its yellow crazy ant abatement program.

Smith & Boland[204] (2011) and Smith et al.[93] modelled trends in Red land crab burrow densities (as a surrogate for crab numbers) across 811 waypoints included seven times in the Island-wide-survey (IWS), 2001 to 2009 inclusive. These authors noted that there had been an 18% decline in Red land crab numbers over the 8 year period from 2001. Nonetheless, their Bayesian hierarchical spatial model indicated densities of crab burrows have remained more-or-less stable since 2001, but with significant localised changes in burrow densities, suggesting a dynamic system. They detected a strong negative relationship between burrow counts and yellow crazy ant density (β = -0.55, 95% CI = -0.60 to -0.50), but the model evidently did not include baiting history as an explanatory variable. Thus analyses of the IWS data to date have not fully explored the extent of Red land crab ecological release achieved from yellow crazy ant supercolony suppression. Smith et al.[93] did recognise, however, that the current management regime of baiting yellow crazy ant supercolonies may be problematic in the sense that baiting is retrospective. The negative relationship between yellow crazy ant density and burrow counts, in addition to field observations by CINP staff, indicates that considerable mortality is likely to occur in Red land crab populations as yellow crazy ant supercolonies form, which, under the current control strategy by necessity precedes baiting. Consequently, yellow crazy ants are likely to be a significant source of Red land crab mortality in the interval between formation of supercolonies and the subsequent delineation of the supercolonies and fipronil baiting campaign.

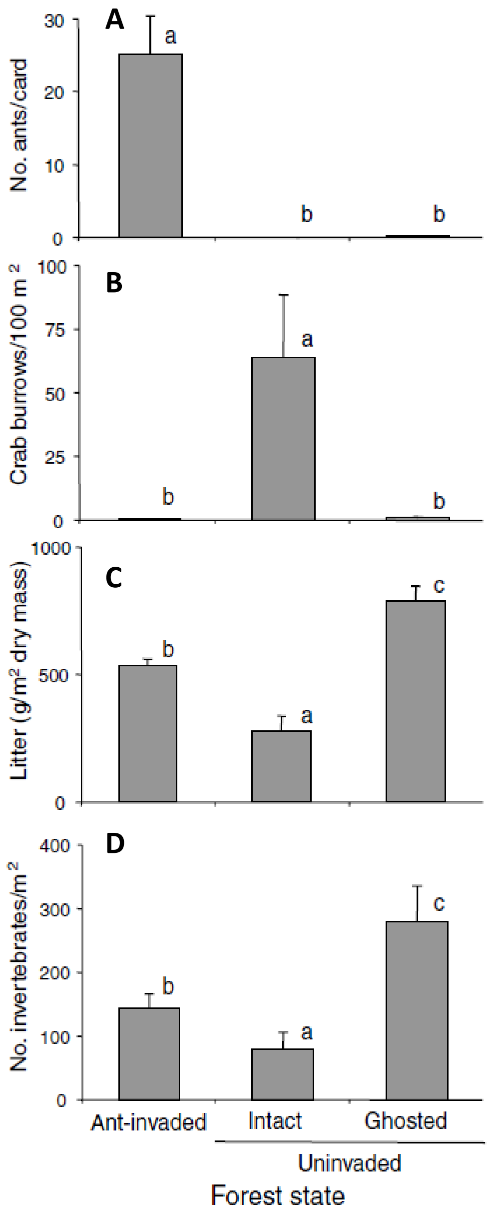
The most recent IWS data, from 2011, has been interpreted as indicating a 3-7% increase in the number of Red land crab burrows since 2009, based solely on the 893 waypoints surveyed in both years[89]. However, these results are as yet not supported by statistical analyses, and inspection of the data suggests the mean change in burrow numbers between 2009 and 2011 may be well within the bounds of fluctuations between biennial surveys. Moreover, the burrow counts in the 'Evergreen forest' zone on the island suggest a strong decline in Red land crab over the period 2001 to 2011.

Scale insects

The presence of carbohydrate-excreting, phloem-sucking, hemipteran scale insects was likely pivotal to the development of supercolonies in yellow crazy ant on Christmas Island by providing a ready resource to 'fuel' the growth of yellow crazy ant populations[24, 202 214, 215, 219]. There is increasing international evidence for the importance of mutualisms with carbohydrate-excreting hemipteran scale insects in invasion success in tramp ants (e.g., [136, 220-222]).

Twenty-one species of introduced scale insects are now known to be present on Christmas Island[91], each considered to have broad host ranges. Of these, at least eight species are known to be tended by yellow crazy ants[91, 215]. The Lac scale (*Tachardina aurantiaca* (Kerriidae)) and the Soft scale (*Coccus celatus* (Coccidae)) are thought to be the species principally tended by yellow crazy ants. These insects are associated with at least 21 and 10 tree species, respectively, including those important in the rainforest canopy[24, 202, 211]. Of particular concern is the tending of Lac scale on Tahitian chestnut (*Inocarpus fagifer*), the native tree dominating the rainforest canopy. The tree suffers high mortality, reduced fecundity, and high seedling mortality in invaded sites and may be listed as a vulnerable species because of yellow crazy ants[24, 91, 188, 214].

Figure 3.8 Relationship between forest state (ant-invaded, intact, and ghosted) on Christmas Island and **A)** activity of the yellow crazy ant, **B)** burrow density of the Red land crab, **C)** litter mass, and **D)** abundance of litter invertebrates >2 mm in length. Means (1 SE) are shown. N = 5 sites for each forest state. For comparison of each variable among forest states, bars with different letter labels almost certainly differ from each other. (From Davis et al.[212], figure 1)



Calculation of a site honeydew index based on forest stand structure and composition, and the capacity of different tree species to host important honeydew-producing scale species has indicated that the Lac scale contributed an estimated average of 70% (range 46-86%) of the total honeydew economy on ten 0.25ha forest stands that supported yellow crazy ant supercolonies in 2000-2002[91]. However, these estimates are likely to have decreased in some supercolonies over the past decade as a result of the decline of Tahitian chestnut, a key host plant of Lac scale. Recent work has documented that removal of the Lac scale will result in declines in yellow crazy ant supercolonies (see Biological Control in Section 2.4).

It is clear that yellow crazy ant supercolonies are a major and on-going threat to biodiversity values on Christmas Island. To date their management has depended on use of toxic bait. Nevertheless, it is well recognised that new supercolonies continue to form. And there is concern for the sustainability of this program in terms of its expense, non-target impacts (see next section), and the resources it diverts from other conservation programs. Long-term, sustainable suppression of yellow crazy ant supercolonies may be achieved through biological control of scale insect (see Section 2.4), and thus reduction of the availability of carbohydrate-rich honeydew that has been shown to fuel supercolony development.

Other ecological cascades

An additional ecological cascade has also been shown to occur with the removal of Red land crabs by the ant. Green et al.[217] showed that invasion by the giant African land snail (GALS) (*Achatina* (*Lissachatina*) *fulica*) was facilitated 253-fold in yellow crazy ant supercolonies but impeded in intact forest where predaceous native Red land crabs remained abundant (Table 3.10). Site comparisons and experiments revealed that ant supercolonies, by killing Red land crabs but not GALS, disrupted biotic resistance and provided enemy-free space. Predation pressure on GALS was lower (28.6%), survival 115 times longer, and abundance 20-fold greater in yellow crazy ant supercolonies than in intact forest.

Invertebrate communities

There has been rather little research into the impact of yellow crazy ants on invertebrate communities on Christmas Island. As components of studies on non-target effects of baiting programs for yellow crazy ants, Marr et al. [213] and Stork et al. [216] investigated invertebrate communities in yellow crazy ant invaded and intact forest sites, on the ground and in the forest canopy, respectively. In neither study were differences in abundance and community structure detected (exclusive of yellow crazy ant) (Table 3.10). However, Marr and colleagues [213] expressed results as density of invertebrates per gram of dry litter and thus did not account for litter mass differences between sites, while in Stork et al.[216] sample sizes were small.

A more recent study by Davis et al.[212] has clearly demonstrated differences in ground-dwelling invertebrate communities between intact forest sites and those invaded by yellow crazy ants (Table 3.10; Figure 3.8). Invertebrate numbers were found to be highest at 'ghost' sites and lowest at intact sites, consistent with levels of standing litter mass. Furthermore, O'Dowd et al.[24] found abundance in ant communities to be 3-fold higher at supercolony sites, but dominated by crazy ants. At non-invaded sites the ant communities were much more diverse. *Paratrechina* sp. A, *Odontomachus simillimus*, *Solenopsis geminata*, and *Monomorium* spp. were only recorded at non-invaded sites. *Pheidole megacephala* was present at non-invaded sites but also co-occurred with crazy ants at invaded sites.

Presently, there is little understanding of shifts in invertebrate community structure (both from taxonomic and functional guild perspectives) that might be occurring in association with yellow crazy ant supercolonies.

Vertebrates

There have been several studies that point to site-scale effects of yellow crazy ant supercolonies on vertebrates. As summarized in Table 3.10, Stork et al.[216], Davis et al.[212], Davis et al.[218] demonstrate that the presence of crazy ants can reduce local abundance and/or modify feeding and nesting behaviours in bird species such as Christmas Island thrush (*Turdus poliocephalus erythropleurus*), Christmas Island emerald dove (*Chalcophaps indica natalis*), and Christmas Island white-eye (*Zosterops natalis*). The study by Stork et al.[216] also suggested that local abundance of Christmas Island gecko (*Lepidodactylus listeria*) may be reduced by yellow crazy ants.

The biennial IWS potentially provides data on trends in vertebrate populations at the whole-of-island scale, and relationships to yellow crazy ant supercolonies. Analyses of data from the 2009 IWS by Smith et al. [203] did not detect evidence of a negative impact of high density yellow crazy ant supercolonies on Christmas Island thrush, Christmas Island emerald dove, Christmas Island white-eye, Christmas Island imperial-pigeon (*Ducula whartoni*) or Abbott's booby (*Papasula abbotti*).

Non-target effects of applied pesticides and other actions

The nature of non-target effects of fipronil observed internationally has been reviewed by Tingle et al. and others [178-180], and in relation to potential effects on Christmas Island by Green[223]. The details of the baiting program are described in Section 2.4. Throughout the era of baiting on Christmas Island there has been high emphasis on minimizing non-target impacts. It has been considered unlikely that the aerial baiting campaigns on Christmas Island have significantly affected non-target species because:

- Baiting has been restricted to areas of high density ant infestations (i.e., supercolonies). In these areas, non-target impacts have been regarded as minimal since most native invertebrates would have already been killed by the yellow crazy ant (e.g.,[22 224]),
- Yellow crazy ant activity is so high in such areas they monopolize and remove the baits - at rates of 7% per minute according to Marr et al. [213], which limits exposure in native species[22, 213, 223],
- Fipronil is not applied near waterways, and
- Any inadvertent effects of the bait are likely to be much lower than the effect of crazy ants on the non-target species.

However, CASAP notes[225] that the assumption that yellow crazy ants consistently monopolize applied baits - to the extent that potential adverse effects on other fauna are negated - has not been adequately investigated. It is not unreasonable to expect the rates of discovery of baits by yellow crazy ants to vary spatially due to heterogeneity in environment and condition of supercolonies and the activity levels of the ants. The EPBC referral in relation to the 2012 aerial baiting program suggests that the assumption of bait monopolization by crazy ants be further investigated[225], but results, if any, are not yet available.

Others have also expressed concern about possible non-target effects of fipronil baiting on Christmas Island[226, 227]. In 2010, the Environmental Working Group noted its concern about the toxicity of metabolite forms of fipronil, residual time, and accumulation in the food chain[227]. A subsequently commissioned independent assessment by CESAR Consultants[23] provided no evidence that fipronil or three toxic degradation by-products, fipronil sulfide, fipronil sulfone and fipronil desulfinyl, were accumulating in the environment on Christmas Island. Soil samples analysed for fipronil and its by-products spanned areas that had been baited between 2000-2008, areas that were aerial baited in 2009, and areas that had no history of baiting. In the case of sediment and freshwater, samples came from sites that had not been directly baited with fipronil (except Jones Spring), although areas immediately adjacent to each site have been baited over the 10 year period in which baiting has been conducted. However, this work by CESAR Consultants did not include internal standards, such as seeding soil samples with fipronil baits, to confirm the analytical methods were of sufficient sensitivity to detect environmental levels of the pesticide relevant to the questions at hand, nor were control samples 'spiked' with fipronil to confirm the lengthy delays in processing did not lead to post-sampling degradation. Moreover, the possibility that fipronil or its degradation by-products were accumulated in the food chain were not addressed, despite this aspect being a key concern of the Environmental Working Group. While it was acknowledged that it is possible the fipronil baits were taken immediately by yellow crazy ants and leaving little opportunity for *in situ* breakdown on the soil surface[23], there was no investigation into the levels of fipronil or its degradation by-products at crazy ant nest sites, where accumulation might be expected to be greatest.

We discuss below, and summarize in Table 3.11 work that has been undertaken on Christmas Island to provide data on possible non-target effects of fipronil bait applied for yellow crazy ant control.

Red land crabs and Robber crabs

Although fipronil is known to be toxic to crabs, the risk posed to the Red land crab population by the aerial baiting campaigns directed at yellow crazy ant supercolonies has been considered minimal because crabs were already heavily diminished within supercolonies. Furthermore, observations suggest that the palatability of the particular bait formulation used, Presto® 01 Ant Bait, to Red land crabs is very low, and residual live crabs near the boundaries of yellow crazy ant supercolonies were unlikely to encounter bait because they rarely emerge from their burrows in the dry season, when aerial baiting operations were conducted[201, 223, 224]. There has been limited experimental evaluation of the effect of fipronil bait applications on Red land crab. Most of the available data comes from trends in Red land crab numbers from the biennial IWS. Green[224], for example, reported that insignificant numbers of dead crabs were found by Christmas Island National Park staff in all survey sites adjacent to yellow crazy ant supercolonies and baited as part of the 2002 aerial baiting program (Table 3.11). Nonetheless, these types of observations have not been formally statistically analysed and therefore remain anecdotal in nature.

Green and colleagues [223] noted that the Robber crab is attracted to and poisoned by the bait formulation used in the baiting campaigns against yellow crazy ant supercolonies. To mitigate losses, a methodology was developed using diversionary food sources to attract robber crabs away from baited areas[226, 227]. Lures comprising poultry food pellets mixed with shrimp paste have been deposited by hand or aerial broadcast around the perimeter of areas to be treated, and in some cases supplemented with fallen and diced senescent palm trees. In association with the 2002 aerial baiting program, Green[224] and Green and O'Dowd[201] reported this mitigation to be highly successful, with 5% mortality in Robber crabs in plots around the periphery of treated yellow crazy ant supercolonies (Table 3.11). Despite the considerable effort by CINP staff, more recent observations suggest that attempts to lure the crabs away from areas to be baited have not always been successful[201]. This in part is due to Robber crabs foraging widely and being active under the dry conditions in which baiting occurs. Nonetheless, it is anticipate that few Robber crabs die from bait relative to the number that would be killed by yellow crazy ant should supercolonies have not been baited.

Other invertebrates

Non-target impacts on invertebrate communities have been investigated for the aerial baiting campaigns in 2002[216] and 2009[23] in commissioned consultancies. These studies found no evidence for adverse effects of fipronil baiting on ground-dwelling invertebrates (sampled by pitfall trapping), aerial insects (sampled by sticky intercept traps), canopy arthropods (sampling by 'fogging' canopy trees with pyrethrum) and freshwater seepage invertebrate (sampled by sediment sieving) (Table 3.11). These studies suffered variously from small sample sizes, identification of invertebrates to higher taxonomic group levels only, and lack of non-yellow crazy ant infested controls. Both Stork et al.[216] and Weeks & McColl[23] allude to the low sample sizes yielded by these sampling methods in

Table 3.11 Documented non-target impacts of baiting for yellow crazy ants on native fauna and flora and on ecosystem properties at the Christmas Island project site

Taxa studied at site	Monitoring methods at site	Impact at site
Invertebrates		
Red land crab (*Gecarcoidea natalis*)[224]	Fifteen 0.25 ha plots allocated in triplets to 3 treatments – i) yellow crazy ant-invaded and baited; ii) invaded but not baited; and iii) non-invaded, intact and not baited. Active burrows counted in 100m x 4m belt transect in each plot.	Burrow densities (no./m^2) 3-fold higher in non-invaded, intact sites compared to either baited or non-baited yellow crazy ant-invaded sites.
	2002 aerial baiting program. Field crews ground searched ‘boundary’ plots after the aerial baiting.	Field crews reported seeing fewer than 10 dead (baited) red crabs during all searches of the boundary plots.
Robber crab (*Birgus latro*)[224]	2002 aerial baiting program. Field crews ground searched 30 sites, each 1.4 ha, in vicinity of yellow crazy ant supercolonies after the aerial baiting.	Average mortality rate of 5% among the 831 crabs found across all plots.
Ground-dwelling ant communities[23, 213]	[23]BACI design in conjunction with the 2009 aerial baiting program. Pitfall trapping at 13 sites along each of 6 transects pre- and post fipronil baiting. Traps 120ml polypropylene vials inserted into a polyvinyl chloride (PVC) sleeves (45 mm dia.), buried flush with the surface, and contained 40ml 70% ethanol as preservative.	[23]Community compositional patterns in Nonmetric multidimensional scaling (NMDS) ordinations combined with Multi-Response Permutation Procedures (MRPP) and GLM multivariate ANOVAs used to detect treatment effects. No effect of fipronil aerial baiting on community structure.
	[213]BACI design, with sampling 1 week before and after ground baiting with fipronil. Fifteen 0.25 ha plots allocated in triplets to 3 treatments – i) yellow crazy ant-invaded and baited; ii) invaded but not baited; and iii) non-invaded, intact and not baited. Litter sampled in 0.25 m^2 quadrats until 1 kg of fine litter was collected and then invertebrates extracted by Winkler eclectors.	[213]GLM analyses (randomised block design with repeated measures) and community compositional patterns in Nonmetric multidimensional scaling (NMDS) ordinations combined with ANOSIM used to detect treatment effects. No effect of fipronil ground baiting on abundance and community structure.
	[213]In a block design with 5 replicates, invertebrates sampled from three fipronil ground baiting treatments - baited 2000; baited 2001; and 1 week after baited in 2002. Litter sampled in 0.25 m^2 quadrats until 1 kg of fine litter was collected and then invertebrates extracted by Winkler eclectors.	[213]GLM (split-plot design) and community compositional patterns in Nonmetric multidimensional scaling (NMDS) ordinations combined with ANOSIM used to detect treatment effects. No effect of fipronil ground baiting on abundance and community structure.

Table 3.11 continued

Taxa studied at site	Monitoring methods at site	Impact at site
Ground invertebrates (excluding yellow crazy ants)[23, 213]	[23]2009 aerial baiting program. Pitfall trapping at 13 sites along each of 6 transects pre- and post fipronil baiting. Traps 120ml polypropylene vials inserted into a polyvinyl chloride (PVC) sleeves (45 mm dia.), buried flush with the surface, and contained 40ml 70% ethanol as preservative.	[23]Community compositional patterns in Nonmetric multidimensional scaling (NMDS) ordinations combined with Multi-Response Permutation Procedures (MRPP) and GLM multivariate ANOVAs used to detect treatment effects. No effect of fipronil aerial baiting on community structure.
	[213]BACI design, with sampling 1 week before and after ground baiting with fipronil. Fifteen 0.25 ha plots allocated in triplets to 3 treatments – i) yellow crazy ant-invaded and baited; ii) invaded but not baited; and iii) non-invaded, intact and not baited. Litter sampled in 0.25 m^2 quadrats until 1 kg of fine litter was collected and then invertebrates extracted by Winkler eclectors.	[213]GLM analyses (randomised block design with repeated measures) and community compositional patterns in Nonmetric multidimensional scaling (NMDS) ordinations combined with ANOSIM used to detect treatment effects. No effect of fipronil ground baiting on abundance and community structure at ordinal- and species-levels.
	[213]In block design with 5 replicates, invertebrates sampled from three fipronil ground baiting treatments - baited 2000; baited 2001; and 1 week after baited in 2002. Litter sampled in 0.25 m^2 quadrats until 1 kg of fine litter was collected and then invertebrates extracted by Winkler eclectors.	[213]GLM (split-plot design) and community compositional patterns in Nonmetric multidimensional scaling (NMDS) ordinations combined with ANOSIM used to detect treatment effects. No effect of fipronil ground baiting on abundance and community structure at ordinal- and species- levels.
Arboreal ant communities[216]	2002 aerial baiting program. Sampled from 5 canopy tree species at 5 sites for yellow crazy ant-invaded (with and without fipronil baiting) and non-invaded, intact forests sites. Canopies 'fogged' with pyrethrum and falling insects collected in 5 0.5m^2 funnels.	Ants virtually absent in canopies of intact forest and invaded forests treated with fipronil 12-24 months earlier, but abundant and yellow crazy ant-dominated in canopies of invaded sites (untreated and treated with fipronil 4-8 days previously) (P= 0.056).
Arthropods in canopy trees[23, 216]	[216]2002 aerial baiting program. Sampled from 5 canopy tree species at 5 sites for yellow crazy ant-invaded (with and without fipronil baiting) and non-invaded, intact forests sites. Canopies 'fogged' with pyrethrum and falling insects collected in 5 0.5m^2 funnels.	[216]Arthropod abundances (excluding yellow crazy ants and Hemiptera) not differing between treatments (P = 0.23), but sample sizes small.

Table 3.11 continued

Taxa studied at site	Monitoring methods at site	Impact at site
	[23]2009 aerial baiting program. Sticky traps - rectangular plastic cards (21cm x 10cm) with sticky surface both sides - set at ~10-12m above ground at 13 sites along each of 4 transects pre- and post fipronil baiting.	[23]Community compositional patterns analysed by Multi-Response Permutation Procedures (MRPP) to detect treatment effects. No effect of fipronil aerial baiting on community structure.
Scale insects in canopy trees[216]	2002 aerial baiting program. Sampled from 5 canopy tree species at 5 sites for yellow crazy ant-invaded (with and without fipronil baiting) and non-invaded, intact forests sites. Canopies 'fogged' with pyrethrum and falling insects collected in 5 0.5m^2 funnels.	Large differences in Hemiptera abundance between treatments, with lowest numbers in canopies of non-invaded intact forest sites. Across treatments, abundance of Hemiptera and ants (mainly yellow crazy ants) were highly correlated (r^2 = 0.58, P<0.001).
Freshwater invertebrates[23]	2009 aerial baiting program. Sampled over 10 minute interval at each of 11 permanent freshwater sites with a 250µm net by either 'sweeping' through pooled water, or by placing the net on the substrate in running water and collecting invertebrates dislodged by hand trowel.	Community compositional patterns in Nonmetric multidimensional scaling (NMDS) ordinations combined with Multi-Response Permutation Procedures (MRPP) and GLM multivariate ANOVAs used to detect treatment effects. No effect of fipronil aerial baiting on community structure.
Birds		
Christmas Island thrush (*Turdus poliocephalus erythropleurus*)[216]	2002 aerial baiting program. Comparison of yellow crazy ant-invaded (with and without fipronil baiting) and non-invaded, intact forests sites. Diurnal observations for 20 minutes at 2 points per plot, repeated 6 times with a few days of fipronil baiting and 5 times 12 months later.	No significances between treatments.
Christmas Island emerald dove (*Chalcophaps indica natalis*)[216]	2002 aerial baiting program. Comparison of yellow crazy ant-invaded (with and without fipronil baiting) and non-invaded, intact forests sites. Diurnal observations for 20 minutes at 2 points per plot, repeated 6 times with a few days of fipronil baiting and 5 times 12 months later.	No significances between treatments.

Table 3.11 continued

Taxa studied at site	Monitoring methods at site	Impact at site
Christmas Island imperial-pigeon (*Ducula whartoni*)[216]	2002 aerial baiting program. Comparison of yellow crazy ant-invaded (with and without fipronil baiting) and non-invaded, intact forests sites. Diurnal observations for 20 minutes at 2 points per plot, repeated 6 times with a few days of fipronil baiting and 5 times 12 months later.	Fewer birds at fipronil baited sites than non-baited sites at sampling 12 month after treatment (P = 0.008).
Christmas Island white-eye (*Zosterops natalis*)[216]	2002 aerial baiting program. Comparison of yellow crazy ant-invaded (with and without fipronil baiting) and non-invaded, intact forests sites. Diurnal observations for 20 minutes at 2 points per plot, repeated 6 times with a few days of fipronil baiting and 5 times 12 months later.	Census immediately after fipronil baiting indicated fewer birds in non-invaded, intact forest sites (P = 0.041). No significant differences between treatments at sampling 12 month after baiting (P = 0.272).
Reptiles		
Blue-tailed skink (*Cryptoblepharus egeriae*)[226, 228, 229]	12 plots surveyed 4 times before and after baiting by hand. Skinks counted in 20 minute searches in ~0.5 ha plots.	ANOVA indicated no effect of fipronil baiting (mean counts pre- and post-treatment 3.8 and 5.1/plot).
Christmas Island gecko (*Lepidodactylus listeria*)[216]	2002 aerial baiting program. Comparison of yellow crazy ant-invaded (with and without fipronil baiting) and non-invaded, intact forests sites. Nocturnal observations for 30 minutes at 2 points per plot, repeated 3 times with a few days of fipronil baiting and 5 times 12 months later.	Lower abundance in invaded sites (both untreated and fipronil baited) than non-invaded, intact forest (approaching significance at P = 0.074-0.076).
Indirect impacts on ecosystem properties and processes		
Litter mass on forest floor[226, 228, 229]	[10]Fifteen 0.25 ha plots allocated in triplets to 3 treatments i) yellow crazy ant-invaded and baited; ii) invaded but not baited; and iii) non-invaded, intact and not baited. Litter sampled from 0.25 m^2 quadrats.	[10]Litter mass/m^2 did not differ between treatments.

Christmas Island rainforests. The consequence was low statistical power to detect treatment differences. If these methods are to be further employed in the Island's rainforests, then sample sizes need to be substantially increased.

Studies following baiting by hand have similarly yielded equivocal evidence for non-target effects. Using the canopy 'fogging' method, Stork et al.[216] demonstrated differences in canopy arthropod communities between non-baited yellow crazy ant-infested sites and those ground baited 12 months earlier. Abundances of yellow crazy ants, total arthropods (excluding yellow crazy ants), and total Hemiptera were significantly reduced by baiting ($P = 0.056$, 0.002 and 0.006, respectively), suggesting little community recovery within 12 months. By contrast, Marr et al.[213] found no evidence for non-target impacts on litter invertebrate communities between non-baited and baited (with fipronil 1 week previously) yellow crazy ant-infested sites, despite baits being applied at a higher rate than in the above mentioned aerial baiting operations. They attributed this to the high spatial and temporal variation in non-target populations of litter invertebrates, dietary preferences among non-target invertebrates, and monopolisation and pre-emption of the bait by yellow crazy ants, the last of which was considered most likely.

In the laboratory, Marr et al.[213] found fipronil baits caused rapid and high mortality in four invertebrate groups commonly found within Christmas Island leaf litter, namely cockroaches, millipedes, beetles, and termites. Interestingly, mortality of ants was not influenced by exposure to the bait in these laboratory experiments. The authors suggested caution in interpretation of their results for termites and beetles because of the small sample sizes. A further complication in these experiments was that specific identity was not determined and varied among replicates, but the authors make no mention of variation among species contributing to reduced levels of response to treatment. Additionally, their experimental design did not allow partitioning of mortality between contact and oral toxicity.

Vertebrates

Among Christmas Island vertebrates, reptiles are potentially most at risk from fipronil non-target effects. While fipronil is known to be toxic to reptiles, the potential impact of the Presto Ant Bait on Christmas Island species is unknown [223], but likely to occur through direct ingestion and subsequent poisoning, or through poisoning of their major prey and reducing food availability. Green and colleagues[223] considered the potential impact of baiting operations on reptiles to be of considerable concern. Despite this, there has been limited research into non-target effects of baiting operations on Christmas Island reptiles (Table 3.11).

Stork et al.[216] found no differences in Christmas Island gecko (*Lepidodactylus listeria*) abundances between non-baited and baited (with fipronil 1-2 weeks and 5 months previously) yellow crazy ant-infested sites. An observational experiment on North West Point[226, 228, 229] indicated Blue-tailed skink (*Cryptoblepharus egeriae*) numbers continued undiminished for more than a year following hand baiting with fipronil, whereas yellow crazy ants was eliminated. These studies suggest no direct or indirect effects of fipronil baiting on these reptiles.

Among Christmas Island birds, Green et al.[223] considered four species - Christmas Island thrush, Christmas Island white-eye, Christmas Island goshawk (*Accipiter hiogaster natalis* [as *Accipiter fasciatus*]) and Christmas Island hawk-owl (*Ninox natalis*), to be at indirect risk from the baiting operation because they may either ingest poisoned insects, or because their invertebrate food resources may be adversely affected. Nonetheless, Stork et al.[216] were unable to detect differences in abundance of 4 diurnal bird species between non-baited and baited yellow crazy ant-infested sites sampled at 1-2 weeks and 5 months after baiting (Table 3.11). The species studied were Christmas Island imperial-pigeon, Christmas Island emerald dove, Christmas Island thrush, and Christmas Island white-eye. Sample sizes were small, however, and the conclusions may not be robust.

To our knowledge, there has to date been no investigation into non-target impacts of fipronil baiting on Christmas Island mammals. Green et al. [223] considered the risk to be low for the flying fox (*Pteropus melanotus natalis*)because it is mainly frugivorous. If the Christmas Island pipistrelle (*Pipistrellus* murrayi) and the Christmas Island shrew (*Crocidura attentuata trichura*) are still extant, they may be affected by consuming poisoned invertebrates or via a reduction in availability of insect prey.

Non-target effects summary

In respect to invertebrates, the studies of non-target impacts of fipronil to date may be adequate. Nonetheless, investigations into the impacts of fipronil baiting in areas without yellow crazy ant infestation would yield information about potential impacts, and usefully complement comparisons of baited yellow crazy ant supercolonies with various types of 'control' areas that have been the feature of studies on Christmas Island to date. Furthermore, detection of non-target effects in studies that focus only on ordinal-or family-level counts, and using single sampling methods, is probably unrealistic. This problem is especially acute where overall sample sizes are small and thus statistical power is low. Also, given the effort and resources required to lure Robber crabs away from supercolonies prior to baiting, it behooves CINP staff to thoroughly investigate whether the effort is saving any crabs.

Our review of the available documents suggests that investigation into the effects of fipronil baiting on Christmas Island native vertebrate species has been cursory. Counts of vertebrates in treated and non-treated areas may be too simplistic given the generally low sample sizes in plots and the often large home ranges relative to the extent of study sites. Species-level studies using specialist expertise, and 'whole of life cycle' approaches, are likely required to properly understand the consequences for vertebrate species of high conservation concern. A combination of monitoring, manipulative experiments, and fate studies in the field, supplemented by laboratory toxicological studies would be appropriate. Experimentally, there is a need to separate out the 'yellow crazy ant effect' from the 'fipronil effect' that can confound comparisons of non-treated and treated yellow crazy ant-infested areas. This will require examining impacts of fipronil baiting in areas without yellow crazy ant infestation. Fipronil toxicology is well understood, and it is not productive to repeat the types of toxicological studies that the pesticide's proprietors and other agencies have undertaken during product development and registrations, but it would be informative to investigate potential sensitivities in species of high conservation concern, through experimentation with toxic baits and common surrogate species, and through labeled non-toxic baits and endangered species.

It is not unreasonable to expect that potential non-target impact increases along a gradient of decreasing yellow crazy ant abundance, so that most exposure in the native fauna will occur around the periphery of baited yellow crazy ant supercolonies and in areas lacking yellow crazy ants but inadvertently treated during the aerial operations. CINP staff have addressed this spatial dimension in respect to vulnerability to baiting in Red land crab and Robber crab, but relevance to other fauna has not been investigated.

Yellow crazy ants, and indeed other fauna killed by ingesting bait, are potential sources of secondary poisoning when they are subsequently fed upon by scavenging invertebrates and vertebrates. Secondary poisoning may not be lethal, but may lend to reduced fitness through disruption of growth, reproduction, and/or predator avoidance and needs to be considered in developing experimental and monitoring protocols. Coprophagy has been shown to provide efficient transfer of fipronil toxicity from poisoned cadavers to untreated individuals in laboratory experiments with invertebrates (e.g.,[230-232]) and occurrence of such phenomena in the field should not be discounted without experimental work.

We thus concur with the Environmental Working Group[227] that non-target effects require further and fuller investigation, if use of fipronil over large areas of Christmas Island is to continue.

CESAR Consultants have been contracted to undertake an independent assessment of non-target impacts and bioaccumulation resulting from the three ant baits (fipronil, pyriproxyfen and S-methoprene) used in the 2012 aerial baiting campaign. CESAR have evidently further developed the methodologies used in 2009[23] to enhance the assessment. One refinement involved baiting sites without yellow crazy ant (not done in 2009) to get a better understanding of the non-target impacts. The referral process provides only for baiting in supercolony areas, so rather than baiting areas with no yellow crazy ant, the modified protocol involves extending the buffer zone around supercolonies to where there is a clear distinction between yellow crazy ant-infested and non-infested areas. A final report on the assessment is due March 2013.

3.6.2 Monitoring and evaluation tools used in the program to measure impacts on biodiversity

Yellow crazy ant abatement has been undertaken within the auspices of the CINP Management Plan 2002-2009[233] and the Draft Management Plan 2012-2022[234]. In this context, the IWS, described in Section 2.4, is the chief data collection method for CINP[84] and is key to of monitoring and evaluating impacts on biodiversity. Data collected in the IWS have been used to model trends in various elements of the native and invasive biota (e.g.,[92-94, 203, 204, 217]). From discussions with CINP staff it is clear that much of the data collected has yet to be fully analysed, but its operational utility is well recognized. The IWS grid of waypoints has also proved to be an invaluable research resource, not only for quantifying trends in key native and invasive species alike, but also offer much potential in advancing understanding of how invasions progress and disrupt communities and ecosystem functions. In this respect the papers by Green et al.[217] and Smith et al.[92] are excellent models of an approach that is predictive in both space and time. It is recommended that future efforts in monitoring non-target impacts of baiting campaigns (and other control approaches), and in quantifying ecological release, utilise the resource provided by the IWS grid of waypoints and associated environmental and biotic data.

The Biodiversity Monitoring Program (BMP) has been established at a subset (50-100) of the IWS waypoints to gather additional information not available through the biennial surveys[226]. This will enable detection of changes in abundance of individual species and to species assemblages over time. Christmas Island is in the process of developing a Regional Recovery Plan and both IWS and

BMP data are being used extensively to model the distributions and temporal changes of a range of listed species.

The abatement has been supported by numerous studies on the impacts on Christmas Island biodiversity arising from yellow crazy ant and control operations. The adopted methodologies in these studies are summarised in Tables 3.10 and 3.11 for crazy ant impacts and baiting non-target effects, respectively. CfOC funding was awarded for continuance of the abatement work during the period of 2011-2015. Most of the operational and research activities related to abatement of yellow crazy ant since 2011 have their origins prior to CfOC funding.

3.6.3 Monitoring and evaluation outcomes (both impacts from tramp ants and /or post recovery of species)

The Director of National Parks has implemented yellow crazy ant management since the late 1990s, developed with La Trobe and Monash Universities under the auspices of the Crazy Ant Scientific Advisory Panel. This management is focused on reducing the adverse impact of yellow crazy ants on Christmas Island ecosystems, but should not be divorced from the context of the many conservation issues on the Island[227, 234 233]. The draft Christmas Island National Park Management Plan 2012-2022[234] has provision for continuance of the yellow crazy ant control program, including monitoring the impact of the ants on components of the native fauna such as on Red land crabs.

The current baiting program is able to suppress yellow crazy ant supercolonies for about two years (see Section 2.4.2) and there is evidence that may be helping Red land crab numbers recover. The current Red land crab population is estimated at 47 million[85]. While Red land crab numbers are presently below historical, pre-supercolony levels, the population is estimated to have increased by 3-7% between 2009 and 2011[85] (but see discussion in Section 3.6.1). Anecdotally, Red land crabs are returning to areas that previously had yellow crazy ant supercolonies, and leaf litter accumulations have declined in treated areas[86]. Suppression of yellow crazy ant supercolonies has also reversed the probability of GALS invasion by allowing recolonisation of Red land crabs[217]; GALS were much less likely (0.79%) to invade sites where yellow crazy ant supercolonies were suppressed than where they remained intact.

However, management of yellow crazy ant supercolonies is currently reactive. With current knowledge, formation of new supercolonies cannot be prevented, and can only be controlled after they form, with continuing impacts on biodiversity. The development of a successful biological control program would break the cycle of supercolony formation and obviate the need for ongoing chemical control (see Section 2.4).

While it is clear that yellow crazy ants severely affect keystone species such as the Red land crab and consequently perturbs ecosystem processes and structure, there remain significant gaps in knowledge of effects on other species. It is unclear the extent to which the continuing decline in many of the Island's vertebrates is related to the development of yellow crazy ant supercolonies and to what extent these threats are being arrested through control efforts. Also, aside from its effects on crabs and scale insects, currently there is virtually no knowledge of the impact of the ant on the unique invertebrate communities in Christmas Island rainforests and associated Ramsar wetlands, other than informal observations.

The funding arrangement between Parks Australia and CfOC in relation to continuance of the abatement of yellow crazy ants on Christmas Island does not specifically require monitoring, evaluation and reporting against CfOC targets and outcomes. There was no requirement for a MERI Plan. It is accepted, however, that suppression of yellow crazy ant supercolonies contribute to biodiversity and natural icons priority outcomes to "....reduce critical threats to biodiversity and to enhance the condition, connectivity and resilience of habitats and landscapes" and "....reduce the impact of invasive species....". Christmas Island constitutes a commonwealth managed protected area over a large part of the island; is important to matters covered by the EPBC Act including nationally threatened species and ecological communities, migratory species and marine species; features strongly in various Threat Abatement Plans and Recovery Plans, not least that in relation to abatement of tramp ants; contains critical habitats for one or more species listed under various international agreements to which Australia is a signatory, including the Convention on Migratory Species (marine turtle nesting-sites and many seabird nesting sites), Agreement on the Conservation of Albatrosses and Petrels (ACAP) and various Migratory Bird Agreements with Japan, China, and Korea (JAMBA/CAMBA/ROKAMBA); and features several sites of international significance under the Ramsar Convention. In 2005, the yellow crazy ant was listed under the EPBC Act as a Key Threatening Process on Christmas Island due to its impacts on biodiversity and ecosystem integrity.

The program encompasses a considerable amount of effort towards suppression of yellow crazy ant prior to CfOC funding in 2011-12 (continuing to 2014-15). Further, it should be noted that this program commenced well before the advent of the CfOC five year business plan framework and associated target outcomes. From the information available to this review it is clear that CfOC funding has provided critical continuity in this important program and is ensuring an enduring legacy of efforts by many parties over many years.

3.6.4 Other biodiversity impacts that may be occurring from tramp ants at the program site

Numerous Christmas Island species have previously been identified as at risk, or potentially so, from yellow crazy ant directly or indirectly, including at least 13 bird species, 3 mammals, 9 reptiles, 3 invertebrates, and 1 plant[24, 92, 227 188, 223, 226, 235-242] (Table 3.10, Appendix 5). Several of these species are subject to monitoring on Christmas Island, but a number are not.

The program site (Christmas Island National Park) and the extent to which yellow crazy ants will spread if not contained (whole of Christmas Island) are practically synonymous. Accordingly, further discussion of native species at risk is thus made in Section 3.6.5.

Though some information is available on total abundance of invertebrates in leaf litter and in the canopy, there is little understanding of shifts in invertebrate community structure (both from taxonomic and functional guild perspectives) that might be occurring in association with yellow crazy ant supercolonies. CINP staff note that differences in invertebrate assemblages are readily apparent between sites with supercolonies and those without. At supercolony sites, kicking over leaf litter reveals just yellow crazy ants and some roaches" [86], but such changes in the litter fauna have yet to be documented. Shifts in invertebrate community structure may have conservation implications for insectivorous species, especially those naturally rare and/or those that are niche specialists. The ecological relationships between crabs and other forest-floor invertebrates are not at all well understood.

Additionally, there has been little consideration of indirect effects of yellow crazy ant–scale mutualisms on Red land crabs and other elements of the fauna in Christmas Island rainforests. Herbivores, and many detritivorous invertebrates are primarily dependent on resources provided by plants such as wood, twigs, leaves, flowers, fruits and seed fall, etc. and changes in the quality of these resources – brought about by scale infestation of the trees producing the resources – may have important bottom-up consequences for these guilds[227]. Scale insects also have the potential to disrupt mutualistic and symbiotic relationships, such as rhizobium N-fixation in dominant canopy trees such as leguminous Tahitian chestnut, thus altering the nitrogen content of fresh leaves and litter. There has been recognition[91] that stress of scale-infested trees may have ecosystem-level effects.

Though the ants of Christmas Island are almost entirely non-native[243] their roles in ecosystem functioning deserves some investigation, particularly as they likely change depending on yellow crazy ant density. CASAP members noted localized very high densities of a *Camponotus* species on the island following suppression of yellow crazy ants[95]. Among ants on Christmas Island, the tramp species the tropical fire ant (*Solenopsis geminata,* see Section 6) and African big-headed ant (*Pheidole megacephala*, see Sections on Lord Howe Island) are elsewhere considered serious threats to biodiversity.

3.6.5 Future risks to biodiversity if the tramp ants are not contained

In this section we focus on potential for the tramp ant to affect the conservation status of native species.

Mechanisms of potential yellow crazy ant impacts

The yellow crazy ant is a generalist, occurring in a broad range of habitats, from open disturbed areas to natural closed forests. It favours moist, warm and shaded areas, but will tolerate very exposed and hot areas, including rocky slopes and beach dunes. The yellow crazy ant has very general nesting requirements, and can be found in trees, leaf litter, cracks and crevices, or underground. On Christmas Island, yellow crazy ants nest and forage both on the ground and in trees[9, 24, 215]. Its foraging is limited by high temperatures (>44˚C) and low humidity. In ideal conditions, foraging takes place in all hours, with peak activity occurring throughout the night, early morning and late afternoons. The ants forage individually, but will actively recruit to a food source.

There have been several previous reviews and other studies of yellow crazy ant impacts in invaded ecosystems (e.g., [3, 117, 185]). Accordingly a full review is not presented here.

Yellow crazy ants affect other species through several processes. We summarise the salient points, relevant to risk assessment, from published reviews and other literature:

Predation on animals

- The yellow crazy ant is a scavenging predator with a broad diet. It preys on a variety of litter and canopy fauna, from small isopods, myriapods, earthworms, molluscs, arachnids, and insects to land crabs, birds, small mammals, and small reptiles.
- Yellow crazy ants spray formic acid as a defence mechanism and to subdue their prey. They do not have a sting or strong mandibles.

- Effects on amphibians poorly studied.

Dependence on carbohydrate sources

- Yellow crazy ants will actively source carbohydrate-rich nutrient sources such as plant nectar or honeydew.

Predation on seeds

- Yellow crazy ants are not known to be particularly effective seed predators.

Behavioural displacement

- Avoidance of areas with high yellow crazy ant densities by birds and mammals
- Disruption of bird nesting attempts and fledgling success
- Disruption of frugivory by birds
- Some tree-nesting birds appear to be able to coexist with yellow crazy ants, although there is a high degree of irritation

Disruption of native myrmecophilous associations

- Native ants can be displaced, with consequent effects on species of insects and plants tended by those native ants.

Competition for food

The yellow crazy ant has a high search efficacy at the colony level and thus high rates of discovery of food items, leading to monopoly of food resources. Consequences for other species include:

- Direct competition with bird, mammal, reptile, amphibian and invertebrate species that overlap in diet and are active in the same habitat space
- Indirect competition with bird, mammal, reptile, amphibian and invertebrate species that may suffer reduced food availability due to yellow crazy ants reducing prey or host abundances through direct competition or predation
- Yellow crazy ants simplify invertebrate communities, with potential negative effects on native species that utilize invertebrates as food

Indirect ecosystem-level effects

- Displacement of ants that provide functional roles not taken over by yellow crazy ants, leading to shifts in ecosystem properties and ecosystem functioning
- Foraging for nectar can lead to displacement of other invertebrate flower visitors, including pollinators, leading to reduced reproductive fitness in some plant species, and in turn leading to shifts in vegetation composition. Impact most important in pollen-limited, arthropod-pollinated plants.
- Yellow crazy ant interactions with hemipterans can lead to outbreaks of these sap-sucking insects and in turn influencing plant fitness and vegetation composition. Ants may increase

hemipteran populations by removing honeydew that contributes to the growth of sooty mould, moving nymphs to better sites, and deterring parasites and predators.

- Ant invasions generally have negative consequences for plants that rely on ants for seed dispersal (myrmecochory). Invasive ants are typically poor seed dispersers due to smaller body size relative to specialist native seed-dispersing ants. This has not been tested for yellow crazy ants.
- Decreases fruit handling by birds and may erode seed dispersal, a key ecological function

Prior risk assessments

Yellow crazy ants had both long been established on Christmas Island before abatement work was initiated and had already affected key elements of biodiversity. In this respect, the emergence of the ant as a threat to biodiversity pre-empted a formal risk assessment.

In April 2005, the yellow crazy ant was listed as a Key Threatening Process on Christmas Island. The ant was eligible to be considered a Key Threatening Process under two criteria:

- It could cause a native plant, a number of animal species, and an ecological community to become threatened; and
- It has the potential to cause a number of nationally listed threatened species to become eligible for listing in a higher degree of endangerment. These species included the Christmas Island Pipistrelle, *Pipistrellus murrayi*, the Christmas Island Shrew, *Crocidura attenuata trichura*, and the Christmas Island Gecko, *Lepidodactylus listeria.*

The following species have previously been considered at risk from yellow crazy ant[24, 132, 188, 203, 226, 227, 229, 235-242] and are re-assessed below: Abbott's booby (*Papasula abbotti*); Christmas Island emerald dove (*Chalcophaps indica natalis*); Christmas Island frigatebird (*Fregata andrewsi*); Christmas Island glossy swiftlets (*Collocalia esculenta natalis*); Christmas Island goshawk (*Accipiter hiogaster natalis*); Christmas Island hawk-owl (*Ninox natalis*); Christmas Island imperial-pigeon (*Ducula whartoni*); Christmas Island thrush (*Turdus poliocephalus erythropleurus*); Christmas Island white-eye (*Zosterops natalis*); Christmas Island white-tailed tropicbird, Golden bosunbird (*Phaethon lepturus fulvus*); Common noddy (*Anous stolidus*); Red-footed booby (*Sula sula*); Red-tailed tropic bird (*Phaethon rubricauda*); Christmas Island flying fox (*Pteropus melanotus natalis*); Christmas Island pipistrelle (*Pipistrellus murrayi*); Christmas Island shrew (*Crocidura attenuata trichura*); Blue-tailed skink, Blue-tailed snake-eyed skink (*Cryptoblepharus egeriae*); Christmas Island blind snake (*Ramphotyphlops exocoeti*); Christmas Island gecko (*Lepidodactylus listeri*); Coastal skink (*Emoia atrocostata*); Forest skink (*Emoia navitatus*); Christmas Island giant gecko (*Cyrtodactylus sadlieri*); Green turtle (*Chelonia mydas*); Hawksbill turtle (*Eretmochelys imbricata*); Blue crab (*Discoplax celeste*) [formerly as *Discoplax hirtipes*]; Little nipper (*Geograpsus grayi*); Red land crab (*Geocarcoidea natalis*); Robber crab, Coconut crab (*Birgus latro*). Among these, the yellow crazy ant was mentioned as a threatening process in the recovery plans of Christmas Island emerald dove, Christmas Island frigatebird, Christmas Island goshawk, Christmas Island hawk-owl, Christmas Island thrush, Christmas Island pipistrelle, Christmas Island shrew, Christmas Island blind snake, and Christmas Island gecko. A number of vertebrate and invertebrate species endemic to Christmas Island, and threatened by yellow crazy ants, are listed as of conservation concern under the EPBC Act.

For the most part these risk assessments were based on a general understanding of the invasion ecology of the tramp ant, rather than definitive evidence of a causal link between yellow crazy ants and decline of vertebrate and invertebrate species on Christmas Island.

A re-assessment of potential impacts of the yellow crazy ant

We assessed risks from yellow crazy ant supercolonies on Christmas Island, focusing principally on listed species, but additionally included species recognized as high priority in the bioregion[188, 227] and species that are common, characteristic or otherwise iconic elements of the regions' fauna and flora[188, 244]. These assessments are summarized numerically in Table 3.12, and detailed narratively in Appendix 5.

Christmas Island has a relatively species-poor terrestrial fauna. We assessed a total of 49 species for potential risk to yellow crazy ants on Christmas Island, comprising 21 birds, 3 mammals, 10 reptiles, and 15 crabs. Among the 49 native species assessed, all but three reptile species (Hawksbill turtle, *Eretmochelys imbricata*; Leatherback turtle, *Dermochelys coriacea*; Loggerhead turtle, *Caretta caretta*) were considered likely to be affected by yellow crazy ants, to varying degrees. While environmental heterogeneity may well mean that supercolonies and foraging ant densities are not uniformly high, it is likely that few sites will escape the attention of foraging ants. If supercolonies are not suppressed, the new ecosystem equilibrium that will prevail on Christmas Island is somewhat unpredictable, but the consequences for most native species and communities will be dire. The isolation of the island means dispersal to other islands is not a viable avoidance strategy for the majority of species. Local extinction will equate to taxon extinction in cases where the species/subspecies are endemic to the island.

Birds

Among birds, species that feed predominately on invertebrates within the forests are identified as at greatest risk, with direct exposure to predation by yellow crazy ants (especially young in the nest), foraging disrupted through likely reductions in invertebrate prey resources, and displacement through avoidance behaviour. The endemic Christmas Island emerald dove (*Chalcophaps indica natalis*), Christmas Island goshawk (*Accipiter hiogaster natalis*), Christmas Island hawk-owl (*Ninox natalis*) and Christmas Island thrush (*Turdus poliocephalus erythropleurus*) have previously been identified as at risk and are here assessed as the species of most concern. These species scored highly for significance and in assessment of impact. Christmas Island emerald dove and Christmas Island thrush are presently abundant and secure, but Christmas Island goshawk and Christmas Island hawk-owl could be vulnerable to extinction with current declines[226] exacerbated should yellow crazy ant supercolonies continue to spread.

Pressures on other birds are likely to accumulate over time. For example, while the Australian kestrel (*Falco cenchroides*) and Christmas Island goshawk (*Accipiter hiogaster natalis*) are not dependent on invertebrates, and thus may not be critically affected in the short term, it is likely that their primary prey--small birds, reptiles and mammals --will decline due to yellow crazy ant acting alone or in concert with other factors.

Table 3.12 Summary of rapid assessments for risk from yellow crazy ants for a sample of fauna in the Indian Territory Islands Bioregion (Christmas Island)

Taxonomic Group	Species or subspecies	EPBC Act listing status	Significance[1]	Impact[2]	Geo[3]	Niche[4]	BS[5]	F&F[6]
Bird	Abbott's booby (*Papasula abbotti*)	E	3	1	3	2	1.5	0
Bird	Australian kestrel (*Falco cenchroides*)	Not listed	1	2	3	1.5	2	2
Bird	Azure kingfisher (*Ceyx azurea*)	Not listed	1	1	1	1.5	1	1
Bird	Brown booby (*Sula leucogaster*)	Not listed	1	1.5	3	2	1.5	0
Bird	Christmas Island emerald dove (*Chalcophaps indica natalis*)	E	3	2	3	2.5	1.5	1.5
Bird	Christmas Island frigatebird (*Fregata andrewsi*)	V	3	1.5	3	2	1.5	0
Bird	Christmas Island glossy swiftlets (*Collocalia esculenta natalis*)	Not listed	3	1	3	1	1	2
Bird	Christmas Island goshawk (*Accipiter hiogaster natalis*)	E	3	2	3	2.5	1.5	1.5
Bird	Christmas Island hawk-owl (*Ninox natalis*)	V	3	2.5	3	2	2.5	2.5
Bird	Christmas Island imperial-pigeon (*Ducula whartoni*)	Not listed	3	1	3	1.5	1	1
Bird	Christmas Island thrush (*Turdus poliocephalus erythropleurus*)	E	3	2.5	3	3	2	2.5
Bird	Christmas Island white-eye (*Zosterops natalis*)	Not listed	3	1	2	2	1	1
Bird	Christmas Island white-tailed tropicbird (*Phaethon lepturus fulvus*)	Not listed	3	1	3	1	1	0
Bird	Common noddy (*Anous stolidus*)	Not listed	1	1	2	2	1	0
Bird	Eastern reef egret (*Egretta sacra*)	Not listed	1	1	1	1	1	0
Bird	Great frigatebird (*Fregata minor*)	Not listed	1	1	1	1	1	0
Bird	Lesser frigatebird (*Fregata ariel*)	Not listed	1	1	1	1	1	0
Bird	Red-footed booby (*Sula sula*)	Not listed	1	1	1	1	1	0
Bird	Red-tailed tropic bird (*Phaethon rubricauda*)	Not listed	1	1	1.5	1.5	1	0
Bird	White-breasted water-hen (*Amaurornis phoenicurus*)	Not listed	1	1	1	1	1	1
Bird	White-faced heron (*Ardea novaehollandiae*)	Not listed	1	1	1.5	1.5	0	1
Mammal	Christmas Island flying fox (*Pteropus melanotus natalis*)	Not listed	3	2	3	2	2	1
Mammal	Christmas Island pipistrelle (*Pipistrellus murrayi*)	CE	3	2.5	3	3	1.5	2.5
Mammal	Christmas Island shrew (*Crocidura attenuata trichura*)	E	3	2.5	3	3	2.5	2.5
Reptile	Blue-tailed skink (*Cryptoblepharus egeriae*)	Not listed	3	2.5	3	3	1.5	2.5

Taxonomic Group	Species or subspecies	EPBC Act listing status	Significance[1]	Impact[2]	Geo[3]	Niche[4]	BS[5]	F&F[6]
Reptile	Christmas Island blind snake (*Ramphotyphlops exocoeti*)	V	3	2	3	3	1.5	2
Reptile	Christmas Island gecko (*Lepidodactylus listeri*)	V	3	2.5	3	3	2.5	2.5
Reptile	Coastal skink (*Emoia atrocostata*)	Not listed	1	1.5	3	1.5	1.5	1.5
Reptile	Forest skink (*Emoia navitatus*)	Not listed	3	2.5	3	3	2.5	2.5
Reptile	Christmas Island giant gecko (*Cyrtodactylus sadlieri*)	Not listed	3	1.5	3	3	1	1.5
Reptile	Green turtle (*Chelonia mydas*)	V	1	1	1	1	1	0
Reptile	Hawksbill turtle (*Eretmochelys imbricata*)	V	1	0	1	1	0	0
Reptile	Leatherback turtle (*Dermochelys coriacea*)	E	1	0	1	1	0	0
Reptile	Loggerhead turtle (*Caretta caretta*)	E	1.5	0	1	1	0	0
Invertebrate	Blue crab (*Discoplax celeste*)	Not listed	3	1	2.5	3	1	1
Invertebrate	Brown crab (*Epigrapsus politus*)	Not listed	1	1	1	1	0	1
Invertebrate	Jackson's crab (*Karstarma jacksoni*)	Not listed	3	1	1	1	0	1
Invertebrate	Little nipper (*Geograpsus grayi*)	Not listed	1	1.5	1	2.5	1.5	1.5
Invertebrate	Mottled crab (*Metasesarma rousseauxi*)	Not listed	1	1	1	1.5	0	1
Invertebrate	Purple crab (*Gecarcoidea lalandii*)	Not listed	1	3	3	3	3	3
Invertebrate	Purple hermit crab (*Coenobita brevimana*)	Not listed	1	1	2	1.5	0	1
Invertebrate	Red hermit crab (*Coenobita perlata*)	Not listed	1	1	1.5	1.5	0	1
Invertebrate	Red land crab (*Geocarcoidea natalis*)	Not listed	3	3	3	3	3	3
Invertebrate	Red nipper (*Geograpsus stormi*)	Not listed	1	1	1.5	1.5	0	1
Invertebrate	Robber crab (*Birgus latro*)	Not listed	2.5	3	3	3	2	3
Invertebrate	Tawny hermit crab (*Coenobita rugosa*	Not listed	1	1	1	1.5	0	1
Invertebrate	White-striped crab (*Labuanium rotundatum*)	Not listed	1	1	1.5	1.5	1	1
Invertebrate	Yellow-eyed crab (*Chiromantes obtusifrons*)	Not listed	1	1	1.5	1.5	1	1
Invertebrate	Yellow nipper (*Geograpsus crinipes*)	Not listed	1	1	1.5	1.5	1	1

[1]Significance = Importance of populations within the Bioregion to the species' security, taking into account the species' conservation status and range size. Low, medium and high translated to numeric 1-3 scale.

[2]Impact = Assessment of likely importance of the tramp ant to persistence of the species within the Bioregion, taking into account Geo, Niche and effects of the tramp ant of breeding success, foraging and food resources. Nil, low, medium and high translated to numeric 0-3 scale. High impact implies the conservation status of the species may change, requiring re-assessment of their respective listed status.

[3]Geo = Extent of likely geographic overlap of the animal species and tramp ant within the Bioregion. Nil, low, medium and high translated to numeric 0-3 scale. Note that species without occurrence in the Bioregion were excluded from the assessments.

[4]Niche = Extent of likely niche overlap of the animal species and tramp ant. Nil, low, medium and high translated to numeric 0-3 scale.

[5]BS = Extent to which breeding success is likely reduced directly or indirectly by the tramp ant. Nil, low, medium and high translated to numeric 0-3 scale.

[6]F&F = Extent to which *foraging* is disrupted, extent to which *food resources* are likely to be reduced directly or indirectly by the tramp ant. Nil, low, medium and high translated to numeric 0-3 scale.

Several seabirds nesting on Christmas Island were assessed as at risk from yellow crazy ants, but not to the same degree as the above-mentioned land birds, in part because the primary threatening processes are in the marine environment.

Mammals

Christmas Island flying fox (*Pteropus melanotus natalis*), Christmas Island pipistrelle (*Pipistrellus murrayi*) and Christmas Island shrew (*Crocidura attenuata trichura*) have previously been identified as at risk from yellow crazy ants. The Christmas Island flying fox is possibly in current decline[226], and our assessment indicates low to medium impact from yellow crazy ants. All life stages of the flying fox are likely to be vulnerable to direct predation by crazy ants. The consequences for the Christmas Island flying fox of increasing scale insect infestations and their effects on fruit yield and quality are presently unknown, and thus the ultimate impact is unpredictable under a scenario of unabated populations of yellow crazy ants. Our assessment is that the Christmas Island pipistrelle and Christmas Island shrew, if they are still extant, are likely highly vulnerable to yellow crazy ants. Both are already rare, if not extinct[227] and while the factors that have led to their declines are poorly known, persistence is unlikely in the face of further pressures from yellow crazy ants that will accrue over time if the ant is not managed. Their body size makes them vulnerable to predation and harassment from yellow crazy ants at all life stages, and dependency on insects as food directly expose these mammals to foraging ants and to depletion and restructuring of invertebrate communities wrought by yellow crazy ants. Moreover, if it is still extant, the pipistrelle may be forced to shift from preferred roosting sites to avoid the ant[227].

Reptiles

Christmas Island is inhabited by six native terrestrial reptiles. Four of these: the Coastal skink (*Emoia atrocostata*), the endemic Lister's gecko (*Lepidodactylus listeri*), the Forest skink (*Emoia nativitatis*) and the Blue-tailed skink (*Cryptoblepharus egeriae*) have declined significantly in recent decades, while Christmas Island blind snake (*Ramphotyphlops exocoeti*) has been found so infrequently over the past century that there are insufficient data to assume a decline. Predation by invasive animals, including yellow crazy ants has been identified as a threatening process for these reptiles by Smith et al.[92], but the agents of decline remain poorly known. Only the Giant gecko (*Cyrtodactylus sadleiri*) is still readily found across the island, and while it appears to be reasonably common here is some qualitative evidence that its numbers are significantly lower than in 1979[92]. It does appear to be able to coexist with the ant[226].

Our assessments indicate that the Coastal skink, Lister's gecko, Forest skink and Blue-tailed skink are at considerable risk if yellow crazy ant supercolonies are not contained. The reptiles' small body size, high niche overlap with the tramp ant, and dependency on insects as food directly expose these reptiles to foraging ants and the associated depletion and restructuring of invertebrate communities. Blue-tailed skink is possibly now extinct in the wild, but the availability of captive populations offer opportunities for re-establishment if yellow crazy ants, and other threatened processes, can be mitigated.

The situation with regard to Christmas Island blind snake is more ambiguous, as there is presently little understanding of how the species responds to the ant. Being fossorial, it has a high likelihood of microhabitat overlap with yellow crazy ants, and its tough scales and other external adaptations for burrowing may provide an effect defense against ant attack[229].

Crabs

Christmas Island is known internationally for its diversity of crabs, many of which, while returning to the sea for spawning, can be regarded as important components of the land fauna. Of 15 species of these land crabs assessed, all were identified as likely affected if yellow crazy ants are not managed. The level of impact is likely to vary among species, reflecting the degree of range and niche overlap with the tramp ant within the island, and potential effects of yellow crazy ants on shelter and food resources. The Red land crab, Robber crab, Little nipper (*Geograpsus grayi*) and Purple crab (*Gecarcoidea lalandii*) were identified as the species most at risk.

The known high levels of impact on Red land crabs and Robber crabs provide for calibration/validation of the risk assessments. A point of note, however, is that the significance assessment is critically dependent on the taxonomic distinctiveness of Red land crab from the widespread Purple crab (*Gecarcoidea lalandii*), known from South East Asia to the Western Pacific. It is possible that the two nominal species are in fact conspecific variants.

As noted in earlier sections, Red land crabs and Robber crabs are killed by yellow crazy ants. There is a documented decline of 15-20% in Red land crabs from 2001-2009[89]. While anecdotal reports assert that Robber crabs are in decline and, indeed, could be seriously at risk from a combination of mortality factors, including yellow crazy ants, adequate data on population trends is presently lacking[227]. The Environmental Working Group[227] recognized the vulnerability of the Robber crab to predation by crazy ants, and the decline in their numbers, as a reason for concern. This species is the world's largest terrestrial arthropod, once numerous on many other tropical islands.

Blue crabs (*Discoplax celeste*) are considered much less at risk because of their more aquatic habits and typically water-filled burrows. Two of the wetland areas that support Blue crabs – the Dales and Hosnie's springs – have been listed as wetlands of international significance under the Ramsar Convention. This reinforces the broader implications of managing and conserving Blue crabs, as they, like the other Christmas Island crabs such as Red land crabs, play an important ecological role in maintaining these ecosystems of international significance. Due to the restricted distribution of Blue crabs on Christmas Island, the species is especially sensitive to any environmental changes[245].

The status of hermit crabs *Coenobita perlata*, *C. brevimana*, and *C. rugosa* may warrant further attention because at least part of their habitat is perturbed by yellow crazy ants.

The other 95% - Taxa neglected in existing assessments

Earlier assessments, and those made here, neglect the majority of invertebrate species potentially at risk from yellow crazy ant on Christmas Island. There is a need to systematically assess risks in the various invertebrate groups represented on the island. This will require expert knowledge of these groups and properly designed experiments, in combination with accessing knowledge of effects observed elsewhere yellow crazy ants have invaded.

3.7 African Big-Headed Ants on Lord Howe Island

3.7.1 Tramp ant impacts on biodiversity at the project site

The program aims to address key threats to the Island's outstanding World Heritage values by (among other tasks) undertaking the eradication of African big-headed ant established within and adjoining the settlement area. The Lord Howe Island Biodiversity Management Plan[246] identified the ant as a major threat to biodiversity elsewhere it has invaded, and field observations on Lord Howe suggest that displacement of native ant species and invertebrate fauna may be occurring.

Being early in the project's life, there has to date been no evaluation on Lord Howe Island of the impact of African big-headed ant on native fauna and flora.

3.7.2 Monitoring and evaluation tools used in the project to measure impacts on biodiversity

As noted above the program is not monitoring the environment for effects of the ant.

The Draft Work Plan of 2012[27] included provision for monitoring for non-target effects and ecological recovery. The settlement area and adjoining Permanent Park Preserve have biodiversity values, but it is unclear from the available documentation as to which areas, and which specific biodiversity values, will be the focus of monitoring efforts.

Monitoring of non-target impacts of baiting on invertebrate communities (inclusive of native ants) is in progress, with data collection in March and October 2012, 1 and 7 months after the February 2012 baiting of infested areas with hydramethylnon (Amdro®)[71]. Monitoring is focused on two treatments: 1) areas infested with African big-headed ant and baited, and 2) those areas without the tramp ant and left untreated. Twelve replicate plots were established in each treatment. Three samples, comprising the top 2cm of soil and leaf litter from a 30cm x 30 cm area, were combined for each plot, and placed into Winkler eclectors. Invertebrates were extracted over a 3 day period.

Provisional analyses of the sampling of March 2012 (1 month after baiting) indicate no impact of hydramethylnon baiting on invertebrate communities (Table 3.13). However, results are provisional as data analyses are not yet complete. Processes and analysis of the samples from October 2012 (7 months after baiting) are due for completion in early 2013.

3.7.3 Monitoring and evaluation outcomes (both impacts from tramp ants and /or post recovery of species)

The results for the initial sampling in March 2012 are yet to be completed but provisional results indicate no differences in any ecological measure (abundance and species richness of ants, abundance and ordinal richness of other invertebrates). The results have been interpreted as indicating that there has been no, or no persisting, non-target impacts from the baiting program, and that any ecological impacts of the African big headed ant are also non-persistent[71]. Pre-treatment sampling where African big-headed ant was present has not been possible[71].

The contract with CfOC[97] includes a requirement for a MERI Plan by which the project is to report on monitoring and evaluation in respect to project targets and in respect to CfOC five-year target outcomes. The project MERI Plan[247] indicates a focus on the *Biodiversity and Natural Icons, Managing World Heritage Areas* target outcomes identified in the CfOC 2011-2012 Business Plan. In particular the MERI Plan indicates a contribution by reducing the impact of invasive species on the Island's outstanding natural values by coordinating priority pest eradications, supported by detailed assessments of treatment efficacy, monitoring and follow-up treatments and post-treatment recovery of the Island's ecological systems.

Funding from CfOC commenced in 2012. As such there has yet to be any monitoring and evaluation of project outcomes[248].

Table 3.13 Documented non-target impacts of baiting for the African big-headed ant at the project site on Lord Howe Island[71]

Taxa studied	Monitoring methods	Impact
Native ants	Sampling of leaf litter and upper 2cm of soil in 12 replicate plots for i) areas infested and baited with hydramethylnon, and ii) areas not infested, not baited. Sampling occurred 1 and 7 months after baiting. Ants extracted in Winkler eclectors.	No impact of baiting. However, results are provisional as data analyses are not yet complete.
Litter invertebrates	Sampling of leaf litter and upper 2cm of soil in 12 replicate plots for i) areas infested and baited with hydramethylnon, and ii) areas not infested, not baited. Sampling occurred 1 and 7 months after baiting. Ants extracted in Winkler eclectors.	No impact of baiting. However, results are provisional as data analyses are not yet complete.

3.7.4 Other biodiversity impacts that may be occurring from tramp ants at the project site

There has been little explicit identification of biodiversity at risk from African big-headed ants at the project site. The program focuses on eradication of African big-headed ants infesting areas within and adjoining the settlement, as a strategic initiative to prevent spread to, and establishment in, areas of high conservation value within the Permanent Park Preserve (which comprises almost 75 per cent of Lord Howe Island and all the other islands within the Group).

There are significant biodiversity values within the project area, with species occurrences including Buff banded rail (*Gallirallus philippensis*), Eastern swamphen (*Porphyrio porphyrio*), Flesh-footed shearwater (*Puffinus carneipes*), Lord Howe woodhen (*Gallirallus sylvestris*), Lord Howe Island currawong (*Strepera graculina crissalis*), Sacred kingfisher (*Todiramphus sanctus*), Sooty tern (*Sterna fuscata*),White-faced heron (*Ardea novaehollandiae*), and Lord Howe Island placostylus (*Placostylus bivaricosus*). The settlement area is now a major stronghold for the Flesh-footed shearwater and critically endangered Lord Howe Island placostylus. The potential vulnerability of the above species is addressed in Section 3.7.5.

3.7.5 Future risks to biodiversity if the tramp ants are not contained

In this section we focus on potential for the tramp ant to affect the conservation status of native species.

Mechanisms of potential African big-headed ant impacts

The African big-headed ant is a generalist, occurring in a broad range of habitats, from open disturbed areas to natural closed forests. It nonetheless favours moist, warm and shaded areas, but can tolerate very exposed and hot areas, including rocky slopes and beach dunes. The African big-headed ant has very general ground-nesting requirements. It forages over all surfaces within its territory, including the vegetation canopy. Workers are most active outside of their nest when temperatures are in the range of 24 to 30˚C and under these conditions foraging takes place in all hours. The ants forage individually, but will actively recruit to a food source. The African big-headed ant tends to be most common in open, disturbed habitats with weedy vegetation that can support high densities of plant-feeding Hemiptera, which the ants tend for honeydew. Nonetheless, the species is known to invade intact closed forest.

There have been several previous reviews and other studies of African big-headed ant impacts in invaded ecosystems (e.g., [117, 118, 249-252]). Accordingly a full review is not presented here.

African big-headed ant affects other species through several processes. We summarise the salient points, relevant to risk assessment, from the published reviews and other literature:

Predation on animals

- African big-headed ants are well known as effective predators of a wide range of invertebrate species. The ant engages in nest raiding of heterospecific ant colonies.
- There is limited evidence for predation by African big-headed ants on nestling birds. Predation may occur on vulnerable life stages of small vertebrates generally.
- African big-headed ants do not sting in defence or in attack.

Predation on seeds

- African big-headed ant is an effective predator of small seeds.

Behavioural displacement

- There is limited evidence for avoidance by vertebrates of areas with high African big-headed ant densities.

Disruption of native myrmecophilous associations

- Native ants can be displaced, with consequent adverse effects on species of insects and plants tended by those native ants.

Competition for food

The African big-headed ant has high search efficacy and thus high rates of discovery of food items, leading to monopoly of food resources. Consequences for other species include:

- Direct competition with bird, mammal, reptile, amphibian and invertebrate species which overlap in diet and which are active in the same habitat space,

- Indirect competition with bird, mammal, reptile, amphibian and invertebrate species that may suffer reduced food availability due to African big-headed ants reducing prey or host abundances through direct competition or predation, and
- Simplification of invertebrate communities, with potential negative effects on native species that utilize invertebrates as food.

Indirect ecosystem-level effects

- Displacement of ants that provide functional roles not taken over by African big-headed ants, leading to shifts in ecosystem properties and ecosystem functioning.
- Foraging for nectar can lead to displacement of other flower visitors, including pollinators, leading to reduced reproductive fitness in some plant species, and in turn leading to shifts in vegetation composition. Impact most important in pollen-limited, arthropod-pollinated plants.
- Interactions with sap-sucking insects can cause outbreaks of these insects and in turn influence plant fitness and vegetation composition. African big-headed ants may increase hemipteran populations by removing honeydew that contributes to the growth of sooty mould, moving nymphs to better sites, and deterring parasites and predators.
- Ant invasions generally have negative consequences for plants that rely on ants for seed dispersal (myrmecochory). Invasive ants are typically poor seed dispersers due to smaller body size relative to specialist native seed-dispersing ants. Reduced seed dispersal can influence recruitment success and lead to shifts in vegetation composition. The potential for disruption of this mutualism by African big-headed ants is not well-documented.

Prior risk assessments

The African big-headed ant has been on Lord Howe Island since about 1993 and remains largely confined to the settlement area (see Section 2.5). It is thought that the high conservation value southern mountains also provide suitable environmental conditions[27, 103], but there has been no formal assessment of the relative risk of spread to other parts of the island or to other islands within the Lord Howe group. In our assessments below, we consider the highest elevations of the southern mountains to be unsuitable to African big-headed ant because ambient temperatures there are suboptimal for the ant.

Much of the Lord Howe Group invertebrate fauna is endemic. Several species are recognised as endangered, and therefore any losses effected by African big-headed ant would be significant. Nonetheless, there been only limited explicit identification of biodiversity at risk from the African big-headed ant should eradication fail. Whitelegge's land snail (*Pseudocharopa whiteleggei*), Magnificent heliocarionid land snail (*Gudeoconcha sophiae magnifica*), Masters' charopid land snail (*Mystivagor mastersi*), Mount Lidgbird charopid land snail (*Pseudocharopa lidgbirdi*) and the Lord Howe placostylus[246, 253-256] have been specifically identified as potentially affected.

The ant has been considered to constitute a minimal threat to ground-nesting birds[257].

A re-assessment of potential impacts of African big-headed ant

We assessed risks in the Lord Howe Islands in total, focusing principally on listed species, but additionally included species recognized as high priority in the bioregion and species that are common, characteristic or otherwise iconic elements of the regions' fauna and flora[258-260]. These assessments are summarized numerically in Table 3.14, and detailed in Appendix 6.

The Lord Howe Island Group has a relatively species-poor terrestrial vertebrate fauna, but a relative rich invertebrate fauna. We assessed a total of 33 vertebrate species and 8 invertebrate species for potential risk to African big-headed ants in the Lord Howe Island Group, on the basis the tramp ant is not contained and becomes distributed throughout. While there would be a time lag before the ant achieves a wide distribution in the Group, and environmental heterogeneity may well mean that foraging ant densities are not uniformly high. A qualitative assessment of climatic suitability suggests few sites will likely scape the attention of the ants, with the exceptions of the highest mountain areas. The consequences for most native invertebrate species and communities will be dire, with potential ecological cascade effects to other components of the foodweb that are dependent on invertebrates as a food resource. Direct impact on vertebrates through predation is likely to be minimal, except in species and life stages of small body size and low mobility. In some cases high densities of foraging ants will lead to displacement of vertebrates and mobile invertebrates through avoidance behaviour.

Birds

Our assessments comprise 26 birds, 4 of which are listed as threatened under the EPBC Act.
The extant land birds of Lord Howe were assessed as not especially vulnerable to the African big-headed ant. The Lord Howe woodhen (*Gallirallus sylvestris*) ('Vulnerable') was assessed as high significance, but low to medium for impact potential from the ant. The high niche overlap with the tramp ant, the ground nesting and foraging activities, and the dependency on invertebrates and small vertebrates as food directly exposes Lord Howe woodhen to foraging African big-headed ants and the associated depletion and restructuring of invertebrate communities. The African big-headed ant may undermine the recovery of the woodhen, which has been taking place as the result of an active recovery plan. The native Buff banded rail (*Gallirallus philippensis*) and Emerald ground-dove (*Chalcophaps indica chrysochlora*) were similarly assessed as low to medium for potential African big-headed ant impact.

The Lord Howe Island Group supports nesting of at least 14 seabird species and as such has among the highest diversity and density of nesting seabirds in Australia. Our assessments highlighted Flesh-footed shearwater (*Puffinus carneipes*), Grey ternlet (western Pacific) (*Procelsterna cerulea albivitta*), Kermadec petrel (*Pterodroma neglecta neglecta*) ('Vulnerable'), Little shearwater (*Puffinus assimilis assimilis*) and Providence petrel (*Pterodroma solandri*) as being of medium to high significance and with not insignificant risk from the effects of African big-headed ants. The primary effect of the ant is likely displacement of breeding birds through avoidance behaviour during nest attempts. Apart from a few pairs on Norfolk Island, Lord Howe Island is the only breeding site in the world for the Providence petrel. They breed in the winter on the two southern mountains of Lord Howe Island and thus probably occur at the lower ambient temperature limits of the African big-headed ant.

Table 3.14 Numeric summary of rapid assessments for risk from the African big-headed ant to native fauna in the Pacific Territory Islands Bioregion (Lord Howe)

Taxonomic Group	Species or subspecies	EPBC Act listing status	Significance[1]	Impact[2]	Geo[3]	Niche[4]	BS[5]	F&F[6]
Bird	Australian kestrel (*Falco cenchroides*)	Not listed	1	1	3	2	1	0
Bird	Black-winged Petrel (*Pterodroma nigripennis*)	Not listed	2	1	3	2.5	1	0
Bird	Buff banded rail (*Gallirallus philippensis*)	Not listed	1	2	3	2.5	1.5	1.5
Bird	Common noddy (*Anous stolidus*)	Not listed	1	1	2	2.5	1.5	0
Bird	Emerald ground-dove (*Chalcophaps indica chrysochlora*)	Not listed	1	1	3	3	1.5	1
Bird	Flesh-footed shearwater (*Puffinus carneipes*)	Not listed	2.5	1.5	3	3	1.5	0
Bird	Grey ternlet (western Pacific) (*Procelsterna cerulea albivitta*)	Not listed	3	1.5	2.5	2	1.5	0
Bird	Kermadec petrel (*Pterodroma neglecta neglecta*)	V	2	1.5	2.5	2.5	1.5	0
Bird	Little shearwater (*Puffinus assimilis assimilis*)	Not listed	3	1.5	2.5	2.5	1.5	0
Bird	Long-tailed cuckoo (*Eudyna mystaitensis*)	Not listed	1	1.5	2	2	0	1.5
Bird	Lord Howe Island currawong (*Strepera graculina crissalis*)	V	3	1	2.5	3	1.5	1
Bird	Lord Howe Island golden whistler (*Pachycephala pectoralis contempa*)	Not listed	3	1	2.5	3	1	1.5
Bird	Lord Howe silvereye (*Zosterops lateralis tephropleura*)	Not listed	3	1	3	3	1	1
Bird	Lord Howe woodhen (*Gallirallus sylvestris*)	V	3	1.5	3	3	1.5	1.5
Bird	Masked booby (*Sula dactylatra fullagari*)	Not listed	3	1	2.5	2.5	1.5	0
Bird	Providence petrel (*Pterodroma solandri*)	Not listed	3	1	2	2	1.5	0
Bird	Purple swamphen (*Porphyrio porphyrio melanotus*)	Not listed	1	1	1.5	1.5	1	1
Bird	Red-tailed tropic bird (*Phaethon rubricauda*)	Not listed	2.5	1	1.5	1.5	1	0
Bird	Sacred kingfisher (*Todiramphus sanctus*)	Not listed	1	1	1.5	1.5	1.5	1
Bird	Silver-eye (*Zosterops lateralis*)	Not listed	1	1	2.5	2	1.5	1
Bird	Shining bronze-cuckoo (*Chrysococcyx lucidus*)	Not listed	1	1	2.5	2	1.5	1.5
Bird	Sooty tern (*Sterna fuscata*)	Not listed	1	1.5	2	2	1.5	1
Bird	Wedge-tailed shearwater (*Puffinus pacificus*)	Not listed	1	1	2.5	2	1.5	0
Bird	White-bellied storm petrel (Australasian) (*Fregetta grallaria grallaria*)	V	3	1	2.5	2.5	1.5	0

Table 3.14 continued

Taxonomic Group	Species or subspecies	EPBC Act listing status	Significance[1]	Impact[2]	Geo[3]	Niche[4]	BS[5]	F&F[6]
Bird	White-faced heron (*Ardea novaehollandiae*)	Not listed	1	1	1.5	2	1	1
Bird	White tern (*Gygis alba*)	Not listed	2	1	2	2.5	1.5	0
Mammal	Large forest bat (*Vespadelus darlingtoni*)	Not listed	1	1.5	2	2.5	1	1.5
Reptile	Green turtle (*Chelonia mydas*)	V	1	0	0	1	1	0
Reptile	Hawksbill turtle(*Eretmochelys imbricata*)	V	1	0	0	1	1	0
Reptile	Leathery turtle (*Dermochelys coriacea*)	E	1	0	0	1	1	0
Reptile	Loggerhead turtle (*Caretta caretta*)	E	1.5	0	0	2	1	0
Reptile	Lord Howe Island skink (*Oligosoma lichenigera*)	V	3	2	2.5	2.5	1.5	1.5
Reptile	Lord Howe Island southern gecko (*Christinus guentheri*)	V	3	2	2.5	2.5	1.5	1.5
Invertebrate	Lord Howe Island earthworm (*Pericryptodrilus nanus*)	Not listed	3	1	1	3	1	1
Invertebrate	Lord Howe Island phasmid (*Dryococelus australis*)	CE	3	1.5	3	2.5	2	1
Invertebrate	Lord Howe Island placostylus (*Placostylus bivaricosus*)	E	3	1.5	3	3	1.5	1
Invertebrate	Lord Howe Island wood-feeding cockroach (*Panesthia lata*)	Not listed	3	1	3	2.5	1	1
Invertebrate	Magnificent heliocarionid land snail (*Gudeoconcha sophiae magnifica*)	CE	3	1	1	3	1	1
Invertebrate	Masters' charopid land snail (*Mystivagor mastersi*)	CE	3	1.5	2	3	1.5	1
Invertebrate	Mount Lidgbird charopid land snail (*Pseudocharopa lidgbirdi*)	CE	3	1.5	2	3	1.5	1
Invertebrate	Whitelegge's land snail (*Pseudocharopa whiteleggei*)	CE	3	1	1	3	1	1

[1]Significance = Importance of populations within the Bioregion to the species' security, taking into account the species' conservation status and range size. Low, medium and high translated to numeric 1-3 scale.

[2]Impact = Assessment of likely importance of the tramp ant to persistence of the species within the Bioregion, taking into account Geo, Niche and effects of the tramp ant of breeding success, foraging and food resources. Nil, low, medium and high translated to numeric 0-3 scale. High impact implies the conservation status of the species may change, requiring re-assessment of their respective listed status.

[3]Geo = Extent of likely geographic overlap of the animal species and tramp ant within the Bioregion. Nil, low, medium and high translated to numeric 0-3 scale. Note that species without occurrence in the Bioregion were excluded from the assessments.

[4]Niche = Extent of likely niche overlap of the animal species and tramp ant. Nil, low, medium and high translated to numeric 0-3 scale.

[5]BS = Extent to which breeding success is likely reduced directly or indirectly by the tramp ant. Nil, low, medium and high translated to numeric 0-3 scale.

[6]F&F = Extent to which *foraging* is disrupted, extent to which *food resources* are likely to be reduced directly or indirectly by the tramp ant. Nil, low, medium and high translated to numeric 0-3 scale.

Mammals

The widely distributed eastern Australian Large forest bat (*Vespadelus darlingtoni*) was assessed as low to medium for impact from African big-headed ants in the Lord Howe Island Group should the ant fail to be contained. While the Large forest bat has wide habitat preferences, and is likely to have minimal direct contact with African big-headed ant, the population on Lord Howe Island is relictual and small and thus vulnerable to further disturbances. African big-headed ant has the potential to influence the Large forest bat by reducing the abundance of insect prey. The Lord Howe long-eared bat (*Nyctophilus howensis*) was excluded from assessment as the species is listed as 'Extinct' under the EPBC Act.

Reptiles

Green turtle (*Chelonia mydas*) ('Vulnerable'), Hawksbill turtle (*Eretmochelys imbricata*) ('Vulnerable'), Leathery turtle (*Dermochelys coriacea*) ('Endangered') and Loggerhead turtle (*Caretta caretta*) ('Endangered') are among marine turtle species that occur in waters around the Lord Howe Island Group. While potentially vulnerable in the pipping stage, none of these turtles nest at Lord Howe, and thus are assessed as not affected by the African big-headed ant.

The SRE terrestrial Lord Howe Island skink (*Oligosoma lichenigera*) ('Vulnerable') and Lord Howe Island southern gecko (*Christinus guentheri*) ('Vulnerable') are threatened with extinction on Lord Howe Island due to predation by rats and cats, but are presently abundant on other islands in the Lord Howe Island Group. These lizards are likely to be adversely affected by the African big-headed ant should it spread throughout the Group. Both of these oviparous lizards are especially vulnerable to predation by African big-headed ants in the pipping and juvenile stages. Furthermore, foraging may be disrupted and abundance of invertebrate prey reduced by African big-headed ants. Accordingly the ant was considered to have medium and low to medium impact on Lord Howe Island skink and Lord Howe Island southern gecko, respectively.

Invertebrates

The Lord Howe Island Group is home to a number of SRE invertebrates, many of which are of high conservation interest due not only to their endemism but also population decline, leading to local extinction in several cases on Lord Howe Island. Many of these are variously listed under the *Threatened Species Conservation Act 1995* (TSC Act), *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and *The Lord Howe Island Act 1953* (LHI Act) [258, 259, 261].

The Lord Howe Island phasmid (*Dryococoelus australis*) ('Critically Endangered'), a giant flightless stick insect, is thought to be extinct on Lord Howe Island, but is known to occur still on Ball's Pyramid. The Lord Howe Island wood-feeding cockroach (*Panesthia lata*) is similarly extinct on Lord Howe Island, but occurs on Blackburn and Roach Islands. The Lord Howe Island placostylus (*Placostylus bivaricosus*) ('Endangered') was once widespread but is now restricted to several lowland localities on Lord Howe Island. Other invertebrates were similarly widespread on Lord Howe Island but now occur as relictual populations in the southern montane forests, namely the Lord Howe Island earthworm (*Pericryptodrilus nanus*), Magnificent heliocarionid land snail (*Gudeoconcha sophiae magnifica*) ('Critically Endangered'), Masters' charopid land snail (*Mystivagor mastersi*) ('Critically Endangered'), Mount Lidgbird charopid land snail (*Pseudocharopa lidgbirdi*) ('Critically

Endangered'), and Whitelegge's land snail (*Pseudocharopa whiteleggei*) ('Critically Endangered'). The African big-headed ant was assessed as a potential risk to each of these species should it not be contained, although much of the montane forest may be spared the ingress of African big-headed ant due to the cool ambient temperatures. Insects and landsnails are vulnerable to predation by African big-headed ant, especially in egg and early post-hatching stages. Foraging may be disrupted by presence of foraging ants.

In addition to direct impacts on invertebrates, African big-headed ant may threaten the ecological integrity of the Lord Howe Island ecosystems. Many of the invertebrates considered as potentially threatened by African big-headed ant are endemic and are likely to be important for ecosystem functioning such as decomposition, nutrient cycling, seed dispersal, pollination and predation[27]. Furthermore, there is concern that mutualistic interactions may initiate or exacerbate outbreaks of tended honey-producing hemipteran insects, as has been observed in other invaded regions. However, more would need to be known about the resident honeydew producing insects to more fully assess the risks. Impacts of the African big-headed ant have the potential to compound existing threats to Lord Howe World Heritage values imposed by rodents, weeds, and climate change, leading to possible further extinctions[262].

The Lord Howe rainforest native vegetation predominately comprises fleshy-fruited species, so there is minimal concern about African big-headed ant effects on survival and dispersal of seeds.

The other 95% - Taxa neglected in existing assessments

Earlier assessments, and those made here, neglect the majority of invertebrate species potentially at risk from African big-headed ants within the Lord Howe Island Group. The Lord Howe Island Group historically hosted more than 1600 terrestrial invertebrate species including 157 land and freshwater snails, 464 beetles, 27 ants, 183 spiders, 21 earthworms, 137 butterflies and moths and 71 springtails. The rate of discovery of new species remains high, indicating that numerous endemic species are yet to be discovered[246].

Lord Howe Island Biodiversity Management Plan[246] recognised potential for displacement of native ants. However, based on available information, the extant native ant fauna is poorly known. Only four other ant species are commonly encountered on the island, and it is possible that none of them are native[71] Comprehensive sampling would need to be done to determine whether any native species remained and whether they would be threatened by African big-headed ants.

There is a need to systematically assess risks in the various invertebrate groups represented within the Lord Howe Island Group. This will require expert knowledge of these groups and properly designed experiments, in combination to accessing knowledge of effects observed elsewhere African big-headed ant has invaded.

3.8 Argentine Ants on Norfolk Island

3.8.1 Tramp ant impacts on biodiversity at the site

The project is aimed at eradicating Argentine ant from Norfolk Island, thereby reducing and ultimately eliminating this threat to the biodiversity of the whole island (3455 hectares) and preventing spread to other islands in the Norfolk Island Group.

There has been no systematic, formal assessment of the effects of Argentine ant on Norfolk Island. Nonetheless Ron Ward, the Argentine Ant Project Coordinator, has observed several impacts[110] (summarized in Table 3.15). He has also noticed reduced plant vigour in fruit trees with Argentine ants, and has observed Argentine ants "harassing impaired insects" and feeding on bird carcasses.

Table 3.15 Summary of documented effects of the Argentine ant treatments at the project site on Norfolk Island[110]

Taxa	Monitoring methods	Impact
Birds		
White terns (*Gygis alba*)	Informal observations	Decreased nesting attempts in Norfolk Island Pines in infested area on west side of island
Plants		
Broadleaf meryta (*Meryta latifolia*)	Informal observations	Dieback. Ants work their way into the soft centre of the branch tips and over time form small hollows that they use for shelter.

3.8.2 Monitoring and evaluation tools used in the project to measure impacts on biodiversity

No systematic monitoring and evaluation to measure impacts of the ant or its control on biodiversity is being undertaken.

3.8.3 Monitoring and evaluation outcomes (both impacts from tramp ants and/or post recovery of species)

No systematic monitoring and evaluation to measure impacts on biodiversity is being undertaken.

The MERI Plan[263] sets out clearly how Argentine ant control is aligned to CfOC target outcomes, although there is no mention of biodiversity gains. Indeed, the MERI Plan makes no mention of monitoring or evaluation of program impacts on biodiversity. The program logic provides no mechanism for linking program targets (e.g., eradication of Argentine ant at the project site) to CfOC priority five-year outcomes, other than quantifying the area being managed for Argentine ants. Methodologies were not developed to demonstrate quantitatively that eradication of Argentine ant, if successful, would contribute to CfOC 2013 biodiversity and natural icons priority outcomes "....reduce critical threats to biodiversity and to enhance the condition, connectivity and resilience of habitats and landscapes" and "....reduce the impact of invasive species....". There is an implicit assumption that eradication of the Argentine ant, if successful, will deliver benefits to biodiversity, but no emphasis on quantifying impacts of Argentine ant on biodiversity within The Norfolk Island Group to establish that this link is real or significant.

3.8.4 Other biodiversity impacts that may be occurring at the project site

The infestations of Argentine an on Norfolk Island encompass important habitat for native species, not least coastal cliffs and foreshore and remnant forest. The current extent of Argentine ant infestation overlaps in part with the distribution of important native bird species, including Norfolk Island green parrot (*Cyanoramphus novaezelandiae cookii*) (EPBC listed "Endangered'), Norfolk Island golden whistler (*Pachycephala pectoralis xanthoprocta*) ('Vulnerable'), Norfolk Island scarlet robin (*Petroica multicolor multicolor*) ('Vulnerable'), Sacred kingfisher (*Todiramphus sanctus norfolkiensis*), Grey fantail (*Rhipidura fuliginosa pelzelni*), Grey gerygone (*Gerygone modesta*), Silvereye (*Zosterops lateralis*), Long-billed white-eye (*Zosterops tenuirostris*), Emerald dove (*Chalcophaps indica*) and Norfolk Island boobook owl (*Ninox novaeseelandiae undulata*) ('Endangered'), and among seabirds, White tern (*Gygis alba*), Sooty tern (*Sterna fuscata*), Little shearwater (*Puffinus assimilis*), Red-tailed tropicbird (*Phaethon rubricauda*), and Fleshy-footed shearwater (*Puffinus carneipes*). Gould's wattled bat (*Chalinolobus gouldii*) similarly may occur in habitat infested by Argentine ant.

Each of the above species is potentially adversely affected directly and/or indirectly by Argentine ant (see Section 3.8.5), but there is insufficient information to gauge present impacts, with uncertainty on degree of present range overlap between the birds and tramp ant, and the density at which the ant occurs within the infested areas.

Lord Howe Island gecko (*Christinus guentheri*) ('Vulnerable') and Lord Howe Island skink (*Oligosoma lichenigera*) ('Vulnerable') are also among the vertebrate species of conservation interest and potentially at risk from Argentine ant (see Section 3.8.5). However, these reptiles are now restricted to islands and islets offshore of Norfolk Island and thus presently do not overlap in range with Argentine ant.

The Argentine ant is well-known to have detrimental effects on native ants and other ground invertebrates in invaded locales internationally[3, 117], and thus the Norfolk Island invertebrate fauna is at risk. Five Norfolk Island land snail species are listed by EPBC as 'Critically Endangered', of which Campbell's helicarionid land snail (*Advena campbellii campbellii*), and Helicarionid land snail (*Mathewsoconcha suteri*) potentially overlap in range with Argentine ant. Numerous other unlisted invertebrate species similarly are likely to occur in habitat currently infested with Argentine ant. For example, Norfolk Island is home to at least 12 ant species[264-266], some of which have been recorded at sites following Argentine ant baiting[107]. The current range of the endemic ant *Oligomyrmex norfolkensis* is not known.

Argentine ants are well-known to tend honeydew-producing hemipteran insects such as aphids, scales, and mealybugs. Tending by Argentine ant can cause these insects to reach high numbers with detrimental effects on the host plant. The observations of Argentine ants on the endemic shrub and fruit trees described by Mr. Ward above strongly suggest that the ant is tending sap-sucking insects on the plants, and that the populations of the sap-sucking insects are high enough to be reducing the vigour of the host plant. Although Mr. Ward did not report seeing any of these insects, depending on the species, they can be easily overlooked, particularly if the Argentine ant is harbouring them in shelters on the plant. Many plants native to Norfolk Island are known suitable hosts of honeydew-producing insects, including well-known examples such as Norfolk Island pine (*Araucaria excels*).

The island is self-sufficient in fruit and vegetable production and therefore relies on consistent crop yields. In addition to direct effects on the host plants, pest outbreaks may result in large applications of pesticides that would likely have adverse effects on natural pest enemies, such as spiders, ladybugs and parasitoid wasps.

3.8.5 Future risks to biodiversity if the tramp ants are not contained

In this section we focus on potential for the tramp ant to affect the conservation status of native species.

Mechanisms of potential Argentine ant impacts

The Argentine ant nests and is active both on the ground and in arboreal sites.

There have been several previous reviews of Argentine ant impacts in invaded ecosystems (e.g.,[3, 117, 118]). Accordingly a full review is not presented here.

The Argentine ant affects other species through several processes. We summarise the salient points, relevant to risk assessment, from the published reviews and other literature:

Predation on animals

- The Argentine ant is well known as an effective predator of a wide range of invertebrate species.
- Argentine ants infest bee hives and nests of social wasps causing increased mortality and reduced productivity of hives and nests.
- Impacts on vertebrates have not been thoroughly studied but are generally minimal.

Predation on seeds

- Argentine ant is an ineffective seed predator (but see effects on seed dispersal below).

Behavioural displacement

Avoidance of areas with high Argentine ant densities

- Nesting and den building attempts, roosting, and general foraging by birds, mammals, reptiles and amphibians may be aborted due high densities of foraging ants and monopoly of sites

Disruption of native myrmecophilous associations

- Native ants can be displaced, with consequent effects on species of insects and plants tended by those native ants.

Competition for food

The Argentine ant has high search efficacy and thus high rates of discovery of food items, leading to monopoly of food resources. Consequences include:

- Direct competition with bird, mammal, reptile, amphibian and invertebrate species which overlap in diet and are active in the same habitat space.
- Competition with bird, mammal, reptile, amphibian and invertebrate species that may suffer reduced food availability due to Argentine ants reducing prey or host abundances through direct competition or predation.
- Argentine ant simplification of invertebrate communities, with potential negative effects on native species that utilize invertebrates as food.

Indirect ecosystem-level effects

- Displacement of ants that provide functional roles not taken over by Argentine ants, leading to shifts in ecosystem properties and ecosystem functioning.
- Foraging for nectar can lead to displacement of other invertebrate flower visitors, including pollinators, leading to reduced reproductive fitness in some plant species, and in turn leading to shifts in vegetation composition. Impact most important in pollen-limited, arthropod-pollinated plants.
- Interactions with sap-sucking insects can lead to outbreaks of these insects and in turn influence plant fitness and vegetation composition. Ants may increase hemipteran populations by removing honeydew that contributes to the growth of sooty mould, moving nymphs to better sites, and deterring parasites and predators.
- Ant invasions generally have negative consequences plants that rely on ants for seed dispersal (myrmecochory). The Argentine ant is a poor seed disperser due to its smaller body size relative to specialist native seed-dispersing ants. Reduced seed dispersal can influence recruitment success and lead to shifts in vegetation composition.

Prior risk assessments

No formal prior risk assessments have been conducted. In its proposal for CfOC funding the Administration of Norfolk Island[28] regarded Argentine ant as the most serious environmental issue facing the Norfolk Island Group because of its likely spread throughout Norfolk Island and transport to nearby Phillip Island. A 2008 report[30] indicated that unrestricted spread of Argentine ants on Norfolk Island would result in severely reduced ant species richness, possible flora ecosystem impacts from reduced seed distribution and burial (leading to increased seed predation by birds and rodents) and impact on bird species which nest on the island.

The Norfolk Island Threatened Species Recovery Plan (2010)[266] recognised Argentine ants as present on the island and highly likely to adversely affect threatened species if not eradicated. As such, Argentine ant was listed as a priority threatening process with the recommendation that a comprehensive eradication program be developed and implemented. However, no native species were explicitly identified as at risk from Argentine ant.

A re-assessment of potential impacts of Argentine Ant

We assessed risks in the Norfolk Island Group, focusing principally on listed species, but additionally included species recognized as high priority in the bioregion and species that are common, characteristic or otherwise iconic elements of the regions' fauna and flora. These assessments are summarized numerically in Table 3.16, and detailed as narrative in Appendix 7.

The Norfolk Island Group has relatively species-poor terrestrial vertebrate and invertebrate faunas. We assessed 33 birds, 1 mammal, 6 reptiles and 5 invertebrate species for potential risk to Argentine ant in the Norfolk Island Group on the basis the tramp ant is not contained and becomes distributed throughout. While there would be a time lag before the ant achieves a wide distribution in the Group, and environmental heterogeneity may well mean that foraging ant densities are not uniformly high, a qualitative assessment of climatic suitability suggests few sites will likely scape the attention of the ants. The consequences for most native invertebrate species and communities will be dire, with potential ecological cascade effects to other components of the foodweb that are dependent on invertebrates as a food resource. Direct impact on vertebrates through predation is likely to be very minimal. In some cases high densities of foraging ants will lead to displacement of vertebrates and mobile invertebrates through avoidance behaviour.

Birds

Our assessment suggests that the majority of birds of the Norfolk Island Group are likely to experience minimal impact if Argentine ants are not contained. Notable exceptions are the insectivorous species, especially Buff-banded rail (*Gallirallus phillippensis*) and Norfolk Island scarlet robin. The level of predicted impact implies the conservation status of these species may change. Norfolk Island scarlet robin are already listed under the EPBC Act as noted above.

Mammals

The single mammal assessed, the widespread eastern Australian Gould's wattled bat will be affected to the extent that the abundance of some invertebrate prey may be reduced. However, this assessment must be qualified as impacts on prey may possibly be offset by increased ant abundance as ants are known to feature in their diet. Roosting and breeding success, and foraging of Gould's wattled bat may be minimally disrupted by high densities of ants.

Reptiles

Four marine turtles of note occur in waters around the Norfolk Island Group: the Green turtle (*Chelonia mydas*) ('Vulnerable'), Hawksbill turtle (*Eretmochelys imbricata*) ('Vulnerable'), Leathery turtle (*Dermochelys coriacea*) ('Endangered') and Loggerhead turtle (*Caretta caretta*) ('Endangered'). While potentially vulnerable to predation by Argentine ants in the pipping stage, none of these turtles nest at Norfolk Island, and thus are assessed as not at risk from the Argentine ant.

Table 3.16 Numeric summary of rapid assessments for risk from Argentine ants to native fauna of the Pacific Territory Islands Bioregion (Norfolk Island)

Taxonomic Group	Species or subspecies	EPBC Act listing status	Significance[1]	Impact[2]	Geo[3]	Niche[4]	BS[5]	F&F[6]
Bird	Australian kestrel (*Falco cenchroides*)	Not listed	1	1	3	2.5	1	1
Bird	Black noddy (*Anous minutus*)	Not listed	1	1	1.5	1.5	1	0
Bird	Black-winged Petrel (*Pterodroma nigripennis*)	Not listed	2	1	1.5	2	1	0
Bird	Buff-banded rail (*Gallirallus phillippensis*)	Not listed	1	1.5	3	2.5	1	1.5
Bird	Common noddy (*Anous stolidus*)	Not listed	1	1	2	2.5	1	0
Bird	Eastern curlew (*Numenius madagascariensis*)	Not listed	1	1	1	1	0	1
Bird	Emerald ground-dove (*Chalcophaps indica chrysochlora*)	Not listed	1	1	3	3	1	1
Bird	Flesh-footed shearwater (*Puffinus carneipes*)	Not listed	2	1	3	3	1	0
Bird	Grey fantail (*Rhipidura fuliginosa pelzelni*)	Not listed	3	1	3	2.5	1	2
Bird	Grey gerygone (*Gerygone modesta*)	Not listed	3	1	3	2	1	2
Bird	Grey ternlet (western Pacific) (*Procelsterna cerulea albivitta*)	Not listed	3	1	2.5	2	1	0
Bird	Kermadec petrel (*Pterodroma neglecta neglecta*)	V	2	1	2.5	2.5	1	0
Bird	Little shearwater (*Puffinus assimilis assimilis*)	Not listed	3	1	2.5	2.5	1	0
Bird	Long-tailed cuckoo (*Eudynamys taitensis*)	Not listed	1	1	2.5	2.5	0	1.5
Bird	Masked booby (*Sula dactylatra fullagari*)	Not listed	3	1	2.5	2.5	1	0
Bird	Norfolk Island green parrot (*Cyanoramphus cookii*)	E	3	1	2.5	2	1	1
Bird	Norfolk Island boobook owl (*Ninox novaeseelandiae undulata*) (hybrid)	E	3	1	2.5	2	1	1
Bird	Norfolk Island golden whistler (*Pachycephala pectoralis xanthoprocta*)	V	3	1	2.5	2	1	1
Bird	Norfolk Island scarlet robin (*Petroica multicolor multicolor*)	V	3	1.5	2.5	2	1	1.5
Bird	Providence Petrel (*Pterodroma solandri*)	Not listed	3	1	2	2	1	0
Bird	Purple swamphen (*Porphyrio porphyrio melanotus*)	Not listed	1	1	1.5	1.5	1	1
Bird	Red-tailed tropic bird (*Phaethon rubricauda*)	Not listed	2	1	1.5	1.5	1	0
Bird	Sacred kingfisher (*Todiramphus sanctus*)	Not listed	1	1	1.5	1.5	1	1
Bird	Silver-eye (*Zosterops lateralis*)	Not listed	1	1	2.5	2	1	1
Bird	Slender-billed white-eye (*Zosterops tenuirostris*)	Not listed	3	1	2.5	2	1	1.5

Table 3.16 continued

Taxonomic Group	Species or subspecies	EPBC Act listing status	Significance[1]	Impact[2]	Geo[3]	Niche[4]	BS[5]	F&F[6]
Bird	Shining bronze-cuckoo (*Chrysococcyx lucidus*)	Not listed	1	1	2.5	2	1	1.5
Bird	Sooty tern (*Sterna fuscata*)	Not listed	1	1	2	2	1	1
Bird	Wedge-tailed shearwater (*Puffinus pacificus*)	Not listed	1	1	2.5	2	1	0
Bird	White-bellied storm petrel (Australasian) (*Fregetta grallaria grallaria*)	V	1	0	1	1	0	0
Bird	White-breasted white-eye (*Zosterops albogularis*)	Ex	3	1	3	2.5	1	1
Bird	White-faced heron (*Ardea novaehollandiae*)	Not listed	1	1	1.5	2	1	1
Bird	White-necked petrel (*Pterodroma cervicalis*)	Not listed	3	1	2.5	2.5	1	0
Bird	White tern (*Gygis alba*)	Not listed	2	1	2	2.5	1	0
Mammal	Gould's wattled bat (*Chalinolobus gouldii*)	Not listed	1	1	3	3	1	1.5
Reptile	Green turtle (*Chelonia mydas*)	V	1	0	0	1	1	0
Reptile	Hawksbill turtle (*Eretmochelys imbricata*)	V	1	0	0	1	1	0
Reptile	Leathery turtle (*Dermochelys coriacea*)	E	1	0	0	1	1	0
Reptile	Loggerhead turtle (*Caretta caretta*)	E	1.5	0	0	2	1	0
Reptile	Lord Howe Island skink (*Oligosoma lichenigera*)	V	3	1.5	2.5	2.5	1	1.5
Reptile	Lord Howe Island southern gecko (*Christinus guentheri*)	V	3	1.5	2.5	2.5	1	1.5
Invertebrate	Endemic centipede (*Cormocephalus coynei*)	Not listed	3	1.5	3	3	1	1.5
Invertebrate	Campbell's helicarionid land snail (*Advena campbellii campbellii)*	CE	3	1.5	3	3	1.5	1
Invertebrate	Gray's helicarionid land snail (*Mathewsoconcha grayi*)	CE	3	1.5	3	3	1.5	1
Invertebrate	Helicarionid land snail (*Mathewsoconcha suteri*)	CE	3	1.5	3	3	1.5	1
Invertebrate	Stoddart's helicarionid land snail (*Quintalia stoddartii*)	CE	3	1.5	3	3	1.5	1

[1]Significance = Importance of populations within the Bioregion to the species' security, taking into account the species' conservation status and range size. Low, medium and high translated to numeric 1-3 scale.

[2]Impact = Assessment of likely importance of the tramp ant to persistence of the species within the Bioregion, taking into account Geo, Niche and effects of the tramp ant of breeding success, foraging and food resources. Nil, low, medium and high translated to numeric 0-3 scale. High impact implies the conservation status of the species may change, requiring re-assessment of their respective listed status.

[3]Geo = Extent of likely geographic overlap of the animal species and tramp ant within the Bioregion. Nil, low, medium and high translated to numeric 0-3 scale. Note that species without occurrence in the Bioregion were excluded from the assessments.

[4]Niche = Extent of likely niche overlap of the animal species and tramp ant. Nil, low, medium and high translated to numeric 0-3 scale.

[5]BS = Extent to which breeding success is likely reduced directly or indirectly by the tramp ant. Nil, low, medium and high translated to numeric 0-3 scale.

[6]F&F = Extent to which *foraging* is disrupted, extent to which *food resources* are likely to be reduced directly or indirectly by the tramp ant. Nil, low, medium and high translated to numeric 0-3 scale.

The terrestrial Lord Howe Island skink (*Oligosoma lichenigera*) is considered extinct on Norfolk Island but still persists in abundance on Phillip Island[266]. The Lord Howe Island southern gecko (*Christinus guentheri*) is to be found on Nepean and Phillip Islands and on three small rocky islets 100m from the northern cliffs of Norfolk Island. It almost certainly occurs on other rocky islets but it has not been found on the main island and became extinct there prior to European settlement[266]. Both of these SRE species were assessed as likely affected by Argentine ant if it is not contained and spreads throughout the Norfolk Island Group. Their dependency on insects as food directly expose these reptiles the depletion and restructuring likely wrought by Argentine ant on invertebrate communities. Reptiles elsewhere have not found the Argentine ant to be palatable and have suffered when their native ant food source is displaced by Argentine ants[267].

Invertebrates

Range contractions since human settlement are common among SRE invertebrates known from the Norfolk Island Group. We assessed the risks posed by Argentine ants to five examples, namely the large endemic centipede (*Cormocephalus coynei*) (confined to Phillip and Nepean Islands); Campbell's helicarionid land snail (formerly widespread, only on Norfolk Island); Gray's helicarionid land snail (Probably extinct on Norfolk Island, but may survive on Phillip Island); Helicarionid land snail (only Norfolk Island) and Stoddart's helicarionid land snail (Norfolk and Phillip islands, but possible extinct). Impacts from Argentine ants on these species as assessed as low to medium. All of the snails are vulnerable to predation by the ant at least in the egg, pipping and young hatchling stages. The centipede is dependent on invertebrates and small vertebrates as a food resource and thus vulnerable to depletion and restructuring of invertebrate communities likely imposed by Argentine ant.

The other 95%

Earlier assessments, and those made here, neglect the majority of invertebrate species potentially at risk from Argentine ants within the Norfolk Island Group. There is a need to systematically assess risks in the various invertebrate groups represented within the Group. This will require expert knowledge of these groups and properly designed experiments, in combination with accessing knowledge of effects observed elsewhere African big-headed ant has invaded.

Native ants and other arthropods may be at risk. The Norfolk Island Group is recorded to have at least 12-14 species of ant[28, 30, 264, 265]. Most are known tramp species. One species, *Oligomyrmex norfolkensis*, is considered endemic. Little is known about the ecology and current distribution of *O. norfolkensi*, but this and other native ants may well be displaced by Argentine ant. Other insects unique to Norfolk Island include the Nythos Island Cricket (*Insulascirtus nythos*), Norfolk Island Spiny Katydid (*Beiericolya tardipes*), another katydid (*Caedicia araucariae*), the Norfolk Island Cicada (*Kikihia convicta*), a leafroller moth *Tracholena hedraea*, and looper moths *Austrocidaria ralstonae* and *Pseudocoremia christiani*. Other endemic invertebrates include a salt marsh snail *Omphalotropis suteri*, and a freshwater shrimp *Paratya norfolkensis*.

The next two sections will cover all six tramp ant projects collectively.

3.9 Other Monitoring and Evaluation Tools to Collect Data on the Tramp Ant Impacts on Biodiversity

The CfOC tramp ant projects in general have lacked a culture of biodiversity impact assessment. There has been a focus on operational activities to achieve the primary outcome, eradication. This situation has been engendered by a lack of explicit requirements for the collection and analysis of biodiversity impact data as a contracted activity with specific performance measures.

That the tramp ant projects have not routinely invested in capture of biodiversity impact data is also a consequence of an absence of a strategic, generic framework within which impact assessment might operate and absence of standardized sampling and reporting protocols. Standardisation across all tramp ant programs would build efficacy, networking and collective knowledge; enable comparative analyses of program benefits; and ultimately enhance predictive capability. In the absence of data collected within a single framework and using standardized, repeatable methodologies, monitoring becomes ad hoc, across program comparisons are at best weak, and response plans to tramp ant incursions are essentially novel experiments.

It is acknowledged that ecologies will vary with the identity of the invading tramp ant and the ecosystem context into which they are invading, demanding that monitoring protocols be flexible and adaptable. However, it should be possible to develop protocols for a minimum core set of measures that both address our above calls for standardisation and enable individual programs to track outcomes for the environment.

It is also acknowledged that in both pest incursion response and pest containment/suppression situations there is a primary focus on operational activities directed at achieving pest control. Often stretched financial and labour resources mean monitoring of outcomes for the environment, including biodiversity, are neglected in favour of delivery of controls and monitoring to confirm pest numbers are reduced. Nonetheless, it should be borne in mind that pest control is only a means to an end. Being able to track and report on higher-level outcomes is not only an integral part of adaptive management feed-back loops upon which operational activities can be honed, but is also central to engendering ongoing support from the public and funding agencies.

This section focuses on an initial scoping of a framework for assessment of biodiversity impact assessment in tramp ant incursion response, as a platform for further and fuller development in a consultative process.

3.9.1 The building blocks of a framework for assessment of impacts on biodiversity

Clear, precise goals are fundamental for any biodiversity monitoring and evaluation framework. Nonetheless, it is only in the last decade that there have been attempts internationally to characterise biodiversity objectives beyond the general all-encompassing desire to maintain the full complement of genetic, taxonomic, and ecosystem diversity in a country, as set out in international agreements such as the Convention of Biological Diversity (CBD). Furthermore, there is growing consensus that goals must be defined in terms that give guidance to setting priorities as to what to monitor, given that numerous choices have to be made.

Ecological integrity – an outcome focus for invasive species management

Following a review of international policies and programs on biodiversity assessment and reporting, Lee et al.[268] suggest that the primary outcome of conservation management at the highest level is to maintain 'ecological integrity', defined as the full potential of native biotic and abiotic features, and natural processes, functioning in sustainable communities, habitats, and landscapes. Pragmatically there is a need to focus on those elements that provide the best guarantee that integrity is being maintained. This is consistent with CBD guidelines on biodiversity-inclusive impact assessment[269], where it is emphasised that potential impacts on biodiversity can be identified without having a complete description of that biodiversity. If an intervention is expected to result in changes of the composition, structure or key processes, there is a serious reason to expect that ecosystems and related ecosystem services will be affected. There are three essential elements (modified from Lee et al.[268]:

1. **Species occupancy** is the extent to which any species biogeographically native to, and capable of living in, a particular ecosystem is actually present at a relevant spatial scale.

2. **Native dominance** is the level of native influence on ecosystem character and processes. It emphasises the goal that indigenous ecosystems contain and are shaped by native plant, animal, and microbial species. The cornerstone of continued native dominance is self-regeneration, a feature that enables the community to perpetuate itself in the absence of active human intervention.

3. **Ecosystem representation** is the degree to which the diversity of ecosystems in a region or country are represented within a protected natural area network (or at least with some form of biodiversity protection), and occupy their full natural environmental range. Ecosystem representation is a major contributor towards ensuring potential biotic representation, within contemporary landscapes as a vehicle for maintaining evolutionary potential or options into the future.

Translation to a framework for assessment of tramp ant impacts

Logically the framework should build upon current knowledge of ant ecology. That is, the framework should build hierarchically from immediate direct impacts of the tramp ants on native ant communities, through to effects on ecosystem dominants, keystone species, and key processes. Table 3.17 and the following discussion outline a framework for assessment of tramp ant impacts (hereafter referred to as the Framework).

Table 3.17 Potential components of a framework for assessment of tramp ant impacts on biodiversity in Australian terrestrial ecosystems

Targeted Outcome	Outcome Objectives	Suggested monitoring foci	Suggested sampling foci and methods
Species occupancy	1. Preventing extinctions and declines	1.1 Occupancy of native invertebrate species endemic to the area (i.e. SRE taxa) and/or whose viability at regional/national scale is critically dependent on persistence in the area.	1.1 Trends in native invertebrate species occupancy. Non-destructive sampling or observations of the taxa or a proxy for it (e.g., burrows for crabs).
		1.2 Occupancy of native vertebrate species endemic to the area (i.e. SRE taxa) and/or whose viability at regional/national scale is critically dependent on persistence in the area.	1.2 Trends in native vertebrate species occupancy. Quantitative observations of the species or signs of its presence (e.g., tracks, scat) or non-destructive sampling.
	2. Maintaining ecosystem composition	2.1 Retention of community composition in native ants.	2.1 Ratios of abundance in native and exotic ants; shifts in community composition. Pitfall and arboreal traps, Winkler bags, occupancy lures.
		2.2 Retention of community composition of non-ant native invertebrates.	2.2 Ratios of abundance in native and exotic invertebrates; shifts in community composition. Pitfall trapping; extract from litter/soil in Tullgren funnels; sweep netting; foliage beating; observations and experiments at resources.
		2.3 Retention of community composition of native vertebrates.	2.3 Ratios of abundance in native and exotic vertebrates; shifts in community composition. Cage trapping and tunnel tracking for mammals, mist netting, and timed counts for birds and bats; nest occupancy and fledgling success; pitfall trapping for reptiles.
		2.4 Retention of community composition of native plants.	2.4 Ratios of abundance in native and exotic plants; shifts in community composition. Soil seed bank; seedling and mature plant counts in quadrats (scaled appropriately); tree basal area.

Table 3.17 continued

Targeted Outcome	Outcome Objectives	Suggested monitoring foci	Suggested sampling foci and methods
Native dominance	3. Maintaining ecosystem processes and their dominance by native species	3.1 Ecological integrity of key myrmecophilous mutualisms, including: Ant-Lepidoptera associations, Ant-Hemiptera associations, and Ant-dependent seed dispersal	3.1 Functionally effective retention of native species mutualisms; consequence of native species displacement; shifts in ecosystem properties and key process rates. Generally specialist sampling methodologies and experimental manipulations; measurement of host plant vigour and fitness; measurement of seed theft, dispersal and establishment.
		3.2 Ecological integrity of soil processes regulated by native ants	3.2 Ratios of abundance of native and exotic ants in functional guilds/groups; shifts in functional composition of ant communities; shifts in ecosystem properties (e.g. nutrient pools) and key process rates (e.g. nutrient turnover). Sampling of ant communities by methods in 2.1, complemented by sorting to functional group; measurements of soil nutrients pools and turnover; changes in microsite hydrology.
		3.3 Pollination	3.3 Ratios of abundance of native and exotic ants in pollinator guild; shifts in composition of invertebrate and vertebrate assemblages visiting flowers; shifts in ecosystem properties and key process rates such as pollination rates. Generally specialist sampling methodologies and experimental manipulations; measurement of host plant vigour and fitness; measurement of pollinator rewards in terms of fitness.
Ecosystem representation	4. Irreplaceability and vulnerability	4.1 Current level of representation of ecosystem	4.1 Contribution of invaded ecosystem to representativeness of the reserve network. Generally involves spatial analyses.

Table 3.17 continued

Targeted Outcome	Outcome Objectives	Suggested monitoring foci	Suggested sampling foci and methods
		4.2 Likelihood of loss of irreplaceable features causing transformation of ecosystem.	4.2 Assessment of vulnerability of invaded system to degradation; Assessment of likelihood of loss of distinctive compositional elements, especially those with important ecosystem functions. General assessments of vulnerability coupled with measures of loss of distinctiveness in community ordination space.

Species occupancy
1. Preventing extinctions and declines

Key question: Is the continued presence of SRE and other vulnerable species – whose viability at regional/national scale is critically dependent on persistence in the area – enhanced by tramp ant containment and eradication?

Logically the focus is on those species identified in a risk assessment process. In particularly the focus should be on species endemic to the area (i.e., SRE taxa) and/or those whose viability at a regional/national scale is critically dependent on persistence in the area. Monitoring seeks to document change, if any, in site occupancy by these species. Spatial scale is important in these assessments, particularly for vertebrates. If the project area is small relative to home ranges of the constituent native species, benefits from tramp ant reduction or eradication may be difficult to document, unless the treated area is critical to maintaining population size.

The requirement of species-level precision is relatively high, and specialist sampling methodologies may be required to monitor species of often very specific ecologies and occurring at low densities. Care must also be taken to avoid destructively sampling species that are already rare.

Species occupancy
2. Maintaining ecosystem composition

Key question: Is native dominance and integrity of communities at the site maintained by tramp ant containment and eradication?

The emphasis for all points below is quantitative documentation of changes in community composition.

2.1 Retention of community composition in native ants

Ants are important components of biodiversity and play key roles in ecosystem processes. It is well-established that native ant assemblages are often perturbed by tramp ant invasions. Frequently, the tramp ant assumes dominance in the community, monopolizing resources. Assessment of ant community composition should be a fundamental focus for monitoring in tramp ant programs.

2.2 Retention of community composition of non-ant native invertebrates

Ground and plant-associated invertebrates are also often affected by invasive ants. These effects may be direct, via predation, or indirect, through perturbation of bottom-up or top-down regulatory processes. Targeted monitoring may involve sampling entire communities associated with a particular stratum (e.g., litter invertebrates); a focus on taxonomic groups (e.g., land snails within the litter invertebrate communities) or a focus on functional guilds (e.g., detritivores within the litter invertebrate communities). Knowledge of unique local features of biodiversity will guide the decision of which taxa have monitoring priority.

2.3 Retention of community composition of native vertebrates

The focus is on vertebrate communities utilizing food, roost, or nest resources in strata frequented by and most likely affected by tramp ants.

2.4 Retention of community composition of native plants

The effect of tramp ants on plant communities is generally indirect, such as via interactions with herbivores or pollinators. Depending on the tramp ant species and the local context, it may be appropriate to focus on components of the plant community likely affected by disruption of myrmecophilous mutualisms and important in maintaining ecosystem character.

Native dominance

3. Maintaining ecosystem processes

Key question: Are the key ecological processes regulated by native ecological communities maintained by tramp ant containment and eradication?

3.1 Ecological integrity of key myrmecophilous mutualisms, including

Ant-Lepidoptera associations

Tramp ants have the potential to disrupt myrmecophilous mutualisms between native ants and obligately or facultatively associated butterfly larvae (often in the family Lycaenidae) by displacing the required native ant and failing to usurp the mutualist role. Attendant ants guard the butterflies against predators and parasites during their vulnerable period of larval growth and pupation in exchange for carbohydrate-rich secretions from specialized glands in the cuticle[165, 270, 271]. The disruption of this native mutualism can potentially lead to local extinction of lycaenid species. Seven Australian species of lycaenid larvae are sometimes tended by African big-headed ants and one species is sometimes tended by Argentine ants[118]. However, African big-headed ants, Argentine ants, red imported fire ants, and yellow crazy ants are all known to prey on caterpillars in other parts of their introduced range[118].

Overlaying known geographic distribution of butterfly species of interest with current or anticipated distribution of the tramp ant would provide some indication of risk. Standard butterfly population abundance sampling methods could be employed to document differences in abundance.

Ant-Hemiptera associations

Ants participate in a wide array of mutualistic associations with other organisms[272-274], but the commonly formed associations between invasive ants and honeydew-producing insects seem especially likely to contribute to ecological success of the invaders. The most extreme and best-documented case is of yellow crazy ants on Christmas Island (see Sections on Christmas Island above). Ants attracted to host-plants by honeydew often have additional effects on the host plant and its associated arthropods via interactions with other herbivores, herbivore enemies, or pollinators[3, 117, 275, 276].

Hemiptera outbreaks can result in reduced plant vigour and fruit production, likely of primary interest to fruit and vegetable growers (e.g., farmers on Norfolk Island). Detecting invasive ant-induced changes in plant-associated arthropods generally will require careful, detailed sampling to see changes that are sub-catastrophic for the host plant (e.g., [117, 276]).

Ant-dependent seed dispersal

Seed dispersal by ants is very important regionally in Australia[277] with many plants relying on, and consequently encouraging, ants to disperse their seeds. Many plants actively encourage ants to disperse their seeds with chemical attractants and nutritional benefits. The ant gains a reward for dispersing the seed, and the plant species has a greater chance of local persistence. In Australia this form of myrmecophilous mutualism is evident in more than 1500 plant species, and occurs in most habitats across the continent.

Ness and Bronstein[120] reported five suboptimal interactions to be prevalent in studies of invasive ant effects on myrmecochorous plants: invasive ants may collect fewer seeds per unit time compared to native ant species; they may function as seed predators; may leave seeds exposed on the surface; may ingest the elaiosome, but fail to move the seed; or they may move the seed shorter distances than the native ants they displace. Effects of low seed dispersal on plant populations will likely only be evidenced over long time periods. Seed café experiments with tagged seeds are a common way to compare invasive and native ant seed dispersal.

3.3 Ecological integrity of soil processes regulated by native ants

Ants are abundant and diverse in Australia and are likely highly important in modifying soil profiles and geochemical properties of the continent's ancient, fragile, and generally nutrient-poor soils. Disruption of native ant communities and other ecosystem processes by invasive tramp ants has the potential to transform Australian native ecosystems.

The focus of monitoring is the impacts on emergent ecosystem-level soil properties.

4. Ecosystem representation

> Key question: Is the integrity of the national protected natural areas network maintained by tramp ant containment and eradication?

4.1 Current level of representation of ecosystem in the protected natural areas network

4.2 Likelihood of loss of irreplaceable features causing transformation of ecosystems

The value of a program in a national context is its complementarity to other efforts to maintain and restore biodiversity across the nation. This complementarity has two components:

- *Irreplaceability*. All else being equal, a tramp ant abatement program operating in an ecosystem type or environment type poorly represented in other biodiversity management/restoration projects is of greater value than a program in an ecosystem or environment well represented by other initiatives. In large part, this irreplaceability is related to distinctiveness of the biotic assemblage in a national context, or in the case of tramp ant management, the distinctiveness and national significance of the biodiversity assets at risk from tramp ants at that place. Thus, a program that seeks to maintain and restore distinctive or otherwise nationally significant biodiversity assets is of greater value than a program that seeks to maintain and restore biodiversity assets that are in general more widespread, more resilient in the face of anthropogenic disturbances, and/or have already been secured at a number of sites.

- *Gains made*. All else being equal, a program that makes large gains in maintaining or restoring biodiversity is of greater value than a program that makes lesser such gains. However, related to irreplaceability issues above, greatest value is where gains are made in the most distinctive elements of the biodiversity represented at that place.

From these perspectives, small gains in highly unique and under-represented ecosystem types are likely to be of much greater national value than large gains in common/well represented ecosystems. There are likely ecological thresholds over which gains made will be ecologically sustainable. In the case of tramp ants, that threshold will often be eradication, as in general in the absence of total eradication there is high potential for re-establishment from residual ant colonies. Further, gains may be transient if biosecurity measures are not in place to prevent establishment from new incursions.

3.10 Practical On-ground Advice that Could Improve the Program Design to Enhance Biodiversity Outcomes

3.10.1 Monitoring impacts

Impact assessment is important, even in failed eradications or suppressions, and under situations of containment, as it is the opportunity to provide data on pest impacts under Australian conditions. The outcome performance of past and present tramp ant management programs will likely influence willingness to invest public funds to respond to future incursions. Robust assessment of program outcomes derived from sound impact assessment data, will be critical to future funding decision processes.

In our evaluation of the tramp ant abatement programs we noted large variance in data collection and management proficiencies, especially in relation to impacts of the tramp ants and applied pesticides on biodiversity. As noted by the National Biosecurity Committee 2009 Review of the Red Imported Fire Ant Program[278] collection, analysis, interpretation, and reporting of data is fundamental to assessing the performance and progress of programs, reviewing and improving surveillance and treatment strategies, and assessing the technical feasibility of eradication, suppression or containment. These are also required to inform reporting to the funding and regulatory authorities on performance against the agreed milestones.

In section 3.9 we outlined a framework from which a minimum core set of measurements might be developed to assess and report on tramp ant impacts on biodiversity in Australian terrestrial ecosystems. It is recommended that this framework be developed further within a consultative process with stakeholders.

Several programs (e.g., [134]) raised concerns about ability to employ proper experimental designs in the face of pressures to eradicate or suppress the tramp ant. However, it is evident that in some cases robust discussions and scientific consultations were not had to fully explore options. Key points to consider are:

- Experimental design

The concepts and sampling methods introduced within the framework are easily adopted within a before-after-control-impact (BACI) experimental design, allowing assessments of biodiversity impacts within the constraints of eradication, suppression or containment imperatives. The framework also does not preclude the flexibility to include additional measures of ecosystem impacts, as invasive species establishment often leads to novel ecologies, which generally are difficult to predict *a priori* but are important to document if both understanding of invasion processes and mitigation of impacts are to advance.

- Allocation of replicate sites to treatments

An often overlooked difficulty in impact assessment is that tramp ant incursions into an area are often not random in respect to environment. Thus tramp ant infested sites and available tramp ant-free control sites may be inherently different in respect to environmental character, albeit often subtle, and thus likely to vary in biodiversity and ecosystem processes. Critical to robust interpretation of results is the proper environmental characterisation of infested sites and candidate non-infested control sites, so as to select control sites that match the infested sites as much as practicable. Several aspects of the environment may be characterized readily from available high-resolution spatial databases, including remote sensed spectral signals and topography, but 'on the ground' such as soil physics and chemistry, and vegetation composition will also be helpful. Armed with this environmental information, it is then possible to adopt appropriate statistically-robust experimental designs such as i) replicated pairs of infested and non-infested sites that can be analysed in paired groups' analyses such as t-test, Wilcoxon-test or McNemar's-test; ii) stratified-random allocation of infested and non-infested sites to replicates for analysis of variance types of analyses; or iii) stratified-random allocation of infested and non-infested sites to one or more environmental gradients that can be modelled in regression or Bayesian approaches to gradient analysis.

- Need to quantify tramp ant abundance

There is a critical need to collect data on tramp ant densities to develop an understanding of the relationship between tramp ant density and levels of impact on biodiversity. Of primary interest is an estimate of average foraging ant density per unit area, at a spatial scale relevant to the biodiversity components being affected. Because ants vary in size, speed, and where they forage, there is no single standard method that will best apply to all ant species. For example, card counts are suitable for measuring yellow crazy ant activity when the ants are very abundant, but when they are not very abundant, or when a different ant is the target (e.g., electric ant), they will not be useful. Within a program it is useful to develop a standard method for comparing abundance across sites (e.g., number of ants attracted to hot dog lures placed on the ground spaced 3m apart) that also takes into account foraging behavior of the target species (e.g., lures will only be placed when the temperature is between 22-28^{o}C, there is no precipitation, and the wind is minimal).

- Need to monitor biodiversity beyond eradication

To fully document recovery of biodiversity, it will be necessary to continue monitoring biodiversity for a period of time after eradication is achieved. The length of time necessary to document any potential recovery will vary with the generation times and dispersal abilities of the taxa involved.

That this basic requirement can be readily meet as a component of eradication at sites is illustrated by the program of yellow crazy ant control in the Arnhem Land. There, native ant communities have been monitored over a number of years, within a BACI experimental design, following baiting of individual the tramp ant infestations[181]. However, in cases where colonies are densely clustered and their effects on biodiversity may not be independent, monitoring will need to extend in time after all colonies have been eradicated.

To accommodate monitoring beyond eradication, it is necessary to build this requirement into funding proposals, with appropriate budgets.

3.10.2 Risk assessment to guide monitoring

Risk assessment should not be seen as an end in itself. A principal reason for risk assessment is to guide further action, either in developing control protocols to minimise the identified risks; to develop monitoring programs so as to be able to robustly report on levels of realised non-target impacts; or both.

In relation to fipronil baiting to control yellow crazy ant on Christmas Island, Green et al.[223] developed a risk assessment for invertebrates, reproduced here in Table 3.18. While there are some deficiencies, this approach could be readily developed as a generic framework for all bait applications, or perhaps more appropriate, readily expanded to differentiate likely risks from different classes of active ingredients (metabolic inhibitors; neurotoxins; insect growth regulators; See Section 2) used in baits to control tramp ants. Green and colleagues' assessment only addressed arthropods, but could readily be expanded to include other invertebrate groups, e.g., annelids, crustaceans, isopods, land snails.

Table 3.18 Risk assessment for invertebrates on Christmas Island, Indian Ocean, during the proposed aerial baiting operation with fipronil ant bait (From Green et al.[223] Table 7)

Group	Common name	Functional feeding group	Risk
Araneida	Spiders	predatory, prefer live prey	low
Blattodea	Cockroaches	omnivorous	high
Coleoptera	Beetles, weevils	various	high, except herbivores (low)
Collembola	Springtails	microorganisms	probably low
Dermaptera	Earwigs	predatory	high
Diptera	Flies	liquid feeders	very low
Hemiptera	Bugs, leafhoppers, aphids etc.	liquid feeders	very low
Hymenoptera	Wasps and Bees	predatory, pollen, nectar	high (wasps), low (bees)
Hymenoptera	Ants	predatory, liquid	high
Isoptera	Termites	detritivorous	high
Lepidoptera	Moths and butterflies (adults)	liquid feeders	very low
Mantodea	Praying mantids	predatory	high
Myriapoda	Millipedes	detritivorous	high
Neuroptera	Lacewings, ant lions larvae	predatory	high
Odonata	Dragonflies and damselflies	predatory, feed on wing	very low
Orthoptera	Grasshoppers, locusts and crickets	various	high, except herbivores (low)
Phasmatodea	Stick insects	herbivorous	very low
Pseudoscopionida	Pseudoscorpions	predatory under bark	very low
Psocoptera	Booklice, barklice	omnivorous	high
Thysanoptera	Thrips	various	high
Thysanura	Silverfish	omnivorous	high
Zoraptera	Zorapterans	fungivorous	very

4. COMMUNITY AWARENESS

The association of tramp ants with humans makes them frequent hitchhikers in just about any kind of cargo or vehicle and facilitates their spread in long-distance dispersal[7], greatly increasing their rate of spread in a landscape. For example, maximum distance of spread by Argentine ant colony budding averages 150 meters per year, but human-mediated jump dispersal distances average three orders of magnitude more[279]. Preventing the further inadvertent spread of these pests is therefore one of the primary goals of raising community awareness common across most of these programs. A second primary goal of community engagement efforts is to educate and motivate the public to detect and report infestations.

In the discussion below, for each project, we evaluate

1. the approaches used to engage the community and build awareness about the tramp ant in question,
2. the effectiveness of these approaches and the usefulness of their participation to the project, and
3. the extent to which the community engagement in these projects has built capacity so that possible future occurrences of tramp ants may be detected and controlled by the community.

For ease of comparing projects, we summarize approaches and goals across programs in Table 4.1. We focus on years in which CfOC funds were awarded. It is worth noting that the contractual requirements and resources for community engagement efforts, as well as project longevity vary immensely across the six programs. Consequently, we avoid comparing goals and progress across programs in favor of developing recommendations for effective community engagement strategies that take into account universal human nature, local context, and the biology of the invader.

Queensland Biosecurity has identified a continuum of stakeholder engagement from passive to proactive, as shown in Figure 4.1[280]. The diagram serves as a useful guide for evaluating all six programs. Building capacity for community-driven detection and control efforts will require that community engagement efforts move toward the “mobilise and empower” end of the spectrum.

Figure 4.1 A continuum of stakeholder engagement[280]

Passive — *Increasing level of engagement* — *Proactive*

Inform	Listen	Involve	Partner	Mobilise& Empower
Newsletters, media, brochures, letters, websites	Toll-free numbers, public meetings, surveys, focus groups, panels	Community advisory groups, joint planning groups, forums	Community management committees, workshops, negotiation processes	Action plans developed and implemented by the community with access to experts and resources available through government and industry

Table 4.1 Summary of community awareness requirements, purpose, and methods for each project, focusing on years of CfOC funding*

	RIFA	EA	YCA-NT	YCA-CI	ABHA	Argentine ants
Contractually required	Yes	Yes	No	No?	Yes, broadly for ports of entry	Yes
Dedicated Budget	Yes	Yes	No	No?	$15k	No
Dedicated personnel	Yes	Yes	No	No	No	No
Purpose	Report new infestations, prevent spread, build community capacity	Gain community support, bring awareness to community, report new infestations, prevent spread	Report new infestations, prevent spread	Garner community support for control and conservation measures generally	Report new infestations, prevent spread	Report new infestations, prevent spread, build community capacity
Methods						
Inform	Community talks, displays, media releases and ensuing newspaper radio and TV coverage, website, social media	Community talks, displays, media releases and ensuing newspaper radio and TV coverage, website, social media	Display at local festivals, signs at infested sites	Public meetings, newspaper articles, flyers to households, talks with visiting school kids, Bird Week, website	Newspaper articles, word of mouth	Newspaper articles, word of mouth, notices to landholders
Listen	Call center	Call center	Contact number	Contact number	Informal; contact number	Informal; contact number
Involve, partner, mobilize	Co-employment of community engagement officers with 2 local councils; Fire ant volunteer rangers	Find the smallest ant sample as cinema entry; training indigenous rangers and environmental tourism operators	20 indigenous rangers and Pacific Alumina staff trained; yellow crazy ants part of mine-site induction		Training Waste Mgmt Center staff	Training farmers and residents; liaising with Norfolk Island Flora and Fauna and National Park staff

* RIFA= red imported fire ant; EA= electric ant, YCA-NT= yellow crazy ant-Arnhem Land, YCA-CI= yellow crazy ant-Christmas Island, ABHA= African big-headed ant, AA= Argentine ant

4.1 Red imported fire ants in Queensland

4.1.1 Approaches used

Community engagement and awareness are arguably most important in projects in urban and suburban areas. NRIFAEP management recognizes the importance of public input and has implemented several avenues to raise public awareness and motivation to look for and report red imported fire ant sightings. For 2008-2010, these approaches included[18, 44, 281, 282]:

- community talks at schools, clubs, and societies
- interactive displays at community events and places of business
- General Awareness and Approved Persons training for industry
- maintaining the website
- media releases and articles leading to coverage in print, radio, television
- recruitment of Fire Ant Volunteers (65 as of 2010-11[42])
- co-employment of Community Engagement Officers with Logan and Ipswich Councils
- tear-off information pads at southeast Queensland hardware outlets
- information placed in doctors surgeries, new in 2009-10
- post-card surveillance trial (Jan 2010)

More recently, efforts to engage with industry have increased and new approaches to engage with the community more broadly have been employed. The program has developed relationships with the Department of Transport and Main Roads, the Australian Chicken Growers Association, Brisbane Organic Growers, and others[42, 48]. Following an incursion of fire ants on mining equipment, and a new detection in a more rural area, the program also developed engagement strategies to target the mining industry and farmers[48]. New approaches for engagement with residents include updated community displays, brochures, and postcards, two trailer-mounted variable message signs, public notices following changes to the Restricted Areas, and the use of social media (e.g., Facebook, Twitter)[42, 48]. In 2011-12, 1000 people participated in the fire ant quiz as part of Fire Ant Detection week on Facebook[48].

Another new approach that is receiving a lot of positive feedback is the "Aka show" [283] . Aka is a retired fire ant sniffer dog who is the centrepiece of a presentation to children in primary schools. Children are shown that some outdoor activities such as playing on swings or in sandpits may no longer be possible if fire ants colonize their backyards. Children are then sent home with a backyard detection kit to do with their parents. Plans are underway to partner with Australia Zoo to provide incentives (e.g., a chance to win free passes) for returning the results of the backyard search to NRIFAEP.

4.1.2 Effectiveness of approaches

Public detection and reporting of red imported fire ant colonies, known as passive surveillance, is far more cost effective than structured surveillance. Based on the amount of active surveillance that would have been required to detect all known fire ant colonies from 2006 to 2010, the estimate of the return on investment in community engagement is 52:1, measured as the savings in active surveillance because of passive surveillance[61].

The direct benefits of raising community awareness for NRIFAEP are reflected by the general level of knowledge about the red imported fire ant, whether residents check their property, and the number of detections reported by the public.

Awareness of the ant

The nearly annual Queensland Regional Householder Survey (QRHS) by the Queensland Office of Economic and Statistical Research is a valuable tool to measure awareness of red imported fire ants and the most effective means of engaging with the community. The survey utilizes a database of landline and mobile telephones and has asked the same or similar questions about fire ants every year. A summary of responses to some questions from the 2002-09 and 2011-12 surveys is in Table 4.2. (Apparently no survey was conducted in 2010.) Awareness of red imported fire ants in Brisbane is consistently above 90%. However, the decline of awareness of nearly 5% from 2010-11 to 2011-12 should be of concern if the trend continues next year. The high level of awareness indicated in the QRHS is consistent with other surveys. A follow-up survey to the January 2010 post-card surveillance trial found that 97% of those who returned the post-card as requested had heard of the red imported fire ant, and this did not differ from those who did not return the post-card[281]. A survey of attendees of a major agricultural fair in 2012, also found 97% of respondents had heard of fire ants[283].

The percentage of respondents who have checked their yard for fire ants in the past 12 months is less positive. In 2001, 73% of respondents had checked their yard[46]. Aside from 2003, there has been a more-or-less steady decline in respondents who had taken this action (Table 4.2). In most recent years, the main motivator for checking has been risks to children (2008: 23.9%[284]; 2011: 18.7%[285]; 2012: 23.0%[286]); in 2009, being stung was the main motivating factor (23.9%[287]). For the past three surveys, the main reason for not checking has been that the respondent does not live in a fire ant area (Table 4.2). This finding is consistent with the 2010 post-card surveillance trial program in which almost 90% of those who returned their post-card stated that finding out their own suburb was affected was their main motivator for acting.

The QRHS also indicates remarkable consistency over the past several years in the means by which respondents have become aware of fire ants (Table 4.2). Despite the variety of outreach efforts, television is always the most remembered medium. In 2012, respondents indicated that they would prefer to be kept aware of fire ants with TV/newspaper/radio/magazine advertisements (43.8%) or feature stories (32.3%) and/or with direct mail-outs from Queensland government (35.1%)[286]. The program benefitted in 2011-12 with media coverage of the public launch of the aerial surveillance methodology[286].

Confidence in the ultimate success of the program has fallen since its inception, with less than half of respondents in 2009 and 2011 thinking that it is likely or very likely to succeed (Table 4.2). This may be a reflection of the number of new detections and the containment approach over the last two years. In 2012, a new question was introduced to the survey that revealed that about half of respondents (53.8%) who had heard of fire ants thought they were still a problem. Almost a fifth of respondents (18.7%) did not think they were and 27.4% did not know[286].

Table 4.2.Summary of red imported fire ant awareness and yard checks based on the Queensland Regional Household Survey 2002-2009, 2011-12[46, 285-287]

Year	Survey dates	Have heard of red imported fire ants (%)	Checked yard in past 12 months[a]	Top reason for not checking[b]	Source of awareness[c]			Success of program likely or very likely (%)
					TV (%)	Newspaper (%)	Radio (%)	
2002		96.3	61.5					69.0
2003		99.5	73.4					54.8
2005		98.7	61.0					76.1
2006		98.7	59.1					60.0
2007		96.0	55.4					54.5
2008		95.9	52.2	Haven't thought about fire ants (19.1%)	66.5	44.3	12.8	68.2
2009	16 Nov-6 Dec	94.1	48.2	Not in fire ant area (20.1%)	62.6	47.5	17.0	46.6
2011	23 May-10 June	96.5	51.8	Not in fire ant area (29.4%)	61.4	40.8	14.2	47.1
2012	28 May -12 June	91.6	44.9	Not in fire ant area (23.6%)	56.1	45.6	14.9	Not asked

Note: prior to 2011 Office of Economic and Statistical Research did not have access to mobile-only households[286]

[a]Of those respondents who were aware of red imported fire ants
[b]Of those respondents who did not check
[c]Respondents allowed multiple answers

Despite the high level of awareness of red imported fire ants, there is clearly scope to build public confidence in the program, and to further educate the public on the problems caused by fire ants and the importance of detecting them.

Number of reports and detections

The number of samples submitted by the public, the percentage of those that are positive for red imported fire ants, and how these change over time and with the introduction of new community engagement methods are also indicative of the effectiveness of community engagement efforts. Table 4.3 shows the history of samples submitted by the public since the inception of red imported fire ant control efforts.

Table 4.3.Summary of samples submitted by the public since the inception of a red imported fire ant control program[18, 42, 44, 48]

Financial year	Samples submitted by public	RIFA samples submitted by public	% of samples that were RIFA
2000-01	3831	30	0.78
2001-02	3077	121	3.93
2002-03	3242	53	1.63
2003-04	2930	11	0.38
2004-05	3011	46	1.52
2005-06	7490	112	1.50
2006-07	989	74	7.48
2007-08	654	125	19.11
2008-09*	740	232	31.35
2009-10*	4050	400	9.88
2010-11	2747	Not provided	
2011-12	2419	Not provided	

*CfOC funding years

Some of the changes in the samples received have been attributed to specific community engagement events:

- The large number of samples submitted in 2005-06 has been attributed to the "Find the Fire Ant Days" campaign[18, 282]. Participants returned a "yard check report" and completed reports that found no suspicious ants were counted as negative samples. The response rate was 6%, which NRIFAEP thought was a good response[282].
- The $500 reward given to anyone who reported a new red imported fire ant colony between 18 April 2008 and 24 June 2008 was associated with 2196 reports, compared to 234 during the same period the previous year. At a cost of just $14,500 for 29 new detections, the scheme was much more economical than scheduled surveillance activities. Analysis of the number of weekly contacts relative to the number of community engagement events reveal an increase in the number of contacts made by the public for the 18 months following the end of the scheme[61]. Overall in 2008-09, 73% of new detections were reported by the public[18].
- There was over a 5-fold increase in submitted samples in 2009-10 from 2008-09. New community engagement initiatives implemented in that year included a pilot of the postcard

surveillance program and placement of red imported fire ant information in hardware stores and doctors surgeries[44].

- In 2010-11, 19,427 postcards were mailed out of which 1317 were returned, with 47 respondents indicating that they suspected they had fire ant on their property[42]. At the time of the report, however, the database needed upgrading to be able to determine how many of these were ultimately positive for red imported fire ants.
- Though the number of positive reports for 2010-2012 is not provided, in 2011-12, 70% of new red imported fire ant infested sites were reported by the public[48].

The percentage of positive samples is much higher from 2007-10 than it was in the earlier years of control efforts (Table 4.3). A large number of negative samples can strain project resources. It appears that the public is becoming more discriminating in what they send to NRIFAEP but the number of samples submitted is not declining.

New detections that are outside the current known area of infestation are the most important because they are least likely to be detected in the scheduled surveillance activities. (Remote sensing should help greatly in this regard, but was not yet implemented in the years of CfOC funding). In 2008-09, 330 colonies were reported by the public, 35 of these at 29 sites were considered “outlier” colonies because they occurred outside Restricted Areas[18]. In 2009-10, 284 colonies were reported by the public, with 40 of these at 32 sites considered outliers[44]. The total number of outlier colonies reported by the public represents 38% of all outlying colonies detected in 2008-09 and 3.2% in 2009-10. The numbers of colonies reported by the public represent 82% of all detected colonies in 2008-09 and 5.4% % in 2009-10. The low percentage in 2009-10 is due to the large number of outlying colonies detected by program staff in the last quarter, rather than a drop-off in the number of colonies detected and reported by the public.

The number of new colonies found at a site is indicative of the age of the infestation. All of the outlier colonies reported by the public in 2009-10 had no more than two colonies, indicating that they were detected and reported by the public relatively quickly. NRIFAEP attributes this to their community engagement efforts[44].

4.1.3 Extent of capacity building

Anthony Wright, the Community Engagement Manager for NRIFAEP states that building capacity is exactly what the NRIFAEP has been working toward with their community engagement efforts[283]. The finding that over 90% of residents know of red imported fire ants is a promising first step to achieve this goal. To continue working toward community capacity building, goals for the future are to 1) maintain this level of knowledge, without reaching message fatigue, and 2) to increase levels of passive surveillance.

New education programs are being employed to work toward achieving both goals. In 2011-12, the program has updated training, flyers, presentations to the communities, and other community education approaches to coincide with the changes in Restricted Areas and to expand the utility of passive surveillance[48].

Two key aspects of this program that are in line with new goals and lessons learned from the past are 1) collection of negative reports, i.e., where the red imported fire ant is absent, and 2) the provision of an incentive beyond avoiding personal risk[283]. Passive surveillance up until the past few years was focused on asking the public to look for and report when they encountered fire ant. No response was requested if the fire ant was not found. Data on where the red imported fire ant does not exist, however, is also very important. So, where previously the main message was 'check your yard and call us if you find fire ant', the new approach is to ask residents to respond with the results of their backyard check, whether positive or negative. NRIFAEP has been updating its data collection and management systems to enable effective storage and utilization of these data. The incorporation of red imported fire ant absences into the database will allow structured surveillance and control efforts to be much more targeted. TASAP raised concerns in June 2008 that community reported absences may not be reliable, and false absences would allow established colonies to spread. However, follow-up visits by NRIFAEP staff to 500 households reporting fire ant absence in the January 2010 post-card survey also found no fire ants at the site, providing important validation and confidence that residents can be effective at checking their property for fire ant[281].

Perception of a risk, for example to health, children, lifestyle, or home, can be an effective short-term motivator for action and has been used throughout the education campaign. However, after a few months when no harm eventuates, the threat of harm will no longer be a sufficient incentive. One previous incentive scheme (the Fire Ant Reward discussed above) was considered a great success for the number of new detections it yielded as well as the increase in report numbers long after the scheme ended[61, 282]. Evidence from psychological studies suggests that people who check their yards in response to an incentive once, are more likely to do so again in the future even in the absence of incentives[283].

With red imported fire ant management efforts in their 12th year and repeated promises of eradication not yet eventuating, message fatigue is a concern. The survey that accompanied the post-card surveillance trial[281] indicated some loss in effectiveness of engagement efforts over time. Post-card recipients who lived in areas that had received attention from NRIFAEP previously were less likely to respond because they were unaware that any action was required and/or they assumed someone from the program would be coming to check anyway, as had happened in the past. NRIFAEP aims to combat this with the new messaging and incentives to stimulate involvement[283].

Rapid dissemination of information and keeping motivation for action will be keys to future success in eradicating, or even containing the red imported fire ant. More should be done to take advantage of the opportunities provided by social media. Biosecurity Queensland has a Facebook page on which information about red imported fire ants and other biosecurity threats is posted. This is a good start, but might be improved by facilitating finding of information that is relevant to specific pests (e.g., a specific page for red imported fire ants, another for electric ants, etc.) rather than a single Biosecurity page with posts for everything from Hendra virus to Asian honey bees. To attract residents to the page, incentives could be given for those who 'like' it (e.g., a chance to win movie tickets). Twitter might be used in a similar way. The advantage of these methods is that they are inexpensive, immediate, targeted, and are likely to engage a younger generation, which will be essential for future capacity building.

With the recent implementation of the remote sensing technology to survey large areas of land for red imported fire ant (see Section 2.1), some review of target communities for community engagement efforts might be useful so that the two approaches maximize complementarity and coverage. Areas with low population density will likely be covered with remote sensing, whereas passive surveillance by the community will still be important in residential areas.

4.2 Electric ants in Queensland

The National Electric Ant Eradication Program (NEAEP) is unique among the six projects in that it has explicitly stated four specific purposes for its community engagement efforts[37]:

1. gain support of Cairns community for surveillance and treatment activities
2. bring awareness to Cairns community about pest ants
3. engage community and industry to achieve compliance with electric ant movement controls
4. encourage participation of community in passive surveillance

4.2.1 Approaches used

Though the NEAEP has a much smaller staff and budget than NRIFAEP, it has employed a similar set of approaches to engage the community [66, 68, 288-293]. For the years of CfOC funding, these include:

- interactive and static displays at community events and shows
- awareness sessions for councils, construction and community groups
- educational awareness sessions for schools, visits to school fetes
- targeted industry engagement (gardening, landscaping, education, housing development, earthmoving, real estate, building/construction, hotels, wholesale nursery)
- media releases leading to mentions in TV, radio, newspaper
- brochures and posters placed in at least 10 GP surgeries in Cairns
- website maintenance
- display in a local hardware store
- signs next to roads in electric ant areas
- an electronic variable message sign for broadcasting messages to the public

Community engagement efforts have targeted the Cairns region, and in 2007-08 in particular, also reached the Tablelands, Townsville, and the Cape York Peninsula[10].

In 2008, the “tiny suspect ant awareness campaign” got underway. Feedback from residents at previous at community events indicated that while residents were aware of the eradication efforts and the description of the ant, they did not always see what had stung them and therefore may have not been reporting electric ant stings. This campaign asked residents to report any tiny ant (“if it’s small, give us a call”)[13]. Ernie Dingo’s voice was used in the radio ads, and his face on community billboards and other print media. Key messages were “watch out for these little blighters” and “don’t get electric ants in your pants”[289]. Ants in resin blocks were included in community education events and displays so that residents could see the actual size of the ants.

In June 2009, a cinema night was held with the support of local community and environmental groups. The event provided a program overview, and update on the program and information on electric ants, and the screening of an animated children’s movie. Attendees were asked to bring the smallest ant they could find for admission to the event[13].

A new major electric ant awareness campaign was held from the 6th-26th of June 2011. The campaign featured radio, television, and print advertising[66, 291, 294]. The campaign led to two additional presentations by the community engagement officer at pest control industry conferences in Cairns and Townsville[66].

In 2011-12, intensive awareness campaigns were conducted at local schools. Community engagement officers attended 12 school events (school fetes, classroom presentations) during the year, and the program hosted two students from local schools for one week work experiences. The program also hosted a university volunteer[65]. In addition, local indigenous rangers and staff from an environmental tourism company were trained so that they can self-monitor for electric ants and other tramp ant species[65].

4.2.2 Effectiveness of approaches

The effectiveness of community engagement efforts can be measured in the general awareness of the electric ant, and public reporting of suspect ants and the number of detections resulting from public reports. Industry compliance is covered in the Management section (Section 2.2).

Awareness of the ant

Again, the NEAEP is unique among the six programs in having explicitly set quantitative goals for what it hoped to accomplish with its community engagement efforts. In 2008, the Queensland Electric Ant Program Plan[62] set as performance indicators:

- 80% of surveyed residents in the Queensland Householder Survey have heard of electric ants
- >60% of residents have checked their yards for electric ants

The Queensland Regional Householder Survey is a nearly annual undertaking by the Queensland Office of Economic and Statistical Research and provides a means of measuring community awareness. The survey utilizes a database of landline and mobile telephones and asks the same or similar questions about electric ants every year. A summary of responses from the 2007-09 and 2011-12 surveys is in Table 4.4. (No survey results are available for 2010). Some caution is warranted in comparisons among years because the 2007-09 surveys included respondents well outside the Cairns region, and in those years community engagement efforts were focused primarily around Cairns.

Aside from a slight decline in 2009 to 79.1%, it appears that over 80% of respondents in the Far North or Cairns region have heard of electric ants (Table 4.4). The consistency of these results over the years is remarkable considering that the transient nature of the Cairns population has been identified as a major challenge to raising awareness in the region[63]. In 2008, 2009, and 2011, around 40-45% of respondents recalled hearing about electric ants on television and/or in newspapers and these two were consistently the most common responses. In 2012, signs and billboards in the area were the most common means of hearing about electric ants (38.6% of respondents) followed by newspapers (38.3%) and television (37.8%). The 2009 survey attempted to find out whether specific campaigns (Ernie Dingo, “What’s this little blighter”), but problems with the wording of the question invalidated results.

Table 4.4 Summary of responses to electric ant questions in the Queensland Regional Household Survey 2007-2009 and 2011-2012

	Region surveyed	Dates	Within Cairns boundary	Number surveyed	Have heard of electric ants	Claim to know what electric ants look like[a]	Correctly state electric ant length is <2mm[b]	Checked yard in past 12 months[b]	Believe electric ants would have envtl effects[b]	Identify high risk means of electric ant spread[c]
2007[295]	Far North Statistical Division	Not stated	59.4%	~600	65.1%	48.3% of 65.1% = 31.4%	31.9% of 31.4% = 10.0%	40.7% of 31.4% = 12.8%	27.7% of 65.1% = 18.0%	50.1%
2008[296]	Northern and Far North regions	25 June – 17 July	Not reported	~300	66.7% overall; 82.5% in Far North	31.9% of 66.7% = 21.2%[d]	41.0% of 21.2% = 8.7%[7]	47.4% of 21.2% = 10.0%[7]	28.5% of 66.7% = 19.1%[7]	48.0%
2009[297]	Northern and Far North regions	18 May-15 June	Not reported	601	58.7% overall; 79.1% in Far North	46.7% of 58.7% = 27.4%[d]	50.5% of 27.4% = 13.8%[7]	42.7% of 27.4% = 11.7%[7]	28.0% of 58.7% = 16.4%	54.4%
2011[298]	Cairns QRHS region	23 May – 10 June	100%	300	86.9%	56.3% of 86.9% = 48.9%	42.3% of 48.9% = 20.7%	48.6% of 48.9% = 23.7%	19.7% of 86.9% = 17.1%	59.9%
2012[299]	Cairns QRHS region	28 May-12 June	100%	323	83.2%	Not asked	Not asked	48.3% of 83.2% = 40.2%	Not asked	Plants: 32.8% Soil: 30.7% Garden waste: 22.3%

[a]Of respondents who have heard of electric ants
[b]Of respondents who have heard of electric ants and state they know what electric ants look like
[c]Pot plants, soil, garden waste/rubbish
[d]Did not differ between Northern and Far North regions

It appears there is still some work to be done to meet the second performance indicator, as the percentage of respondents who had checked their yard in the past 12 months is consistently well below 60% (Table 4.4). In 2007-09, around 10% of respondents had checked their yard in the past 12 months. Although these surveys also questioned respondents outside of the Cairns region, there were no significant differences in yard-checking among regions. In the most recent survey, 40.2% of respondents had checked their yard for electric ants in the past 12 months. This was the first survey, however, that did not ask whether respondents knew what electric ants looked like. Previous surveys showed that at most 50% of respondents who thought they knew what electric ants looked like were correct about the size of the ant (Table 4.4), so it is quite possible that many of the 40.2% who did check their yards in 2012 did not know what to look for.

A very common reason given by respondents for not checking their yards was that they did not believe they were within an electric ant area. It follows that across all survey years, the most common response to the question "What would encourage you to check your yard for electric ants?" was "being advised I'm in an electric ant area" (Table 4.4). Area is a nebulous term, so it is unclear how close respondents would have to be to an infestation before they considered themselves to be 'in an electric ant area.' It might refer to Restricted Areas, where movement controls are in place. The most useful detections however, will be in areas where the ants are not currently known to occur.

Less than one fifth of respondents across all survey years believe the electric ant would have an environmental impact if it is left unchecked (Table 4.4). Without a clear understanding of the consequences of not detecting or reporting electric ants, it is less likely that residents will be motivated to do so.

It is disappointing that in 2012, fewer than a third of respondents identified high risk materials (pot plants, soil, garden waste/rubbish) as means of electric ant spread (Table 4.4). The percentage of respondents that don't know how electric ants spread has declined, however, from 29.4% in 2007, 32.3% in 2008, and 28.2% in 2009 to 21.0% in 2011 and 2012[295-299].

Number of reports and detections

Despite the lower than desired yard-checking rate, NEAEP is succeeding in large part because of reports and detections by the public. Table 4.5 summarizes samples and detections by the public over the years of the program. At least 19 of 26 electric ant detections have been the result of a public report or sample. The marked increase in reports by the public in 2010-2011 is in part attributed to the media campaign in June 2011 which resulted in a 438% increase in calls to Biosecurity Queensland to report suspicious ant activity[66, 294].

4.2.3 Extent of capacity building

The high percentage of adults in the Cairns area that have heard of electric ants is a promising start to capacity building. However, it is clear from the low percentages checking their yards and believing that electric ants pose a serious risk to the environment, an understanding of the risks posed by electric ants and motivation to avoid risk are still largely lacking.

Table 4.5 Summary of public reporting and samples submitted to the NEAEP[20, 65, 66, 68, 288, 300]

Financial year	Samples submitted by public	Electric ant samples submitted by public	Significant detections by public/total significant detections
Up to 2008-09	1076	1	¼
2008-09*	345	4	4/4
2009-10*	232	2	2/2
2010-11*	496	44	11/13
2011-12	623	2	≥1/3

*CfOC funding years

Getting those points across may mean developing stronger messages about risks and consequences of not acting. For example, the reports of a goanna and a pet dog being blinded by electric ants[63] could be developed as a motivation for residents to check their properties. Education and training should also emphasize that even if you live outside of known electric ant areas, it is worth checking your property.

Most of the community engagement efforts to date have been on the passive end of the Stakeholder Engagement Continuum (Figure 4.1), focusing on informing and listening. These approaches have been necessary for achieving the first two of the four stated goals for the Community Engagement part of the program (gaining support of the community and bringing awareness to the community).

Achieving the last two goals (engaging the community to achieve compliance, and encouraging participation in passive surveillance) will further build community capacity to deal with future incursions of tramp ants. The recent training of indigenous rangers and environmental tourism operators to identify electric ants is exactly the type of activity that will develop community capacity and extend the resources of the program.

Despite being part of Biosecurity Queensland, the NEAEP does not appear to have taken advantage of social media as much as NRIFAEP has. A 'Find the Electric Ant' week on Facebook, similar to the 'Find the Fire Ant' week run by NRIFAEP might be worth developing, especially if small incentives can be offered. YouTube videos demonstrating how to check for electric ants have been proposed[63] and are worth developing. The program may need to plan on how to overcome being a victim of its own success; engaging with the community may become more difficult as the program succeeds and fewer people are bothered by electric ants or know of anyone who is.

4.3 Yellow crazy ants in Arnhem Land

This project had no specified contractual requirements for community engagement and no dedicated budget. However, the project has taken steps to raise community awareness of the yellow crazy ant so that inadvertent spread is prevented and the public is motivated to report any suspected occurrences.

4.3.1 Approaches used

Efforts to raise community awareness of yellow crazy ants and their effects included for 2008-2009 included[71]:

- an educational display for the Gove Peninsula Festival in July and the Garma festival in August 2008. The display was manned by an indigenous Dhimurru ranger as well as a field technician throughout the day so that any questions could be answered
- 200 printed factsheets in English and Yolngu that were handed out during field work in the local communities and given away at public events. The factsheet provided a clear description and photo of yellow crazy ants, a summary of why they are of concern, and instructions on what to do if they were sighted.
- 100 Roadside signs that were placed throughout Arnhem Land where the ant is known to occur. The signs are in English and Yolngu and identify the site as a Crazy Ant site (including the unique site number), that there is an eradication campaign at the site, a plea to not spread the ants from the site, and a contact number for further information.

Part of the management philosophy of Dhimurru is to have active collaborations. For the yellow crazy ant management program, Dhimurru has actively engaged with many organizations including regional stakeholders (Yirrkala rangers, Yirrkala Business Enterprises, Gumatj Association, Yirrkala Dhanbul Association) as well as the Northern Land council, Conservation Volunteers Australia, and local schools[78].

The project has a history of partnering with Pacific Alumina (formerly Rio-Tinto Alcan) and has received in-kind and financial contributions to facilitate project success. Basic information about yellow crazy ants is included in the on-site minesite induction, a training session required of anyone who visits or works at the minesite. Much of the population of the largest town in the region, Nhulunbuy, is employed by the minesite. Inclusion of yellow crazy ants in the induction is another avenue for raising public awareness.

The project received coverage by one television network, 25 radio stations, and one newspaper in 2009.

4.3.2 Effectiveness of approaches

No specific data have been captured that quantify the effects of these efforts to engage with and educate the community. However, with approximately 75% of the local population, or 3000 people, attending the Garma festival, and the deployment of rangers to the local outlying communities, the project coordinator, Ben Hoffmann, anticipates that most locals are aware of yellow crazy ants and the importance of managing them[71]. The media coverage of this project has also likely raised awareness at the national level.

4.3.3 Extent of capacity building

The project has two major legacies that build capacity for community management of future yellow crazy ant problems. At least 20 indigenous people have been trained in yellow crazy ant identification, chemical application, and general knowledge of the impacts of this invasive species[76]. The project adopted the model of "both ways" management practiced by the Dhimurru Land Management Corporation. This entails specific requirements for employing local landowners and structuring landowner participation in planning and implementation[76].

In addition, key staff employed by Pacific Alumina have been trained by yellow crazy ant staff and now manage YCA populations on the minesite lease. These infestations are among the densest on the Gove Peninsula[72].

The project has also been instrumental in getting yellow crazy ants to be considered in soil-moving protocols on the Pacific Alumina mining lease and for the placement of the Telstra fibre-optic cable between Nhulunbuy and Darwin. Yellow crazy ants are now also included in protocols for new mineral exploration throughout northeast Arnhem Land[76].

4.4 Yellow crazy ants on Christmas Island

The yellow crazy ant project on Christmas Island differs from the other five projects in that its primary goals for community engagement are to garner and maintain community support for control efforts rather than to detect new infestations and prevent spread[86]. The ant is well-established on the island and since the focus is on removing supercolonies of the ant rather than complete eradication, detection of every colony is not a goal.

4.4.1 Approaches used

The project primarily communicates with residents when major operational events, such as aerial spraying or the Island Wide Survey, are nearing. Articles and fact sheets in the local newspaper, *The Islander*, and public community meetings are the two primary means through which information is distributed. Flyers are also printed in Malay and Chinese and put in individual post boxes to reach the non-English speaking part of the population. In years past, there was strong community concern about the use of fipronil to control yellow crazy ant supercolonies. Now there is strong community support for efforts to control the ant[86].

Reports of ant detections by the community are still received and acted on. Public reports of ants are usually in the urban areas and cannot be treated. However, the interaction with the public is still welcomed as part of a broader strategy to involve the community in conservation activities.

Since receiving CfOC funding in 2011, community engagement activities have included:

- five public presentations, with audiences ranging from “almost no one” to over 50 people
- Hosting a school group of ~50 14 year old students from Singapore
- Presentation and field excursion with ~50 visitors to the island for “Bird Week”
- a newspaper article on the upcoming aerial campaign
- a newspaper article following the completion of the Island Wide Survey at the end of last year
- email on activities to list of stakeholders

4.4.2 Effectiveness of approaches

Given that the goal of community engagement efforts for the program is to garner community support, there are few measures of the effectiveness of the campaign other than that residents of the island are all aware of yellow crazy ants and no longer protest the use of fipronil to control ants. Buy-in from the public was achieved with public meetings and a decrease in the amount of fipronil used in the baiting process.

The national park staff and their conservation goals benefit from good relations with the public. For example, the public are asked to report sightings of rare native reptiles. Christmas Island National Park staff cannot risk poor relations with the public in its management of yellow crazy ants, not only because it will make managing the ant more difficult, but also because it might impinge on public involvement in attaining other goals.

4.4.3 Extent of capacity building

Capacity building to empower the community to detect and control future invasive ant incursions has not been a goal to date for this project. Nonetheless, the high familiarity of the public with yellow crazy ants, the goals of yellow crazy ant management, and the management techniques provide an important foundation for moving toward motivating and empowering the community to play a more active role in yellow crazy ant management if the management structure changes in the future.

4.5 African big-headed ants on Lord Howe Island

Community engagement has been an implicit part of the goal to "implement a strategy to eradicate African big headed ant infestations on Lord Howe Island," the CfOC funded project's second of five components. The fourth component, to "Improve biosecurity/quarantine awareness at Lord Howe Island entry points (airport/jetty)" is a more explicit requirement for raising community awareness, but with requirements for the message to extend also to the threat posed by weeds, myrtle rust, and rodents[247]. This component of the project is still at the conceptual stages[248].

4.5.1 Approaches used

The population of Lord Howe Island is 350 people, and according to Hank Bower, the project manager, informal communication is as important as more formal means of communicating messages to the public. Much of the communication is face to face, when the actual work is being done. There is strong interest in the community to come and see what on- the-ground staff are doing[100].

More traditional approaches to community education have also been employed. A notice was published in the well-read local paper prior to the first round of baiting and will also be done before the next round. The project has also produced a brochure that describes the threat of African big-headed ants to island biodiversity, how to identify and distinguish African big-headed ants from the native big-headed ant, and the three step process of the eradication program, along with large photos of major and minor workers, a website address and contact information for the manager and a ranger[103]. Missing from this factsheet is information for residents about steps they can take to avoid inadvertent spread of ants around the island (e.g., in pot plants or soil).

Program staff have also trained staff at the Waste Management facility so that they can readily identify African big-headed ants. If the ants are encountered, Waste Management staff alert program staff and the ants are traced back to the source[100].

4.5.2 Effectiveness of approaches

Residents of Lord Howe Island depend on tourism to make a living and therefore have a strong connection to the biodiversity values of the island. There are no statistics about the number of calls or reports from the public because many of these happen in informal settings outside of the office (e.g., chance meetings at a restaurant, or while out in the neighborhood). Hank Bower of the Lord Howe Island Board, is confident that all island residents are very comfortable about contacting him when they have an ant problem[100]. Prior to an ant identification training exercise by Ben Hoffmann, everyone on the island including the Lord Howe Island Board staff, thought that the more commonly found, possibly native *Pheidole*, was the African big-headed ant. Program staff received many phone calls reporting the presence of this ant. Mr. Bower is not aware of any infestations of African big-headed ants that were reported by the public.

4.5.3 Extent of capacity building

Community engagement efforts on Lord Howe Island have focused on raising awareness of the African big-headed ant and its effects, and preventing its spread. Capacity for identifying and treating the ant has been built among the 6-7 permanent staff at the Lord Howe Island Board. Mr.

Bower is very confident that the eradication effort will be successful and that any future infestations can be dealt with quickly. The community regards the ant as a nuisance and is strongly motivated by avoiding property damage (e.g., pavers being dug up by the ant) and the threat to Lord Howe's biodiversity and World Heritage values. Any future efforts to empower the community to control the ant could build on this motivation.

4.6 Argentine ants on Norfolk Island

Contractual requirements regarding community engagement are very specific for the Norfolk Island Argentine Ant Eradication project. According to the Project Schedule[105], the project must "increase the recruitment and retention of volunteers in community groups involved in managing natural resources…in particular youth" by five (two in 2010-11 and three in 2011-12) over the life of the project ([105] Target 2). The project also must increase by six (two in 2010-11 and four in 2011-12) the number of farmers "adopting activities…that contribute to the ongoing conservation and protection of biodiversity."

Other activities to raise community awareness were not explicitly required but have been undertaken to prevent spread of Argentine ants around the island and to encourage the public to report suspicious ants[112].

4.6.1 Approaches used

Norfolk Island is a community of 1800 people, and like Lord Howe Island, word spreads very fast through informal networks. According to Alan McNeil, "everyone knows each other" and the community is very comfortable about ringing to report pest ants[112].

Formal community engagement efforts have included[109, 112]:

- Newspaper ads to recruit casual field staff
- Recruitment and training of 20 field staff and 6 farmers over the course of the project[113]
- Six Argentine ant updates published in the well-read weekly local newspaper and Norfolk online News. These detail progress and importance of the eradication effort, how to prevent spread, and who to call for more information (e.g., [301])
- Direct contact with and information sheets for affected landholders explaining what Argentine ants are, how to minimize risks of harboring and spreading them, and who to contact for more information[302]
- Production of distribution maps identifying infested areas placed for viewing in public places[109]

4.6.2 Effectiveness of approaches

The project recruited up to 20 staff, including several youths to assist with field work on a casual basis. Though the contract had stipulated "volunteers," Mr. McNeil stated that the work they are asked to do is pretty difficult because of the terrain, and therefore payment was necessary. The project was successful in meeting its target to engage with six farmers whose properties were at risk of Argentine ants. The farmers worked on baiting and surveillance activities with staff across all affected properties.

As of spring 2011, there were ten zones of infestation on Norfolk Island, three of these had been detected and reported by private residents and two had been detected and reported by the conservators of Commonwealth public lands. In July 2012, another new detection was reported by a private citizen, which turned out to extend across several properties[112, 301]. The resident phoned in response to seeing information about Argentine ants in a newspaper article. In sum, of the 11 distinct zones of invasion known in September 2012, four have been detected and reported by private residents[110].

4.6.3 Extent of capacity building

Alan McNeil believes the specific targets to engage with five volunteers and six farmers set by CfOC will definitely build future capacity to address any future invasive ant problems. Over the course of the two years, the project engaged with 30-40 individuals, representing a mix of farmers and other residents. These individuals were given a full explanation of why baiting for Argentine ants is important. They were fully trained in bait application, including safety precautions and caulking gun use. In the course of their work, they often saw firsthand how Argentine ants behave differently than native ants, and how they swarm over the bait, as well as other protein sources, including chicks. As a result, the participants became very motivated to check for the results of their work and check their own neighborhood for Argentine ants.

One impediment to local capacity building to deal with Argentine ants or any other ant invader on Norfolk Island is the lack of strong local ability to identify ants. In the two years of this CfOC funded eradication effort, any ants that staff were unsure about the identity of had to be sent overseas for identification[106]. Staff skills increased over the course of the project, but the lack of this skill locally was a challenge that project staff had to work around[106, 112]. A labelled and properly curated reference collection of all ant species that occur on the island as well as a simple key or list of distinguishing features to enable confident recognition of any non-native will be an important step for building local capacity to continue to address the Argentine ant invasion and any future invasions by other ant species.

5. CONCLUSIONS ON THE CARING FOR OUR COUNTRY PROJECTS

As noted in Section 2, all of these tramp ant control programs are very ambitious relative to other efforts around the world. In the course of our interviews and emails with project personnel, we have been impressed with the level of personal commitment and dedication by staff across all programs. Staff perseverance is a key ingredient in managing tramp ants[201]. We are aware of staff incurring personal expense and working long hours to increase the likelihood of program success.

In Table 5.1 we summarize some of the history of the programs, the challenges they've faced and their achievements. We draw on these findings as we:

1. identify what control programs have been most effective in gaining biodiversity recovery ,
2. discuss whether successful biodiversity recovery can be replicated across other tramp ants programs, and
3. discuss the degree to which the programs have been appropriate, effective, and efficient within their scope and area of attention to meet and contribute to reducing impacts on biodiversity, with particular emphasis on the programs' achievements, lessons learned, and overall legacy.

Where practical we highlight events that transpired during periods of CfOC funding, but for the most part, since the successful managing of tramp ants builds on previous knowledge and experience, it is not possible or useful to try to discern which achievements correspond to which periods of funding. For the four largest and longest running programs, CfOC has never been the sole source of funding in any financial year.

5.1 Control Programs Effective in Gaining Biodiversity Recovery

Gaining biodiversity recovery implies that some biodiversity has been lost due to the tramp ant. Three programs, yellow crazy ants on Christmas Island and in Arnhem Land, and the red imported fire ant in Queensland, have documented some recovery following tramp ant control. A fourth, the electric ant program, has documented loss. These results are all described in detail in Section 3, so we only summarize them briefly here.

5.1.1 Biodiversity recovery

Yellow Crazy Ants on Christmas Island

Protection of native biodiversity is the *raison d'être* for the Christmas Island National Park. Yellow crazy ants have had a dramatic impact, particularly on the iconic Red land crab. Red land crablings that emerge from the ocean must migrate inland to the forest floor of the island's Central Plateau. As they pass through areas occupied by yellow crazy ants they can be blinded, paralysed, and eventually killed by the ants. Red land crabs are also killed and displaced from their burrows in the forested island interior. It is estimated that one quarter to one third of the crabs were killed during the late 1990s[202]. The loss of the crabs has resulted in dramatic changes in the island's forests. However, aerial baiting has halted this decline and there are indications Red land crab numbers may be increasing. This is a significant turnaround from 15-20% decline estimated to have occurred from 2001-2009[89].

However, recovery has not yet been documented for other species and processes affected by yellow crazy ants. It is too early to tell whether the slight increase in Red land crab numbers will translate to recovery of the forest. Forests where yellow crazy ant supercolonies have been eliminated but where Red land crabs have not returned ('ghosted' forests) differ significantly in litter mass and abundance of litter invertebrates from intact forests[212]. The dieback of native trees, including the Tahitian chestnut (*Inocarpus fagifer*) due to scale insects tended by yellow crazy ants[91, 202], is only reversible over the long-term. Whether vertebrates such as Christmas Island thrush (*Turdus poliocephalus erythropleurus*), Christmas Island emerald dove (*Chalcophaps indica natalis*), Christmas Island white-eye (*Zosterops natalis*), Christmas Island flying fox (*Pteropus melanotus natalis*), and Blue-tailed skink (*Cryptoblepharus egeriae*) utilise the newly supercolony-free sites is unknown. It also remains to be seen whether the yellow crazy ant-facilitated incursion of giant African land snails (GALS) is reversed with supercolony suppression, or whether the GALS invasion represents another crossed threshold, past which it will be difficult to return to the pre-supercolony state. The Christmas Island pipistrelle (*Pipistrellus murrayi*) may have gone extinct in part due to ecosystem level changes wrought by yellow crazy ant supercolonies[188].

Yellow Crazy Ants in Arnhem Land

The management of yellow crazy ants in Arnhem Land has been accompanied by monitoring the recovery of native ants with pitfall traps. The results would benefit from statistical analyses but do show that abundance of native ants, and possibly their species richness, in treated sites is higher than in the same sites pre-treatment, and about the same as untreated non-invaded reference sites[181]. This shows 1) that yellow crazy ants were having a detrimental effect on native ant abundance, 2) that removing the tramp ant reversed that effect, and 3) that the treatment regime did not adversely affect native ants. All three are important for documenting recovery of the ecosystem following tramp ant management.

No relationships have been found between yellow crazy ant abundance and total abundance or abundance of individual macro-invertebrate orders collected in pitfall traps[176].

Red Imported Fire Ants in Queensland

The red imported fire ant program is in the process of documenting the response of native ants to the fire ants, their removal, and to the baiting regime[42, 58]. Preliminary analyses have revealed that 1) the presence of polygyne colonies was associated with reduced abundance of native ants, and 2) removing the red imported fire ant increased the presence of five of the ten common ant genera. However, one native ant genus declined and this was attributed to bait toxicity[58]. Full analyses will hopefully be done at the species level and also elucidate which of the three baits tested resulted in adverse effects for native ant species. Early sampling done by Natrass and Vanderwoude[130] is of insufficient scientific rigour to document effects of the red imported fire ant.

Electric Ants in Queensland

Results of environmental monitoring for effects of electric ants showed 81-99% declines in the abundance and richness of native ants. Effects on other taxa were mixed. The program has not documented recovery of any taxa.

Other Programs

It is too early for either the African big-headed ant project on Lord Howe Island, or the Argentine ant project on Norfolk Island to have documented recovery of native species. Project staff on Norfolk Island have observed some recovery of native ants following bait treatments and have also noted Argentine ant harassment of native White tern (*Gygis alba*).

5.1.2 Prevention of biodiversity loss

The prevention of biodiversity loss is much harder to demonstrate than biodiversity recovery, but given the many limitations to recolonisation, is probably easier to achieve. In Section 3 we assessed risks to biodiversity from the tramp ant species for the greater bioregion in the event the tramp ants spread. It is clear that the red imported fire ant, electric ant, yellow crazy ant, African big-headed ant and Argentine ant will adversely affect many endemic or native taxa. As an example, our assessment for a reasonably large sample of vertebrate species indicates fire ants are likely to affect most species in the SE Queensland Bioregion, with effects sufficiently severe to cause population declines in ~45% of birds, ~38% of mammals, ~69% of reptiles and ~95% of amphibians. Similarly, yellow crazy ant infestations in the Northern Territory have the potential to affect ~97% of birds, ~41% of mammals and ~96% of reptiles. Therefore, containing the tramp ants to relatively small areas of these bioregions should be viewed as preventing biodiversity loss. For the programs that have been in existence long enough that there has been post-treatment monitoring (all but African big-headed ant), there have been documented or anecdotal reports of large declines in, or local elimination of, the target tramp ant (summarized in Table 5.1).

Prevention of losses to non-target species where baiting occurs is also important for preventing overall native biodiversity loss. Most programs have not adequately tested for effects on non-target species, and have assumed that the impact of the tramp ant on other species will far outweigh any effect of the toxic bait. The preliminary analysis of native ant recovery in the red imported fire ant program indicates that for some taxa, this is not true[42, 58]. In contrast, the monitoring of native ants in Arnhem Land suggests no effect of the bait[181], and preliminary results on Lord Howe Island also indicate that the bait is not adversely affecting non-target ground invertebrates[71]. Non-target effects may vary with the active ingredient in the bait, the attractiveness of the bait carrier, the bait application rate, the native fauna present, and the environmental conditions where and when the bait is applied.

The yellow crazy ant program on Christmas Island has the best track record of investigating non-target effects of the baiting regime, and may also have the most vulnerable native fauna. Early investigations found no significant differences in canopy arthropods, arboreal geckoes, land birds[23, 216] or leaf litter invertebrates following aerial baiting[23, 213]. However, it is also clear that the fipronil bait is highly attractive to Robber crab. Consequently, the program attempts to lure robber crabs away from supercolonies prior to baiting. It is unclear how successful this is[90, 201]; five robber crabs were reported to have died following the 2012 aerial baiting exercise[86], but this is likely much lower than the mortality of the robber crabs if the supercolonies are not suppressed.

Table 5.1 Summary of the six tramp ant programs: history, challenges, and achievements*

	RIFA	EA	YCA-NT	YCA-CI	ABHA	AA
First detected	2001	2006	1975	1915-1934; first supercolony1989	2003, likely there since 1993	2000; confirmed in 2005
Initial estimated infested area (year)	>36,000ha (2001)	76ha (Aug 2006)	450ha (2002)	Widespread; ~200ha supercolonies by 1998, 2500ha by 2003	120ha, but revised to 20ha following correct ant identification (2012)	>76ha (2010)
Location	Mainland; suburban, rural, industrial	Mainland; suburban agricultural, rainforest	Mainland; bushland, minesite rehabilitation	Island; predominantly National Park	Island; predominantly settlement area	Island; mixed property types
Program goal	Eradication	Eradication	Regional containment	Supercolony suppression	Eradication	Eradication
Program years	2001-present	2006-present	2004-present	2000- present	Ad hoc until this project	2009-present
CfOC project funding years for this review	2008-09, 2009-10	2008-09, 2009-10, 2010-11	2008-09	2011-2015	2011-13	2010-12
CfOC project funds for this review	2008-09: $2.181 million 2009-10: $7.5 million	2008-09: $704,911 2009-10: $728,500 2010-11: $471,042	$250,000	$3,920,000	$195,000	$157,000
Other committed funds	National Cost Sharing 2008-09: $8,729 million 2009-10: $7.5 million	National Cost Sharing 2008-09: $704,911 2009-10: $728,500 2010-11: $471,042	$747,000	$80,000		$67,500

Table 5.1 continued

	RIFA	EA	YCA-NT	YCA-CI	ABHA	AA
Major challenges	Not being able to detect infestations fast enough; persistent re-infestation of disturbed areas	Bait application in dense vegetation; lack of attractiveness of bait used near water	Unclear jurisdiction and responsibility for management; large areas of infestation	Complex terrain; susceptibility of non-target species; logistics of acquiring bait and the helicopter	Delay in receiving CfOC funds; confusion about the identity of the ant; uncooperative occupants	Lack of island expertise in identifying ants; logistics of acquiring bait; treatment of steep slopes
Control achievements	Eradication of 2 of the 3 original infestations comprising 1084 and 12,367ha, respectively; 99.5% of infestations fire ant-free after 3 seasons	4 infestations (14.4ha) declared pest-free; 13 more (64.6ha) slated to be pest free in 2013-14	21 local eradications (246ha) achieved (as of 2009)	Suppression of supercolonies to 60-99% of pre-bait activity levels in 2011 aerial baiting program	Treatment of 14 of 20 infested ha	Treatment of all known infested sites at least once; “good knockdown” achieved
Other Major achievements	Development and implementation of remote sensing technology; reduced genetic diversity of population; high public awareness and reporting of ant	New infestations detected earlier; improvement of bait attractiveness; high public awareness and reporting of ant	Creation of a multi-agency collaboration; long-term capacity building by training indigenous rangers and partnering with Pacific Alumina	Comprehensive regular data collection (IWS); identification of biological control agents for scale insects and demonstration of proof of concept	Correct identification of the ant and delimitation has reduced area to be treated to 10% of original estimates; uncooperative resident has been persuaded	Success in obtaining additional funding for project continuation

Table 5.1 continued

	RIFA	EA	YCA-NT	YCA-CI	ABHA	AA
Threats to biodiversity	Native ants; no specific threats at species-level identified at infestation site. Numerous species in SE Queensland Bioregion identified at risk.	Native ants; Apollo jewel butterfly, Moth butterfly and Southern cassowary identified a risk in vicinity of infestation site	Native ants; Gove Crow Butterfly identified as potentially at risk.	Numerous species identified as affected or potentially at risk, including Red land crabs, Robber crabs, Christmas Island pipistrelle, and the Christmas Island gecko.	Native ants; several native species identified as at risk, including Lord Howe placostylus within or near the project site.	Native ants; no specific threats at species-level identified at infestation site.
Monitoring of species identified as being at risk	Some monitoring of native ant genera.	No monitoring of native species undertaken.	No monitoring of native species undertaken.	Monitoring of trends in species ongoing through Island-wide-survey and other methods. Includes Red land crab, Robber crab, various birds and reptiles.	Monitoring of trends in several native species undertaken, but not specifically in relation to the tramp ant.	Monitoring of trends in several native species undertaken, but not specifically in relation to the tramp ant.
Biodiversity recovery	Unpublished data on reversal of decline in native ants.	No monitoring undertaken.	Recovery documented in native ant abundance and species richness.	Red land crabs numbers since 2001 have been stabilized. Little understanding of recovery in invertebrate communities. Little evidence for recovery of 'ghosted' forests, a legacy of former tramp ant supercolony presence.	None yet – early in program life cycle.	None yet – early in program life cycle.

* See previous sections for details and references; RIFA= red imported fire ant; EA= electric ant, YCA-NT= yellow crazy ant-Arnhem Land, YCA-CI= yellow crazy ant-Christmas Island, ABHA= African big-headed ant, AA= Argentine ant

5.2 Replicating Successful Biodiversity Recovery across Tramp Ant Programs

5.2.1 Differences among programs and their effects on biodiversity recovery

As indicated in Table 5.1, the programs differ significantly in history, scope, location, and the nature of the beast that they are attempting to manage. Particularly relevant differences affecting program progress and comparisons in biodiversity recovery are as follows:

- Size and history

Both of the Queensland eradication efforts are embedded in large, multi-million dollar national cost-share programs that have been running for 11 years in the case of the red imported fire ant, and 6 years in the case of the electric ant. Both yellow crazy ant programs are also part of longer term programs that have received millions of dollars since their inception. These four programs differ significantly in size and scope from management of African big-headed ants on Lord Howe and Argentine ants on Norfolk Island, both of which are more accurately considered projects and have had coordinated, ongoing management only recently. Tramp ant abatement efforts within longer term programs have benefitted from insights gained in earlier years about the timing and methods of treatment. They also generally have dedicated staff, infrastructure, and other resources. The smaller projects are not just smaller in budget and resources; they also generally have a smaller infested area to manage.

- Program goals

Four of the programs (red imported fire ant, electric ant, African big-headed ant, Argentine ant) are aiming for complete eradication, whereas regional containment and supercolony suppression are the goals of the yellow crazy ant programs in Arnhem Land and Christmas Island, respectively. The goals affect the monitoring and treatment methods used and the priority areas for treatment. When eradication is the aim, all infestations of the tramp ant need to be identified and treated, and extensive post-treatment surveillance is required to ensure program success. When containment or suppression is the goal, management activities and resources can be directed to areas of highest biodiversity concern. Containment or suppression programs need ongoing management, whereas eradication programs are designed with an end-date after which ongoing management will not be necessary.

- Program location

Location affects the likelihood of human-mediated dispersal of the tramp ant, logistics, legal mandates and funding sources, and the biodiversity that will be at risk. Tramp ants in populated areas are more likely to be spread via movement of goods, soil, or machinery than tramp ants occurring in a national park or bushland. All four eradication programs occur at least to some extent in populated areas and therefore have to identify and manage the movement of high risk items to prevent inadvertent spread. Many aspects of program logistics are affected by location including acquisition of bait, bait dispersal methods, access to properties for surveillance and treatment, and timing of program activities with respect to seasonal changes in ant activity. Two of the three island programs (Christmas Island and Norfolk Island) have had delays in treatment due to the logistics of receiving the bait, and for Christmas Island, the helicopter, as well. Legal mandate to enact movement controls are also location dependent as are the availability of funds and the body overseeing the project. For example, the yellow crazy ant program in Arnhem Land, which initially had to overcome a vacuum of jurisdictional responsibility to manage the ant, has no legal mandate to implement movement controls to contain the ant, whereas both Queensland programs are run by Biosecurity Queensland and have the authority to enforce strict movement controls under Queensland's *Plant Protection Act 1989*. Location also determines the biodiversity that will be at risk. The yellow crazy ant on Christmas Island adversely affects the crab fauna, native trees, and their roles in ecosystem functioning. In contrast, in Arnhem Land the native ant fauna, the Gove crow butterfly, and broader anticipated threats to ecosystem functioning from the yellow crazy ant have been the impetus for its control.

- Biology and behaviour of the tramp ant

The biology and behaviour of the tramp ants affect public support of the program, control and surveillance methods and seasonality, and the risk to biodiversity. The red imported fire ant and electric ant programs likely benefit from the stinging behaviour of their target ant species. Stinging ants capture the attention of the public and contribute public health and public nuisance considerations to the argument for control. Stinging is also a means by which these ants harm other fauna, particularly vertebrates. The cost-benefit analyses conducted for red imported fire ant and electric ant control both estimate heavy costs due to changes in agricultural practices, and the need for individual treatment of residences because of the threat of stings, if eradication were to fail[303, 304]. Ant biology and climate interact to determine the seasonality of ant behaviour. NRIFAEP learned early on that fire ants forage when ground temperatures exceed 20°C and therefore treatments occur when the ground has reached this temperature, usually September-early May. Both African big-headed ant and Argentine ant are less active in the cooler winter months on Lord Howe and Norfolk Island, respectively, and therefore surveillance needs to occur in warmer months. Electric ant behaviour is not noted to vary seasonally, but it is well-known for entering houses and extensive canopy foraging, necessitating the development of specific traps for sampling ants in these locations. The ants also differ in their food preferences, and therefore in the most effective bait carriers.

5.2.2 Lessons from the yellow crazy ant-Christmas Island program

In Section 5.1 we noted the success of the yellow crazy ant program on Christmas Island in the apparent beginning of a recovery of the Red land crab, and for investigating effects of the baiting program on non-target species. The program on Christmas Island was able to document levels of Red land crab recovery because:

- Red land crabs are an iconic species and their decline was well-documented and largely directly attributed to yellow crazy ants
- The program has an island-wide survey conducted at regular spatial and temporal intervals during which data on Red land crabs and other species of interest are collected at the same time as yellow crazy ant supercolony surveillance is conducted
- The aim of the program is supercolony suppression, and treatment applied biennially appears to be sufficient to achieve this, albeit it is recognised that biodiversity loss occurs during supercolony development

- The program's location, predominantly in the Christmas Island National Park, obviates the need to tailor surveillance and chemical control dispersal methods to different land uses, (although different application methods and bait types are required near wetlands).

In contrast, for the other five programs:

- There are no iconic species documented to be in decline due to the tramp ant
- The aim is complete eradication, or local eradication leading to regional containment. For complete eradication, resources must be spent on preventing spread through raising community awareness and/or enforcement of movement controls.
- No data on other flora or fauna are collected during tramp ant surveillance, rather for at least the programs aiming for total eradication, the emphasis is on rapid detection, delimitation and treatment. Barring seasonal limitations, treatments are often conducted as soon as possible after detection and delimitation. Adding other data collection tasks to ant surveillance would likely slow the management process down.

Therefore, the other five programs are not likely to be able to emulate the Christmas Island program in documenting biodiversity recovery of an iconic species. Documenting effects of the tramp ant and its removal on other species might be facilitated by collection of other species data at the same time as surveillance for the tramp ant. However, for all programs, additional staff and funding would be necessary so as not to take away from resources for treatment and surveillance.

The documentation of non-target effects of baiting for yellow crazy ants on Christmas Island has benefitted from:

- Progress made early in the program (key reports investigating non-target effects are from 2002 and 2003);
- Close association and partnerships with academic institutions
- Funds available to pay consultants

The red imported fire ant, yellow crazy ant-Arnhem Land, and the African big-headed ant programs have samples from several years ago that are in various stages of analysis for determining whether there are non-target effects. For all programs, additional funding or partnering with academic institutions might facilitate progress in investigating and mitigating non-target effects.

5.2.3 Opportunities for documenting biodiversity recovery

The five tramp ant species have in common a reputation for largely displacing native ant faunas wherever they invade[3, 117]. Though Australia's ant fauna is often considered to be provide some biotic resistance to ant invasions[7], in all three programs in which it has been investigated (red imported fire ant, electric ant, and yellow crazy ant-Arnhem Land), as well as in published work[176], there has been some loss of native ant species in association with the tramp ant incursion, and for two of these, some recovery following tramp ant management has been documented as well. It is likely that recovery of native ants with the removal of tramp ants is occurring and could be demonstrated for each program with appropriate sampling. Christmas Island may be an exception, since the other ants present are almost all non-native. However, knowledge of the ant assemblage response to the removal of yellow crazy ant supercolonies would still be useful, as several species occur on the island that are known to have their own effects on biodiversity (African big-headed ant, *Solenopsis geminata*) and removal of the dominant species may lead to greater abundance in the previously suppressed species and further changes in the ecology of the island.

If ants are sampled with pitfall traps, as is customary, other ground arthropods will also be captured and can be analyzed for responses to the baiting regime and the presence and absence of the tramp ant. The red imported fire ant, electric ant, and yellow crazy ant in Arnhem Land programs have all utilized pitfall traps to sample native ants at project sites. Only the electric ant program has also analyzed the samples for the abundance of other arthropod taxa, albeit only to document the baseline rather than the recovery. Sorting of pitfall trap catches can be time-consuming and may require some entomological expertise depending on the taxonomic level to which taxa are sorted. However, it makes sense to capitalize on all the data offered by the method to obtain data on the recovery or otherwise of ground arthropod fauna, the most likely affected non-target group.

The main impediment to measuring and documenting any biodiversity recovery is the necessarily higher priority placed on the actual management of the tramp ants, including detecting and delimiting infestations, and purchasing and applying chemical treatments. On the basis of the well-known effects of these tramp ants elsewhere in the world, we can be reasonably confident that biodiversity recovery is occurring with their removal, and that funding tramp ant management programs is a wise investment. More fully resourcing programs and setting programs outcomes or milestones that specify the investigation of biodiversity recovery would increase the likelihood that biodiversity recovery would be documented.

5.3 Achievements, Lessons Learned, and Overall Project Legacy in Reducing Impacts on Biodiversity

5.3.1 Achievements

Table 5.1 summarizes the major achievements and challenges faced and overcome by each program. The high potential for the five tramp ant species targeted by these programs to wreak havoc on local biodiversity makes their management highly appropriate. In all cases, these tramp ants have high potential to adversely affect biodiversity at infestation sites and adjoining areas should these abatement programs fail. Furthermore, these tramp ants have high potential for spread to other regions of Australia and to inflect further losses on biodiversity. As discussed in Section 6, in each of these programs the infestation site is within or closely adjacent to areas designated of high conservation value by State and/or Commonwealth governments, and by international conventions and agreements (see Table 6.5) because of outstanding biodiversity and other natural features of international significance. Our assessment is that the red imported fire ant, electric ant, yellow crazy ant, African big-headed ant, and Argentine ant are of such significance that abatement programs at all infestation sites justify ongoing resourcing.

All projects for which some post-treatment surveillance has been conducted have shown abatement of the target tramp ant species. Since many species have been identified as at risk if the tramp ants spread regionally (see Section 3), the demonstration of the efficacy of control methods is a necessary milestone in achieving the ultimate program goal, whether it is full eradication, regional containment, or supercolony suppression. CLIMEX models[132] indicate all five tramp ant species are presently nowhere near their potential distributional range within Australia that theoretically could be achieved if management efforts fail.

For the red imported fire ant program, the development and implementation of remote sensing technology has been a world first and is anticipated to put eradication back onto the management agenda. That fire ants in southeast Queensland have lower genetic diversity than populations of red imported fire ants in other countries indicates that there are unlikely to be undetected populations in southeast Queensland, and that the program is disrupting mating. The low genetic diversity may be imposing fitness costs on the ant, with potential benefits to the longer-term success of the abatement efforts. Discovery of the low rate of intranidal mating and the strong association between colonization and disturbance, has allowed more efficient use of resources in surveillance and treatment.

The red imported fire ant, electric ant, and yellow crazy ant programs have all incorporated lessons learned from experience in the program as well as scientific knowledge of their target ants into their treatment and surveillance protocols. These programs have also had a strong research component, essential for addressing knowledge gaps and adapting surveillance and control methods to local conditions. The result is improved program efficiency over time.

The yellow crazy ant program in Arnhem Land, Northern Territory stands out as building capacity within the broader community, including training indigenous rangers. This has facilitated leveraging support from Pacific Alumina and their capability to manage a large part of infestation.

The Lord Howe and Norfolk Island programs have both delimited all known infestations of their target tramp ants and have completed, or nearly completed at least one round of treatment on all of these. No new infestations have been detected on Lord Howe.

5.3.2 Lessons learned

- Respond early

For several programs there has been a considerable time lag between suspected time of arrival of the ant and either detection and/or implementation of control (Table 5.1). This delay has allowed the spread of tramp ants both naturally and with human help, and has increased the complexity and cost of treatment. Following detection of African big-headed ants and Argentine ants on Lord Howe Island and Norfolk Island, respectively, years passed before there was any concerted attempt to control them, even though information on their environmental effects was documented in the literature by then. Crucial time was wasted, probably as a result of a lack of local knowledge of the threats the ants posed. Yellow crazy ants were detected in Arnhem Land and Christmas Island long before anything was documented on their real or potential environmental impacts anywhere in the world. Nonetheless, the decades long delays between detection and the implementation of a management program meant that yellow crazy ants were too widespread in these locales for total eradication to be an achievable goal. In contrast, the red imported fire ant program commenced treatment within a few weeks of confirmation of the ant's identity, a remarkable achievement considering the complexity of the funding arrangement, probably because it has a well-earned and widespread reputation for its economic and environmental costs. It is unclear why five years later, with the same government bodies involved, there was a four-month delay between detection of the electric ant and its first treatment.

- Expect to find a greater area of infestation than initially anticipated

At some stage, all programs have encountered unanticipated additional infestations (or on Christmas Island, more supercolonies) and therefore program scope has increased beyond initial expectations. The only possible exception is Lord Howe Island, in which correct identification of ant species resulted in a large reduction in the area estimated as infested by the African big-headed ant. In Arnhem Land, discovery of additional infested areas made eradication unfeasible. NRIFAEP is still finding new areas of infestation, but with the implementation of remote sensing, anticipates finally being able to 'get ahead' of the invasion. NEAEP implemented footpath surveillance to enable early detection of infestations, and the approach appears to be working. These programs, as well as the Norfolk Island program, have greatly benefitted from engagement with the community in detecting new infestations.

- Insufficient funds and a lack of contingency plans will hamper progress

Several programs have had to postpone or reduce planned treatments as a result of delays in receiving funding, budget cuts, or unanticipated additional detections. As noted above, any delay in implementing treatments provides opportunity for further spread of the tramp ant, and therefore the potential for further resource shortfalls with increased infestation areas, unless there is some contingency plan or funds available to meet the unanticipated needs. Funds provided initially need to be sufficient for full and accurate delimiting of the area of infestation. If there are consistent budget shortfalls, these need to be addressed early on so that proven protocols are not compromised. For example, as discussed in Section 2.1, since 2005, NRIFAEP funding has been consistently insufficient to meet treatment protocol requirements.

The determination of what is sufficient funding should encompass all program needs to achieve the long-term goal, from delimitation and treatment through to sufficient post-surveillance treatment and the documentation of effects on biodiversity. It is unclear, for example, why CfOC funding for eradication of tramp ants on Lord Howe and Norfolk Island will or has terminated, respectively, long before eradication could possibly be declared considering the requirement for years of post-treatment surveillance. Even though the Administration of Norfolk Island has been able to secure additional CfOC funding, this incremental funding approach has certainly affected the program, in part because it was accompanied by delays in payment. We further discuss problems with a short-term funding structure under Legacy, below.

- Investment in research and development can improve program efficiency

Programs that have been able to invest in research have reaped the benefits of their findings with increased program efficiency in detecting and treating areas of infestation. Even when basic protocols or appropriate chemical control options are available from elsewhere, investigation into how local habitats and climate may affect efficacy are paramount to ensure maximum return on investment. Experimentation with lure attractiveness, detection traps, remote sensing, bait carriers, active ingredients in baits, bait application rates, number of treatments, and treatment timing, as well as time taken to understand the biology of the tramp ant in the local habitat, have variously informed treatment activities for NRIFAEP, NEAEP, and the yellow crazy ant programs over the years. The Lord Howe and Norfolk Island programs, which have come about only recently, have not had resources available for research, though they would likely benefit from, at a minimum, trials to determine the number of treatment rounds necessary to ensure 100% elimination of the target ants.

- Community engagement is a worthwhile investment

For invasions in populated areas, community engagement efforts pay for themselves in new detections. These efforts also help to maintain public support, keep the public informed about the use of public funds, and provide reasons and incentives assisting with the abatement program.

- Multiple treatment rounds and/or extremely effective post-treatment surveillance is required to confidently declare eradication has been achieved

It is not possible to visually detect small remnant infestations that have survived treatment, a crucial requirement for programs aiming for eradication. Treatment protocols should ideally be developed and tested under local conditions to provide confidence in their efficacy. Post-surveillance needs to be sufficiently sensitive and delayed long enough that any remnant infestations would have built up to detectable levels. The NRIFAEP and the NEAEP have had success with treatment protocols calling for six rounds of treatment and post-treatment surveillance protocols that utilize highly sensitive odour detection dogs and monitor sites 24 and 18 months after treatment, respectively.

5.3.3 Legacy

As we have noted elsewhere in this report, it is impractical, if not impossible, to separate achievements and lessons learned as a result of CfOC funding from gains made when programs were funded by other sources. Achievements and success in any year of any program have built on knowledge and experience accumulated from previous efforts. Achieving eradication or abatement of tramp ants at the scale that these programs are attempting is a long-term process, requiring a sustained, dedicated effort, and lots of trial and error along the way. Unless and until long-term management solutions are achieved (e.g., complete eradication, regional containment, or sustained biological control), the legacy of these programs will always be threatened by discontinuous or insufficient funding. And even then, appropriate mechanisms must be put in place to reduce the likelihood of reintroduction. Long-term management solutions are unlikely to be achieved with a focus on short-term gains. Short-term, piecemeal funding, while better than no funding, creates staffing problems, increases administrative burdens and the likelihood of gaps in funding, jeopardizes progress that has been made, and prioritizes short-term gains. These collectively may diminish the likelihood of efficiently achieving the ultimate program goal.

The legacy of these programs will derive from attainment of their program goal. For the programs aiming for eradication, complete elimination of the target ant would be the desired program legacy. CfOC funding has certainly enabled progress toward this goal in all four of these programs. The knowledge and experience that have developed as well as the actual treatment and containment of the tramp ants increase the likelihood that eradication will be achieved. For the yellow crazy ants in Arnhem Land program, steps toward eradication of the ant from areas where it is most likely to spread with human assistance, move the program toward achieving its goal of regional containment. If these five programs fall short of these goals (i.e., full eradication or containment is not achieved) due to lack of funding or any other reason, then the only real legacy of the funding will be the attained knowledge and experience, because eventually remnant infestations will build up again and spread well beyond current areas of infestation. For Christmas Island, the desired legacy would be a return to the pre-yellow crazy ant supercolony ecosystem functioning as a result of supercolony suppression. The suppression of supercolonies for two years following 2009 aerial baiting demonstrates that suppression is likely achievable with ongoing management, although it has not adequately been demonstrated that suppression in this manner is sufficient to prevent biodiversity losses. The ideal legacy would be self-sustaining suppression of supercolonies with biological control.

As pointed out in the self-evaluation of the CfOC program for yellow crazy ants in Arnhem Land[73], there are no systems in place to monitor or evaluate projects beyond the term of the funding Deed. In all cases, the CfOC funding period evaluated here has ended or will end before program goals (eradication, regional containment, or supercolony suppression, depending on the program, see Table 5.1) are achieved. The possible exception is Christmas Island, which may have a self-sustaining biological control program in place by the time CfOC funding ends in 2015. However, the research and development conducted to develop biological control as a viable alternative to pulsed aerial baiting has not been funded by CfOC to date.

5.4 Advice for Future Management of Tramp Ants in Australia

5.4.1 For programs

We have provided advice for management of each program individually in Section 2. Two recommendations made for nearly every program are:

- Publish results

Publishing of results is an important vehicle for scientific peer review of the program activities, and for building a collective body of knowledge and understanding, both within Australia and internationally.

- Ensure that there is sufficient institutional memory

Put in place mechanisms for institutional memory. It is critical that lessons learned are not lost with changeover in personnel or at the end of a particular program. Already this has been the case with staff at some of the longer running programs not being able to answer questions regarding decisions earlier in the programs.

5.4.2 A coordinated national approach

To ensure that tramp ant incursions in Australia are managed most effectively, a coordinated approach is required. The Tramp Ant Threat Abatement Plan (TAP)[115] and its background document[132] make a strong case for a more integrated approach with national and regional components. The background document describes allocation of roles and responsibilities at different levels of government, stakeholder participation, and setting priorities based on risk as some of the key considerations in developing such an approach. The TAP is comprehensive and lists specific Actions and Performance Indicators to meet six objectives:

1. Increase science-based knowledge and expertise, incorporate Indigenous traditional ecological knowledge, quantify impacts, and improve access to information for priority tramp ant species

2. Prevent entry and spread of tramp ants by increasing diagnostic capacity, offshore surveillance, inspection, treatment, and national and state and territory surveillance

3. Prepare for rapid response to tramp ant incursions and spread through risk assessment of tramp ant species and pathways of introduction, and development of contingency plans

4. Enhance emergency response to tramp ant incursions by improving reporting and response rates, and by developing tools for response and follow-up
5. Build stewardship by engaging, educating, and informing the Australian community about the impacts of invasive tramp ants and effective means of response
6. Coordinate Australian Government, state and territory government, and local management activities in Australia and the region.

The TAP was signed in June 2006. But to date it appears very little, if any, of it has been implemented[305]. Indeed if some of the high priority or very high priority short-term Action Groups had been acted upon, such as Action 2.1 "Improve diagnostic capacity and service", Action 3.2 "Develop generic, specific, and context-dependent contingency plans" or Action 4.2 "Accelerate response to new detections of tramp ants" it is likely that the tramp ant incursions on Lord Howe Island and Norfolk Island and their threats would have been recognized earlier, and coordinated management could have commenced sooner and more efficiently.

Programs that were already in existence in 2006, would likely also benefit from and be able to contribute to implementation of many of the Actions. As noted above, programs need to ensure that the knowledge and experience accumulated is part of their legacy and does not disappear with changes in staff. A "central repository or linked network for knowledge relevant to the management of tramp ants", as described in Action 1.4 could be an ideal mechanism for achieving this goal. The TAP further calls for addressing some of the problems we have highlighted above including the need for early responses to incursions and the assessment of tramp ant impacts in Australia.

5.4.3 Funding mechanisms and program outcomes

In addition to issues already raised and addressed in the TAP, our review has identified specific improvements that could be made to existing funding mechanisms (not limited to CfOC) so that they more effectively reduce the threat of tramp ants to Australian biodiversity. These are:

- If measuring impacts and recovery of biodiversity are priorities, set them as specific project tasks with dedicated funding and a sufficient time frame for achievement

Assessing biodiversity impacts needs to be a specific program output or milestone with specific resources attached to it. If resources have to be taken from surveillance and treatment activities, measurement of impacts on biodiversity will likely continue to be a lower priority, under the assumption that removing the tramp ant will ultimately remove the threat to biodiversity.

- Ensure the mechanisms are in place so that payments are made on a schedule that does not hinder program progress

Tramp ant surveillance and treatment activities have strong seasonal components and a delay of a few months can translate to a significant alteration of plans and expansion in the incursion. Small administrations cannot be expected to fill the gap.

- Create a mechanism for approving and distributing immediate funds in response to incursions.

As noted above, any lag between detection and treatment provides an opportunity for the ants to spread. That Lord Howe Island and Norfolk Island had to apply for funding through CfOC's open call for proposals is not an appropriate response to invasive species incursions that threatened nationally and internationally significant biodiversity assets. Commonwealth and state governments, in a coordinated manner, need to take the lead in immediate response to biosecurity incursions

6. OTHER TRAMP ANTS

Of the over 12,500 species of ants recorded in the world, at least 150 have been identified as tramp ants for their close associations with humans and their often human-mediated dispersal[2, 3]. In a biogeographic analysis of 147 of these, approximately 25 had been transferred to the Australian region, in comparison to approximately 80 to Pacific Islands[2].

In our assessment of risks to Australian biodiversity from other tramp ants, we first compiled a list of other tramp ant species that are present in Australia. The Background document to the *Threat Abatement Plan to Reduce the Impacts of Tramp Ants on Biodiversity in Australia and its Territories*[132] identified seven tramp ant species, other than the five that are the subject of Sections 1-5. One of the seven, *Lasius neglectus*, the European garden ant, has not established in Australia, and therefore is not assessed here. Another on the list, *Technomyrmex albipes*, underwent taxonomic revision along with the rest of its genus in 2007. The *T. albipes* previously reported from Australia became *T. jocusus* (predominantly in the south) and *T. dificilis* (predominantly in the north)[306]. Both of these are considered native species[71] and are therefore omitted from further discussion. To the remaining five (*Tapinoma melanocephalum*, *Paratrechina longicornis*, *Monomorium destructor*, *M. pharaonis*, and *Solenopsis geminata*) we add another five tramp ant species known to be present in Australia[71]: *Monomorium floricola*, *M. mayri*, *Plagiolepis alluaudi*, *Tetramorium bicarinatum*, and *T. simillimum*.

An exhaustive compilation of the ant species of Christmas Island designates 28 species as tramp ants and 3 species as invasive (yellow crazy ant, African big-headed ant, and *Solenopsis geminata*) of the 53 species known from the island[243]. Nine of these are included in our list above. We do not include the remaining 19 because some of them are considered native to the mainland, and most of them are cryptobiotic, with little known of their ecological effects. In comparison to the yellow crazy ant, any ecological effects of these ants on the island are likely infinitesimal.

In the four sections below, we

1. outline what is known about the impacts of each tramp ant species on biodiversity in Australia, noting that this is limited,
2. identify what information is needed and how this may be obtained to understand the impacts of each tramp ant on biodiversity in Australia,
3. where there is sufficient information, compare the potential biodiversity impacts of these species to the red imported fire ant, electric ant, yellow crazy ant, African big-headed ant, and Argentine ant, and
4. where there is sufficient information, summarize which species may be causing the greatest impact and where, with the view to future opportunities for control work.

6.1 Current Knowledge of Impacts of the Ten Other Tramp Ant Species on Biodiversity in Australia

6.1.1 Traits of the ten other tramp ant species

Table 6.1 summarizes the distribution and appearance of the ten tramp ant species, and for comparison, includes the five species discussed in the previous sections. From the available information, it appears that most of these species have established in Australia in tropical or subtropical regions of the mainland or on islands. This is broadly consistent with their distribution globally. (Because we are interested in effects on biodiversity, we have not included information about temperate distributions where they are limited to climate-controlled structures.) With the exception of *S. geminata*, all of these are thought to originate in either Asia or Africa, in contrast to the high representation from South America in the original five species of interest. Workers of the 15 species vary in length from 1mm (electric ant) to 4mm (yellow crazy ant). Most species have workers of approximately the same size and allometry (monomorphic).

As noted in Section 1, tramp ants generally have several life history traits in common. Though information is incomplete for some of these species (*M. mayri*, *T. simillimum*), it is thought that their dispersal is human-mediated (long distance) and by budding (short-distance). *Monomorium destructor* undergoes nuptial flights of unknown importance[3, 307]. *Solenopsis geminata* queens also mate and disperse via nuptial flights[308]. All 15 of the tramp species are polygynous, and with the possible exception of *P. longicornis*[309], all are thought to be somewhere on the spectrum of unicoloniality[310] (see references for each species in Table 6.1). As with the red imported fire ant, *S. geminata* also occurs in a monogyne form which exhibits intraspecific aggression and does not achieve the high colony density that the polygyne form does[308]. It is unclear whether the *S. geminata* that occurs in Australia is monogyne or polygyne. It does not completely lack intraspecific aggression, but there are also no clear boundaries among nests[71].

Table 6.2 summarizes the known ecology of the ten tramp species, along with the original five species included for comparison. As with tramp ants generally[3, 5, 6], several species are noted for their tendency to occur in disturbed habitats, their flexibility in nest location, and their omnivory. Data are lacking on the numbers of queens and workers typically found in a nest and the achievable nest density for most of the species. With the possible exception of *P. alluaudi*, they are all omnivorous to some extent. *Solenopsis geminata* is particularly noted for its granivory[3]; its major workers have mandibles adapted for seed milling and the species collects eight times more seeds than red imported fire ants[308]. Foraging strategies are largely divided between the quick and opportunistic (*P. longicornis, T. melanocephalum*) and the slow and stealthy or cryptic (*P. alluaudi*, *Monomorium* species, *S. geminata*, *T. simillimum*). *Solenopsis geminata*, *T. bicarinatum* and *T. simillimum* have stings with which they subdue prey.

Table 6.1 Summary of ranges and appearance for ten tramp ant species in comparison to the five species that are the subject of CfOC program funding

Subfamily & Species	Common name	Reported distribution in Australia	Worldwide distribution*	Native range	Worker size and appearance
Dolichoderinae					
Tapinoma melanocephalum [311,312, 313]	Ghost ant	Widely established in north	Widely distributed in tropics and subtropics	Asia or Africa	Monomorphic, ~1.5mm
Formicinae					
Paratrechina longicornis [309, 314, 315]	Crazy ant, longhorn crazy ant	Widely established in coastal regions	Widely distributed, primarily in tropics and subtropics; probably one of the most widely distributed of all tramp ants	Asia or Africa	Monomorphic, 2.3-3mm, dark brown to black, extremely long antennal scape
Plagiolepis alluaudi [316-320]	Little yellow ant	Widespread; Norfolk Island is the southernmost	Pacific and Indian Ocean islands	Africa	Monomorphic, 1.3 mm, pale yellow
Myrmicinae					
Monomorium destructor [307, 321-323]	Singapore ant, destructive trailing ant, destroyer ant	Widely established in north, small population in Perth	Widely distributed throughout the tropics	Asia	Polymorphic, 1.8-3.5mm, head and mesosoma light yellow, gaster darker
Monomorium floricola [324-327]	Bicolored trailing ant, flower ant	Northern and northeastern coastal regions	Widely distributed, primarily in tropics and subtropics; probably one of the most widely distributed of all tramp ants	Possibly tropical Asia	Monomorphic, 1.5-2.0mm, pale mesosoma, darker brown head and gaster, shiny
Monomorium mayri [39, 40, 71, 328 ,329, 326, 327]	None	Widely established in north	recorded from Sahel countries of Africa and eastwards to West Malaysia	Described from India	Monomorphic, very similar to *M. destructor*, but uniformly dark brown

Table 6.1 continued

Subfamily & Species	Common name	Reported distribution in Australia	Worldwide distribution*	Native range	Worker size and appearance
Monomorium pharaonis[330-333]	Pharaoh ant	Widespread but not common	Widespread in tropics, on all continents except Antarctica and on some islands in the Indian and Pacific Oceans; probably most widely distributed ant species	Asia or Africa	Monomorphic, 2.2-2.4mm, body color ranging from light brown to red
Solenopsis geminata[3, 308, 334, 335]	Tropical fire ant or ginger ant	Incursions in northern coastal areas, Ashmore Reef	Widely distributed in tropics and subtropics	South and Central America, southern North America	Polymorphic, 3-8mm, brown head, reddish brown body, sting present
Tetramorium bicarinatum[336-340]	Pavement ant, penny ant; also known as the guinea ant based on an erroneous synonymy	NT, Qld, limited in NSW, Melbourne; Coral Sea and other islands	Widely distributed in tropics and subtropics, except for Afrotropical regions; on almost all Pacific islands, several Atlantic and Indian Ocean islands	Southeast Asia	Monomorphic, 3.4-4.5mm, light yellow to bright orange yellow head, mesosoma, and waist; gaster deep brown, sting present
Tetramorium simillimum[341-343]		Tropical north as well as Perth and NSW	Widespread in tropics, including Americas, and Caribbean, Indian, and Pacific Ocean islands	Africa	Monomorphic, 2.0-2.7mm, yellowish to reddish brown head, mesosoma, and waist; dark brown shiny gaster, sting present
Five species managed with CfOC funding (see previous sections for references)					
Solenopsis invicta	Red imported fire ant	SE Queensland	Asia, United States, some Caribbean islands	South America	Polymorphic, 2-6 mm, coppery brown
Wasmannia auropunctata	Electric ant, little fire ant	Cairns region	Africa, North America, South America, Caribbean and Pacific Ocean islands	South America	Monomorphic, 1-1.5mm, golden brown, slow moving

Table 6.1 continued

Subfamily & Species	Common name	Reported distribution in Australia	Worldwide distribution	Native range	Worker size and appearance
Anoplolepis gracilipes	Yellow crazy ant, long-legged ant	Christmas Island, northeast Arnhem Land, Cairns region, incursions elsewhere	Moist tropical lowlands of Asia, and Pacific and Indian Ocean islands	Africa or Asia	Monomorphic, 4mm, yellow-brown, erratic
Pheidole megacephala	African big-headed ant, coastal brown ant	Widespread	Widespread; on tropical and subtropical islands, also in North America, South America, northern Africa, Europe, Asia	Africa	Dimorphic, 2mm (minors) 3.5mm (majors) major workers have distinctively large heads; light brown
Linepithema humile	Argentine ant	Widespread in more temperate regions	Widespread in Mediterranean-type climates in Africa, Europe, North America, and South America, also in Japan, and New Zealand	South America	Monomorphic, 3mm, brown

*Does not include temperate distributions where these are dependent on climate-controlled structures

For established tramp ants, adverse ecological effects on biodiversity generally occur when

- Populations become abundant relative to native ant fauna,
- The tramp ant penetrates into intact environments or areas with significant biodiversity, and
- The tramp ant displaces native ants and/or changes the functioning of ants in the ecosystem.

The effects of a tramp ant in one part of its introduced range can indicate likely outcomes elsewhere in the introduced range provided climate and habitat are similar. However, in ways that are still being discovered, the ultimate outcome of an invasion may be dependent on species-specific interactions with other flora and fauna. Perhaps the most well-known example is the dramatic shift in yellow crazy ant status on Christmas Island from benign to pestiferous following the arrival of the Lac scale (see Section 3.6). The honeydew provided by the scale caused the formation of supercolonies of yellow crazy ants (populations became abundant). The ant became established throughout much of the National Park (penetrated into an area with significant biodiversity), and it killed Red land crabs and caused tree dieback as a result of its tending of scale insects (changed functioning of ants in the ecosystem)[202].

6.1.2 Impacts of the other ten tramp ant species

There are very few documented ecological impacts of the ten other tramp ant species in Australia (Table 6.2). *Monomorium floricola* is reportedly able to become locally abundant in disturbed habitats in the Northern Territory[344, 345] and in mangrove habitats in Florida, and is a significant predator of native insects in Guam[324]. However, there are no reports of adverse effects of this ant on biodiversity in Australia and the ant was not reported to reach high densities in mangrove habitats near Darwin[327]. To date, documented effects in Australia appear to be limited to *S. geminata*) on Ashmore Reef and possibly to *T. bicarinatum* on North East Herald Cay in the Coral Sea.

Ashmore Reef

A preliminary risk assessment of the ecological effects of the *S. geminata* on Ashmore Reef, which included some documentation of the ants' ecological effects on the Reef, was completed in 2007[346]. Ashmore Reef Nature Reserve provides important nesting sites for seabirds and turtles. Its ecosystems are recognized by the Japan-Australia Migratory Bird Agreement and the China-Australia Migratory Bird Agreement and its wetlands have been designated to the List of Wetlands of International Importance under the Ramsar Convention. *Solenopsis geminata* has been on the Reef since at least 1992 and occurs on all three Ashmore Reef Islands at varying densities. The assessment focused on potential impacts on birds, but also noted that breeding turtles may also be at risk. Fifteen species of seabirds and two species of egret have been observed breeding on the Reef. At the time of sampling, only dead chicks of the Common noddy (*Anous stolidus*) and Brown booby (*Sula leucogaster*) were found, and only the former occurred in high enough numbers for statistical analyses. Density of *S. geminata* was sampled with pitfall traps and lures and compared to the distribution of dead Common noddy chicks. The mortality rate attributed to *S. geminata* was 34% for the smaller, more vulnerable age/size class, and 11% for the larger class on the most affected island. Of all seabirds that nest on the Ashmore Reef Islands, the Common noddy is probably one of the least susceptible to *S. geminata* because if nesting failure occurs it will re-lay up to three times.

Solenopsis geminata is also reported to have negative effects on turtles on one of the islands[347].

North East Herald Cay

The Coringa Herald Group of coral sand islets in the Coral Sea 400km east of Cairns are designed Class 1A reserve because of the large population of sea birds and turtles that nest there[339]. Two of these islets, the North East Herald Cay (NEHC) and Magdelaine Island, together have 11% of Australia's *Pisonia grandis* trees. The tree is considered an endangered species in Australia because its stands comprise a total area of 190ha[339]. *Pisonia grandis* forests occur only where there is a large population of nesting seabirds, but are widespread on Indian and Pacific Ocean islands. *Pulvinaria urbicola* is a non-native coccoid scale insect that can reach high abundance on *P. grandis* and cause dieback[339, 348]. On NEHC, *Pulvinaria* numbers increased 150-fold between 1997 and 2001 and were tended by a *Tetramorium* that was not identified to species[339]. Initially the increase was attributed to climatic factors[339]. Subsequent review of pitfall trap samples has revealed that another explanation for the great increase in *P. urbicola* is that *T. bicarinatum* may have been introduced to NEHC between 1997 and 2001 and have begun tending the scale. Between 1997 and 2007, the ant fauna on NEHC changed from approximately equal parts *M. pharaonis*, *Tetramorium lanuginosum*, and *Cardiocondyla* sp. to being almost entirely *T. bicarinatum*. Further support for the idea comes from other Cays that still have *T. lanuginosum* but not *T. bicarinatum*, and still have low abundance of *P. urbicola* on their *P. grandis* trees[349]. The change in ant fauna to *T. bicarinatum* dominance was also associated with a decline in the representation of other arthropods in the samples from greater than 60% to 30% or less[349].

6.2 Information Needed to Understand the Impacts of Each Tramp Ant on Biodiversity in Australia and How to Obtain It

As noted above, following establishment, tramp ants generally cause adverse effects on biodiversity when they become abundant, invade areas with significant biodiversity, and displace native ants and/or function differently than native ants. None of the ten tramp ant species have been studied to the same extent that the highly invasive red imported fire ants and Argentine ants have, and therefore there are significant gaps in knowledge and predictability about the effects of these ants. Drawing on knowledge of well-studied tramp ants, we outline specific lines of investigation that would help to fill these knowledge gaps and increase the predictability of tramp ant effects. These are summarized in Table 6.3 and discussed below.

6.2.1 What is the likelihood that the ants will become abundant?

Invasive ants typically numerically dominate resident ant fauna. The displacement of the resident ant fauna is both a cause and an effect of the numerical asymmetry. Higher numbers enable the invader to excel at both exploitation competition (finding and monopolizing resources) and interference competition (preventing other species from having access to resources)[3, 6].

Table 6.2 Summary of ten tramp ant species' biology and effects on biodiversity in comparison to the five species that are the subject of CfOC program funding

Subfamily & Species	Nesting habits	Foraging and diet	Reported biodiversity effects world-wide	Reported biodiversity effects-Australia
Dolichoderinae				
Tapinoma melanocephalum [311, 312, 344, 345]	Disturbance specialist, highly flexible nesting habits, often in buildings	Opportunistic; dead and live insects, honeydew; displaced by dominant ants	None; mostly absent from undisturbed habitats, never numerically or behaviourally dominant	None; minor component of monsoon vine forest remnant
Formicinae				
Paratrechina longicornis [120, 309, 314, 315, 345]	Disturbance specialist, highly mobile, in buildings, outside on the ground or sometimes in trees; up to 2000 workers and 40 queens	Omnivorous and opportunistic; dead and live insects, honeydew, seeds; displaced by dominant ants	None; mostly absent from undisturbed habitats, limited ability to displace other ant species	None; can become locally common sometimes restricted to human settlements
Plagiolepis alluaudi [316, 317, 319]	Under bark and in vegetation, in houses; some colonies large	Primarily attracted to sugar (honeydew) and fats (in houses); does not forage in great numbers; does not dominate	None; not known to cause ecological or agricultural harm; coexists with dominant species	None
Myrmicinae				
Monomorium destructor [307, 321, 322, 345]	Arboreally, in soil, inside buildings; large colonies in urban areas, unknown colony size in tropical non-urban areas	Omnivorous; dead and live insects, honeydew, nectar, seeds; slow moving, forages along trails; limited ability to compete with diverse ant faunas, but can become locally abundant	None; minor component of ant community outside of urban areas, effects on invertebrates likely to be minor	None; but has become abundant in car parks of Kakadu

Table 6.2 continued

Subfamily & Species	Nesting habits	Foraging and diet	Reported biodiversity effects world-wide	Reported biodiversity effects-Australia
Monomorium floricola [324-327, 345, 350]	Primarily arboreal, able to nest in tiny cavities, common urban species; up to 7 dealate queens	Living and dead insects, nectar, honeydew; slow moving and unaggressive; can be dominant in flooded mangrove habitats in Florida where there is less competition	Significant arboreal predator of insect eggs, attacks native butterfly eggs in Guam;	None; can become locally common in disturbed habitats
Monomorium mayri [71]	In Australia, almost always associated with buildings, or in disturbed sites	Originally considered a different form of *M. destructor*, so probably very similar to *M. destructor*	None	None
Monomorium pharaonis [330-333, 345, 351]	Rarely found outdoors; almost anywhere indoors; can have several thousand workers	Omnivorous, primarily nocturnal; insects, carbohydrate resources	Caused 1% of Tristam Storm Petrel nest failures on Laysan Island	None; restricted to disturbed areas
Solenopsis geminata [3, 117, 120, 308, 334, 335, 346]	Primarily disturbed areas; nests in soil, commonly around vegetation, can have extensive underground and covered foraging trails and multiple entrances; polygyne forms have greater nest density (2500/ha in Mexico); 4000 to hundreds of thousand workers	Omnivorous and granivorous; live insects, seeds, honeydew; cover food with soil particles, also forage underground; slow to find food but will defend it, has a sting to subdue prey; does not often forage arboreally	Reports of attacks on birds, reptiles, and mammals, and predation of invertebrates, including pests; interferes with seed dispersal; may interfere with pollination	Positive correlation between *S. geminata* density and Common noddy mortality on Ashmore Reef, especially for smaller size classes; concerns for other seabirds and turtles that breed there
Tetramorium bicarinatum [336, 337, 339, 345, 349]	In exposed soil, under stones, rotting logs, in plant stems, under bark; small to moderate colony size	Live and dead prey, honeydew, can sting	None; can achieve dense populations in disturbed habitats	Associated with reduced arthropods and population explosion of soft scale leading to damage of *Pisonia* trees on Coral Sea islet

Table 6.2 continued

Subfamily & Species	Nesting habits	Foraging and diet	Reported biodiversity effects world-wide	Reported biodiversity effects-Australia
Tetramorium simillimum[342, 343, 345, 350]	Soil in open areas, often around buildings, roads, or parking lots; can be large colonies	Predaceous, also farms aphids; relies on small body size and stealth; prefers lower relative humidity for foraging, can sting	None; can achieve dense populations in disturbed habitats	None; can become locally common in disturbed habitats
Five species managed with CfOC funding[3, 117, 120, 132]; see Section 3 for details				
Solenopsis invicta	Typically in constructs earthen mounds in open habitats, prefers recently disturbed soil	Omnivorous and granivorous; live and dead prey, tends honeydew producing insects, including those on root systems, can sting	Multiple documented effects on invertebrate and vertebrate fauna including birds and reptiles; may disrupt seed dispersal	Associated with a decline in prevalence of some native ant genera; effects on other fauna anticipated; see Section 3.3.1
Wasmannia auropunctata	Opportunistic nesting in soil, twigs, leaf litter, foliage or furniture or buildings	Omnivorous; live and dead prey, tends honeydew producing insects; slow moving but discovers and monopolizes resources quickly because of high abundance, can sting	Multiple documented effects on invertebrate and vertebrate fauna, including blinding; also affects plants by tending scale insects, may disrupt seed dispersal	Associated with 81-99% decline in native ant species and changes to invertebrate community composition; see Section 3.4.1
Anoplolepis gracilipes	Opportunistic nesting in soil, leaf litter, or other plant debris, in cracks and crevices, tree hollows	Omnivorous; live and dead prey, tends honeydew producing insects, sprays formic acid to subdue prey	Multiple documented effects on invertebrate and vertebrate fauna; also affects plants by tending scale insects	Ecosystem level changes on Christmas Island; displacement of native ants in Arnhem Land; see Sections 3.5.1 and 3.6.1
Pheidole megacephala	Generally in soil, often with loose soil piled around the entrances; may also nest under rocks or other objects or at the base of vegetation	Omnivorous and granivorous; live and dead prey, tends honeydew producing insects; has adaptations to carry liquid droplets	Multiple documented effects on invertebrate fauna; also affects plants by tending scale insects	Associated with declines in arthropod richness and abundance in rainforest[251] and outbreaks of scale in *Pisonia grandis*[252] Cays[352]; changes in invertebrate fauna[353-355]

Table 6.2 continued

Subfamily & Species	Nesting habits	Foraging and diet	Reported biodiversity effects world-wide	Reported biodiversity effects-Australia
Linepithema humile	Shallow sometimes ephemeral nests at the base of vegetation or under rocks or logs; prefers mesic habitats but can exist in more xeric habitats with access to water	Omnivorous; live and dead prey, tends honeydew producing insects; has chemical defense to subdue prey	Multiple documented effects on invertebrate fauna and some vertebrates such as reptiles; displaces pollinators, disrupts seed dispersal	More likely to disperse seeds of non-native plants[356]; associated with displacement of some native ant species[355]

Table 6.3 A summary of information needed to assess risks of tramp ant to biodiversity, and possible sources of information

Line of inquiry	Source of information	Example evidence	Applicable to
What is the likelihood that the ants will become abundant?			
Abundant elsewhere	Literature or direct measurements	Numerically dominates, displaces other ants, or becomes a pest	*M. destructor*, *M. floricola*, *M. pharaonis*, *S. geminata*, *T. bicarinatum*, possibly *P. longicornis*, *T. simillimum*
Mechanism elsewhere	Literature or direct measurements	Unicoloniality	Likely to some degree for all 11 species
		Generalist habits	Most species (see table)
		Ecological release	Unknown for most species
		Genetic changes	*S. geminata*, unknown for others
Mechanism possible in region or site of interest	Direct measurements or knowledge of habitat and attributes of tramp ant of interest	Presence of attractive honeydew-producing insects	Unknown for all species
Will tramp ants invade areas with significant biodiversity?			
Identify sites/regions of interest	Literature, government reports	Islands with high levels of endemism or other significance	Christmas Island, Cocos-Keeling, Ashmore Reef, World Heritage Areas
Pathways for transfer	Analysis of trade routes, commodity transfer from infested areas	Interception data from ports	Likely available for all species
Climate matching/ microsite suitability	Regional scale correlations with areas of known distribution; direct measurements of responses to variation in temperature and humidity	CLIMEX modeling, ecophysiological distribution models	*S. geminata* potential distribution modeled with CLIMEX; only regional scale correlations available (as in Table 6.1)
Spread into intact bushland	Literature, direct observations	Spread outside of disturbed environments or in areas of biological significance	*P. longicornis*, *M. floricola*, *S. geminata*, *T. bicarinatum*
How would function be affected?			
Dominate other ants	Literature, direct measurements	Displaces from resources	*M. floricola*, *S. geminata*
Nesting and food resources available	Direct observation, measurements	Ability to establish and persist	Most species omnivorous and have flexible nesting requirements
Behaviour relative to resident ants	Direct observation, measurements	Disrupt mutualism, enter new mutualisms	Largely unknown relative to native ants

Table 6.3 continued

Line of inquiry	Source of information	Example evidence	Applicable to
Myrmecophilous species present	Flora and fauna surveys, knowledge of biology, comparison to records elsewhere	Ant-tended plants (e.g., with extrafloral nectaries)	Depends on site; comparison of resident ant with tramp
		Ant-dispersed seeds	*S. geminata*, *P. longicornis*; but unknown relative to resident ants
		Ant-tended butterfly larvae	Unknown relative to native ants
		Honeydew producing insects	Possibly all but *M. pharaonis*; unknown relative to resident ants
Vulnerable or threatened species present	Flora and fauna surveys, knowledge of biology, comparison to records elsewhere	Invertebrate prey items (e.g., soft-bodied insects)	Possibly all but *P. alluaudi*; unknown relative to resident ants
Modified community structure	Direct observation, measurements	Simplified invertebrate communities or reduced invertebrate abundance	*S. geminata*, *T. bicarinatum*

The relative abundance of an invasive ant species is often measured by relative representation at baits or in pitfall traps. The number of nests per unit area may also be counted for comparison to other sites. Activity levels (e.g., number of ants trailing up a tree or crossing a card) are also used as a proxy for abundance or density, particularly to compare results for a single species across multiple sites. The best method is dependent on the biology and behavior of the ant species of interest.

In some cases, invasive ants achieve numerical dominance only years or decades after they have become established. In the case of the yellow crazy ant on Christmas Island, the eventual population explosion was likely due to the arrival of the Lac scale, and the sequence of events revealed the mechanism behind the increase (see Sections 2.4 and 3.6). For other species, the time lag remains unexplained. *Myrmica rubra* (from Europe) and *Pachycondyla chinensis* (from Japan) both established in the U.S. at least 70 years ago, but have only recently expanded their range[7].

Abundance in the introduced range of tramp ant species is largely attributed to unicoloniality, the generalist habits of the species, and the ability to harvest hemipteran honeydew[6]. Unicoloniality is considered to be a continuum of social organization and resource exchange[310]. Its hallmark is the lack of intraspecific aggression to workers from nearby nests, which allows resources that would have been used defending the colony to be diverted into foraging or other tasks. The loose nesting requirements and broad diets enable high nest densities in small areas. The physiological ability to utilize hemipteran honeydew may be particularly important for enabling dominant species to attain and maintain high densities and levels of activity[144, 357]. Carbohydrates are also known to increase aggression for Argentine ants and yellow crazy ants[91, 358].

Other mechanisms may be uncovered as tramp ant species are explored in more detail. Identifying which of these mechanisms are relevant for each of the tramp species of interest, particularly those that have been reported to reach high abundance elsewhere in the introduced range (see Tables 6.2 and 6.3), may yield some insights into the risks they pose to biodiversity in Australia.

Available data indicate that *T. melanocephalum* and *P. alluaudi* do not become abundant or numerically dominant. No information is available for *M. mayri*. The remaining seven species are noted to become at least locally abundant and/or dominant.

6.2.2 Will tramp ants invade areas with significant biodiversity?

Information needed to answer this question is dependent the ecology of the area of interest and the biology of the tramp ant species. Table 6.3 summarizes some of the key questions and gaps in our knowledge.

There are several different perspectives (not necessary mutually exclusive) from which potential priorities for abatement of tramp ants might be approached from the standpoint of areas of biodiversity interest:

- Impacts on critical habitat

Critical habitats are areas necessary for persistence or regional representation of particular native species. The focus is generally on short range taxa listed as threatened under Commonwealth EPBC Act and state - Threatened Species Conservation Act, or on taxa dependent on seasonal foraging or breeding grounds as subjects of international agreements, as there is mandate for conservation action. Tramp ants can exacerbate declines in native species imposed by pre-existing threatening processes (e.g., habitat loss and/or predation by feral animals), or by imposing a novel threatening processes (e.g., tending of scale insects, leading forest collapse on Cays of Great Barrier Reef).

- Impacts in biodiversity hotspots

These are areas with important biodiversity values at risk from multiple threatening processes. In October 2003, the Australian Government announced 15 national biodiversity hotspots, identified by the Australian Government's Threatened Species Scientific Committee. The hotspots were identified to increase public awareness of the cost-effectiveness of strategic and timely action to conserve biodiversity. In hotspot areas, timely intervention may prevent long-term and irreversible loss of their values, and provide high return for conservation investment. Often these areas are prone to tramp ant invasion due to prior habitat disturbance. Tramp ants can exacerbate declines in species abundance imposed by pre-existing threatening processes (e.g., habitat loss and/or predation by feral animals).

- Impacts on unique island assemblages

Because of remoteness and the associated development of biotic assemblages driven by chance dispersals and unique evolutionary trajectories, islands are often characterized by relatively simply but highly distinctive ecosystems and species. These systems are prone to the novel influences of invasive species. Tramp ants can diminish key stone species, leading to collapse of ecosystems (e.g., yellow crazy impacts on Red land crab on Christmas Island).

- Impacts in under-represented, under-protected ecosystems

These are ecosystem types poorly represented in the reserve network which aims to identify and protect the full complement of the country's indigenous ecosystems. Ecosystem types that are naturally of small extent or now present as remnants of formerly more widespread systems, have particularly high conservation value because their unique assemblages of species are vulnerable to ongoing degradation. Tramp ants have the potential to contribute to this degradation. Impacts will be most significant where numerically dominant or keystone species are affected.

On the ant side, we need to know how likely it is that the ant will be transported to the areas of biodiversity significance. Given the slow natural dispersal rate of these species, transport will be dependent on human commerce and other forms of traffic to the site or region of interest. An analysis of the types of traffic and commodities incoming from infested areas, as has been done for risk assessments of various tramp ant species in New Zealand (e.g., [308, 311, 314]), will likely provide some indication of the relative risk of arrival.

If the ants are transported, the next question is how likely are they to establish? Climate matching and ecophysiological distribution models have been used to predict the introduced range of other invasive species (e.g., red imported fire ants, Argentine ants)[7, 359]. These models benefit from knowledge of the individual species response to temperature and moisture. For *S. geminata*, some temperature and dessication tolerance data are available[308], and its distribution in Australia has been predicted with CLIMEX[132]. Tolerance to a range of temperatures has been tested for *M. floricola*, *M. pharaonis*, and *T. bicarinatum* in the laboratory[360], but as yet no comprehensive models of their likely geographic spread have been developed.

Abiotic and biotic factors at smaller spatial scales will also be important in determining likelihood of establishment. Most of the 11 species are described as 'disturbance specialists' or associated with 'disturbed' sites (*T. melanocephalum*, *P. longicornis*, *M. destructor*, *M. pharaonis*, *T. simillimum*). In ecology disturbance is considered as a discrete event that disrupts the community through changes the physical environment or in the availability of space, or food[361]. Disturbed sites may have more food resources, more suitable microclimates, or lack competitors[6], and disturbance-associated ants may be responding to any one or all three of these factors. Though the definition is broad, it is also generally considered opposite of pristine, or 'intact' environments. Species that are not able to spread into intact environments will have a lower chance of affecting biodiversity.

Interactions with the resident ant community will also influence whether a tramp ant can establish in intact environments. A diverse assemblage of resident ants may effectively compete against the tramp ant, thereby providing biotic resistance against invasion[362]. There is some evidence that the biotic resistance of dominant ants in Australia can limit the competitive abilities of Argentine ants, at least under certain abiotic conditions and in some habitats[6]. However, native ants have not stopped the spread of the African big-headed ant or yellow crazy ant in the Northern Territory[176, 251, 363]. Several of the tramp ant species are noted as not being able to dominate other ant species (*T. melanocephalum*, *P. longicornis*, *P. alluaudi*, *M. destructor*) and this may be what limits them to disturbed areas. Islands are thought to be readily invaded by tramp ants because of their depauperate resident ant faunas[7].

The recipient habitat must also have suitable food and nesting sites for the tramp ant to establish. Given that omnivory and flexibility in nesting materials are almost hallmarks of tramp ants, it is unlikely that these alone will limit tramp ant establishment.

6.2.3 How would function be affected?

From what we know of other ant invasions, changes in species interactions and ecosystem functioning occur following invasion when the invasive ant behaves differently than resident ants. The invasive ant may disrupt functions normally carried out by resident ants (e.g., seed dispersal), or it may usurp a function that was either not done by resident ants (e.g., killing chicks) or done with different effect (e.g., tending of honeydew producing insects). The effects of *S. geminata* on Ashmore Reef and *T. bicarinatum* on NEHC are indicative of these species ability to disrupt the functioning of their adopted habitats. Developing a capacity to predict whether these scenarios would be repeated in other locations is critical to assessing potential risks posed by tramp ants, but will require much improved understanding of the responsiveness of the invading ant and the invaded ecosystem. *T. bicarinatum*, for example, appears to be exceptionally responsive to the honeydew provided by *P. urbicola*, but knowledge of whether it only responds to *P. urbicola* honeydew is presently lacking. Knowledge of where else *P. urbicola/Pisonia* forests occurs within Australian territories and how likely *T. bicarinatum* is to reach other *P. urbicola*/*Pisonia* forests is also critical.

The possibility that *M. floricola* would also disrupt functioning under the right circumstances should also be investigated. It is known to prey on butterfly eggs and silkworms[324, 364] and it can become dominant in flooded mangrove habitats in Florida[327] (albeit not where it has been studied in Australia[365]). Several species of native butterfly have associations with mangrove forests in Australia, including *Adoxophyes templana*, *Cleora injectaria*, *Doratifera quadriguttata*, *Dysphania numana*, *Hypochrysops apelles*, *H. narcissus*, *H. phorbas* and *Syntherata janetta*. Further knowledge of the distribution of this ant relative to Australia's mangrove forests, as well as the potential triggers for its ability to become locally abundant[350], would increase the capacity to predict the risk it may pose to this system.

For regions of biodiversity significance, knowledge of the presence of myrmecophilous (ant-loving) species or species that are likely to be particularly susceptible to tramp ant effects, based on knowledge elsewhere, will also help to understand potential risks posed by tramp ants in Australia. See Table 6.3 for examples of how tramp ants would affect myrmecophilous and vulnerable species.

6.3 Comparison of the Potential Biodiversity Impacts of These Species to the Red Imported Fire Ant, Electric Ant, Yellow Crazy Ant, African Big-Headed Ant, and Argentine Ant

A number of factors influence the potential impacts of tramp ants on biodiversity. In Table 6.4 we apply a scorecard approach to assessment of risks to enable a comparison of *T. melanocephalum*, *P. longicornis*, *P. alluaudi*, *M. destructor*, *M. floricola*, *M. mayri*, *M. pharaonis*, *S. geminata*, *T. bicarinatum*, and *T. simillimum* with those tramp ant species that have been the focus of abatement programs supported by CfOC. A total of 19 factors were scored, drawing extensively on the published literature.

We score four factors for invasiveness – the propensity to establish at non-urban sites given dispersal or transport occurs, and a further three factors for pathways to and within Australian territories through freight movement. This scoring indicates these ten tramp ant species have high likelihood of further spread within Australia, and in this regard are of only marginally lower risk than red imported fire ants, electric ants, yellow crazy ants, African big-headed ants, and Argentine ants which are predicted to further spread if current abatement programs do not succeed.

Most of these tramp ants are associated with disturbed habitats both within their current range in Australia and internationally (see Table 6.2), and our scoring for habitat preferences indicates low to moderate risk of establishing in undisturbed environments, especially in closed forests. Notable exceptions are *M. floricola* and *T. bicarinatum* which are known to occur in both closed and open habitats, albeit often of relatively simple vegetation composition, and *S. geminata* in the more open habitats, especially those sites of low productivity and/or with low ant diversity[71].

Four factors are scored that may hinder detection and eradication efforts. *Tapinoma melanocephalum, M. floricola* and *P. alluaudi* in particular are scored as cryptic, reflecting their small size and absence of a painful sting or bite that would otherwise draw attention. *Monomorium pharaonis* and *S. geminata* are known to produce winged, colony-forming dispersal stages, and *T. melanocephalum* and *P. longicornis* exhibit high nest mobility, traits that may frustrate containment initiatives. For *P. alluaudi, M. floricola,* and *T. simillimum* presently there is a dearth of information on appropriate chemical control options.

Lastly we score for impacts on native flora and fauna. In contrast to the severe impacts scored for the original five species of interest, most of the other tramp ant species are scored low for likely impacts on native ants and other invertebrates. The exceptions are *S. geminata*, and to a lesser degree *M. floricola and T. bicarinatum,* which can attain dominance in ant communities and affect other invertebrates. With the exception of *S. geminata*, none of these tramp ants are scored as having significant impacts on vertebrates, and thus are indicated not to pose a significant threat to this component of biodiversity. *Solenopsis geminata* and *T. bicarinatum* are also scored high for likely adverse effects on seed dispersal.

Most of the tramp ants tend honeydew-producing hemipterans and thus there is the potential for adverse effects on plants hosting these insects. However, the available literature indicates these effects on the plants will rarely be significant, but under certain circumstances – as yet poorly understood – can be severe.

These risk assessment are made with acknowledgement that macroclimatic conditions will influence the geographic range of the tramp ant species within Australia. This, coupled with the spatial pattern of natural heritage values across the Australia territories, will mean impacts will not be uniformly distributed.

Note that we include here only species that are already known to occur in Australia. However, Australia would likely provide suitable habitat for several other ant species that are expanding outside their native range, often with adverse ecological consequences. These include *Nylanderia* nr.*pubens , Lasius neglectus*, *Myrmica rubra*, *Pachycondyla chinensis*, *Tetramorium tshushimae*, and *T. caespitum.*

Table 6.4 Assessment of risk for further spread and impacts of tramp ants within Australia and its island territories

	Invasiveness[a]				Pathways[b]			Habitat[c]		Detection and eradication[d]				Impact on native environment[e]						
Factor:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	
Ant species	Dominance	Gyny	Supercolony	Diet breadth	Human assoc	Nest flexibility	Fertile workers	Non-disturb forest	Non-disturb other	Cryptic	Nuptial flights	Nest mobility	Chemical control	Other ants	Invertebrates	Vertebrates	Disrupt seed dispersal	Tends bugs	Disrupt mutualisms	**Total score**
Tapinoma melanocephalum	2	3	3	2	3	3	1	1	2	3	1	3	2	1	1	1	1	2	1	36
Paratrechina longicornis	2	3	2	3	3	3	1	1	1	2	1	3	2	1	1	1	2	2	2	36
Plagiolepis alluaudi	1	3	2	1	3	2	1	1	2	3	1*	1*	3	1	1	1	1	2	1	31
Monomorium destructor	2	3	3	3	3	3	3	1	2	2	2	2	1	1	1	1	1	2	1	36
Monomorium floricola	2	3	3	1	3	2	1*	2	2	3	1	2*	3	2	2	1	1	2	2	38
Monomorium mayri	1	3#	3#	3	3	3	3#	1	1	2	2#	2#	1#	1	1	1#	1#	2#	1#	35
Monomorium pharaonis	2	2	2	1	3	2	1	1	2	2	3	1*	1	1	1	1	1	1	1	29
Solenopsis geminata	2	2	2	3	3	3	1	1	2	1	3	1	2	2	3	3	3	2	2	41
Tetramorium bicarinatum	2	3	3	2	3	3	1	2	2	1	1	1*	2	2	2	1	2	3	2	38
Tetramorium simillimum	1	3	2	1	3	2	1	1	2	2	1	1*	3	1	1	1	2	2	2	32
Five species managed with CfOC funding[3, 117, 118]																				
Solenopsis invicta	3	3	2	3	3	1	1	2	3	1	3	1	1	3	3	3	3	3	3	45
Wasmannia auropunctata	3	3	3	3	3	3	1	3	3	3	2	3	1	3	3	2	3	3	3	51
Anoplolepis gracilipes	3	3	3	3	3	3	1	3	3	1	2	2	1	3	3	3	2	3	3	48
Pheidole megacephala	3	3	3	3	3	3	1	3	3	2	2	1*	1	3	3	1	3	3	3	47
Linepithema humile	3	3	3	3	3	2	1	3	3	2	2	3	1	3	3	2	3	3	3	51

a. *Biological traits conferring invasiveness*

Factors: **1.** Recruits large numbers to food and monopolizes it – low(1), some(2), high(3); **2.** Reproductive queens – monogyne, variable, polygyne; **3.** Supercolonies with reduced intraspecific aggression – no(1), variable; or some aggression (2), yes(3); **4.** Diet breadth – low(1), medium(2), high(3).

b. *Pathways to and within Australian territories through freight movement*

Factors: **5.** Common association with anthropogenic environments – low(1), medium(2), high(3); **6.** Flexibility in nesting sites (and thus likely to nest in freight) – low(1), medium(2), high(3); **7.** Workers fertile (and thus capable of founding new colonies) – no(1), possibly(2), yes(3).

c. *Habitat preferences*

Factors: **8.** Non-disturbed closed forest – low(1), medium(2), high(3); **9.** Non-disturbed woodlands and other open habitats – low(1), medium(2), high(3).

d. *Ease of detection and eradication*

Factors: **10.** Cryptic – no(1), possibly(2),yes(3); **11.** Winged, nuptial colony-forming dispersals – no/unlikely(1), some(2), yes(3); **12.** Nest mobility – low(1), medium(2), high(3); **13.** Availability of chemical control – yes(1), limited(2), no(3).

E. *Impact on native environment*

Factors: **14.** Detrimental impacts on native ant communities – unlikely(1), limited(2), likely(3); **15.** Detrimental impacts on native invertebrates (other than other ants) – unlikely(1), limited(2), likely(3); **16.** Detrimental impacts on vertebrates – unlikely(1), limited(2), likely(3); **17.** Detrimental impacts on plant recruitment through disrupting seed dispersal unlikely(1), limited(2), likely (3); **18.** Detrimental impacts on plant fitness through tending of Hemiptera – unlikely(1), limited(2), likely (3); **19.** Detrimental impacts on myrmecophilous mutualisms by displacement of native host ant(s) - unlikely(1), limited(2), likely (3).

*Uncertainty, few details available in the published literature

Biology of *Monomorium mayri* is poorly known and here assumed to be similar to *M. destructor* for these factors

Note that the assessment is intended to be broadly indicative of risks only. Caution is advised in drawing conclusions drawn about quantitative differences among species' scores.

6.4 A Summary of Species Causing the Greatest Impact with the View to Future Opportunities for Control Work

Red imported fire ants, electric ants, yellow crazy ants, African big-headed ants, and Argentine ants are currently the foci of abatement programs supported by CfOC (See Sections 1-4). In all cases, these tramp ants have high potential to adversely affect biodiversity at infested sites and adjoining areas should these abatement programs fail. Furthermore, these tramp ants have high potential for spread to other regions of Australia and to inflict further losses on biodiversity. In each of these programs the infestation site is within or closely adjacent to areas designated of high conservation value by State and/or Commonwealth governments, and by international conventions and agreements (Table 6.5) because of outstanding biodiversity and other natural features of international significance. Our assessments described in Section 3, coupled with the risk assessment presented above (Table 6.4), lead to the conclusion that these tramp ant species are the highest priority, and are indeed of such significance that abatement programs at all infestation sites justify ongoing resourcing.

6.4.1 Other infestations in areas of biodiversity significance

Yellow crazy ants also infests other sites within Australia that are of equally high conservation, namely in the northeast Queensland Wet Tropics World Heritage Area, and the Cocos (Keeling) Islands (Table 6.5). The Queensland infestation was the focus of an abatement program by Biosecurity Queensland over the past few years but has recently been disbanded (see Section 6.4.2). If the ant is not contained, the impact on the internationally renowned and significant biodiversity of the Wet Tropics World Heritage Area is likely to be dire.

The Keeling (Cocos) are recognized internationally for their outstanding biodiversity values, not least the Pulu Keeling National Park (North Keeling Island) Ramsar Site and North Keeling World Heritage Reserve. The infestation of yellow crazy ant in the islands is under investigation by CINP staff but presently not under active management[225, 366, 367]. It appears yellow crazy ants have not formed an association with scale insects there yet[86].

Yellow crazy ants were reported from Hervey Bay on Fraser Island, also a World Heritage area, but have apparently been controlled[368].

African big-headed ants occur at a number of locations on mainland Australia and in a number of island territories. Of particular note are infestations on Capricornia Cays[252, 369], in the southern part of the Great Barrier Reef World Heritage Area, on the Tiwi Islands, and in Howard Springs Nature Park and Hunting Reserve in the Northern Territory[370, 371]. The Capricornia Cays constitute the Capricornia Cays National Park within the Great Barrier Reef World Heritage Area. African big-headed ants tend *Pulvinaria urbicola*, and the high abundance of these scale insects resulted in dieback of the *Pisonia* forest on Tryon Island. Generally dominated by *Pisonia* forest, the cays host breeding populations of globally threatened sea turtle species and a number of seabirds. The Tiwi Islands are designated a Site of Conservation Significance by the Northern Territory government[372]. Partly because of their isolation and because they occupy a climatic extreme (high rainfall), the Tiwi Islands support many endemic species, as well as a number of range-restricted Northern Territory species. The Tiwi Islands, under freehold ownership by Tiwi Aboriginal Land Trust, contain the Territory's best-developed example of tall eucalypt forest, along with an unusually high density and

Table 6.5 Location of selected tramp ant infestations in Australian territories and their relationship to designated areas of high conservation significance at State, Commonwealth, and International levels

Tramp ant	Program or infestation site	Areas of Conservation Significance		Tramp Ant Management
		Within program/infestation site	Adjacent to program/infestation site	
Five species managed with CfOC funding (evaluated in this report) [3, 117, 118]				
Red imported fire ant	Brisbane and environs, SE Queensland	Reserves and forest parks – several, including The Mount Coot-tha Reserve	<u>EPBC Act List of Threatened Ecological Communities:</u> Littoral Rainforest and Coastal Vine Thickets of Eastern Australia ('Critically Endangered'); Lowland Rainforest of Subtropical Australia ('Critically Endangered'); Swamp Tea-tree (*Melaleuca irbyana*) Forest of South-east Queensland ('Critically Endangered') <u>World Heritage Gondwana Rainforests National Parks</u>: e.g., Lamington National Park; Tamborine Mountain National Park; Mt Barney National Park; Mt French/Moogerah Peaks National Park; Main Range National Park <u>Other National Parks:</u> numerous, including Naree Budjong Djara; D'Aguilar; Fort Lytton; Moreton Island; Naree Budjong Djara; Southern Moreton Bay Islands; Venman Bushland <u>Ramsar Sites</u>: Moreton Bay; Bool and Hacks Lagoons <u>Parks and Reserves:</u> several, including Brisbane Forest Park	See Section 2.1
Electric ant	Cairns and environs, NE Queensland	Wet Tropics World Heritage Area (in part)	<u>Wet Tropics World Heritage Area</u> <u>EPBC Act List of Threatened Ecological Communities:</u> Broad leaf tea-tree (*Melaleuca viridiflora*) woodlands in high rainfall coastal north Queensland ('Endangered'); Littoral Rainforest and Coastal Vine Thickets of Eastern Australia ('Critically Endangered'); Mabi Forest (Complex Notophyll Vine Forest 5b) ('Critically Endangered') <u>National Parks:</u> Barron Gorge; Kuranda; Green Peaks; Green Island; Fitzroy Island; Bellenden Ker; Graham Range; Ella Bay; Daintree	See Section 2.2

Table 6.5 continued

Tramp ant	Program or infestation site	Areas of Conservation Significance		Tramp Ant Management
		Within program/infestation site	Adjacent to program/infestation site	
Yellow crazy ant	East Arnhem Land, Northern Territory	Sites of Conservation Significance NT: Gove Peninsula and north-east Arnhem coast; Maningrida coastal habitats; Boucaut Bay and associated coastal floodplains; Castlereagh Bay and associated islands; Arafura Swamp; Buckingham Bay and associated coastal floodplains; Blue Mud Bay and associated coastal floodplains.; Blyth-Liverpool wetlands (Bawinanga Aboriginal Corporation)	EPBC Act List of Threatened Ecological Communities: Arnhem Plateau Sandstone Shrubland Complex ('Endangered') Sites of Conservation Significance NT: Croker Island group; Cobourg Peninsula; Elcho Island group; Wessel and English Company Island groups; Groote Eylandt group; Western Arnhem Plateau Ramsar Sites: Cobourg Peninsula; Kakadu National Park National Parks: Kakadu National Park	See Section 2.3
Yellow crazy ant	Christmas Island	Christmas Island National Park; The Dales Ramsar Site; Hosnies Spring Ramsar Site	National Parks: Pulu Keeling (North Keeling Island) (already infested, see below) Ramsar Sites: Pulu Keeling National Park (North Keeling Island) (already infested, see below)	See Section 2.4
African big-headed ant	Lord Howe Island	TSC Act List of Endangered Ecological Community - Lord Howe Island Group (Sallywood (*Lagunaria*) Swamp Forest). World Heritage Area (in part). Stephens Reserve.	World Heritage Area Permanent Park Reserve	See Section 2.5
Argentine ant	Norfolk Island	Norfolk Island National Park (in part). Reserves: Selwyn (in part); Headstone; Hundred Acres; Cascade; Ball Bay	Norfolk Island National Park (includes Phillip Island). Norfolk Island Botanic Garden Reserves: Anson Bay; Selwyn; Nepean Island	See Section 2.6

Table 6.5 continued

Tramp ant	Program or infestation site	Areas of Conservation Significance		Tramp Ant Management
		Within program/infestation site	Adjacent to program/infestation site	
Other species and infestations not managed with CfOC funding				
Yellow crazy ant	Cairns and environs, NE Queensland	Little Mulgrave National Park, within Wet Tropics World Heritage Area	Wet Tropics World Heritage Area EPBC Act List of Threatened Ecological Communities: Broad leaf tea-tree (*Melaleuca viridiflora*) woodlands in high rainfall coastal north Queensland (E); Littoral Rainforest and Coastal Vine Thickets of Eastern Australia ('Critically Endangered'); Mabi Forest (Complex Notophyll Vine Forest 5b) ('Critically Endangered') National Parks: Barron Gorge; Kuranda; Green Peaks; Green Island; Fitzroy Island; Bellenden Ker; Graham Range; Ella Bay; Daintree	Discontinued; surveillance ongoing, funded by CfOC, coordinated by WTMA
Yellow crazy ant	Cocos (Keerling) Islands[28, 29, 30]	Pulu Keeling National Park (North Keeling Island) Ramsar Site; North Keeling World Heritage Reserve	Christmas Island (already infested and under abatement) (See above)	Ecological surveys by CINP
Yellow crazy ant	Fraser Island, SE Queensland[21]	Fraser Island World Heritage Area. Great Sandy National Park		Reportedly controlled
African big-headed ant	Several cays in Capricornia Cays[22, 23], southern Great Barrier Reef	Great Barrier Reef World Heritage Area (in part); Great Barrier Reef Marine Park (in part); Capricornia Cays National Park	Great Barrier Reef World Heritage Area Great Barrier Reef Marine Park	Ants baited and scale insects controlled with biological control agent

Table 6.5 continued

Tramp ant	Program or infestation site	Areas of Conservation Significance		Tramp Ant Management
		Within program/infestation site	Adjacent to program/infestation site	
African big-headed ant	Bathurst and Melville islands, Tiwi Islands, Northern Territory[25, 26, 27]	Sites of Conservation Significance NT- Tiwi Islands	EPBC Act List of Threatened Ecological Communities: Arnhem Plateau Sandstone Shrubland Complex ('Endangered') Sites of Conservation Significance NT: Croker Island group; Cobourg Peninsula; Western Arnhem Plateau Ramsar Sites: Cobourg Peninsula; Kakadu National Park National Parks: Kakadu National Park; Gurig National Park	Eradication program in progress
Other ten tramp ant species infestations				
Solenopsis geminata	Ashmore Reef (West, Middle, and East Islets)[6]	Ashmore Reef National Nature Reserve	Cartier Island and surrounding reef Hibernia Reef	Abatement program in progress
Solenopsis geminata	Bathurst and Melville islands, Tiwi Islands, Northern Territory[25, 26, 27]	Sites of Conservation Significance NT- Tiwi Islands	EPBC Act List of Threatened Ecological Communities: Arnhem Plateau Sandstone Shrubland Complex ('Endangered') Sites of Conservation Significance NT: Croker Island group; Cobourg Peninsula; Western Arnhem Plateau Ramsar Sites: Cobourg Peninsula; Kakadu National Park National Parks: Kakadu National Park; Gurig National Park	Eradication program in progress
Tetramorium bicarinatum	North East Herald Cay [7, 9]	Coringa-Herald National Nature Reserve (IUCN Class A1) (in part); Coral Sea Reserves Ramsar Site (in part)	Coringa-Herald National Nature Reserve (IUCN Class A1). Coral Sea Reserves Ramsar Site	

extent of rainforests. The coasts support important nesting sites for marine turtles, internationally significant seabird rookeries, and some major aggregations of migratory shorebirds. Some 19 plant and 19 animal species found on the Tiwi Islands are listed as threatened at the Northern Territory orNational level. The Northern Territory government identifies several Sites of Conservation Significance on the adjacent mainland including 'Howard Sand Plains', 'Darwin Harbour', 'Adelaide River coastal floodplain' and 'Mary River coastal floodplain'. Each contains areas of rainforest, mangroves and other terrestrial habitats vulnerable to invasion by African big-headed ant. The sites contain some of the most floristically and faunally rich mangrove systems globally. These mangroves support a highly specialised fauna including over 306 invertebrate species and 112 species of mammals and birds. Significant fauna at these sites include Northern quoll (*Dasyurus hallucatus*) (EPBC listed 'Endangered'), Gouldian finch (*Erythrura gouldiae*) ('Endangered'), Masked owl (*Tyto novaehollandiae kimberli*) ('Vulnerable'), Partridge pigeon (*Geophaps smithii*) ('Vulnerable'), Red goshawk (*Erythrotriorchis radiatus*) ('Vulnerable'), a number of SRE species such as the Howard River toadlet (*Uperoleia daviesae*), and numerous birds, including many listed under international conventions or bilateral agreements protecting migratory species.

Members of the other ten tramp ants also infest areas of high conservation value in Australia, notably on islands. In Table 6.5 we list *Solenopsis geminata* on Ashmore Reef off the coast of northern Western Australia in the eastern Indian Ocean[346], and on Tiwi Islands in the Northern Territory[370, 373]. The fauna of the Ashmore Reef National Nature Reserve, along with the adjacent Cartier Island Marine Reserve and Hibernia Reef, is considered regionally and internationally significant. A number of species present, such as marine turtles, dugongs, migratory birds and some seabird species are protected under international agreements. Several species found in the Reserves are on the 1996 IUCN Red List of Threatened Animals. Many bird species found in the Reserves are listed on the Japan–Australia and China–Australia Migratory Bird Agreements (JAMBA and CAMBA)[374]. A number of species in the Reserves are protected under the EPBC Act. The designation of the Tiwi Islands as a Site of Conservation Significance by the Northern Territory government[372] is discussed above.

Tetramorium bicarinatum occurs on North East Herald Cay[349] which constitutes part of the Coringa-Herald National Nature Reserve and Coral Sea Reserves Ramsar Site. As discussed above, North East Herald Cay is important for its *P. grandis – Cordia subcordata* forest. Furthermore, the cays have been recognized by BirdLife International as the Coringa-Herald Reefs International Bird Area because of its importance as a breeding site for seabirds, and constitute part of the Coral Sea Reserves Ramsar Site.

It should be noted that many sites in mainland Australia and in island territories are infested with multiple tramp ant species. For example, while Table 6.5 focuses on *S. geminata and* African big-headed ants for the Tiwi Islands, these islands are also infested by *P. longicornis*, *T. melanocephalum*, *M. floricola*, *M. pharaonis*, *M. destructor*, *T. bicarinatum* and *T.* simillimum[346, 371] . Likewise, in addition to the yellow crazy ant, *S. geminata*, *T. bicarinatum*, *T. simillimum, M. destructor* and *P. longicornis* are known to be present in the Cocos (Keeling) Islands[366]. Where there are multiple species present, if control is to be initiated, care must be taken to ensure that inadvertent adverse effects are not engendered by removing one of the species. For example, the removal of African big-headed ant from an islet in Hawaii resulted in population increases of *S. geminata*, *T. bicarinatum*, and yellow crazy ants with adverse consequences for seabird nesting success[375]. A population crash of African big-headed ants on Melville Island in the Tiwi Islands also resulted in spread of *S. geminata*[71].

6.4.2 Future opportunities for controlling tramp ants

Based on the ecology of the different tramp ant species and likely or demonstrated impacts in areas of biodiversity significance, we identify two infestations:

1. Yellow crazy ants in the World Heritage Wet Tropics Area, and

2. *Solenopsis geminata* on Ashmore Reef

where continued investment in tramp ant abatement is likely to see a high return on benefits to biodiversity relative to cost.

The stand-out opportunity that will potentially yield the greatest benefit to biodiversity of those listed above is eradicating the yellow crazy ant from the World Heritage Wet Tropics Area (WHWTA) in Queensland. The yellow crazy ant was discovered in Cairns in 2001 and was subject to Biosecurity Queensland treatment and surveillance with the goal of eradication [376]. Recognizing the potential threat to the Wet Tropics World Heritage Area, in 2010, the Wet Tropics Management Authority (WTMA) applied for CfOC funds to determine the threat of tramp ants (both electric ants and yellow crazy ants) to the Wet Tropics World Heritage Area[377] and in mid-2012 received $268,000 from CfOC to commence surveillance and treatment of the ant in collaboration with Conservation Volunteers Australia [378]. The action proved prescient as in early 2012, the ants were discovered in Edmonton on the fringes of the World Heritage Area, having been moved there in cyclone debris in 2011[378]. Approximately 300ha are thought to be infested, 20ha within the rainforest, and 280ha in predominantly sugar cane[377]. The infestation was treated by Biosecurity Queensland in July 2012, in what was supposed to be the first of three bait applications. However, in November 2012, Biosecurity Queensland declared the ant not eradicable with current resources[376], and placed responsibility for managing the pest with landholders, effectively putting an end to the possibility of eradication[379], and possibly also reducing cooperation of private landowners in the surveillance effort[377]. Public outcry resulted in another round of bait being applied just before Christmas, but only to the infestation in the sugar cane[377].

The current known area of infestation (300ha) is less than half of the area being baited in the yellow crazy ant-Arnhem Land project in December (>600ha). Not completing the planned three treatments now, when the infestation is in its relatively early stage, will fail to decrease risks to biodiversity and will mean that any future management attempts will be require a much larger investment in resources. WTMA has not had the resources to investigate the effects the ant has had to date, but based on knowledge from elsewhere, anticipates great risk to World Heritage Wet Tropics Area biodiversity[377].

On Ashmore Reef, a two year pilot program is being conducted to reduce *S. geminata* numbers and impact on migratory sea birds and to see if eradication is a possibility[347]. Baiting occurred on one of the islands (Middle Island) in May, August, and November 2011, and February, May, June and July/August 2012. By October 2012, no *S. geminata* were detected on Middle island, whereas numbers on the untreated East Island were still high. Preliminary baiting has now commenced on West Island so that the threat to turtles can be reduced. To date the program has cost about

$140,000, with costs kept down due to logistical support from the Australian Customs and Border Protection Command. Future plans are to develop a funding proposal to continue the program for three to five years. If the program receives further funding the goal will be to control ant numbers at low levels on all islands at Ashmore with a view to attempting eradication. If current support from Customs continues, it is estimated that the program would cost less than $100k/year for the first two years, when baiting is occurring, and less after that for the follow-up monitoring[347]. Given the low cost and the likelihood that *S. geminata* is having and will continue to have adverse effects on the Reef's wildlife if it is not managed, this is a worthwhile investment and funding should continue.

Management of a third infestation, the African big-headed ant in Howard Springs Nature Reserve in the Northern Territory, would also likely provide great benefits to biodiversity. Given the high success rate in controlling this ant in the Northern Territory[102, 345, 380], the likelihood of success would be high. However, any eradication attempt would require dedication and political will on the part of the Parks and Wildlife Commission NT, which has been lacking so far[71]. The infestation has grown from 20ha in 1996[363] to 45ha by 2005[251], and is currently estimated to be 90ha[71]. Though the impact of the ant has been well-documented, to our knowledge, no management activities have been attempted.

As for the other infestations identified above, both *S. geminata* and the African big-headed ant on Melville Island in the Tiwi islands are part of an ongoing management effort. They are both currently managed because they are a social nuisance, rather than a threat to biodiversity[71]. But it is anticipated that treating them now will prevent their becoming biodiversity threats being realised. The management effort has been ongoing for about ten years, and has continued past initial funding from the Indigenous Land Corporation opportunistically. *Solenopsis geminata* is the greater problem, but treatment with a nest drenching method is showing good results. If eradication at the largest infestation (~250ha) is achieved, as is expected, it will be the largest documented eradication of this species by a factor of ten[71].

African big-headed ants have also been controlled in the Capricornia Cays as part of a larger program to protect the *Pisonia* forests[369]. In 2006, on Wilson Island, the ants were baited prior to the introduction of native ladybugs (*Cryptolaemus montrouzieri*) that prey on the scales. With the ants removed, the predators can greatly reduce the scale population. Once the scale population has declined, the threat to *Pisonia* is reduced and the ants do not have an abundant supply of honeydew with which to build their population.

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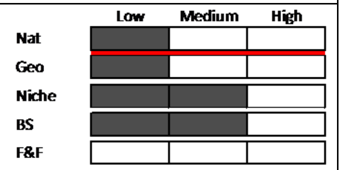
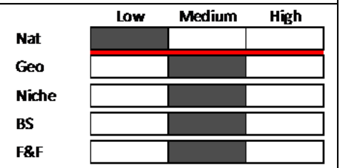
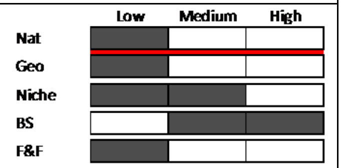
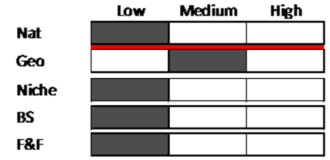
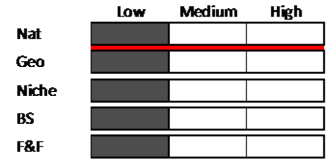
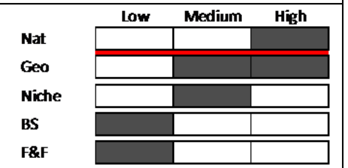
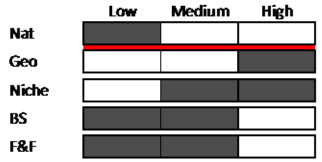
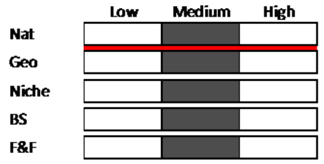
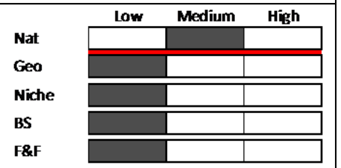
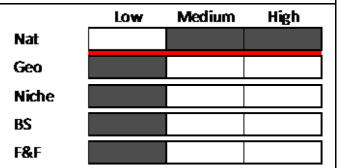
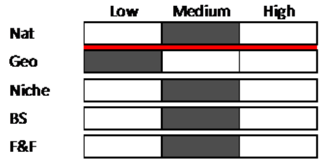
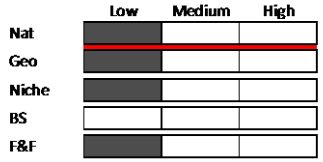
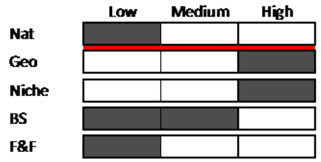
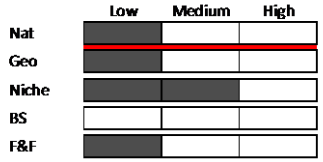
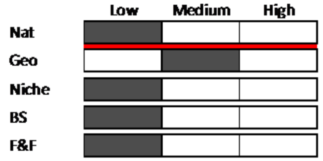
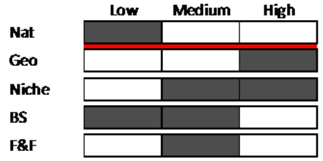
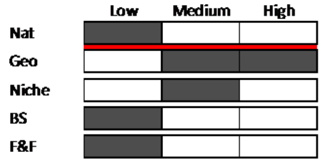
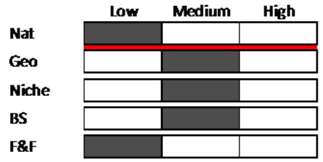
Appendix 1 Rapid assessment of native species potentially at risk from Red imported fire ant in the SE Queensland Bioregion

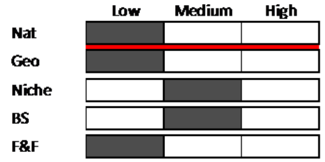
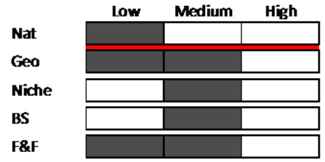
Common Name (scientific name)	EPBC Act Listing Status	Range	Recovery Plan	Habitat and behaviour	Potential or presumed level of impact and mechanisms for Red imported fire ant effect	
Birds						
Albert's lyrebird (*Menura alberti*)[1]	Not listed	se Qld, ne NSW	No.	Rainforests and wet sclerophyll forests with mesic understorey. Ground foraging insectivore. Nests both arboreal and on ground.	High significance; Medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced, but may be off-set partially by increased ant abundance.	
Azure kingfisher (*Ceyx azurea*)[1] [=*Alcedo azurea*]	Not listed	WA, NT, Qld, NSW, Vic, e SA, Tas(also New Guinea, Moluccas)	No. Degradation of wetland waters.	Near water - ponds, rivers, lakes and mangroves. Diet mostly fish and insects. Roosts arboreal. Nests in burrows in earth banks and cliffs.	Low significance; Low impact. May compete for nest sites. Nesting attempts and fledgling success may be disrupted.	
Australian brush-turkey (*Alectura lathami*)[1]	Not listed	Qld, NSW	No.	Primarily occurs in rainforests and wet schlerophyll forests, but also in drier scrublands. Terrestrial. Communal nests. Feed on insects, seeds and fallen fruits.	Low significance; Medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Beach stone-curlew (*Esacus neglectus*)[1]	Not listed (Marine)	WA, NT, Qld, NSW, Vic, SA (also New Guinea)	Yes (2006). Habitat loss; human disturbance; predation by feral animals.	Wader. Occurs on open, undisturbed beaches, islands, reefs and estuarine intertidal sand and mudflats. Nest a scrape on ground.	Low significance; Low to medium impact. Nesting and fledgling success may be disrupted. Minimal disruption of foraging and food resources.	

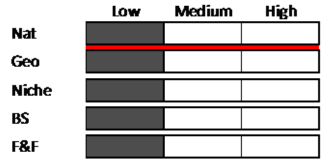
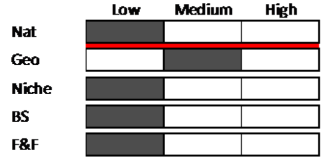
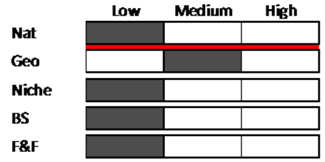
Black-breasted button-quail (*Turnix melanogaster*)[1, 3, 5]	V	se Qld, ne NSW	Yes (2009). Habitat fragmentation; disturbance and predation by feral animals.	Ground birds that live in grasslands (open habitat). Nests consist of a scrape in the ground. Diet is mostly invertebrates (including ants), but also seeds, taken from litter on the ground.	High significance; Medium to high impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced, but may be off-set partially by increased ant abundance.	
Black bittern (Australasian) (*Ixobrychus flavicolllis australis*)	Not listed	n WA, n NT, n Qld to s NSW	No. Habitat loss; disturbance by livestock; predation by feral ants.	Lowland terrestrial and estuarine wetlands, generally in areas of permanent water and dense vegetation. Nocturnal. Forages for reptiles, fish and invertebrates. Roosts in trees or on the ground amongst dense reeds. Nests on branch overhanging water.	Low significance; Low impact. Nesting attempts and fledgling success may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced.	
Black chinned honeyeater (*Melithreptus gularis gularis*)[1]	Not listed	m & s Qld, NSW, Vic, SA	No. Habitat loss; displacement by aggressive species such as the Noisy miner.	Upper levels of drier open forests and woodlands dominated by eucalypts. Feeds and nests in canopy. Insectivore and nectivore.	Low significant; Low impact. Foraging and breeding unlikely to be significantly affected. Abundance of invertebrate prey may be reduced.	
Black-throated finch (southern) (*Poephila cincta cincta*)[1]	E	me Qld to ne NSW (extinct over part of former range)	Yes (2007). Habitat loss, fragmentation, and degradation by grazing livestock; predation by feral animals.	Grassy, open woodlands and forests, and tussock grasslands. Nesting above the ground, generally close to water. Seed feeders.	High significance; Low impact. Nesting and fledgling success, and foraging may be disrupted.	

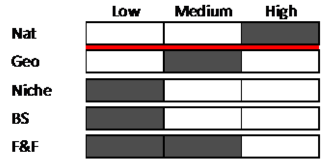
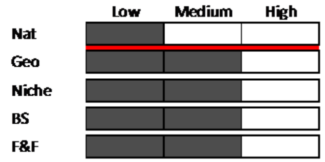
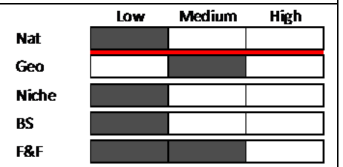
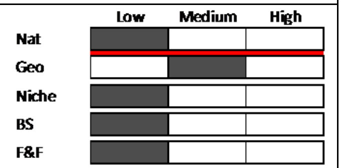
Buff-banded rail (*Gallirallus phillippensis*)	Not listed [*Gallirallusphilippensismacquariensis*, Macquarie Island, Extinct]	WA, NT, Qld, NSW, ACT, Vic, SA, Tas, LH, NI (also Philippines, Indonesia, New Guinea, Cocos (Keeling) Islands, w Pacific, New Zealand)	No.	Rainforests and woodlands, and adjoining grasslands. Omnivorous scavenger, feeds on invertebrates and small vertebrates, seeds, fallen fruit and other vegetable matter, as well as carrion. Nests on ground in dense grassy or reedy vegetation close to water.	Low significance; Medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced.	
Bush stone-curlew (*Burhinus grallarius*)[1,4]	Not listed	Qld, NSW	No. Habitat disturbance through human activity, livestock grazing, cultivation, and wildfires; predation by feral animals.	Lightly timbered, open forests, woodlands and pastures. Nocturnal. Nests and forages on ground. Feeds on invertebrates (including ants), frogs, reptiles and some vegetation.	Medium significance; Medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced, but off-set partially by increased ant abundance.	
Cotton pygmy-goose (*Nettapus coromandelianus*)[1]	Not listed	Qld, NSW	No. Habitat loss and modification through hydrological changes.	Wetlands, particularly lakes. Nest in hollows of trees that stand in or beside water. Feeds almost entirely aquatic, chiefly on seeds and vegetable matter but also insects and crustaceans.	Medium significance; Low impact. Foraging and breeding marginally affected.	
Coxen's fig-parrot (*Cyclopsitta diophthalma coxeni*)[1]	E	se Qld, n NSW	Yes (NSW 2002). Habitat loss and fragmentation.	Preference for rainforests, but occurs in range of forested habitats. Arboreal (canopy) feeding and nesting. Feeds on seeds, nectar and lichens.	Medium to high significance; Low impact. Feeding and nesting unlikely to be significantly affected.	

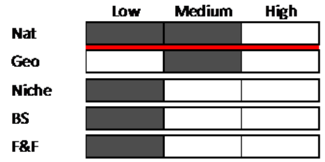
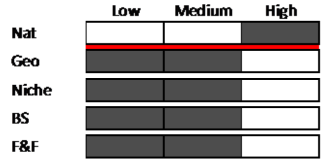
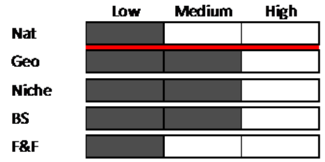
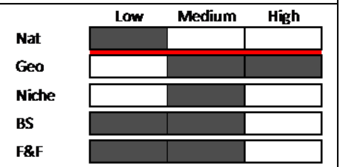
Eastern bristlebird (*Dasyornis brachypterus*)[1, 3, 5]	E	seQld, NSW, e Vic.	No. Habitat loss; human disturbance; fire; predation by feral animals.	Montane, tall open forests and woodlands with a dense grassy understorey close to rainforest areas. Nest usually near the ground in clumps of grass or small shrubs. Forages on ground. Omnivore, diet includes ants.	Medium significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced, but may be off-set in part by increased ant abundance.	
Eastern curlew (*Numenius madagascariensis*)[1]	Not listed (Marine)	All Aus; LH, NI (breeds in Russia and north-eastern China)	No. Human disturbance; habitat degradation.	Sheltered coasts, especially estuaries, bays, harbours, inlets and coastal lagoons. Migratory. Roosts terrestrially in salt-marshes, behind mangroves, and on sandy beaches. Forages on soft intertidal sand- and mud-flats.	Low significance; Low impact. Roosting and foraging minimally affected. Not breeding in Australia.	
Emerald ground-dove (*Chalcophaps indica chrysochlora*)	Not listed	Qld, NSW, LH, NI	No.	Lowland rainforests and semi-urban areas. Roosts in trees. Forages on ground and low vegetation for seeds and fruit. Nests in trees.	Low significance; Medium impact. Nesting and fledgling success, and foraging may be disrupted.	
Freckled duck (*Stictonetta naevosa*)[1]	Not listed	sw WA, Vic, NSW (vagrant elsewhere in AUST)	No. Loss and hydrological changes to habitat; illegal hunting.	Plankton-rich wetlands. Forages at wetland edges and in the shallow productive waters at dusk, feeding on macrophytes, algae, seeds, small invertebrates, and small fish. Nests near water level.	Low significance; Low impact. Generally not nesting in Bioregion. Roosting and foraging minimally affected, but abundance of non-aquatic invertebrate prey may be reduced.	

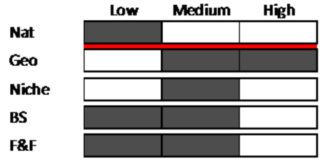
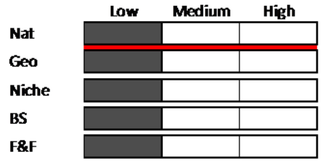
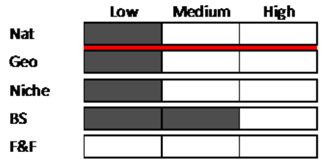
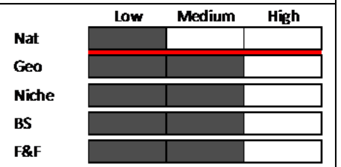
					Vagrant in Qld during dry years.	
Glossy black-cockatoo (*Calyptorhynchus lathami*)[1]	Not listed	Qld, NSW, Vic	No.	Forests on sites of low nutrient status, reflecting the distribution of *Allocasuarina* spp. Feeds exclusively on seeds extracted from the wooden cones of casuarinas. Nests in tree holes.	Low significance; Low impact. Nesting, roosting and foraging minimally affected.	
Grey fantail (*Rhipidura albiscapaa listeri*)	Not listed	Qld, NSW, ACT, Vic, SA	No.	Range of wooded habitats. Insectivore, feeds on insects, mostly caught in flight but sometimes gleaned off the ground and vegetation. Nests in subcanopy.	Low significance; Medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Grey goshawk (*Accipiter novaehollandiae*)[1]	Not listed	WA, NT, Qld, NSW, Vic, Tas. (also the Lesser Sunda Islands, Moluccas, New Guinea, Solomon Islands.)	No. Habitat loss and fragmentation.	Tending coastal. Forests, tall woodlands, and timbered watercourses. Feeds on small vertebrates and insects. Nests arboreal.	Low significance; Low impact. Nesting, roosting and foraging minimally affected.	
Ground parrot (*Pezoporus wallicus wallicus*)[1, 3]	Not listed	Qld, NSW, Vic, formerly SA	No. Habitat loss; predation by feral animals; wildfire.	Occurs mostly in dense coastal heathlands and sedgelands. Ground dweller. Seed feeder, mostly of sedges of families Cyperaceae and Restionaceae. Nests on ground.	Low significance; Medium impact. Nesting, fledgling success, foraging and roosting may be disrupted. Suffers from a high level of intrinsic egg failure (i.e. infertility) which, although not necessarily a threat in itself, may be important in	

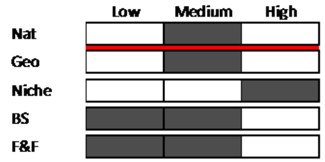
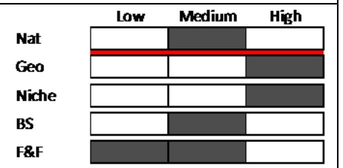
					conjunction with other threatening processes such as tramp ants.	
Freckled duck (*Stictonetta naevosa*)[1]	Not listed	s Qld, WA, Vic, NSW	No. Habitat loss; hydrological changes; illegal hunting.	Wetlands. Aquatic, feeds on algae, seeds and vegetative parts of aquatic grasses and sedges, and on small invertebrates. Nests near water-level.	Low significance; Low impact. Minimal geographic overlap in breeding season. Foraging minimally affected.	
Little tern (*Sterna albifrons*)[1, 3]	Not listed (Marine)	Widespread globally. Coastal Qld, NSW, Vic, SA, WA, NT	Yes (2003). Habitat loss; human disturbances; predation and disturbance by feral animals. Mentions ant effects on nesting success.	Migratory. Ground-nesting on sandy beaches and close to the high-tide mark. Estuarine feeder.	Low significance; Low to medium impact. Nesting attempts and fledgling success likely disrupted.	
Major Mitchell's cockatoo (*Cacatua leadbeateri*)[1]	Not listed	NT, Qld, NSW, Vic, Sa, WA	No. Habitat loss, including removal of nesting trees in agricultural areas.	Primarily semi-arid open woodlands, but utilizing a range of other habitats, including agricultural fields. Nests in tree hollows. Forages on ground and in foliage of trees and tall shrubs for seeds, fruits, and tubers.	Low impact; Low impact. Very low geographic overlap. Nesting attempts, fledgling success, and foraging may be disrupted.	
Masked lapwing (*Vanellus miles*)[1]	Not listed	NT, Qld, NSW, Vic, SA, Tas (also Indonesia; New Zealand; Papua New Guinea; Timor-Leste, Singapore)	No. Habitat disturbance through human activity, livestock grazing, cultivation and wildfires; predation by feral animals.	Wetlands and in other moist, open habitats, including parks and pastures. Insectivore, feeds on insects (including ants) and earthworms. Nests on ground.	Low significance; Medium impact. Nesting and fledgling success may be disrupted. Abundance of invertebrate prey may be reduced, but possibly off-set by increased ant abundance.	

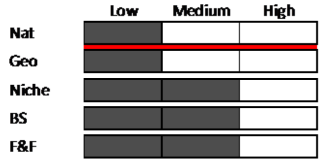
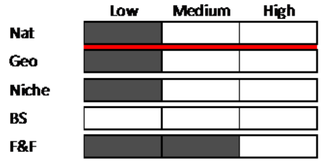
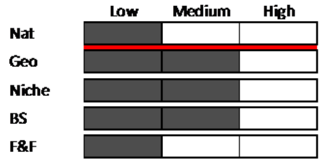
Olive whistler (*Pachycephala olivacea*)[1]	Not listed	se Qld, NSW, Vic, SA	No. Habitat loss and fragmentation; fire; predation by feral animals.	Wet forests, usually montane. Forages in trees and shrubs and on ground, feeds on berries and insects. Nests arboreal.	Low significance; Low impact. Nesting and fledgling success not greatly affected. Abundance of invertebrate prey may be reduced, but possibly off-set partially by increased ant abundance.	
Painted honeyeater (*Grantiella picta*)[1]	Not listed	NT, Qld, NSW, Vic, SA	No. Loss and fragmentation of habitat; removal of large, old trees with heavy mistletoe infestations; heavy grazing of grassy woodlands.	Forests and woodlands. Nomadic, at low densities throughout range. Arboreal, foraging exclusively on mistletoes, mainly in upper canopy. Nests 3-20m from the ground.	Low significance; Low impact. Nesting attempts, fledgling success, and foraging only affected in lower forest tiers.	
Painted snipe (*Rostratula benghalensis*)[1]	Not listed	Qld, NSW, Vic, SA, WA, NT, Tas, LH	No. Habitat loss and modification through hydrological changes; predation by feral animals; disturbance by grazing livestock.	Inhabits inland and coastal shallow freshwater wetlands. Forages nocturnally on mud flats and in shallow water for seeds and invertebrates. Nest a scrape in the ground.	Low significance; Low impact. Nesting attempts and fledgling success may be affected. Foraging minimally affected.	
Powerful owl (*Ninox strenua*)[1]	Not listed	se Qld, NSW, Vic	Yes (2006). Habitat loss; fragmentation; logging; predation by feral animals.	Woodlands and open sclerophyll forests to tall open wet forests and rainforests. Carnivore, preys mainly on medium-sized arboreal marsupials. Nests in tree hollows.	Low significance; Low impact. Nesting attempts and fledgling success may be affected. Foraging minimally affected. Prey abundance unlikely affected.	

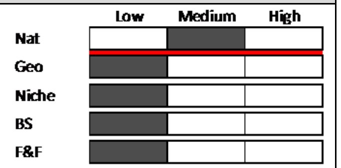
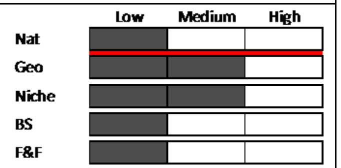
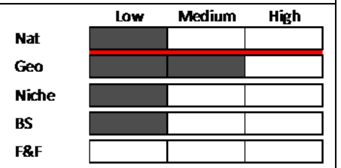
Plumed frogmouth (*Podargus ocellatus plumiferus*)[1]	Not listed	se Qld, ne NSW	No.	Rainforests, but also use rainforest trees within sclerophyll forests. Principally feeds on larger arthropods, although will also take frogs. Arboreal nesting and roosting.	High significance; Low to medium impact. Nesting and fledgling success, and foraging may be affected, especially in lower tiers. Prey abundance may be reduced.	
Rainbow bee-eater (*Merops ornatus*)[1]	Not listed (Marine)	All Aus (also New Guinea, Solomon Islands, Indonesia, SE Asia, Japan)	No. Not considered threatened.	Migratory over part of Australian range. Open forests and woodlands, shrublands, and in various cleared or semi-cleared areas. Insectivore, feeds on insects (primarily on bees and wasps, but including ants, beetles, etc.) in flight and on ground. Nests in burrows in banks.	Low significance; Medium impact. Nesting and fledgling success may be disrupted. Abundance of invertebrate prey may be reduced, but possibly off-set partially by increased ant abundance. May compete directly for nest sites in banks.	
Red-browed treecreeper (*Climacteris erythrops*)[1]	Not listed	me & se Qld, NSW, Vic	No. Habitat loss and fragmentation.	Forests and woodlands, along watercourses and in gullies. Insectivore, feeds primarily on insects on tree trunks and under bark.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Prey abundance possibly reduced, especially in lower forest tiers.	
Red goshawk (*Erythrotriorchis radiatus*)[1]	V	NSW, Qld, NT, WA	Yes (2012). Habitat loss.	Coastal and sub-coastal woodlands and forests. Predatory on other birds and to lesser extent other vertebrates. Arboreal nesting.	Low significance; Low impact. Nesting and fledgling success may be disrupted. Minimal affect on prey abundance.	

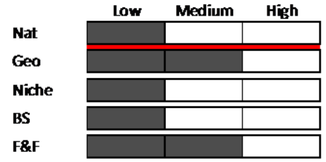
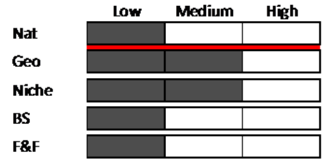
Regent's honeyeater (*Anthochaera phrygia*)[1]	E	se Qld, NSW, Vic	Yes (1999). Loss, fragmentation and degradation of habitat.	Dry Box-Ironbark eucalypt woodlands and dry sclerophyll forest associations, and occasionally coastal forests and shrublands. Nectar feeders. Nests in canopy.	Medium significance; Low impact. Nesting and fledgling success, and foraging may be disrupted in low stature habitat.	
Rufous scrub-bird (*Atrichornis rufescens*)[1]	Not listed	se Qld, ne NSW	No. Logging and wildfires.	Rainforests adjacent to open eucalypt forests with or without a rainforest understorey; also heaths; mostly at higher elevations. Feeds on small invertebrates, including snails, earthworms, amphipods and insects (including ants) in leaf litter. Nests in low vegetation.	High significance; Medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced, but possibly off-set by increased ant abundance.	
Sacred kingfisher (*Todiramphus sanctus*)	Not listed (Marine)	WA, NT, Qld, NSW, ACT, Vic, SA, Tas, LH, NI (also New Zealand, New Guinea, Indonesia, n and w Melanesia; vagrant CI, nw Pacific)	No. Not threatened.	Mangroves, woodlands, forests, and disturbed open area. Migratory over part of range. Forages mainly on land, only occasionally capturing prey in water. Feeds on invertebrates, fish and small vertebrates. Nest in burrows in earth banks, tree hollows, etc.	Low significance; Low to medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of some invertebrate and vertebrate prey may be reduced.	
Shining bronze-cuckoo (*Chrysococcyx lucidus*)	Not listed (Marine)	WA, NT, Qld, NSW, ACT, Vic, SA, Tas, NI (also Indonesia, New Caledonia, New	No.	Forests. Migratory. Insectivore, feeding predominately on caterpillars and beetles. Brood parasite of birds	Low significance; Low to medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance	

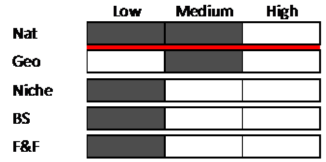
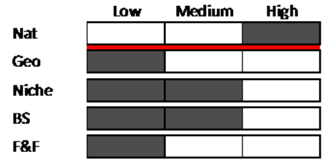
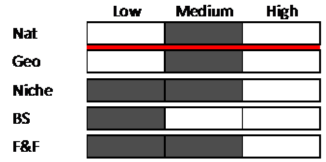
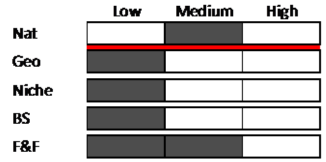
		Zealand, Papua New Guinea, Solomon Islands, and Vanuatu)		nesting in subcanopy.	of some invertebrate prey may be reduced.	
Silver-eye (*Zosterops lateralis*)	Not listed (Marine)	WA, Qld, NSW, ACT, Vic, SA, Tas, LH, NI (also New Caledonia, Vanuatu, Fiji, New Zealand)	No. Not threatened.	Rainforests and shrublands, and wooded urban areas. Insectivore, nectarivore, and frugivore forages in forest understory and canopy, and rarely on forest floor. Nests in canopy and subcanopy.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of some invertebrate prey may be reduced.	
Sooty owl (*Tyto tenebricosa*)[1]	Not listed	Qld, e NSW, NE Vic (also New Guinea)	No. Habitat loss and logging.	Rainforests and moist eucalypt forests. Nocturnal. Carnivore, preying on small vertebrates. Roosts and nests in large tree hollows, caves and in dense foliage.	Low significance; Low impact. Nesting and fledgling success may be disrupted in lower forest tiers. Prey abundance possibly reduced indirectly through effects on invertebrate abundance.	
Sooty Oystercatcher (northern) (*Haematopus fuliginosus opthalmicus*)	Not listed	Qld, NSW, Vic, Tas	No.	Coastal. Rocky coastlines, but occasionally estuaries. Forages in the intertidal zone. Nests in rock crevices and small hollows on the ground.	Low significance; Low impact. Nesting attempts and fledgling success may be disrupted.	
Southern emu-wren (*Stipiturus malachurus malachurus*)[1]	Not listed	se Qld, NSW, Vic, s SA	No.	Marshes, lowland heaths and dune areas. Nests in low vegetation. Primarily insectivorous but supplements diet with seeds.	Low significance; Medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of insect prey may be reduced. Importance of	

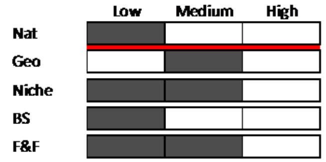
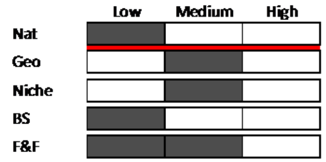
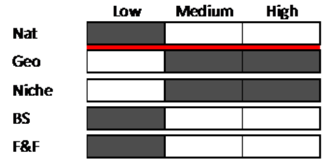
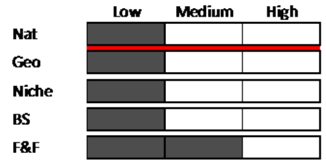
					ants in diet not known and species may benefit from increased ant abundance.	
Square-tailed kite (*Lophoictinia isura*)[1]	Not listed	e Qld, NSW, Vic, SA, WA, NT	No. Habitat loss; illegal hunting.	Open country, including open woodlands and heaths. Specialist hunter of passerines. Arboreal nesting.	Low significance; Low impact. Nesting and fledgling success unlikely affected. Abundance of prey may be indirectly reduced through effects on invertebrates.	
Squatter pigeon (*Geophaps scripta scripta*)[1]	V	Qld, NSW	No. Habitat loss; disturbance by grazing livestock; predation by feral animals.	Mainly grassy woodlands and open forests that are dominated by eucalypts, especially near open water bodies. Feeds mainly on seeds, but also insects. Nest a scrape in the ground.	Medium significance; Medium impact. Nesting attempts and fledgling success, and foraging may be disrupted. Abundance of insect prey may be reduced. Importance of ants in diet not known but degree to which species may benefit from increased ant abundance likely to be minimal.	
Star finch (eastern) (*Neochmia ruficauda ruficauda*)[5]	E	e Qld ne NSW	No. Loss and degradation of habitat due to agriculture. Red imported fire ant considered a threat.	Mainly in grasslands and grassy woodlands located close to bodies of freshwater; also suburban areas. Nests arboreal (to about 9m). Feeds on seeds of grasses and other annual plants, and on insects.	Medium significance; Medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of insect prey may be reduced, and may compete for seeds. Importance of ants in diet not known but degree to which species may benefit from increased ant abundance likely to be	

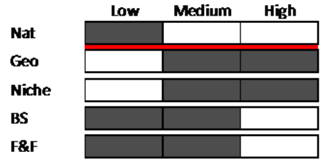
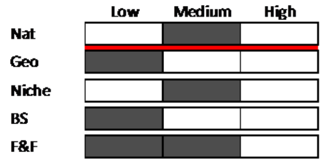
					minimal.	
Superb lyrebird (*Menuran ovaehollandiae*)[1]	Not listed	se Qld, e NSW, e Vic, Tas	No. Habitat loss and degradation; predation by feral animals.	Rainforests. Ground dwelling. Insectivore, gleans food from the litter and logs. Nests on ground.	Low significance; Low to medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced, but may be off-set partially by increased ant abundance.	
Swift parrot (*Lathamus discolour*)	E	s Qld, NSW, ACT, Vic, se SA, Tas	Yes (2011). Habitat loss and fragmentation; competition for nectar from birds and insects.	Dry sclerophyll eucalypt forests and woodlands; occasionally in wet sclerophyll forests. Migratory. Primarily an arboreal forager on nectar, mainly from eucalypts, but also eats psyllid insects and lerps, fruit; occasionally on ground feeding on seeds, fruits, etc. Nests in large trees.	Low significance; Low impact. Foraging may be disrupted. Abundance of nectar and invertebrate prey may be reduced.	
Turquoise parrot (*Neophema pulchella*)[1]	Not listed	se Qld, NSW, ne Vic	No. Habitat loss.	Vicinity of Great Dividing Range, occurs in eucalypt woodlands and open forests, with a ground cover of grasses and low understorey of shrubs. Granivore. Nests in hollows, usually less than 2m above ground.	Low significance; Medium impact. Nesting attempts and fledgling success may be disrupted. Foraging probably minimally affected.	

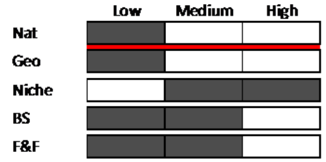
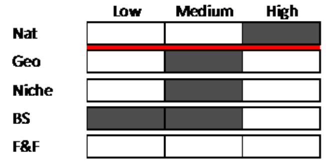
White-faced heron (*Ardea novaehollandiae*)	Not listed	WA, NT, Qld, NSW, ACT, Vic, SA, Tas, CI, LH, NI (also New Guinea, Indonesia, New Caledonia, New Zealand; vagrant se Asia, Cocos Islands, Solomon Islands)	No. Not threatened.	Mainly diurnal. Forages in wet grasslands, wetlands, estuaries and lagoons. Locally nomadic, and dispersive in non-breeding season. Diet highly varied – invertebrates and small vertebrates. Nests in trees.	Low significance; Low impact. Nesting and fledgling success may be disrupted. Abundance of some invertebrate and vertebrate prey may be reduced. Not breeding CI	
Mammals						
Brown antechinus (*Antechinus stuartii*)[3]	Not listed	se Qld, NSW	No. Not threatened.	Occurs in wide variety of forest types; seldom found in disturbed areas. Mostly nocturnal and arboreal, and females build large communal nests. Insectivore, prey including ants.	Medium significance; Low impact. Nesting and foraging minimally impacted. Species may benefit from increased ant abundance.	
Brush-tailed rock-wallaby (*Petrogale penicillata*)[1]	V	se Qld, NSW, ACT, Vic	Yes (2010). Habitat degradation; fire; hunting; disease and competition; and predation by feral animals.	Prefers rocky habitats, open under dense canopy. Shelter during the day in rock crevices, caves and overhangs, yet often basking in exposed sunny spots. Feeds primarily on grasses.	Low significance; Low impact. Resting, breeding and foraging minimally impacted. Possibly displaced by ant activity.	
Duck-billed platypus (*Ornithorhynchus anatinus*)[1, 4]	Not listed	e Qld, e NSW, Vic, Tas (formerly SA) (introduced to Kangaroo Island, SA)	No. Threats primarily related to freshwater habitat loss and degradation.	Dependent on rivers, streams, and bodies of freshwater. Feeds exclusively on benthic macroinvertebrates. Nesting chamber in bank leads from the water's	Low significance; Low impact. Nesting attempts may be disrupted. Eggs and young vulnerable in nest chamber if accessed by ants.	

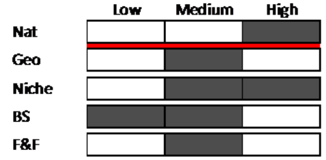
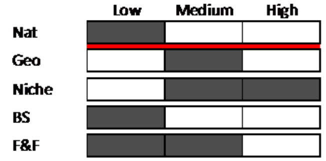
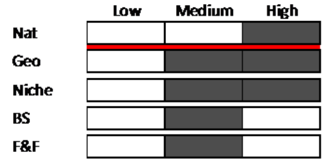
				edge. Young defenceless.		
Eastern long-eared bat (*Nyctophilu stimoriensis*)[1]	V	m & s Qld, NSW, ACT, nw Vic, se SA	No (draft 2010). Habitat loss, fragmentation and degradation by fire and livestock grazing; predation by feral animals.	Inland woodland types, including box, ironbark and cypress pine woodlands. Roosts in tree hollows and under loose bark. Insectivore, with food taken in flight, by gleaning vegetation, and by ground foraging.	Low significance; Low impact. Roosting, breeding and foraging may be disrupted, especially in lower forest tiers. Abundance of invertebrate prey may be reduced, but possibly off-set partially by increased ant abundance.	
False water-rat, Water mouse (*Xeromys myoides*)[1]	V	n WA, n NT, Qld, ne NSW (also New Guinea)	Yes (2010). Habitat loss and degradation; predation by feral animals.	Coastal. Mangroves and the associated salt-marshes, sedgelands, heathlands and freshwater wetlands. Nesting in mounds and mud ramps. Carnivorous, feeding on estuarine/wetland invertebrates such as crabs, worms and molluscs.	Low significance; Low impact. Nesting and foraging may be minimally disrupted.	
Golden-tipped bat (*Kerivoula papuensis*)[1]	Not listed	Qld, n NSW (also New Guinea)	No. Habitat loss and fragmentation; predation by feral animals.	Rainforests, and rainforest ecotone areas. Feeds on a range of both gleaned and aerially acquired invertebrates, especially spiders. Roosts mainly in disused suspended nests of Yellow-throated scrubwren and Brown gerygone, but also tree hollows, caves and buildings.	Low significance; Low impact. Roosting and foraging may be disrupted in lower forest tiers. Abundance of invertebrate prey may be reduced.	

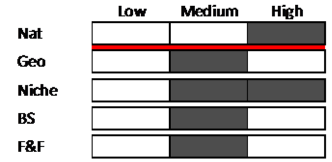
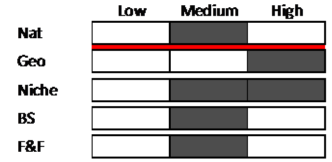
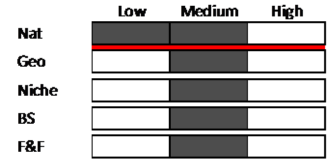
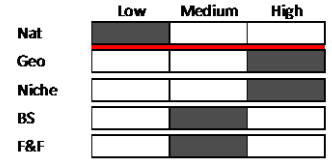
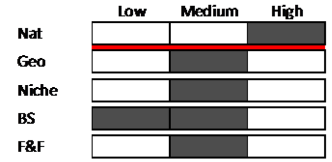
Grey-headed flying-fox (*Pteropus poliocephalus*)	V	Qld, NSW, ACT, Vic, se SA	No. Habitat loss and fragmentation; illegal shooting.	Rainforests, open and closed forests, and woodlands. Nomadic. Canopy-feeding frugivore and nectarivore. Roosts in trees, typically near water. Newborn carried by females but subsequently left at maternal camps in trees.	Low to medium significance; Low impact. Breeding and foraging may be disrupted.	
Hasting River mouse (*Pseudomy soralis*)[1]	E	se Qld, ne NSW	No. Habitat loss,and modification by livestock grazing.	Scrublands and grasslands with open canopy and shrub layer, between 410 and 1100m elevation. Shelters and breeds in rock rubbles, log hollows and other crevices on ground. Foraging on ground and lower vegetation. Feeds on seeds, leaves, flowers and pollen, insects, fungi.	High significance; Low to medium impact. Nesting and foraging may be disrupted. Insect prey and other food resources may be reduced. Importance of ants in diet unknown but species may benefit from increased ant abundance. Possibly displaced by ant activity.	
Koala (*Phascolarctos cinereus*)	Not listed (V - Qld, NSW, ACT)	Qld, NSW, ACT, Vic, SA	Yes (2008). Habitat loss; urbanisation, including dog attacks and road-kill; disease.	Arboreal herbivore, feeds almost entirely on eucalypt leaves. Roosts in trees, disperses on ground.	Medium significance; Low to medium impact. Breeding and foraging may be disrupted. Possibly displaced by ant activity.	
Large-eared pied bat (*Chalinolobus dwyeri*)[1]	V	se Qld, e NSW	Yes (2011). Disturbance of primary nursery (roost) sites by feral animals (particularly goats) and humans.	Requires sandstone escarpment, for roosting, adjacent to higher fertility sites, particularly box gum woodlands or river/rainforest corridors, which are used for foraging. Roost in caves. Insectivorous.	Medium significance; Low impact. Roosting, breeding and foraging may be minimally disrupted. Insect prey may be reduced. Importance of ants in diet not known but species may benefit from increased ant abundance.	

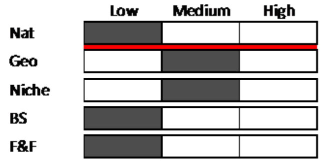
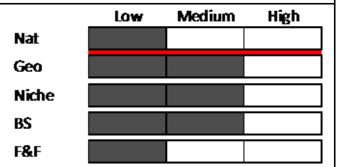
Little pied bat (*Chalinolobus picatus*)[1]	Not listed	c & s Qld, w NSW, ne Vic, ne SA	No. Habitat loss and disturbance from logging.	Dry, open woodlands, dry sclerophyll forests and Araucarian notophyll vine forests. Roots in tree hollows, caves and buildings. Feeds on moths and possibly other flying insects.	Low significance; Low to medium impact. Roosting and breeding minimally impacted. Insect prey resources likely reduced.	
Long-nosed potoroo (*Potorous tridactylus tridactylus*)[1]	V	se Qld, e NSW, ACT, Vic, se SA	No. Predation by feral animals.	Terrestrial, nocturnal. Open forests, woodlands and heaths. Feeds primarily on fungi, but plant material and invertebrates are included in the diet.	Low significance; Low to medium impact. Vulnerable as entirely ground dwelling, and of small body size. Breeding and foraging may be disrupted. Food resources likely reduced. Importance of ants in diet not known but species may benefit from increased ant abundance.	
Red-legged pademelon (*Thylogale stigmatica*)	Not listed	e Qld, n NSW (also New Guinea)	No.	Rainforests, wet sclerophyll forests, vine thickets and areas around swamps. Nocturnal. Solitary, except when feeding. Herbivorous, feeds on foliage and fallen fruits and seeds.	Low significance; Low impact. Breeding and foraging may be disrupted.	
Semon's leaf-nosed bat (*Hipposideros semoni*)[1]	E	e Qld (primary in N) (also New Guinea)	Yes (2001). Loss of roost sites through quarrying; disturbance by tourist visits to caves; loss of habitat through forest clearance.	Tropical rainforests, monsoon forests, wet sclerophyll forests and open savannah woodlands. Feed primarily on moths, but also take huntsman spiders and beetles. Generally forages	Low significance; Low impact. Breeding minimally impacted. Foraging may be disrupted. Abundance of prey may be reduced. Importance of ants in diet not known but species	

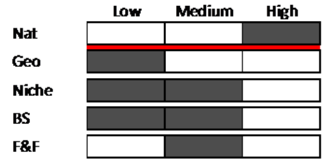
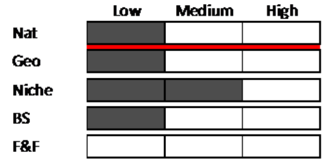
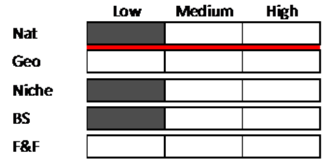
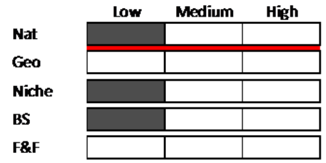
				within 1m of ground, hawking prey in the undergrowth and gleaning prey from surfaces such as tree trunks, rock surfaces and the ground. Roosts in caves.	may benefit from increased ant abundance.	
Short-beaked echidna (*Tachyglossus aculeatus*)[1]	Not listed	ALL AUST (also New Guinea)	No. Not threatened.	Rainforests, open woodlands, semi-arid and arid savannahs, grasslands and heathlands; also agricultural areas. Semi-fossorial, digging for hibernation cover and to construct nursery burrows. Lay a single egg directly into pouch. Young evicted from the pouch (when they start to develop spines) and are left in the burrow; young defenceless. Forages on ants, termites and other invertebrates.	Low significance; Medium impact. Young in nursery burrows highly vulnerable. Abundance of prey may be reduced. Given importance of ants in diet the species may benefit from increased ant abundance. Possibly displaced by ant activity.	
Spotted-tailed quoll (SE mainland population) (*Dasyurus maculatus maculatus*)[1]	E	se Qld, e NSW, ACT, Vic, se SA	No.	Wet forests. Nocturnal, rests during the day in dens such as log and tree hollows, rock outcrops and caves. Young raised initially in den, during which time they are defenceless. Carnivore, preying mainly on medium-sized mammals, but also frogs, birds, lizards and insects.	Medium significance; Low to medium impact. Vulnerable in den; breeding may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced. Importance of ants in diet not known but species may benefit from increased ant abundance. Possibly displaced by ant	

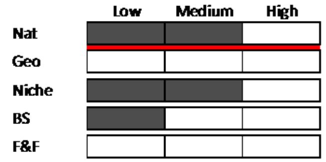
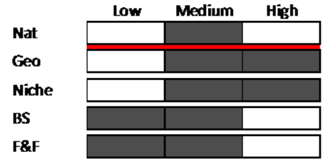
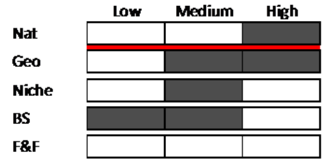
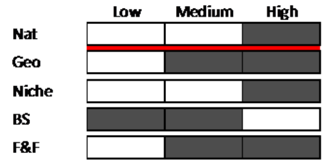
					activity.	
Reptiles						
Brigalow scaly-foot (*Paradelma orientalis*)[1]	V	me & se Qld, n NSW	No. Primary threats are habitat loss through woodland clearance, and predation by feral animals.	Brigalow Belt endemic. Open forest to woodland. Nocturnal. Diet of plant material, sap and invertebrates. Primarily ground dwelling, but will climb to glean insects and sap from wattles. Oviparous.	Low significance; Low to medium impact. Vulnerable in all life stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Role of ants in diet not known but probably minimal as preference evidently for macro-invertebrates.	
Brisbane short-necked turtle (*Emydura macquarii signata*)	V	ne NSW	Yes (2001). Threats not confirmed.	SRE (Bellinger River). Omnivorous, aquatic feeder of small crustaceans, insects, filamentous algae and possibly macrophytes. Oviparous. Nests excavated in the riverbanks.	High significance; Medium to high impact. Vulnerable to predation in non-aquatic stages. Feeding on rafting ants may cause mortality.	
Bunya Mountains sunskink (*Lampropholis colossus*)[1]	Not listed	se Qld	No	SRE, only known from the Bunyas' balds and associated rainforests. Rare. Diurnal, highly active. Insectivore, feeding on small invertebrates associated with leaf litter and logs (ants not included). Oviparous.	High significance; Low to medium impact. Vulnerable in all life stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Burrowing skink (*Ophioscincus ophioscincus*)[2]	Not listed	ce&se Qld	No.	Coastal heaths, woodlands, and rainforests. Burrows in soil and leaf litter. Feeds on invertebrates (ants not	Medium to high significance; Low to medium impact. Vulnerable in all life stages. Breeding and	

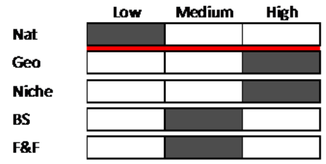
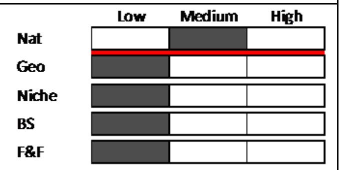
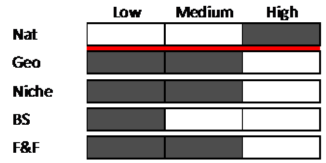
				included). Oviparous.	foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Collared delma (*Delma torquata*)[1]	V	se Qld, ne NSW	No. Habitat loss and degradation through conversion to agriculture; predation by feral animals.	Eucalypt-dominated woodlands and open-forests, especially on rocky ground. Diurnal. Burrowing and sheltering under rocks, logs, leaf litter and in soil cracks. Insectivore, with diet including ants. Oviparous.	High significance; Medium impact. Vulnerable in all life stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced, but possibly off-set partially by increased ant abundance.	
Common death adder (*Acanthophis antarcticus*)[1]	Not listed	e NT, Qld, NSW, n Vic, s SA	No.	Rainforests and wet sclerophyll forests, woodlands, grasslands and heaths. In leaf litter. Carnivore, primarily preying on birds and small mammals, but also insects (ants not included), frogs, and lizards. Produce litters of live young.	Low significance; Medium impact. Vulnerable to as juveniles. Breeding and foraging may be disrupted. Abundance of vertebrate and invertebrate prey may be reduced. Possibly displaced by ant activity.	
Cooloola blind snake (*Ramphotyphlops silvia*)[1]	Not listed	se Qld	No.	Rainforests. Poorly known. Found in ant and termite nests, as well as leaf litter and rotting logs. Believed to feed on earthworms, as well as the larvae and eggs of ants and termites. Oviparous.	High significance; Medium to high impact. All stages vulnerable. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance, but tramp ant unlikely to accept nest intrusion.	

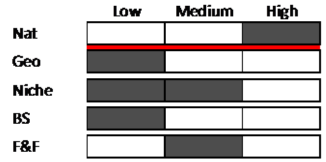
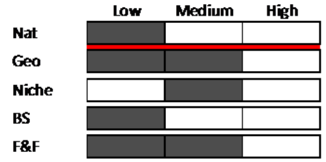
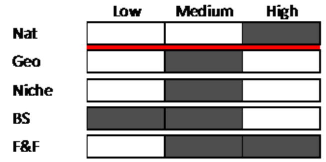
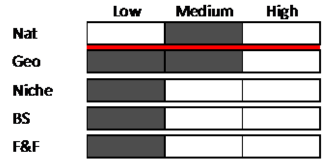
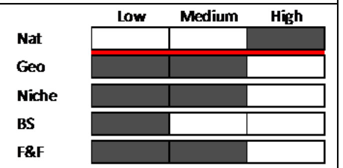
Cooloola snake-skink (*Ophioscincus cooloolensis*)[1]	Not listed	se Qld	No.	Coastal heaths, woodlands, vine thickets and rainforests on white sands. Burrows in soil and leaf litter. Feeds on invertebrates(ants not included). Oviparous.	High significance; Medium to high impact. All stages vulnerable. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Dunmall's snake(*Furina dunmalli*)[1]	V	me & se Qld, n NSW	No. Habitat loss and disturbance through human activities; predation by feral animals.	Open dry sclerophyll forests, woodlands and scrublands. Nocturnal and terrestrial. Shelters in soil cracks and under fallen timber which is embedded in deep-cracking clay soils. Diet consists of small skinks and geckos. Oviparous.	Medium significance; Medium impact. Vulnerable in all life stages. Breeding and foraging may be disrupted. Abundance of vertebrate prey may be reduced.	
Dwarf crowned snake (*Cacophis krefftii*)	Not listed	ce& se Qld, e NSW	No.	Rainforests and wet sclerophyll forests in coastal regions. Nocturnal. Feeds on lizards, and reptile eggs. Oviparous.	Medium significance; Medium impact. Vulnerable in all life stages. Breeding and foraging may be disrupted. Abundance of vertebrate prey may be reduced.	
Eastern grass skink (*Lampropholis delicata*)[2]	Not listed	e Qld, e NSW, ACT, e Vic, e Tas, se SA (introduced to Lord Howe, New Zealand, Hawaii)	No. Not threatened.	Open woodlands and forests. Common in suburban gardens. Terrestrial. Communal nesting. Oviparous. Insectivorous.	Low significance; Medium impact. Vulnerable in all life stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Elf skink (*Eroticoscincus graciloides*)[1]	Not listed	se Qld	No.	Heaths, vine thickets, rainforests and wet sclerophyll forests. Shelters in damp leaf litter, logs and under	High significance; Medium impact. Vulnerable in all life stages. Breeding and foraging may be disrupted.	

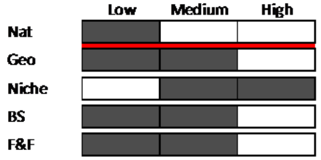
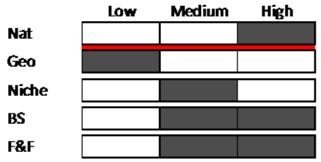
				stones. Forages in shaded, moist environments. Insectivore (ants not included).Oviparous.	Abundance of invertebrate prey may be reduced.	
Green snake, Common tree snake (*Dendrelaphis punctulata*)	Not listed	WA, NT, Qld, n NSW (also New Guinea)	No.	Rainforests to woodlands, and urban areas, especially near water. Diurnal. Active on ground and arboreally, feeds on frogs, lizards, fish, and frogs. Rest at night in hollow trees, logs, foliage, and rock crevices. Oviparous.	Low significance; Low impact. Breeding and foraging may be disrupted. Abundance of some vertebrate prey may be reduced.	
Green turtle (*Chelonia mydas*)[1]	V (Marine)	WA, NT, Qld, NSW, Vic, SA, LH (tropical and subtropical waters throughout the world)	Yes (2003). Loss of nesting sites to urban development; human disturbance; predation by feral animals.	Marine. Pelagic as young. More inshore as adults, mainly feeds on seagrass and algae. Oviparous. Nests on sandy beaches.	Low significance; Low impact. Vulnerable in pipping and hatchling stages. Breeding may be disrupted, but nesting not important in Qld.	
Grey snake (*Heriaspis damelii*)[1]	Not listed	Qld, NSW, SA	No. Habitat loss, including hydrological changes to freshwater habitat; predation by feral animals; poisoning by cane toads.	Woodlands, usually on cracking clay soils, in association with water bodies and damp gullies and ditches. Shelter under rocks, logs and other debris as well as in soil cracks. Nocturnal, feeds on frogs and lizards. Live-bearing.	Low significance; Low impact. Vulnerable at all stages, but especially as juveniles. Breeding and foraging may be disrupted. Abundance of vertebrate prey may be reduced.	

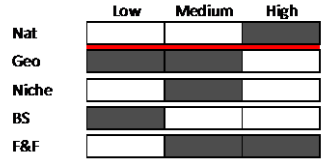
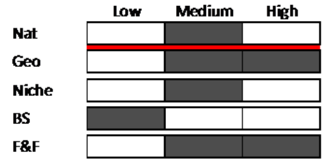
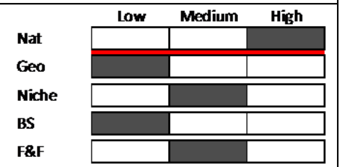
Gully skink (*Saproscincus spectabilis*)[1]	Not listed	se Qld, e NSW	No.	Rainforests. Litter dwelling. Insectivore. Oviparous.	High significance; Medium impact. Vulnerable to in all life stages. Abundance of invertebrate prey may be reduced, possibly off-set partially by increased ant abundance.	
Flatback turtle (*Natator depressus*)[1]	V (Marine)	WA, NT, Qld, NSW, CI	Yes (2003).Human activities such as commercial and recreational fishing; coastal development; Indigenous harvest; predation by feral animals.	On continental shelf of northern Australia. Marine. Bays, coral reefs, estuaries and lagoons. Benthic feeding on seagrass, invertebrates including molluscs, jellyfish and shrimp, soft corals and sea cucumbers; and on fishes. Oviparous. Nests on sandy beaches.	Low significance; Low impact. Vulnerable in pipping and hatchling stages. Breeding may be disrupted.	
Hawksbill turtle (*Eretmochelys imbricata*)[1]	V (Marine)	WA, NT, Qld, NSW, e Vic, CI, LH, NI (global in subtropical to tropical waters)	Yes (2003). Habitat disturbance; by-catch from fisheries and shark control.	Open ocean to lagoons and mangrove swamps in estuaries. Young entirely pelagic. Adults in-shore, benthic, feeding on sponges, jellyfish, sea anemones and algae. Oviparous. Nests on sandy beaches.	Low significance; No impact. Vulnerable in pipping and hatchling stages. Breeding may be disrupted, but nesting not important in se Qld.	
Leathery turtle, Luth (*Dermochelys coriacea*)	E (Marine)	All coastal AUS (tropical, subtropical and temperate waters throughout the world)	Yes (2003). Minimal on-shore threats.	Pelagic feeder on soft-bodied creatures such as jellyfish and tunicates. Oviparous. Nesting on sandy beaches. No recent records on nesting in eastern Australia.	Low significance; No impact. Vulnerable in pipping and hatchling stages. Breeding may be disrupted, but nesting not important in se Qld.	

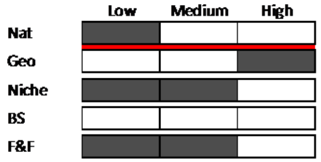
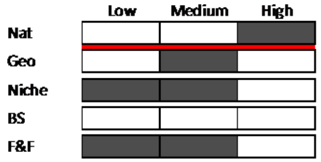
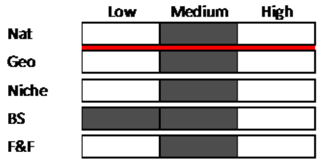
Loggerhead turtle (*Caretta caretta*)[1]	E (Marine)	ALL AUST (coastal marine) (global distribution throughout tropical, sub-tropical and temperate waters)	Yes (2003). Loss of nesting sites to urban development; predation by feral animals.	Marine. Carnivorous, feeding primarily on marine benthic invertebrates. Oviparous. Nests on beaches.	Low to medium significance; Low impact. Vulnerable in pipping and hatchling stages. Breeding may be disrupted, but ne Qld not important breeding sites.	
Major skink (*Bellatorias frerei*) [*Egernia frerei*]	Not listed	e Qld	No.	Diurnal. Lives in small communities in complex burrow systems; active on ground and arboreally. Feeds on insects, snails, other lizards and vegetable material. Live-bearing.	Medium significance; Low to medium impact. Vulnerable in juvenile stages. Breeding and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Mary River turtle (*Elusor macrurus*)[1]	E	se Qld	No. Illegal harvesting; flooding; predation by feral animals.	Flowing, well-oxygenated sections of Mary River system. Nesting on a small number of sand banks. Mainly herbivorous, but eats some animal matter (especially as juveniles). Feeding evidently entirely aquatic.	High significance; Medium impact. Vulnerable in egg and hatchling stages. Breeding may be disrupted.	
Nangur spiny skink (*Nangura spinosa*)[1]	CE	se Qld	Yes (2010). Hoop pine harvesting and replanting; infrastructure development; predation by feral animals.	SRE. Rare. Known only from hoop pine plantations and semi-evergreen vine thickets/forests. Burrows in soil. Insectivore (ants not included), with beetles and spiders preferred	High significance; Medium impact. Vulnerable, especially as eggs and juveniles in burrows. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	

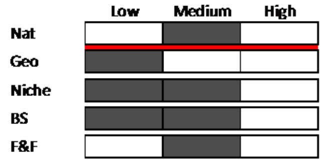
				prey. Probably a live-bearer.		
Pale-flecked garden sunskink (*Lampropholis guichenoti*)	Not listed	Qld, NSW, ACT, Vic, SA	No. Not threatened.	Sclerophyll woodlands, open forests, moist tussock grasslands, and suburban gardens. Leaf litter and rock rubble. Feeds on small invertebrates such as insects (including ants), molluscs and earthworms, and on fruit. Oviparous, often with communal nests.	Low significance; Medium impact. Vulnerable in all life stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Rainforest cool-skink (*Cautula zia*)	Not listed	se Qld, ne NSW	No.	Montane rainforests. Diurnal. Insectivorous (ants not included in diet). Oviparous.	Medium significance; Low impact. Vulnerable in all life stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Ringed thin-tailed gecko (*Phyllurus caudiannulatus*)[1]	Not listed	se Qld	No. Threats not confirmed.	Subtropical vine forests, adjacent wet sclerophyll forests and hoop pine plantations between 180-600m. Nocturnal and active both arboreally and terrestrially. Shelters in buttress cavities of trees, under bark and rock piles. Insectivore. Oviparous.	High significance; Medium impact. Moderately vulnerable in all life stages. Breeding and foraging may be disrupted in lower vegetation tiers and on ground. Abundance of invertebrate prey may be reduced, but possibly off-set partially by increased ant abundance.	

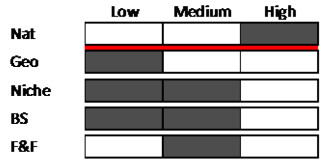
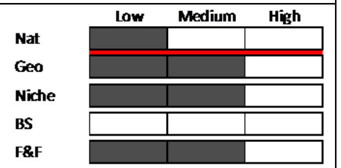
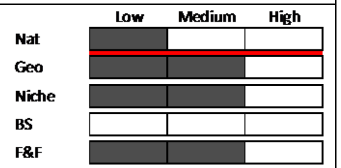
Rose's shadeskink (*Saproscincus rosei*)[1]	Not listed	se Qld, ne NSW	No.	Rainforests. Leaf litter. Insectivore (ants not included in diet). Oviparous.	High significance; Low impact. Vulnerable in all life stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Saw-shelled turtle (*Myuchelys latisternum*)	Not listed	ne Qld to n NSW	No.	Coastal rivers and streams. Feeds on aquatic insects, molluscs, crustaceans, fish, tadpoles, frogs and toads. Oviparous.	Low significance; Low to medium impact. Breeding and foraging minimally disrupted. Abundance of invertebrate and some vertebrate prey may be reduced.	
Short-limbed snake-skink (*Ophioscincus truncatus*)[1]	Not listed	se Qld, ne NSW	No.	Mountain rainforests, sclerophyll forests, coastal heaths and woodlands. Burrowing. Insectivore (ants not included in diet). Oviparous.	High significance; Medium impact. Vulnerable in all life stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Stephens' banded snake (*Hoplocephalus stephensi*)[1]	Not listed	se Qld, ne &ce NSW	No. Main threats are timber harvesting, clearance for agriculture, and urban development.	Closed mesic forests. Nocturnal. Arboreal (individuals dependent on tree hollows) but disperse on ground. Feeds on diverse array of small vertebrates, especially lizards and mammals. Live-bearing.	Medium significance; Low impact. Vulnerable, especially as juveniles. Breeding and foraging may be disrupted in lower vegetation tiers. Abundance of vertebrate prey may be reduced.	
Three-toed snake-tooth skink (*Coeranoscincus reticulatus*)[1]	V	se Qld, ne NSW	No. Habitat loss, fragmentation and disturbance (e.g. by logging).	Rainforests and moist eucalypt forests. In leaf litter on well-mulched, friable soil. Feeds on invertebrates (ants not included in diet) and may	High significance; Medium impact. Vulnerable in all life stages, especially in burrows. Breeding and foraging may be disrupted.	

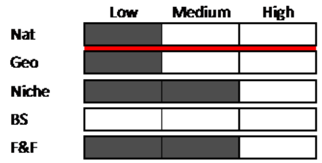
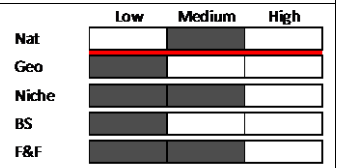
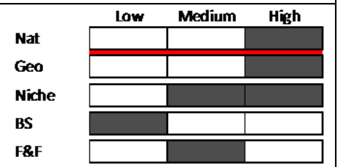
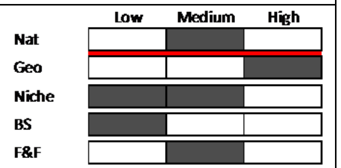
				specialise on earthworms. Oviparous, eggs laid in a nest in soil.	Abundance of invertebrate prey may be reduced.	
Yakka skink (*Egernia rugosa*)[1]	V	e Qld [RIFA, EA]	No. Habitat loss and degradation through human activities.	Open dry sclerophyll forests, woodlands and scrublands. Gregarious. Takes refuge in cavities under and between partly buried rocks, logs, tree stumps, root cavities, abandoned animal burrows, and its own extensive burrows. Omnivorous, consuming soft plant materials and fruits and a wide variety of invertebrates (ants not included). Live-bearing.	Low significance; Medium impact. Vulnerable, especially juveniles and generally in burrows. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Amphibians						
Australian marsupial frog (*Assa darlingtoni*)[1,3]	Not listed	se Qld, ne NSW	No. Not threatened.	Under logs, rocks, and leaf litter in montane rainforests and wet eucalypt forests. Insectivore. Eggs laid in large jelloid mass on ground in late summer. The male approaches hatching tadpoles and allows them to wriggle up onto his back and into hip pouches where they remain for about 2 months before emerging as tiny frogs.	High significance; Low to medium impact. Vulnerable, especially non-aquatic egg and tadpole stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Role of ants in diet not known.	

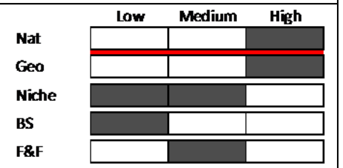
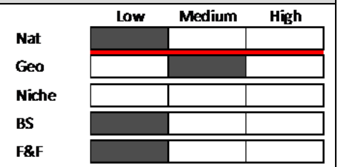
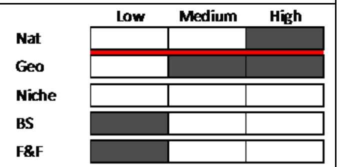
Black-soled frog (*Lechriodus fletcheri*)[1]	Not listed	se Qld, ne NSW	No. Logging of sclerophyll forest.	Rainforests and wet sclerophyll forests. Insectivore. Hides amongst leaves and other ground cover on the forest floor, and in tree hollows. Active in leaf litter, especially after rain. Breeds in ephemeral water bodies.	High significance; Medium impact. Vulnerable except in aquatic immature stages. Mating and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Role of ants in diet not known but possibly significant.	
Brown broodfrog (*Pseudophryne major*)[1]	Not listed	ce to seQld	No. Not threatened.	Damp areas in dry forests, woodlands, sclerophyll forests and heathlands. Lives in burrows, damp leaf litter, and under rocks and logs. Insectivore. Eggs laid in moist situations and hatch after heavy rain floods the nest site where tadpoles continue their development in temporary to semi permanent water.	Medium significance; Medium impact. Vulnerable except in aquatic tadpole stages. Mating and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Role of ants in diet not known but possibly significant.	
Cascade tree frog (*Litoria pearsoniana*)[1]	V	se Qld, ne NSW	Yes (2002). Habitat degraded by livestock, weed invasion, timber harvesting and upstream deforestation; chytrid fungus.	Rainforests and wet scleophyll forests. Nocturnal, active on the ground and on low shrubs bordering fast-flowing streams. Insectivore. Aquatic breeder.	High significance; Low to medium impact. Vulnerable except in aquatic stages. Mating and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Role of ants in diet not known but possibly significant.	
Cooloola sedge frog (*Litoria cooloolensis*)[1]	Not listed	se Qld	No. Hydrological and other human disturbances of wetland habitat.	Sandy coastal and island freshwater lakes and wallum creeks, where it has a preference for dense reed beds. Insectivore.	High significance; Medium impact. Vulnerable in non-aquatic stages. Mating and foraging may be disrupted.	

				Breeding aquatic.	Abundance of invertebrate prey may be reduced. Role of ants in diet not known but possibly significant.	
Eastern dwarf tree frog (*Litoria fallax*)	Not listed	ne Qld to NSW	No. Not threatened.	Coastal swamps, lagoons, and other wetlands in forests, wallum heathlands, farmlands and gardens. Lives in reeds and similar situations both near and away from water. Insectivore. Breeding aquatic.	Low significance; Low to medium impact. Vulnerable in non-aquatic stages. Mating and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Role of ants in diet not known but possibly significant.	
Fleay's barred-frog (*Mixophyes fleayi*)[1]	E	se Qld, ne NSW	Yes (2002). Habitat degradation through human activities and feral animals (e.g. pigs).	SRE. Rainforests and adjoining wet sclerophyll forests. Occurs along streams and moist leaf litter away from water bodies. Insectivore. Breeding aquatic.	High significance; Low to medium impact. Vulnerable in non-aquatic stages. Mating and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Role of ants in diet not known but possibly significant.	
Giant barred-frog (*Mixophyes iterates*)[1]	E	se Qld, e NSW	Yes (2002). Clearing and degradation of riparian vegetation.	Rainforests and wet sclerophyll forests, including remnants in gazed agricultural land. Occurs along streams and moist leaf litter away from water bodies. Insectivore. Stream breeding - eggs deposited out of the water, under overhanging banks or on steep banks of large pools.	Medium significance; Medium impact. Vulnerable in non-aquatic stages, included eggs. Mating and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Role of ants in diet not known but possibly significant.	

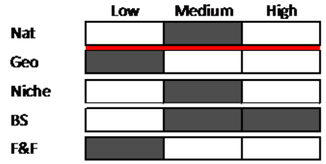
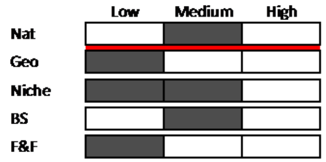
Great barred-frog (*Mixophyes fasciolatus*)[1]	Not listed	me Qld to me NSW	No. Habitat loss and fragmentation. chytrid fungus.	Rainforests, Antarctic beech forests, wet sclerophyll forests, and adjacent farmlands. Near running water. Insectivore. After laying the eggs, the female will flick them onto the bank for development. The eggs/hatchlings will then be washed into the stream or pond after the first rain, and develop as tadpoles.	Medium significance; Low to medium impact. Vulnerable in non-aquatic stages, included eggs. Mating and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Role of ants in diet not known but possibly significant.	
Green-thighed frog (*Litoria brevipalmata*)[1]	Not listed	se Qld, ne NSW	No. Habitat loss and fragmentation through roading and residential developments.	Rainforests, wet sclerophyll and open forests. Insectivore. In leaf-litter and low vegetation. Breeding aquatic, in ephemeral pools.	High significance; Medium impact. Vulnerable in non-aquatic stages, included eggs. Mating and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Role of ants in diet not known but possibly significant.	
Kroombit tinker frog (*Taudactylus pleione*)[1]	CE	se Qld	Yes (2002). Causes of decline not well understood.	SRE (Kroombit Tops). Montane rainforest. Found around rocky shelves and boulders, under rocks and in deep rock piles near temporary stream lines, seepage zones and in sheltered rocky screes. Insectivore. Probably breeds in seepage areas amongst rock piles.	High significance; Low to medium impact. Vulnerable in all life stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Role of ants in diet not known but possibly significant.	

Loveridge's mountain frog (*Philoria loveridgei*)[3]	Not listed	se Qld (possibly also ne NSW)	No. Disturbances upstream and at site, such as livestock grazing.	SRE. Montane rainforests (>500m) in areas on moist friable soils. Insectivore. Eggs deposited in a frothy jelly nest in a burrow. Larvae emerge from the eggs after several days and then move to the top of the jelly mass to complete development on the yolk from the eggs.	High significance; Low to medium impact. Vulnerable in all life stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Role of ants in diet not known but possibly significant.	
Masked mountain frog (*Philoria kundagungan*)[3]	Not listed	se Qld, ne NSW	No. Disturbances upstream and at site, such as livestock grazing.	SRE. Montane rainforests. Among saturated or moist leaf-litter and vegetation near small creeks and seepage areas. Insectivore. Large yolky eggs deposited in water-filled burrows. Larvae remain within the nest throughout development and live off the yolk.	High significance; Low to medium impact. Vulnerable in all life stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Role of ants in diet not known but possibly significant.	
Ornate burrowing frog (*Platyplectrum ornatum*)	Not listed	n WA, NT, Qld, n NSW	No.	Seasonally inundated habitats. Found in dry sandy watercourses some distance from permanent water. Ground-dwelling. Insectivore. Shelter and aestivate in burrows. Breeding aquatic.	Low significance; Low to medium impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Striped rocket frog (*Litoria nasuta*)	Not listed	n WA, NT, Qld, me NSW	No.	Coastal. Open forests and forested edges of permanent swamps. Forages among leaf litter of t forest floor and open flats exposed by receding	Low significance; Low to medium impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced;	

				waters. Insectivore. Aquatic breeder.	possibly off-set partially by increased ant abundance.	
Superb collared frog (*Cyclorana brevipes*)	Not listed.	Qld, ne NSW	No.	Open grassland and lightly forested areas. Insectivore. Burrows in soil during dry season. Breeding aquatic.	Low significance; Low to medium impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Tusked Frog (*Adelotus brevis*)	Not listed	me Qld to ne NSW	No. Loss and degradation of habitat through agricultural and urban development; chytrid fungus.	Open grasslands, large swamps, low woodlands, dry and wet sclerophyl forests and rainforests. Ground dwelling. Insectivore. Aquatic breeder.	Medium significance; Low to medium impact. Vulnerable in all non-aquatic stages. Mating and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Role of ants in diet not known but possibly significant.	
Wallum froglet (*Crinia tinnula*)[1]	Not listed	se Qld [RIFA]	Yes (2006). Habitat loss and fragmentation due to agriculture, pine plantation, urban & resort development.	Coastal wetlands and heaths. Nocturnal, terrestrial. By day sheltering down burrows or leaf litter often distant from water, including that in rainforest, eucalypt forest and eucalypt woodland. Insectivorous adults. Breeding aquatic.	High significance; Medium impact. Vulnerable in non-aquatic stages. Mating and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Role of ants in diet not known but possibly significant.	
Wallum rocket frog (*Litoria freycineti*)[1]	Not listed	se Qld, ne & me NSW	Yes (2006). Loss of habitat for agriculture, pine plantations, housing and other infrastructure.	Heaths and Wallum swamps. Aquatic breeding. Insectivore.	Medium significance; Low impact. Vulnerable in non-aquatic stages. Mating and foraging may be disrupted. Abundance of invertebrate prey may be	

					reduced. Role of ants in diet not known but possibly significant.	
Wallum sedge frog (*Litoria olongburensis*)[1]	V	se Qld, ne NSW	Yes (2006). Loss of habitat for agriculture, pine plantations, housing and other infrastructure.	Ephemeral, semi-permanent and permanent wetlands with emergent reeds, ferns and/or sedges, in undisturbed coastal wallum, and including adjacent forests, woodlands and heaths. Insectivore. Aquatic breeder.	High significance; Low impact. Vulnerable in non-aquatic stages. Mating and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Role of ants in diet not known but possibly significant.	
Freshwater Fishes						
Australian bass (*Macquaria novemaculeata*)[1]	Not listed	e Qld, e NSE, e Vic	No. Not threatened.	Primarily freshwater in coastal rivers and streams, but migratory to estuarine environments for spawning. At night display pelagic ("near-surface") behaviour, actively hunting prey in shallow water and at the water's surface; diet comprises terrestrial and aquatic insects, shrimps (freshwater), prawns (estuarine) small fish, and small mammals.	Low significance; Low impact. Abundance of invertebrate and vertebrate prey may be reduced. Feeding on rafting ants may cause mortality.	
Honey blue-eye (*Pseudomugil mellis*)[1]	V	se Qld	No. Habitat degradation through residential development and invasive fish species.	Entirely aquatic. Freshwater to lacustrine streams and lakes in coastal heath (wallum) ecosystems. Generalist, feeding on insects, small	High significance; Low impact. Abundance of terrestrial invertebrates, that constitute part of the diet, may be reduced. Feeding	

				crustaceans, and desmids and diatoms.	on rafting ants may cause mortality.	
Oxleyan pygmy perch (*Nannoperca oxleyana*)[1]	E	se Qld, ne NSW	Yes (2005). Habitat loss and degradation due to human activities; introduced fish species; harvesting for aquarium trade.	Entirely aquatic. Coastal wallum heath ecosystems. Feeds on insects and plankton containing cladocerans, ostracods, copepods, rotifers and other invertebrates.	High significance; Low impact. Abundance of terrestrial invertebrates, that constitute part of the diet, may be reduced. Feeding on rafting ants may cause mortality.	
Rainbow fish (*Rhadinocentrus ornatus*)[1]	Not listed	se Qld, ne NSW	No. Habitat loss and degradation due to land clearance, constructions of such as dam, and major housing developments.	Wallum coastal heaths, and rainforests, in freshwater and marshy rivers, streams and lakes. Forms small schools. Feeds on insects, small crustaceans, and algae.	High significance; Low impact. Abundance of terrestrial invertebrates, that constitute part of the diet, may be reduced. Feeding on rafting ants may cause mortality.	
Invertebrates						
Australian fritillary (*Argyreus hyperbius inconstans*)[1]	Not listed	se Qld, ne NSW	No. Habitat destruction due to coastal development, burning, drainage of wetlands and farming (which includes herbicide use).	Open forests, heaths and scrub adjacent to estuaries and coastal wetlands. Larvae feed on the ground herb *Viola betonicifolia*.	Medium significance; Medium to high impact. Highly vulnerable, especially in immature stages. Minimal impact on host plant. Breeding and foraging may be disrupted. Tramp ant likely to acerbate decline due to loss of habitat.	
Illidge's ant-blue (*Acrodipsas illidgei*)[1, 4]	Not listed	se Qld, ne NSW	No. Loss of mangrove habitat.	Mangroves. Myrmecophile. Eggs in stubs on Grey mangrove trees in presence of *Crematogaster* ants. Larvae are transported by the ants to their nest	High significance; Medium to high impact. Highly vulnerable, especially in immature stages, through both predation and displacement of the host ant. Minimal	

				inside mangrove stems. Ants feed on excretions from the larvae, while the larvae on the other hand feed on developing ants (or their regurgitations).	effect on host mangroves. Breeding and foraging may be disrupted.	
Pale imperial hairstreak (*Jalmenus eubulus*)[1]	Not listed (but CE proposed due to recognition of specific status)	me Qld to n NSW	No. Habitat loss.	Old-growth open-forests and woodlands in the Brigalow Belt. Monophagous, feeding exclusively on foliage of *Acacia harpophylla*. Myrmecophile. Eggs, larvae and pupae are tended by several ant species, principally *Iridomyrmex* spp.	Medium significance; Low to medium impact. Highly vulnerable, especially in immature stages, through both predation and displacement of the associated native ants. Minimal effect on host acacias but loss of tending native ants will perturb breeding and feeding. Tramp ant likely to acerbate decline due to loss of habitat.	
Richmond birdwing (*Ornithoptera richmondia*)[1]	Not listed	me Qld to ne NSW]	No.	Rainforests. Feeds, as larvae, only on two endemic Aristolochiaceae – *Pararistolochia praevenosa* in lowland habitats; *P. laheyana* in montane habitats.	Medium significance; Low to medium impact. Highly vulnerable, especially in immature stages. Breeding and foraging may be disrupted. Minimal effect on host plants.	
Satin opal (*Nesolycaena albosericea*)	Not listed	se Qld	No.	Eucalypt woodlands and banksia heathlands. Host plants *Boronia odorata*, *B. glabra* and *B. obovata* (Rutaceae). Eggs deposited on flowers, on which the early larval	High significance; Medium to high impact. Highly vulnerable, especially in immature stages. Minimal effect on host plants. Breeding and foraging may be disrupted.	

				instars feed. Later instars on foliage. Not tended by ants. Adults feed on *Boronia*, and rest on ground.	Tramp ant likely to acerbate decline due to loss of habitat.	

Ex = Extinct, CE = Critically Endanagered, E= Endangered, V= Vulnerable, M = marine. From http://www.environment.gov.au/cgi-bin/sprat/public/

Appendix 1 References

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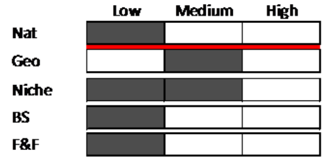
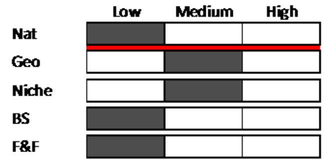
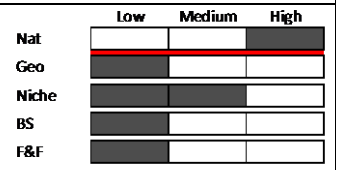
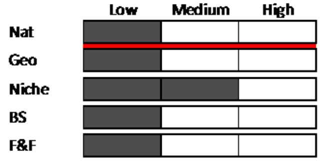
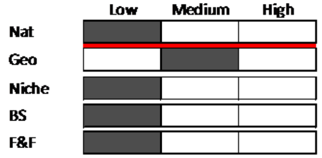
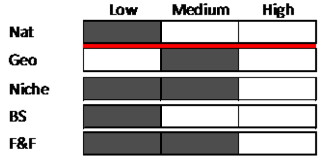
Appendix 2 Litter-dwelling land snail species resident in the SE Queensland and identified as potentially at risk from Red imported fire ant

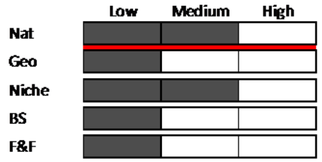
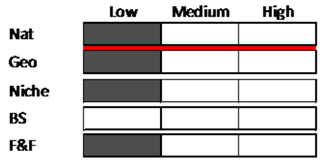
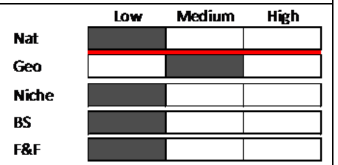
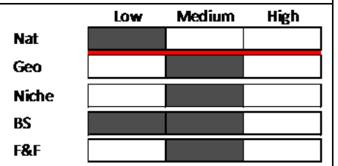
Adrian’s carnivorous snail (*Montidelos canerisi*)
Amber-flamed pinwheel snail (*Gyrocochlea greenae*)
Appleton’s pinwheel snail (*Gyrocochlea appletoni*)
Beerwah microturban (*Georissa beerwah*)
Binna Burra pinwheel snail (*Ygernaropa binnaburra*)
Black-spotted semi-slug (*Macularion aquila*)
Black-tasselled semi-slug (*Fastosarion papillosa*)
Bold-ribbed pinwheel snail (*Koreelahropa paucicostata*)
Border Ranges bristle snail (*Austrochloritis porteri*)
Border Ranges chrysalis-snail (*Signepupia pineticola*)
Border Ranges rainforest snail (*Thersites darlingtoni*)
Border Ranges staircase-snail (*Velepalaina strangei*)
Brisbane carnivorous snail (*Griffithsina brisbanica*)
Brown turban pinwheel snail (*Ngairea levicostata*)
Burleigh pinwheel snail (*Gyrocochlea burleigh*)
Byron Bay chrysalis-snail (*Hildapina subpolita*)
Byron Bay pinwheel snail (*Gyrocochlea conjuncta*)
Canungra pinwheel snail (*Gyrocochlea paucilamellata*)
Clarence River carnivorouis snail (*Montidelos urarensis*)
Clarence River keeled snail (Ventopelita leucocheilus)
Colman’s pinwheel snail (*Rhophodon colmani*)
Corrugated glass-snail (*Nitor subrugata*)
Convolute pinwheel snail (*Gyrocochlea convoluta*)
Cunninghams Gap bristle snail (*Austrochloritis cunninghamiana*)
Dark spiral pinwheel snail (*Gyrocochlea austera*)
Davie’s pinwheel snail (*Leurocochlea daviei*)
Deeply channelled pinwheel snail (*Elsothera genithecata*)
Domed pinwheel snail (*Rotacharopa densilamellata*)
Dwarf chrysalis-snail (*Signepupina strangei*)
Flatten whorl pinwheel snail (*Gyrocochlea prava*)
Gladstone droplet-snail (*Pleuropoma gladstonensis*)
Glastonbury carnivorous snail (*Echotrida substrangeoides*)
Giant carnivorous snail (*Strangesta maxima*)
Glenugie carnivorous snail (*Annabellia assimilans*)
Glenugie chrysalis-snail (*Signepupina glenugie*)
Greater Brisbane woodland snail (*Ponderconcha morosa*)
Hyaline semi-slug (*Mysticarion hyalinus*)
Kenilworth chrysalis-snail (*Hildapina Kenilworth*)
Kenilworth scaly snail (*Squamagenia yabba*)
Kenilworth waxy pinwheel snail (*Luturopa Kenilworth*)
Kessner’s pinwheel snail (*Gyrocochlea kessneri*)

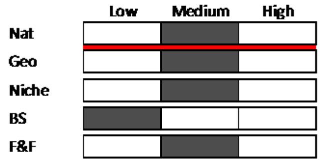
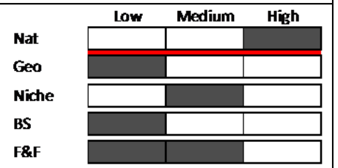
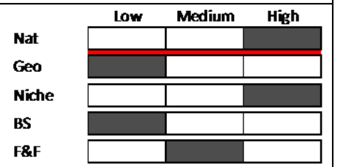
Keeled droplet-snail (*Pleuropoma talusata*)
Lamington carnivorous snail (*Pseudechotrida bordaensis*)
Lamington channelled pinwheel snail (*Gyrocochlea canalis*)
Maconell's panda-snail (*Hedleyella maconelli*)
Mahogany pinwheel snail (*Gyrocochlea vinitincta*)
Marlborough chrysalis-snail (*Signepupina tenuis*)
Maryborough dark snail (*Sphaerospira sidneyi*)
Minute pinwheel snail (*Rhophodon minutissimus*)
Mitchell's rainforest snail (*Thersites mitchellae*)
Mount Mee chrysalis-snail (*Necopupina costata*)
Mount Warning bristle snail (*Austrochloritis monita*)
Mountain Coot-tha bristle snail (*Calvigenia cootha*)
Multi-spoked pinwheel snail (*Gyrocochlea multicosta*)
Myora pinwheel snail (*Gyrocochlea myora*)
Northern rivers bristle snail (*Austrochloritis stanisici*)
Northern rivers pinwheel snail (*Gyrocochlea eurythma*)
Northern temple pinwheel snail (*Mussonula verax*)
Orange-flamed pinwheel snail (*Gyrocochlea flammulata*)
Parkin's semi-slug (*Cucullarion parkini*)
Peregrine pinwheel snail (*Rhophodon peregrinus*)
Pine Rivers bristle snail (*Squamagenia separanda*)
Pink glass-snail (*Nitor pudibunda*)
Raven's pinwheel snail (*Gyrocochlea raveni*)
Richmond Range bristle snail (*Austrochloritis toonumbar*)
Richmond Range carnivorous snail (*Montidelos exiguus*)
Richmond River keeled snail (*Thersites richmondiana*)
Richmond River pinwheel snail (*Rhophodon consobrinus*)
Robust chrysalis-snail (*Signepupina robusta*)
Ruby red glass-snail (*Sigaloeista rubra*)
Sickle-bladed pinwheel snail (*Coenocharopa macromphala*)
Simple chrysalis-snail (*Necopupina simplex*)
Southern flat-coiled snail (*Pedinogyra rotabilis*)
Southern temple pinwheel snail (*Mussonula fallax*)
Spiral-lined carnivorous snail (*Echotrida strangeoides*)
Tamborine carnivorous snail (*Strangesta ramsayi*)
Tiny carnivorous snail (*Pseudechotrida micros*)
White-mottled semi-slug (*Cucullarion albimaculosa*)
Wilcox's chrysalis-snail (*Signepupia wilcoxi*)
Yellow silk glass-snail (*Sigaloeista bordaensis*)

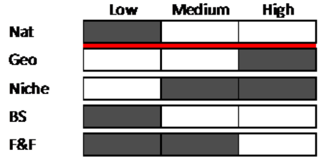
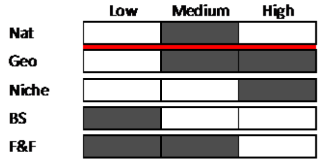
Appendix 3 Rapid assessment of native species potentially at risk from Electric ant in the Wet Tropics Bioregion

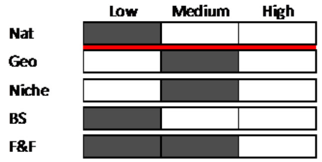
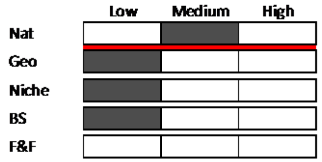
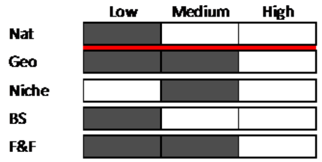
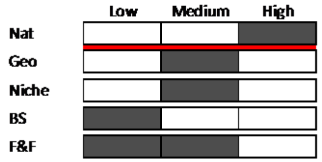
Common Name (scientific name)	EPBC Act listing status	Range	Recovery Plan	Habitat and behaviour	Potential or presumed level of impact and mechanisms for Electric ant effect	
Birds						
Atherton scrubwren (*Sericornis keri*)	Not listed	n Qld	No. Not threatened.	Montane rainforests. Insectivore, forages on ground and a few metres above. Arboreal nesting, often communal.	High significance; No impact. Minimal geographic overlap. Nesting attempts and fledgling success may be disrupted. Abundance of invertebrate prey may be reduced.	
Azure kingfisher (*Ceyx azurea*) [=*Alcedo azurea*]	Not listed	WA, NT, Qld, NSW, Vic, e SA, Tas (also New Guinea, Moluccas)	No. Degradation of wetland waters.	Near water - ponds, rivers, lakes and mangroves. Diet mostly fish and insects. Roosts arboreal. Nests in burrows in earth banks and cliffs.	Low significance; Low impact. Nesting attempts and fledgling success may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced.	
Australian brush-turkey (*Alectura lathami*)[1]	Not listed	Qld, NSW	No.	Primarily occurs in rainforests and wet schlerophyll forests, but also in drier scrublands. Terrestrial. Communal nests. Feed on insects, seeds and fallen fruits.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Australian king parrot (northern) (*Alisterus scapularis minor*)	Not listed	n Qld	No. Not threatened.	Upland rainforest, eucalypt woodlands, shrublands, but also suburban parks and gardens, and farmlands. Gregarious. Diurnal. Feeds on nectar, flowers, fruits,	High significance; Low impact. Minimal geographic overlap. Nesting attempts, fledgling success, and foraging may be disrupted. Abundance	

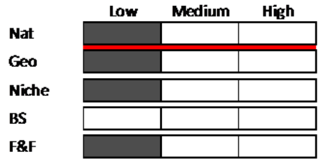
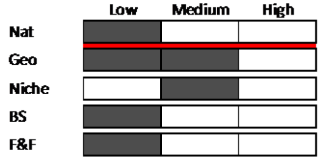
				seeds and small insects. Primarily arboreal but comes to ground to feed on fallen seeds. Nests in tree hollows.	of invertebrate prey and nectar may be reduced.	
Beach stone-curlew (*Esacus neglectus*)[1]	Not listed (Marine)	n WA, n NT, Qld, (NSW)	No. Habitat loss; human disturbance; predation by feral animals.	Wader. Occurs on open, undisturbed beaches, islands, reefs and estuarine intertidal sand and mudflats. Nests a scrape on ground.	Low significance; Low impact. Nesting and fledgling success may be disrupted. Minimal disruption of foraging and food resources.	
Black bittern (Australasian) (*Ixobrychus flavicolllis australis*)	Not listed	n WA, n NT, n Qld to s NSW	No. Habitat loss; disturbance by livestock; predation by feral ants.	Lowland terrestrial and estuarine wetlands, generally in areas of permanent water and dense vegetation. Nocturnal. Forages for reptiles, fish and invertebrates. Roosts in trees or on the ground amongst dense reeds. Nests on branch overhanging water.	Low significance; Low impact. Nesting attempts and fledgling success may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced.	
Black-chinned honeyeater (*Melithreptus gularis*)	Not listed	n WT, NT, Qld, NSW, Vic, e SA	No. Not threatened.	Upper levels of open eucalypt forests and woodlands, often along waterways. Gregarious. Forages on nectar in the canopy, and by probing bark tree trunks and branches for insects. Nests arboreal.	Low significance; Low to medium impact. Nesting attempts, fledgling success, and foraging may be disrupted. Abundance of invertebrate prey and nectar may be reduced; but off-set partially by increased ant and homopteran abundance.	

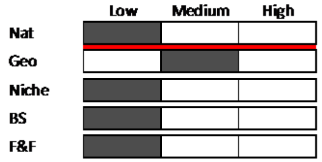
Black-faced woodswallow (Cape York Peninsula) (*Artamus cinereus normani*)	Not listed	ne Qld	No. Fire.	Woodlands. Nomadic except when breeding. Feeds on nectar and insects. Nests suspended in small trees.	Low to medium significance; Low impact. Nesting attempts, fledgling success, and foraging may be disrupted. Abundance of invertebrate prey and nectar may be reduced; but off-set partially by increased ant and homopteran abundance.	
Black-necked stork (*Ephippiorhynchus asiaticus australis*)	Not listed	WA, NT, Qld, ne NSE (also New Guinea)	No. Not threatened.	Wader in natural and artificial wetlands. Forages on range of vertebrate and invertebrate prey, mostly aquatic. Nests usually in trees.	Low significance; Low impact. Nesting attempts and fledgling success probably not disrupted. Abundance of non-aquatic invertebrate and vertebrate prey may be reduced.	
Black-throated finch (southern) (*Poephila cincta cincta*)	E	ne Qld to ne NSW	Yes (2007). Loss and disturbance of grasslands; fire; predation by feral animals.	Grassy, open woodlands and forests, grasslands and riparian areas. Feeds on seeds of grasses and herbaceous plants. Nests in tree hollows and forks.	Low significance; Low impact. Nesting attempts, fledgling success, and foraging probably minimally disrupted.	
Blue-faced parrotfinch (*Erythrura trichroa*)	Not listed	e Qld (also Orient and W Pacific)	No. Not threatened.	Montane to lowland moist forests, forest edges, grasslands and disturbed areas. Gregarious outside breeding season. Feeds on grass seeds and insects. Young are primarily fed insects. Nests arboreal.	Low significance; Low impact. Nesting attempts, fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	

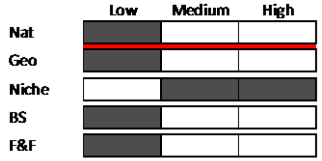
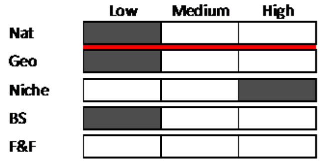
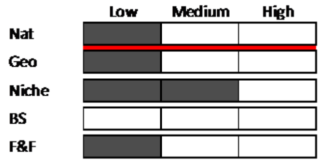
Boobook owl (*Ninox novaeseelandiae lurida*)	Not listed	ne to ce Qld	No.	Rainforests. Nocturnal. Carnivore, preys on birds, small mammals, reptiles and invertebrates. Nests in tree hollows.	Medium significance; Low impact. Nesting attempts, fledgling success, and foraging may be disrupted. Abundance of invertebrate and invertebrate prey may be reduced.	
Bower's shrike-thrush (*Colluricincla boweri*)	Not listed	ne Qld	No. Not threatened.	Rainforests, primarily above 250m. Feeds on insects, occasionally frogs, gleaned on the ground and from tree trunks, branches and foliage to mid-canopy. Nests in tree forks a few metres above the ground.	High significance; Low impact. Low level of geographic overlap. Nesting attempts, fledgling success, and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced, but possibly off-set partially by increased ant abundance.	
Brown gerygone (*Gerygone mouki mouki*)	Not listed	ne Qld	No. Not threatened.	Rainforests above 250m. Forages at all heights of the canopy for flying insects. Nests suspended in trees and shrubs.	High significance; Low impact. Low level of geographic overlap. Nesting attempts and fledgling success may be disrupted. Abundance of invertebrate prey may be reduced.	
Bridled honeyeater (*Lichenostomus frenatus*)	Not listed	ne Qld	No. Not threatened.	Upland rainforests, mostly above 600m but extending in winter to lowland forests. Feeds on nectar and insects, generally from mid strata but occasionally on ground. Nests 1-3 m in forest understorey.	High significance; Low impact. Low level of geographic overlap. Nesting attempts, fledgling success, and foraging may be disrupted. Abundance of invertebrate prey and nectar may be reduced; but off-set	

					partially by increased ant and homopteran abundance.	
Brown treecreeper (Cape York Peninsula) (*Climacteris picumnus melanotus*)	Not listed	ne Qld	No. Habitat loss. Fire.	Eucalypt woodlands. Insectivore, feeds on insects (including ants) from trunks of live and dead trees, fallen branches, and leaf litter. Nests in tree hollows.	Medium significance; Low impact. Nesting attempts, fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced, but may be off-set partially by increased ant and homopteran abundance.	
Buff-banded rail (*Gallirallus phillippensis*)	Not listed [*Gallirallus philippensis macquariensis*, Macquarie Island, Extinct]	WA, NT, Qld, NSW, ACT, Vic, SA, Tas, LH, NI (also Philippines, Indonesia, New Guinea, Cocos (Keeling) Islands, w Pacific, New Zealand)	No. Predation by feral animals.	Rainforests and woodlands, and adjoining grasslands. Omnivorous, feeds on invertebrates and small vertebrates, seeds, fallen fruit and other vegetable matter, as well as carrion. Nests on ground in dense grassy or reedy vegetation close to water.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced, but may be off-set partially by increased ant abundance.	
Buff-breasted button-quail (*Turnix olivii*)	E	ne Qld	Yes (2009). Threats poorly understood.	SRE. Grasslands, and grassy areas associated with open eucalypt woodlands, various shrublands, and rainforests. Feeds on insects and seeds. Nesting and foraging on ground.	Medium significance; Low to medium impact. Nesting attempts, fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced but may be off-set partially by increased ant abundance.	

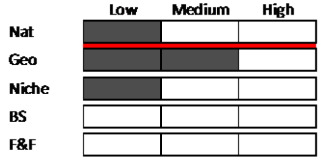
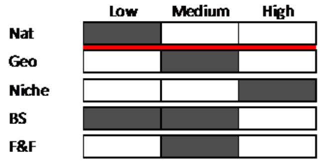
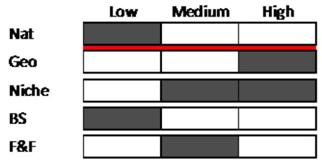
Bush stone-curlew (*Burhinus grallarius*)	Not listed	WA, NT, Qld, NSW, Vic, SA (also New Guinea)	Yes (2006). Habitat disturbance through human activity, livestock grazing, cultivation, and wildfires; predation by feral animals.	Lightly timbered, open forests, woodlands and pastures. Nocturnal. Feeds on invertebrates (including ants), frogs, reptiles and some vegetation. Nests and forages on ground.	Medium significance; Low to medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced, but off-set partially by increased ant abundance.	
Cotton pygmy-goose (*Nettapus coromandelianus*)	Not listed	Qld, NSW	No. Habitat loss and modification through hydrological changes.	Wetlands, particularly lakes. Feeds almost entirely aquatic, chiefly on seeds and vegetable matter but also insects and crustaceans. Nests in hollows of trees that stand in or beside water.	Medium significance; Low impact. Foraging and breeding marginally affected.	
Crimson finch (*Neochmia phaeton phaeton*)	Not listed	N WA, NT, Qld (also southern Indonesia & Papua New Guinea)	No. Habitat loss and degradation.	Moist riparian savannahs and shrublands, and shrub-dominated wetlands. Feed on seeds of grasses and other plants, nectar, and on insects (including ants). Nesting above ground.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced, but off-set partially by increased ant abundance.	
Double-eyed fig parrot, Macleay's fig-parrot (*Cyclopsitta diophthalma macleayana*)	Not listed	ne Qld	No. Not threatened.	Rainforests and eucalypt forests. Arboreal. Diurnal. Gregarious. Generally forages for fruits (especially figs), berries, seeds, nectar, and grubs of wood-boring insects. Nest in tree hollows.	High significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey and nectar may be reduced.	

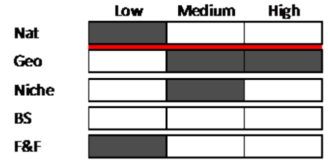
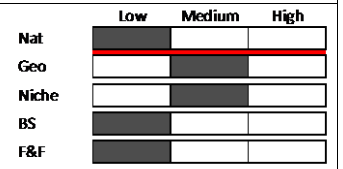
Eastern curlew (*Numenius madagascariensis*)	Not listed (Marine)	All Aus; LH, NI (breeds in Russia and north-eastern China)	No. Human disturbance; habitat degradation.	Sheltered coasts, especially estuaries, bays, harbours, inlets and coastal lagoons. Migratory. Roosts terrestrially in salt-marshes, behind mangroves, and on sandy beaches. Forages on soft intertidal sand- and mud-flats.	Low significance; Low impact. Roosting and foraging minimally affected.	
Eastern whipbird (*Psophodes olivaceus lateralis*)	Not listed	ne Qld	No. Loss of habitat to urban development.	Rainforests and wet sclerophyll forests, generally near water. Diurnal. Insectivorous, recovering insects and other invertebrates from leaf litter on the forest floor. Nesting in shrubs at <4 m height.	High significance; Medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced, but off-set partially by increased ant abundance.	
Emerald ground-dove (*Chalcophaps indica chrysochlora*)	Not listed	Qld, NSW, LH, NI	No.	Lowland rainforests and semi-urban areas. Roosts in trees. Forages on ground and low vegetation for seeds and fruit. Nests in trees.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted.	
Emu (mainland) (*Dromaius novaehollandiae novaehollandiae*)	Not listed	WA, NT, Qld, NSW, Vic, SA	No. Population fragmentation; loss of habitat; predation by feral animals; road kills and illegal hunting/poisoning.	Lowland grasslands, heathlands, shrublands, open and shrubby woodlands, forests, and swamp and sedgeland communities, and farmland. Diurnal. Nomadic. Feeds on fruits, seeds, arthropods, and small vertebrates	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced.	

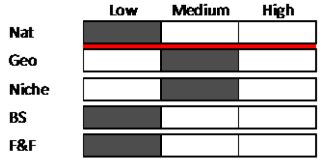
				(mammals, amphibians, reptiles). Nests on ground.		
Fern wren (*Oreoscopus gutturalis*)	Not listed	ne Qld	No. Not threatened.	Rainforests, generally >600m. Forages in moist leaf litter for insects (including ants) and other invertebrates. Nests on ground, against a tree trunk or small earth bank.	High significance; Low impact. Minimal geographic overlap. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced, but off-set partially by increased ant abundance.	
Freckled duck (*Stictonetta naevosa*)	Not listed	sw WA, Vic, NSW, vagrant elsewhere in Aust.	No. Loss and hydrological changes to habitat; illegal hunting.	Plankton-rich wetlands. Forages at wetland edges and in shallow productive waters at dusk, feeding on macrophytes, algae, seeds, small invertebrates, and small fish. Nests near water level.	Low significance; Low impact. Vagrant in Qld during dry years. Generally not nesting in Bioregion. Roosting and foraging minimally affected, but abundance of non-aquatic invertebrate prey may be reduced.	
Glossy black-cockatoo (*Calyptorhynchus lathami*)	Not listed	Qld, NSW, Vic	No.	Forests on sites of low nutrient status, reflecting the distribution of *Allocasuarina* spp. Feeds exclusively on seeds extracted from the wooden cones of casuarinas. Nests in tree hollows.	Low significance; Low impact. Nesting, roosting and foraging minimally affected.	
Golden bowerbird (*Prionodura newtoniana*)	Not listed	ne Qld	No.	SRE. Rainforests >700m. Primarily feed on fruits, but also eat flowers and insects. Nests in tree crevices ~2m above	High significance; No impact. Minimal geographic overlap. Nesting and fledgling success may be	

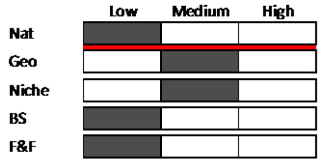
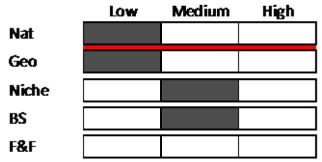
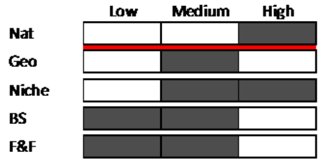
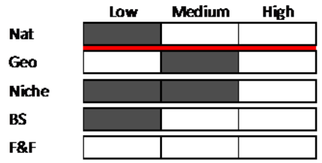
				ground. Exhibits anting behaviour[1].	disrupted. Abundance of invertebrate prey may be reduced, but off-set partially by increased ant abundance.	
Gouldian finch (*Erythrura gouldiae*)	E	n WA, n NT, n Qld	Yes (2006). Loss and degradation of habitat due to livestock grazing, fire; predation by feral animals. Potential predation by Red imported fire ant.	Open woodlands with grass ground cover. Feeds almost entirely on grass seeds, but will take arthropods and honeydew. Nests on ground.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey and honeydew may be reduced, but off-set partially by increased ant and homopteran abundance.	
Grass owl (eastern) (*Tyto capensis longimembris*)	Not listed	N WA, NT, Qld, NSW, SA (also s Asia, Orient, W Pacific)	No. Not threatened.	Tall grasslands, but also heaths, swamps, coastal dunes, treelined creeks, treeless plains, grassy gaps between trees and crops. Nocturnal. Roosts, forages and nests on ground. Feeds predominantly on small rodents.	Low significance; Low impact. Nesting, fledgling success, and foraging may be disrupted. Abundance of vertebrate prey likely minimally affected.	
Great-billed heron (*Ardea sumatrana*)	Not listed	N WA, n NT, n Qld (also se Asia/Orient)	No. Not threatened.	Largely coastal, coral reefs, mangroves, large rivers deltas, estuaries. Wader. Foraging largely aquatic, on fish, small mammals, birds, snakes, lizard, frogs, crabs, molluscs and insects. Nests generally	Low significance; Low impact. Nesting and fledgling success may be disrupted. Abundance of invertebrate and vertebrate may be reduced in non-aquatic part of foraging range.	

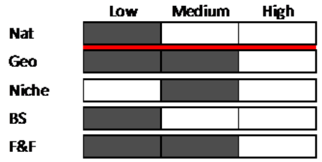
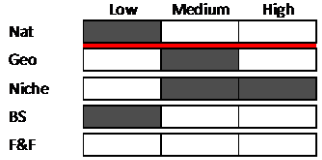
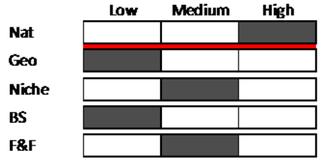
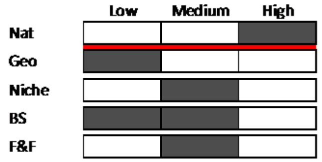
[1] anting – the use of live ants, held in the beak, to anoint the features. Most likely the ant's secretions (formic acid) help to rid the birds of parasites (Simmons 1966). Simmons, K.E.L. 1966. Anting and the problem of self stimulation. J. Zool., Lond. 149: 145-162.

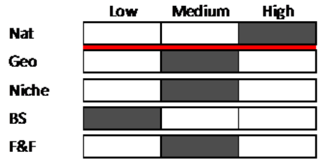
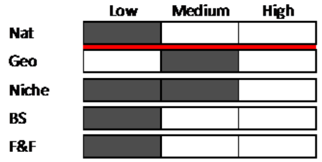
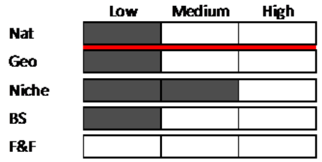
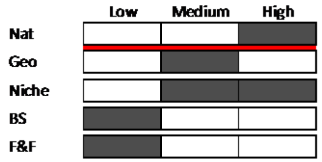
				large twig platforms built on trees.		
Great crested grebe (*Podiceps cristatus australis*)	Not listed	WA, NT, Qld, NSW, ACT, Vic, Tas, SA (also New Zealand)	No. Not threatened.	Vegetated areas of freshwater lakes. Foraging almost entirely aquatic, mainly on fish, but also small crustaceans, insects, molluscs, crustaceans and frogs. Nests on the water or at water's edge, on a platform of reeds, etc. Disperse to coasts, estuaries and large lakes etc outside breeding season.	Low significance; No impact. Nesting attempts and fledgling success may be minimally disrupted. Foraging unlikely affected.	
Grey-crowned babbler (eastern) (*Pomatostomus temporalis temporalis*)	Not listed	e Qld, NSW, Vic (formerly SA, ACT) (also New Guinea)	No. Loss and fragmentation of habitat, including removal of dead timber; degradation of habitat by grazing and invasive weeds.	Open woodlands dominated by mature eucalypts. Forages for insects and other invertebrates in leaf litter, fallen timber and on bark of trees. Live and breed in co-operative territorial groups, with roost-nests and brood-nests in tree forks.	Low significance; Low to medium impact. Roost and brood nesting attempts, fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced, but off-set partially by increased ant abundance.	
Grey fantail (*Rhipidura albiscapa alisteri*)	Not listed	Qld, NSW, ACT, Vic, SA	No.	Wide range of wooded habitats. Insectivore, feeds on insects, mostly caught in flight but sometimes gleaned off the ground and vegetation. Nests in subcanopy.	Low significance; Low to medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced, but off-set partially by increased ant abundance.	

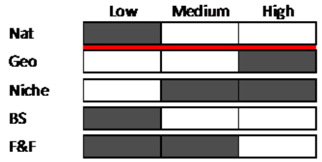
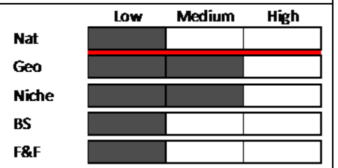
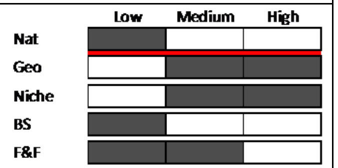
Grey fantail (*Rhipidura fuliginosa frerei*)	Not listed	ne Qld	No. Not threatened.	Most wooded habitats. Insectivore, forages primarily for flying insects, but also gleaning from tree trunks and foliage. Nests on outer branches of trees and shrubs 3-5m from ground.	High significance; Low to medium impact. Roosting, nesting attempts and fledgling success may be disrupted. Abundance of invertebrate prey may be reduced, but off-set partially by increased ant abundance.	
Grey goshawk (*Accipiter novaehollandiae*)	Not listed	WA, NT, Qld, NSW, Vic, Tas. (also the Lesser Sunda Islands, Moluccas, New Guinea, Solomon Islands.)	No. Habitat loss and fragmentation.	Tending coastal. Forests, tall woodlands, and timbered watercourses. Feeds on small vertebrates and insects. Nests arboreal.	Low significance; Low impact. Nesting, roosting and foraging minimally affected. Abundance of invertebrate and some vertebrate prey may be reduced.	
Grey-headed robin (*Heteromyias cinereifrons*)	Not listed	ne Qld [probably conspecific with New Guinea *H. albispecularis*]	No.	Lowland to primarily montane moist forests. Insectivore, foraging for insects on ground. Nests up to 10 m above ground.	High significance; Low impact. Roost and brood nesting attempts, fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced, but possibly off-set partially by increased ant abundance.	
Ground parrot (*Pezoporus wallicus wallicus*)	Not listed	Qld, NSW, Vic, formerly SA	No. Habitat loss; predation by feral animals; wildfire.	Occurs mostly in dense coastal heathlands and sedgelands. Foraging and nesting on ground. Seed feeder, mostly of sedges of families Cyperaceae and Restionaceae.	Low significance; Low impact. Nesting, fledgling success, foraging and roosting may be disrupted. Suffers from a high level of intrinsic egg failure (i.e. infertility) which, although not	

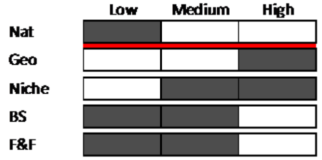
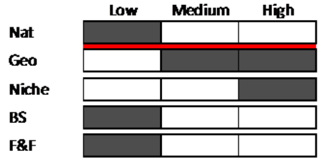
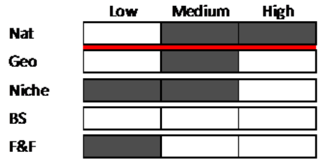
					necessarily a threat in itself, may be important in conjunction with other threatening processes such as tramp ants.	
Herald petrel (*Pterodroma heraldica*)	CE	ne Qld (also Pacific)	Yes (2005). Threats poorly understood.	Forages in marine waters, probably on cephalopods (squid). Nests on sandy ridges on islands, atolls, cays and rocky islets.	Low significance; No impact. No breeding mainland Qld, but nesting attempts and fledgling success potentially disrupted if co-occurring.	
Latham's snipe (*Gallinago hardwickii*)	Not listed (Marine)	Qld, NSW, Vic, Tas (also Japan, e Russia)	No. Loss and modification wetlands.	Non-breeding visitor to se Australia; passage migrant through northern Australia. Permanent and ephemeral wetlands up to 2000 m. Omnivorous, probes mud for seeds, other plant material, and invertebrates.	Low significance; Low impact. No breeding mainland Qld. Abundance of invertebrate prey may be reduced at wetland margins.	
Lesser sooty owl (*Tyto multipunctata*)	Not listed	ne Qld [probably conspecific with *T. tenebricosa*]	No. Not threatened.	Rainforests. Roosts in tree crevices. Feeds on mammals and birds, both on ground and arboreally. Nests in tree hollows.	High significance; Low impact. Nesting attempts, fledgling success, and roosting may be disrupted. Minimal effect on vertebrate prey.	
Lewin's rail (eastern) (*Rallus pectoralis pectoralis*)	Not listed	Qld, NSW, Vic, SA, Tas	No. Loss and modification of wetland habitat; predation by feral animals.	Vegetated wetlands. Feed on aquatic plants and invertebrates. Nests in cover of 'reed' over water.	Low significance; Low impact. Nesting attempts, fledgling success, and roosting may be minimally disrupted. Minimal effect on invertebrate prey.	

Little bittern (Australasian) (*Ixobrychus minutus dubius*)	Not listed	sw & n WA, Qld, NSW, ACT, Vic (also New Guinea)	No. Loss and modification of wetland habitat; predation by feral animals.	Freshwater wetlands, inhabiting dense emergent vegetation. To some extent migratory. Feeds on aquatic invertebrates; sometimes on small vertebrates such as fish and frogs. Nocturnal. Nests on 'reed' platform over water.	Low significance; Low impact. Nesting attempts, fledgling success, and roosting may be disrupted. Minimal effect on invertebrate prey.	
Little tern (*Sterna albifrons*)	Not listed (Marine)	Widespread globally. Coastal Qld, NSW, Vic, SA, WA, NT	Yes (2003). Habitat loss; human disturbances; predation by feral animals. Mentions ant effects on nesting success.	Migratory. Ground-nesting on sandy beaches and close to the high-tide mark. Estuarine feeder.	Low significance; Low to medium impact. Nesting attempts and fledgling success likely disrupted. Minimal affect on foraging and food sources.	
Macleay's honeyeater (*Xanthotis macleayana*)	Not listed	ne Qld	No. Not threatened.	Rainforests and adjacent treed habitats. Arboreal. Feeds primarily on arthropods gleaned from foliage, but also utilizes nectar and fruits. Nests arboreal, suspended.	High significance; Low to medium impact. Nesting attempts, fledgling success, and foraging likely disrupted. Abundance of invertebrate prey and nectar may be reduced, but possibly off-set partially by increased ant and homopteran abundance.	
Magpie goose (*Anseranas semipalmata*)	Not listed (Marine)	n WA, n NT, n & e Qld, ne NSW, sw Vic, se SA (also s New Guinea)	No.	Floodplains and wet grasslands, generally coastal. Gregarious outside of the breeding season. Feeds on aquatic vegetation. Nesting on ground.	Low significance; Low impact. Nesting attempts and fledgling success may be disrupted.	

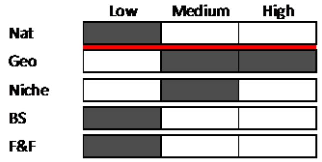
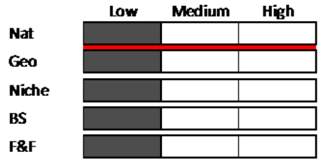
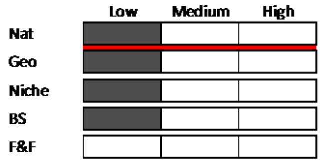
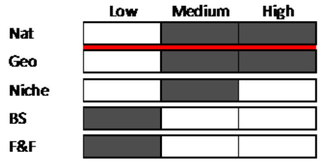
Masked lapwing (*Vanellus miles*)	Not listed	NT, Qld, NSW, Vic, SA, Tas (also Indonesia; New Zealand; Papua New Guinea; Timor-Leste, Singapore)	No. Habitat disturbance through human activity, livestock grazing, cultivation and wildfires; predation by feral animals.	Wetlands and in other moist, open habitats, including parks and pastures. Insectivore, feeds on insects (including ants) and earthworms. Nests on ground.	Low significance; Low to medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced, but possibly off-set by increased ant abundance.	
Masked owl (northern) (*Tyto novaehollandiae kimberli*)	V	N WA, NT, n Qld	Yes (2004). Threats poorly understood but declines may be related to declines in prey.	Open woodlands. Large home range. Feeds on small to medium-size mammals. Nests in tree hollows.	Low significance; Low impact. Nesting and fledgling success may be disrupted. Abundance of vertebrate prey unlikely affected.	
Mountain thornbill (*Acanthiza katherina*)	Not listed	ne Qld	No.	Rainforests, above 450m. Gregarious. Foraging amidst trees and shrubs for insects (including Homoptera). Nests arboreal.	High significance; Low impact. Minimal geographic overlap. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced, but possibly off-set partially by increased ant and homopteran abundance.	
Northern logrunner, Chowchilla (*Orthonyx spaldingii*)	Not listed	ne Qld	No.	Lowland to montane rainforests. Ground-dwelling. Feeds mainly on invertebrates, but also small vertebrates. Nests on or near ground, often on ferns, stumps or logs.	High significance; Low to medium impact. Nesting and fledgling success, and foraging likely disrupted. Abundance of invertebrate and vertebrate prey likely reduced, but possibly off-set partially by increased ant abundance.	

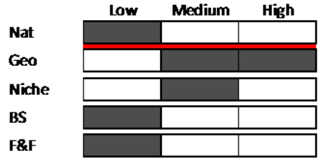
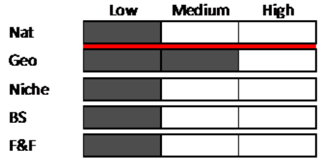
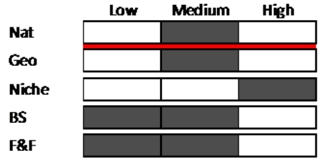
Orange-footed scrubfowl (eastern Queensland) (*Megapodius reinwardt castanotus*)	Not listed	ne Qld	No.	Closed forest, mainly tall rainforests, vine thickets and mangroves. Ground-dwelling. Feeds on berries, seeds, roots and insects. Nests large mounds on ground.	High significance; Low impact. Nesting and fledgling success, and foraging likely disrupted. Abundance of invertebrate prey likely reduced, but possibly off-set partially by increased ant abundance.	
Painted honeyeater (*Grantiella picta*)	Not listed	NT, Qld, NSW, Vic, SA	No. Loss and fragmentation of habitat; removal of large, old trees with heavy mistletoe infestations; heavy grazing of grassy woodlands.	Forests and woodlands. Nomadic, at low densities throughout range. Arboreal, foraging exclusively on mistletoes, mainly in upper canopy. Nests 3-20m from the ground.	Low significance; Low impact. Nesting and fledgling success, and foraging likely disrupted.	
Painted snipe (*Rostratula benghalensis australis*)	Not listed	Qld, NSW, Vic, SA, WA, NT, Tas, LH	No. Habitat loss and modification through hydrological changes; predation by feral animals; disturbance by grazing livestock.	Inhabits inland and coastal shallow freshwater wetlands. Forages nocturnally on mud flats and in shallow water for seeds and invertebrates. Nest a scrape in the ground.	Low significance; Low impact. Nesting attempts and fledgling success may be affected. Foraging minimally disrupted.	
Pale-yellow robin (*Tregellasia capito nana*)	Not listed	ne Qld	No. Not threatened.	Lowland rainforests. Arboreal. Predominantly insectivorous, but supplements diet with seeds. Nest to 10 m above ground.	High significance; Low impact. Nesting and fledgling success, and foraging likely disrupted. Abundance of invertebrate prey likely reduced, but possibly off-set partially by increased ant and homopteran abundance.	

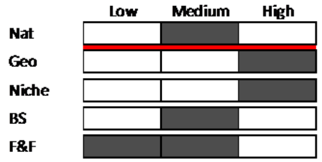
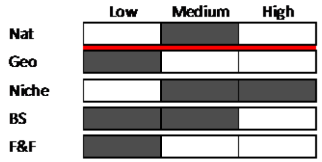
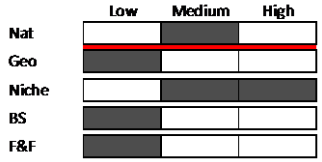
Pied currawong (*Strepera graculina*)	Not listed	Qld, NSW, Vic, ACT, LH	No. Not threatened.	Forests and shrublands; well adapted to suburban areas. Gregarious outside breeding season. Forages in both living and fallen trees for small lizards, birds, small mammals, insects, and berries. Nests in tree fork, up to 20 m above the ground. Exhibits anting.	Low significance; Low impact. Nesting attempts, fledgling success, and foraging may be disrupted. Abundance of invertebrate and some vertebrate prey may be reduced, but possibly off-set partially by increased ant abundance.	
Pied monarch (*Arses kaupi*)	Not listed	ne Qld	No. Not threatened.	Rainforest edge habitats and secondary growth, primarily coastal. Feeds at the mid level, and rarely close to the ground, typically probing trunks and larger branches for insects, but also catch prey in flight. Nests suspended in trees and vines.	High significance; Low impact. Nesting attempts and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced, but possibly off-set partially by increased ant and homopteran abundance.	
Radjah shelduck (Australian) (*Tadorna radjah rufitergum*)	Not listed	n WA, n NT, Qld, n NSW	No. Not threatened.	Mangrove forests, estuaries, littoral zone; visiting freshwater wetlands in wet season. Diet largely aquatic molluscs, insects, plant material and algae. Nests in tree hollows.	Low significance; Low impact. Nesting attempts and fledgling success may be affected. Abundance of invertebrate prey may be reduced in terrestrial part of foraging range.	
Rainbow bee-eater (*Merops ornatus*)	Not listed (Marine)	All Aus (also New Guinea, Solomon Islands, Indonesia, SE Asia, Japan)	No. Not considered threatened.	Migratory over part of Australian range. Open forests and woodlands, shrublands, and in various cleared or semi-cleared areas. Insectivore, feeds on insects (primarily on	Low significance; Low to medium impact. Nesting and fledgling success may be disrupted. Abundance of invertebrate prey may be reduced, but possibly off-set partially by	

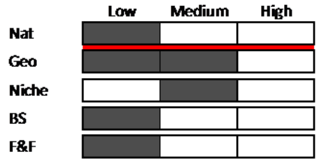
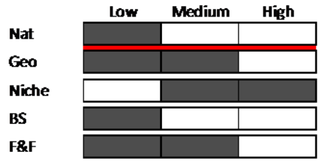
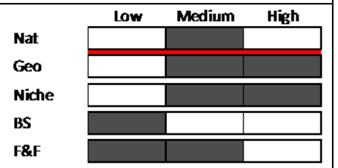
				bees and wasps, but including ants, beetles, etc.) in flight and on ground. Nests in burrows in banks.	increased ant abundance. May compete directly for nest sites in banks.	
Red-backed button-quail (Australian) (*Turnix maculosa melanota*)	Not listed	n WA, NT, n & e Qld, n NSW	No. Habitat loss and modification by grazing and fire.	Coastal and subcoastal, in grasslands and grassy woodlands, rainforest margins, and crops and gardens. Forages and nests on ground. Feeds on seeds, green shoots and insects.	Low significance; Low to medium impact. Nesting attempts, fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced, but possibly off-set partially by increased ant abundance.	
Red goshawk (*Erythrotriorchis radiatus*)	V	NSW, Qld, NT, WA	Yes (2012). Habitat loss.	Coastal and sub-coastal woodlands and forests. Predatory on other birds and to lesser extent other vertebrates. Arboreal nesting.	Low significance; Low impact. Nesting and fledgling success may be disrupted. Minimal affect on prey abundance.	
Red-tailed tropicbird (*Phaethon rubricauda*)	Not listed (Marine)	WA, NT, Qld, CI, NI, LH (also Indian & Pacific Oceans)	Yes (2010) LH.	Pelagic, foraging on squid, fish and crustaceans. Non-migratory. Nests a scrape on ground in inaccessible cliffs.	Low significance; No impact. Not nesting mainland Australia.	
Rufous owl (southern subspecies) (*Ninox rufa queenslandica*)	Not listed	ne Qld	No. Not threatened	Closed and open forests. Nocturnal. Generally solitary. Roosts and nests in forest canopy. Predator, preying on birds, and small mammals and insects.	Medium to high significance; Low impact. Nesting and fledgling success unlikely disrupted. Abundance of some invertebrate and vertebrate prey may be reduced.	

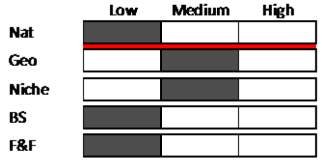
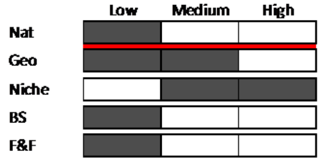
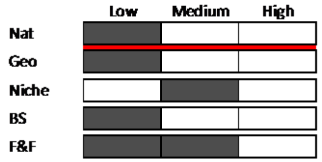
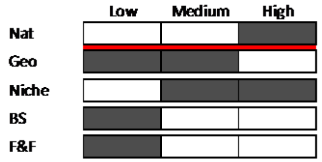
Sacred kingfisher (*Todiramphus sanctus*)	Not listed (Marine)	WA, NT, Qld, NSW, ACT, Vic, SA, Tas, LH, NI (also New Zealand, New Guinea, Indonesia, n and w Melanesia; vagrant CI, nw Pacific)	No. Not threatened.	Mangroves, woodlands, forests, and disturbed open area. Migratory over part of range. Forages mainly on land, only occasionally capturing prey in water. Feeds on invertebrates, fish and small vertebrates. Nest in burrows in earth banks, tree hollows, etc.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of some invertebrate and vertebrate prey may be reduced.	
Sarus crane (Australian) (*Grus antigone gillae*)	Not listed	n WA, e NT, n & e Qld	No. Not threatened.	Dry savannah woodlands with ephemeral pools during breeding season; gregarious and frequenting open and man-made wetlands in non-breeding season. Forage in seasonally wet woodlands and grasslands for invertebrates and small vertebrates. Nests in grassy platforms.	Medium significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of some invertebrate and vertebrate prey may be reduced.	
Satin bowerbird (*Ptilonorhynchus violaceus minor*)	Not listed	e Qld, NSW, Vic	No. Not threatened.	Rainforests and tall wet sclerophyll forests. Predominantly frugivorous as adults, but also eat leaves, seeds and insects; young fed insects. Nests on ground. Exhibits anting.	Medium significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of some invertebrate prey may be reduced, but possibly off-set partially by increased ant abundance.	

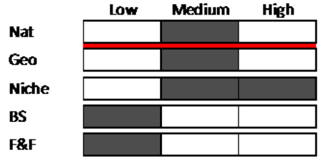
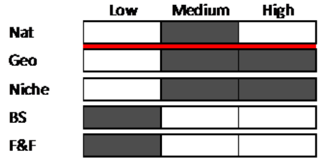
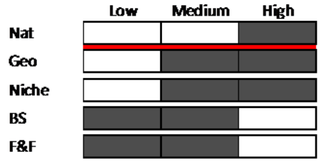
Silver-eye (*Zosterops lateralis*)	Not listed (Marine)	WA, Qld, NSW, ACT, Vic, SA, Tas, LH, NI (also New Caledonia, Vanuatu, Fiji, New Zealand)	No. Not threatened.	Rainforests and shrublands, and wooded urban areas. Insectivore, nectarivore, and frugivore foraging in the forest understory and canopy, and rarely on the forest floor. Nests in canopy and subcanopy.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of some invertebrate prey may be reduced, but partially offset by increased homopteran abundance.	
Sooty owl (*Tyto tenebricosa*)	Not listed	Qld, e NSW, NE Vic (also New Guinea)	No. Habitat loss and logging.	Rainforests and moist eucalypt forests. Nocturnal. Carnivore, preying on small vertebrates. Roosts and nests in large tree hollows, caves and in dense foliage.	Low significance; Low impact. Nesting and fledgling success may be disrupted. Abundance of some prey may be reduced indirectly through affects on invertebrates.	
Sooty Oystercatcher (northern) (*Haematopus fuliginosus opthalmicus*)	Not listed	Qld, NSW, Vic, Tas	No.	Coastal. Rocky coastlines, but occasionally estuaries. Forages in the intertidal zone. Nests in rock crevices and small hollows on the ground.	Low significance; Low impact. Nesting attempts and fledgling success may be disrupted.	
Southern cassowary (*Casuarius casuarius*)[3, 4]	E	ne Qld	Yes (2007). Habitat loss, fragmentation and degradation; predation by feral animals; illegal hunting; road-kill.	Rainforests, and associated habitat such as mangrove Melaleuca, eucalypt woodlands and swamp forests, that provide a year-round supply of fleshy fruit, the main diet. Also feeds on bracket fungi, foliage and flowers, insects, snails, fish, bird's eggs, frogs, and small mammals. Requires	Medium to high significance; Low impact. Nesting and fledgling success may be disrupted. Abundance of some invertebrate prey may be reduced.	

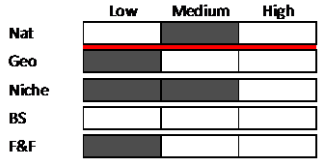
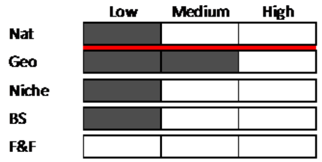
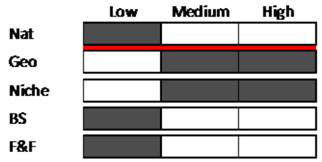
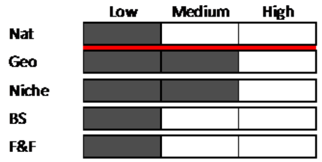
				permanent freshwater for drinking and bathing. Nests on the ground, usually near base of a large tree or stump.		
Spotted catbird, Black-eared catbird (*Ailuroedus melanotis maculosus*)	Not listed	ne Qld	No. Not threatened.	Rainforests. Feeds on fruit, seeds, flowers, insects, and eggs and young of other birds.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of some invertebrate prey may be reduced.	
Square-tailed kite (*Lophoictinia isura*)	Not listed	e Qld, NSW, Vic, SA, WA, NT	No. Habitat loss; illegal hunting.	Open country, including open woodlands and heaths. Specialist hunter of passerines. Arboreal nesting.	Low significance; Low impact. Nesting and fledgling success unlikely affected. Abundance of prey may be indirectly reduced through effects on invertebrates.	
Squatter pigeon (*Geophaps scripta scripta*)	V	Qld, NSW	No. Habitat loss; disturbance by grazing livestock; predation by feral animals.	Mainly grassy woodlands and open forests that are dominated by eucalypts, especially near open water bodies. Feeds mainly on seeds, but also insects. Nest a scrape in the ground.	Medium significance; Low to medium impact. Nesting attempts and fledgling success, and foraging may be disrupted. Abundance of insect prey may be reduced. Importance of ants in diet not known, but degree to which species may benefit from increased ant abundance likely to be minimal.	

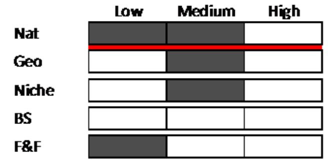
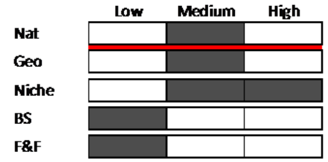
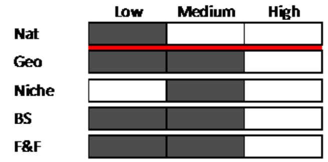
Star finch (eastern) (*Neochmia ruficauda ruficauda*)	E	e Qld ne NSW	No. Loss and degradation of habitat due to agriculture. Red imported fire ant considered a threat.	Mainly in grasslands and grassy woodlands located close to bodies of freshwater; also suburban areas. Nests arboreal (to about 9m). Feeds on seeds of grasses and other annual plants, and on insects.	Medium significance; Low to medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of insect prey may be reduced, and may compete for seeds. Importance of ants in diet not known, but degree to which species may benefit from increased ant abundance likely to be minimal.	
Tooth-billed catbird, Tooth-billed bowerbird (*Scenopoeetes dentirostris*)	Not listed	ne Qld	No. Not threatened.	Rainforests, mainly between 600 and 1400m. Diet mainly of fruits and young leaves, but also insects. Nests in tree hollows.	Medium significance; Low impact. Modest geographic overlap. Nesting and fledgling success, and foraging may be disrupted.	
Victoria's riflebird (*Ptiloris victoriae*)	Not listed	ne Qld	No. Habitat loss; Illegal shooting.	Rainforests (including Antarctic beech rainforest), mostly in mountains and foothills, and adjoining wetter eucalypt forests. Forages for insects by probing timber and bark; also feeds on fruits from trees. Nests arboreal.	Medium significance; Low impact. Low level of geographic overlap. Nesting and fledgling success, and foraging may be disrupted. Abundance of insect prey may be reduced. Importance of ants in diet not known, but degree to which species may benefit from increased ant abundance likely to be minimal.	

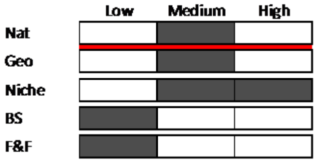
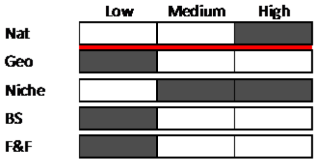
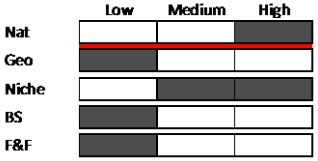
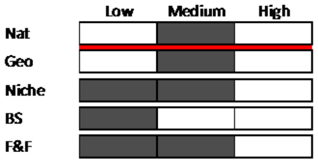
White-faced heron (*Ardea novaehollandiae*)	Not listed	WA, NT, Qld, NSW, ACT, Vic, SA, Tas, CI, LH, NI (also New Guinea, Indonesia, New Caledonia, New Zealand; vagrant se Asia, Cocos Islands, Solomon Islands)	No. Not threatened.	Mainly diurnal. Forages in wet grasslands, wetlands, estuaries and lagoons. Locally nomadic, and dispersive in non-breeding season. Diet highly varied – invertebrates and small vertebrates. Nests in trees.	Low significance; Low impact. Nesting and fledgling success may be disrupted. Abundance of some invertebrate and vertebrate prey may be reduced.	
white-rumped swiftlet (*Aerodramus spodiopygius*) [formerly *Collocalia spodiopygius*]	Not listed	ne Qld (also New Guinea and sw Pacific)	No. Not threatened.	Closed and open forests. Coastal. Dark caves used for roosting and nesting sites throughout the year. Diurnal. Gregarious. Insectivore, feeds aerially from near ground level to above canopy. Nest tiny bracket of plant material, cemented to the cave wall or roof by the bird's saliva.	Low significance; Low impact. Nesting and fledgling success may be disrupted. Abundance of insect prey may be reduced.	
Yellow-breasted boatbill (*Machaerirhynchus flaviventer secundus*)	Not listed	ne Qld	No. Not threatened.	Rainforests, and broadleaf thickets and shrublands. Active in subcanopy and canopy. Insectivore, catching insects in flight and gleaned from foliage. Nests arboreal, ~20 m from ground.	Medium significance; Low impact. Nesting, fledgling success, and foraging minimally disrupted. Abundance of insect prey may be reduced.	
Mammals						

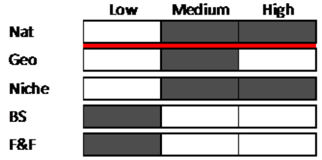
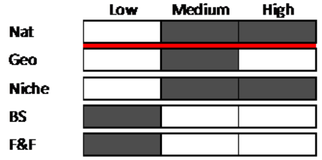
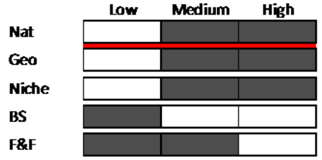
Agile Wallaby (*Macropus agilis*)	Not listed	n WA, NT, n Qld (also New Guinea)	No. Not threatened.	Coastal. Along river banks and open forests. Gregarious. Grazes native grasses, and digs for succulent roots.	Low significance; Low impact. Breeding and foraging minimally disrupted.	
Atherton antechinus (*Antechinus godmani*)	Not listed	ne Qld	No.	SRE (Atherton Tableland). Rainforests above 600m. Mostly nocturnal or crepuscular. Carnivorous, feeds mostly on invertebrates. Nests or dens in tree hollows and amongst litter of epiphytes.	High significance; Low impact. Minimal geographic overlap. Breeding and foraging minimally disrupted.	
Bare-backed fruit bat (*Dobsonia moluccensis*)	Not listed	ne Qld (also New Guinea, Indonesia)	No. Not threatened.	Lowland to upland rainforests, wet open forests, rural gardens, and fruit and coconut plantations. Gregarious roosts, in caves, sinkholes, boulder piles, old mines, disused buildings, and dense vegetation. Solitary forager, feeding on fruits.	Low significance; Low impact. Breeding and foraging minimally disrupted.	
Bare-rumped sheathtail bat (*Saccolaimus saccolaimus nudicluniatus*)	CE	n NT, ne Qld (also New Guinea, sw Pacific, Indo-Malay)	Yes (2007).	Woodlands. Gregarious, in tree hollow roosts; may also utilize caves, overhangs and man-made structures. Insectivore, taking insects in flight.	Low significance; Low impact. Breeding may be disrupted. Foraging minimally disrupted but abundance of invertebrate prey may be reduced.	
Bennett's tree-kangaroo (*Dendrolagus bennettianus*)	Not listed	ne Qld	No.	SRE. Lowland to upland rainforests and occasionally eucalypt woodlands. Primarily arboreal, but disperses on	Low significance; Low impact. Breeding and foraging minimally disrupted.	

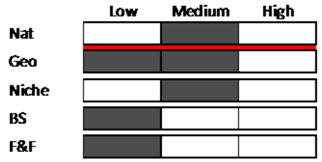
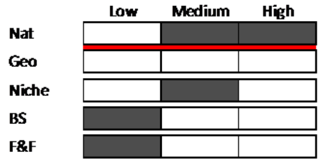
				ground. Herbivore, feeding on foliage and fruit.		
Black-footed tree-rat (*Mesembriomys gouldii*)	Not listed	n WA, NT, n Qld	No. Loss, fragmentation and degradation of habitat; predation by feral animals.	Lowland to lower montane, in eucalypt forests and woodlands, rainforests, and open coastal forests. Nocturnal, often terrestrial, but forages and nests in trees. Folivore and frugivore, diet supplemented by invertebrates such as termites and molluscs.	Medium significance; Low impact. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Coastal sheathtail bat (*Taphozous australis*)	Not listed	n Qld (also New Guinea)	No.	Coastal dune scrublands and paperbark swamps. Roosts, often gregarious, in sea caves, rocky areas, crevices, boulder piles, and old buildings. Insectivore, forages above the canopy.	Medium significance; Low impact. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Common dunnart (N Qld) (*Sminthopsis murina tatei*)	Not listed	ne Qld	No.	Rainforest edges and swamps. Nocturnal, active on ground and lower vegetation. Roost nests in log hollows, grass clumps, and grass trees. Insectivore.	High significance; Low to medium impact. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Daintree River ringtail possum (*Pseudochirulus cinereus*)	Not listed	ne Qld	No.	Cool wet upland rainforests above 450m. Nocturnal. Arboreal herbivore.	High significance; Low impact. Minimal geographic overlap. Foraging may be disrupted.	

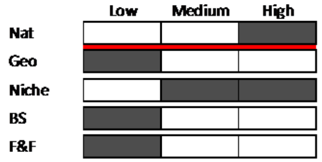
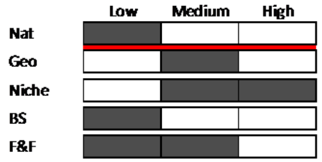
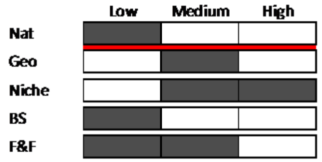
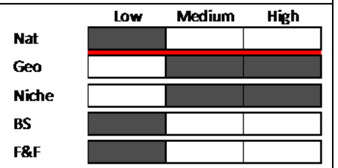
Diadem leaf-nosed bat (*Hipposideros diadema reginae*)	Not listed	n Qld	No.	Rainforests. Aerial hunter, launching from perch to capture in flight large insects and, to lesser extent, birds. Roosts in caves, somewhat communal. Female carries young.	Medium significance; Low impact. Abundance of insect prey may be reduced.	
Duck-billed platypus (*Ornithorhynchus anatinus*)	Not listed	e Qld, e NSW, Vic, Tas (formerly SA) (introduced to Kangaroo Island, SA)	No. Threats primarily related to freshwater habitat loss and degradation.	Dependent on rivers, streams, and bodies of freshwater. Feeds exclusively on benthic macroinvertebrates. Nesting chamber in bank leads from the water’s edge. Young defenceless.	Low significance; Low impact. Nesting attempts may be disrupted. Eggs and young vulnerable in nest chamber if accessed by ants.	
Eastern tube-nosed bat (*Nyctimene robinsoni*)	Not listed	n Qld, n NSW (also New Guinea)	No. Habitat loss; predation by feral animals.	Rainforests and moist eucalypt forests, but foraging in other habitats, including orchards. Roosts in canopy. Solitary. Feeds on nectar, blossoms and fruits.	Low significance; Low impact. Roosting and foraging may be minimally disrupted.	
False water-rat, Water mouse (*Xeromys myoides*)	V	n WA, n NT, Qld, ne NSW (also New Guinea)	Yes (2010). Habitat loss and degradation; predation by feral animals.	Coastal. Mangroves and the associated salt-marshes, sedgelands, heathlands and freshwater wetlands. Nesting in mounds and mud ramps. Carnivorous, feeding on estuarine/wetland invertebrates such as crabs, worms and molluscs.	Low significance; Low impact. Nesting and foraging may be minimally disrupted.	

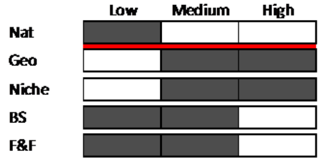
Ghost bat (*Macroderma gigas*)	Not listed	n WA, NT, n Qld	No. Loss of habitat, especially roost sites; predation by feral animals.	Rainforests, monsoonal and vine scrublands, mangroves, and savannah woodlands. Carnivore, commonly feeds on mice, other bats, small birds, legless lizards, geckos, snakes, and invertebrates. Hunting nocturnal, by sit and wait technique. Roosts in caves, mines, etc. Females aggregate in breeding season.	Low to medium significance; Low impact. Roosting and breeding minimally disrupted. Foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced.	
Giant white-tailed rat (*Uromys caudimaculatus*)	Not listed	n Qld (also Indonesia and New Guinea)	No.	Rainforests, closed sclerophyll forests, wet open woodlands, swamps, and mangroves. Nocturnal. Omnivore, forages for fruit, seeds, truffles, bark, insects, small reptiles, amphibians, crustaceans, birds' eggs and nestlings in canopy and on ground. Daytime shelters and maternal nests in tree hollows, burrows under logs and in stream banks.	Medium significance; Low impact. Breeding, roosting and foraging success may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced.	
Golden-tipped bat (*Kerivoula papuensis*)	Not listed	Qld, n NSW (also New Guinea)	No. Habitat loss and fragmentation; predation by feral animals.	Rainforests, and rainforest ecotone areas. Feeds on a range of both gleaned and aerially acquired invertebrates, especially spiders. Roosts mainly in disused suspended nests of Yellow-throated	Low significance; Low impact. Roosting, breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Importance of ants in diet not known, but degree to	

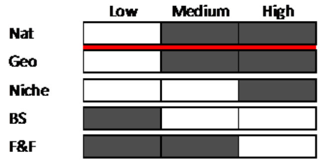
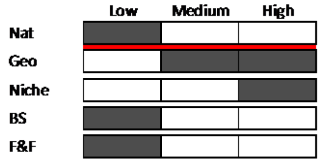
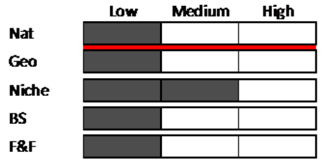
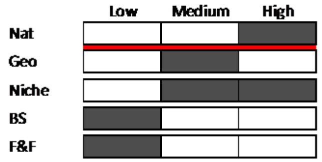
				scrubwren and Brown gerygone, but also tree hollows, caves and buildings.	which species may benefit from increased ant abundance likely to be minimal.	
Greater large-eared horseshoe bat (large form) (*Rhinolophus philippinensis*)	E	ne Qld (possibly also New Guinea)	Yes (2001). Loss and disturbance of habitat, especially roost sites; predation by feral animals.	Lowland rainforests, open eucalypt forests, Melaleuca forests, and open savannah woodlands. Nocturnal. Roosts in caves, mines and possibly tree hollows and other cavities. Insectivore, prey taken by aerial hawking and to a lesser extent gleaning, often very close to or on the ground.	Medium significance; Low impact. Roosting, breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Importance of ants in diet not known, but degree to which species may benefit from increased ant abundance likely to be minimal.	
Green ringtail possum (*Pseudochirops archeri*)	Not listed	ne Qld	No.	SRE. Cool rainforests above 300m. Nocturnal, solitary and arboreal. Roosts by day on an open branch. Herbivorous, feeds mostly on leaves.	High significance; Low impact. Minimal geographic overlap. Foraging may be disrupted.	
Herbert River ringtail possum (*Pseudochirulus herbertensis*)	Not listed	ne Qld	No.	SRE. Cool, wet upland rainforests and wet sclerophyll margins above 300 m. Nocturnal. Roosts in canopy fern clumps and tree hollows. Herbivorous, feeds mostly on leaves.	High significance; Low impact. Minimal geographic overlap. Foraging may be disrupted.	
Koala (*Phascolarctos cinereus*)	Not listed (V - Qld, NSW, ACT)	Qld, NSW, ACT, Vic, SA	Yes (2008). Habitat loss; urbanisation, including dog attacks and road-kill; disease.	Rainforests and eucalypt forests and woodlands. Arboreal herbivore, feeds almost entirely on eucalypt leaves. Roosts in	Medium significance; Low impact. Breeding and foraging may be disrupted.	

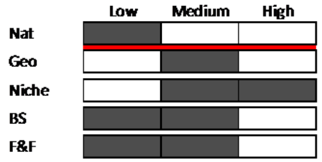
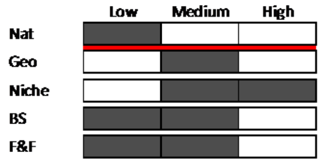
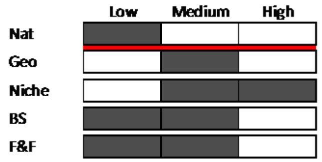
				trees, disperses on ground.		
Lemuroid ringtail possum (*Hemibelideus lemuroids*)	Not listed	ne Qld	No.	SRE. Rainforests above 450m. Arboreal. Social. Herbivorous, feeding of foliage and flowers. Roosts in tree hollows.	High significance; Low impact. Minimal geographic overlap. Breeding and foraging may be disrupted.	
Long-tailed pygmy-possum (*Cercartetus caudatus macrurus*)	Not listed	ne Qld	No.	Rainforests and fringing Casuarina forests from coastal plains to 1600m. Arboreal. Feeds on nectar, pollen and insects.	Medium to high significance; Low impact. Breeding and foraging may be disrupted. Abundance of invertebrate prey and nectar may be reduced.	
Lumholtz's tree-kangaroo (*Dendrolagus lumholtzi*)	Not listed	ne Qld	No.	Rainforests and eucalypt forests, lowland to montane at ~1600m. Social. Arboreal. Herbivorous, feeds of foliage and fruits.	Medium to high significance; Low impact. Breeding and foraging may be disrupted. Abundance of invertebrate prey and nectar may be reduced.	
Mahogany glider (*Petaurus gracilis*)	E	ne Qld	Yes (2008). Habitat loss, fragmentation and degradation; predation by feral animals.	Dry coastal lowland eucalypt and paperbark woodlands. Arboreal. Roosts and maternal dens in tree hollows. Omnivorous to feeds primarily on nectar and pollen from a wide variety of trees and understorey plants, supplemented by arthropods, fruit, plant exudates, Acacia arils and honeydew.	Medium significance; Low to medium impact. Roosting, breeding and foraging may be disrupted. Abundance of invertebrate prey and nectar may be reduced. Importance of ants in diet not known, but degree to which species may benefit from increased ant abundance likely to be minimal.	

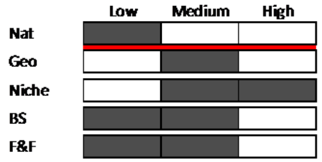
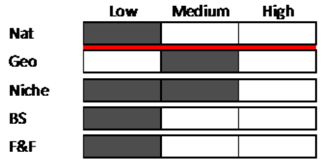
Mareeba rock-wallaby (*Petrogale mareeba*)	Not listed	ne Qld	No.	Lowland to montane open habitat, associated with areas of rocky hills, cliffs, and gorges. Gregarious. Herbivorous.	Medium significance; Low to impact. Breeding and foraging minimally disrupted.	
Masked white-tailed rat, Thornton Peak uromys (*Uromys hadrourus*)	Not listed	ne Qld	No.	SRE. Montane rainforests above 550m. Habitat specialist, requiring permanent creek systems with dense undergrowth and large logs. Ground dwelling, territorial. Feeds predominantly on plant material but also insects.	Medium to high significance; No impact. Geographic overlap minimal. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Importance of ants in diet not known, but benefit from increased ant abundance likely to be minimal.	
Mount Claro rock-wallaby, Sharman's rockwallaby (*Petrogale sharmani*)	Not listed	ne Qld	No. Predation by feral animals.	SRE. Rocky slopes, outcrops, boulder piles, cliffs and gorges, usually associated with woodlands with a grassy understorey or vine-thicket rainforests. Social. Nocturnal. Herbivore, feeds on grass shoots, fruits, seeds and flowers.	High significance; Low impact. Breeding and foraging may be disrupted.	
Musky rat-kangaroo (*Hypsiprymnodon moschatus*)	Not listed	ne Qld	No. Not threatened.	Rainforests, lowland to montane at ~1100m. Diurnal. Solitary. Arboreal and on ground. Roosts in nest against tree buttress. Omnivore, feeds on fallen fruit and large seeds, tubers, as well as small invertebrates.	High significance; Low to medium impact. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Importance of ants in diet not known, but benefit from increased ant abundance likely to be	

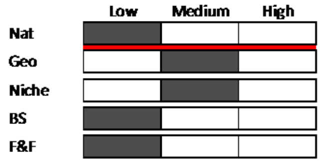
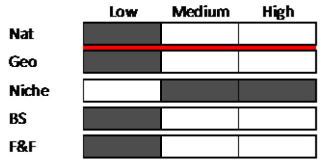
					minimal.	
Northern bettong (*Bettongia tropica*)	E	ne Qld	Yes (2001). Habitat loss and degradation; competition for truffles from feral animals (i.e. pigs); predation by feral animals.	SRE. Eucalypt forests, with grassy understorey, above 400m. Terrestrial. Solitary, nocturnal. Nests in dense undergrowth and among rocks. Feeds mostly on underground fungi (truffles), but also on tubers, fruits, seeds and invertebrates.	High significance; Low impact. Minimal geographic overlap. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Northern brown bandicoot (*Isoodon macrourus*)	Not listed	n Qld (also New Guinea)	No. Habitat loss and degradation; Predation by feral animals.	Open forests (dry season) and grasslands (wet season). Nocturnal. Territorial. Roosts in nests among litter. Omnivore, feeds on fruit, berries, grass seeds, and invertebrates.	Low significance; Low to medium impact. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Northern quoll (*Dasyurus hallucatus*)	E	WA, NT, Qld	Yes (2010). Lethal toxic ingestion caused by Cane toad; loss and degradation of habitat; inappropriate fire regimes; predation by feral animals.	Range of habitats including eucalypt forests and woodlands, rainforests, sandy lowlands and beaches, shrublands, grasslands and deserts; especially on rocky ground. Omnivores, feeds on invertebrates, fruits, nectar, bird's eggs, and carrion.	Low significance; Low to medium impact. Breeding and foraging may be disrupted. Abundance of invertebrate prey and nectar may be reduced.	
Red-legged pademelon (*Thylogale stigmatica*)	Not listed	e Qld, n NSW (also New Guinea)	No.	Rainforests, wet sclerophyll forests, vine thickets and areas around swamps. Nocturnal. Solitary, except when feeding. Herbivorous,	Low significance; Low impact. Breeding and foraging may be disrupted.	

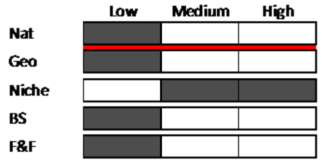
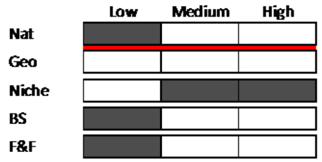
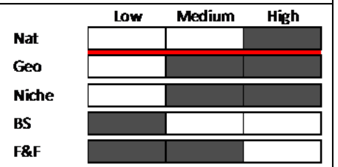
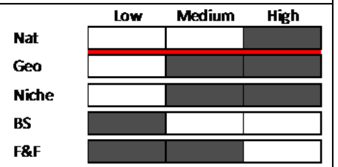
				feeds on foliage and fallen fruits and seeds.		
Semon's leaf-nosed bat (*Hipposideros semoni*)	E	e Qld (primary in N) (also New Guinea)	Yes (2001). Loss of roost sites through quarrying; disturbance by tourist visits to caves; loss of habitat through forest clearance.	Rainforests, monsoonal forests, wet sclerophyll forests and open savannah woodlands. Feed primarily on moths, but also take other invertebrates. Generally forages within 1m of ground, hawking prey in the undergrowth and gleaning prey from surfaces such as tree trunks, rock surfaces and the ground. Roosts in caves.	Low significance; Low impact. Breeding minimally impacted. Foraging may be disrupted. Abundance of prey may be reduced. Importance of ants in diet not known, but species may benefit from increased ant abundance.	
Short-beaked echidna (*Tachyglossus aculeatus*)	Not listed	ALL AUST (also New Guinea)	No. Not threatened.	Rainforests, open woodlands, semi-arid and arid savannahs, grasslands and heathlands; also agricultural areas. Semi-fossorial, digging for hibernation cover and to construct nursery burrows. Lay a single egg directly into pouch. Young evicted from the pouch (when they start to develop spines) and are left in the burrow; young defenceless. Forages on ants, termites and other invertebrates.	Low significance; Low to medium impact. Young in nursery burrows highly vulnerable. Abundance of prey may be reduced. Given importance of ants in diet the species may benefit from increased ant abundance.	

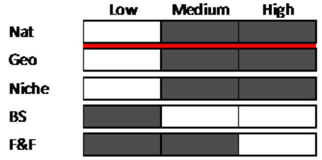
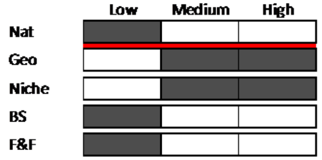
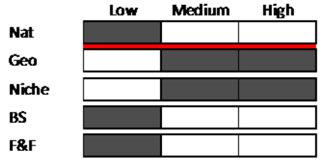
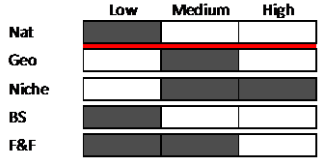
Southern brown bandicoot (Cape York) (*Isoodon obesulus peninsulae*)	Not listed	ne Qld	No.	Dry open woodland to wet allocasuarina–eucalyptus forests. Active day and night. Use dense, low vegetation, log hollows and burrows for nest and shelter sites. Omnivore, feeds on invertebrates, roots and tubers, grass and forb foliage, fruits and hypogeous fungi.	Medium significance; Low to medium impact. Roosting, breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Importance of ants in diet not known, but degree to which species may benefit from increased ant abundance likely to be minimal.	
Spectacled flying-fox (*Pteropus conspicillatus*)	V	ne Qld (also New Guinea, Indonesia, Solomon Islands)	Yes (2010). Habitat loss and disturbance; tick paralysis.	Rainforests. Roosts communally in canopy. Feeds on fruits, flowers and nectar.	Low significance; Low impact. Roosting, breeding and foraging may be disrupted.	
Spectacled hare-wallaby (mainland) (*Lagorchestes conspicillatus leichardti*)	Not listed	n WA, NT, n Qld	No. Predation by feral animals; competition with grazing livestock.	Open forests and woodlands, tall shrublands, tussock grasslands and hummock grasslands. Solitary, nocturnal herbivore.	Low significance; Low impact. Roosting, breeding and foraging may be disrupted.	
Spotted-tailed quoll (North Queensland) (*Dasyurus maculates gracilis*)	E	ne Qld	No. Habitat loss and disturbance.	Rainforests. Nocturnal and solitary. Dens for resting and for raising young, in tree hollows, logs, rock crevasses. On forest floor, hunts small and medium sized mammals, also birds, reptiles, insects and carrion; also an agile climber and hunts for possums in canopy.	Low significance; Low impact. Nesting, breeding and foraging may be disrupted. Abundance of invertebrate and some vertebrate prey may be reduced.	

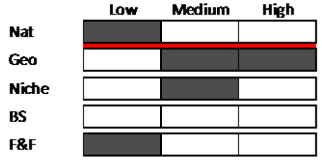
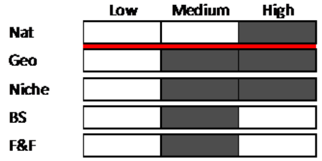
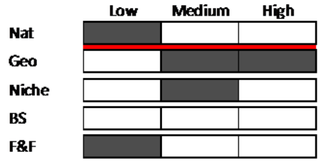
Squirrel glider (*Petaurus norfolcensis*)	Not listed	Qld, NSW, Vic, SA	No. Habitat loss and disturbance; inappropriate fire regimes; predation by feral animals.	Dry sclerophyll forests and woodlands, wet eucalypt forests. Dens communally in tree hollows; dependent young in den for 10 months. Forage in upper and lower forest canopies and shrub understorey, feeds on insects, fruits, flowers, nectar, pollen and sap.	Low significance; Low to medium impact. Vulnerable, especially young in den. Roosting, breeding and foraging may be disrupted. Abundance of invertebrate prey and nectar may be reduced. Importance of ants in diet not known, but degree to which species may benefit from increased ant abundance likely to be minimal.	
Striped possum (*Dactylopsila trivirgata*)	Not listed	ne Qld (also New Guinea)	No. Not threatened.	Rainforests and nearby woodlands. Solitary, mostly nocturnal, arboreal. Builds nests in tree branches and hollows. Feeds on wood boring insects extracted from tree trunks; also eats leaves, fruits, and small vertebrates.	Low significance; Low to medium impact. Vulnerable, especially young in nest. Roosting, breeding and foraging may be disrupted. Abundance of invertebrate and some vertebrate prey may be reduced.	
Sugar glider (*Petaurus breviceps*)	Not listed	ne Qld (also New Guinea, Indonesia, Moluccas)	No.	Rainforests, and adjacent eucalypt and melaleuca woodlands. Arboreal. Gregarious. Dens in tree hollows. Omnivorous, feeds on invertebrates, small vertebrates (mostly lizards and small birds), fungi, nectar, seeds, fruits, pollen, and gum produced by acacias and some eucalypts.	Low significance; Low to medium impact. Vulnerable, especially young in den. Roosting, breeding and foraging may be disrupted. Abundance of invertebrate and some vertebrate prey, and nectar may be reduced.	

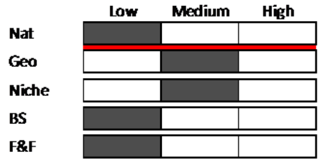
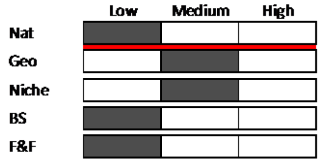
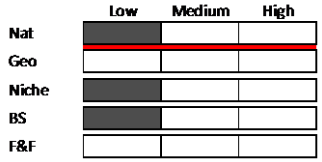
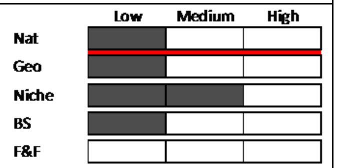
Tube-nosed insect bat (*Murina florium*)	Not listed	ne Qld (also New Guinea, Indonesia, Sulawesi)	No. Loss and disturbance of habitat; predation by feral animals.	Rainforests and wet sclerophyll forests with a rainforest understorey; lowland to montane (up to 1100m). Roosts arboreal, under snagged palm fronds, epiphytic ferns, in aerial termite mounds and in disused bird nests. Insectivore, feeds on insects caught in flight and gleaned from foliage.	Low significance; Low to medium impact. Roosting, breeding and foraging may be disrupted. Abundance of invertebrate prey, and nectar may be reduced.	
Water rat, Rakali (*Hydromys chrysogaster*)	Not listed	WA, Qld, Vic, Tas (also Indonesia, New Guinea)	No.	Lowland to upland (to ~1900m), in damp areas with permanent water - rivers, lakes and estuaries. Burrows in banks. Nests in bankside tunnels or logs. Most food taken aquatic but will forage in riparian vegetation; feeds on aquatic insects, fish, crustaceans, mussels, snails, frogs, birds' eggs, water birds, and lizards.	Low significance; Low impact. Nesting, breeding and foraging may be disrupted. Abundance of terrestrial invertebrate and small vertebrate prey may be reduced.	
White-footed dunnart (northern population) (*Sminthopsis leucopus*)	Not listed	ne Qld	No.	Montane rainforests. Nocturnal. Terrestrial to arboreal. Dens in log hollows, etc. Insectivore, feeds on arthropods; also on small vertebrates.	High significance; No impact. Minimal geographic overlap. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced. Importance of ants in diet not known, but may benefit from increased ant	

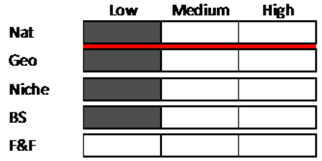
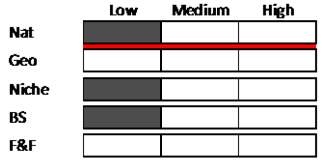
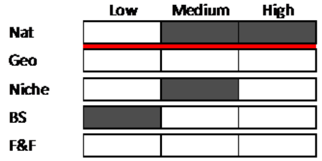
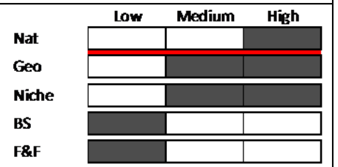
					abundance.	
Yellow-bellied glider (Wet Tropics), Fluffy glider (*Petaurus australis*) (unnamed subspecies)	V	ne Qld	No. Threats poorly understood.	Tall eucalypt forests in uplands (>700m). Social groups sedentary and territorial. Dens and general activity arboreal. Feeds on eucalypt sap, nectar and pollen; also arthropods and honeydew.	High significance; No impact. Minimal geographic overlap. Breeding and foraging may be disrupted. Abundance of invertebrate prey and nectar may be reduced. Importance of ants in diet not known, but may benefit from increased ant.	
Reptiles						
Amethystine python, Scrub python (*Morelia amethistina*)	Not listed	ne Qld (also Indonesia, New Guinea)	No. Not threatened.	Open and closed forests from rainforests to woodlands and open scrublands, up to 1600m; prefer areas near water. Diet generally consists of birds, fruit bats, rats, possums, and other small mammals; also frogs and reptiles. Oviparous. Eggs incubated by female.	Low significance; Low impact. Breeding and foraging minimally disrupted. Abundance of small vertebrate prey may be reduced.	
Atherton delma (*Delma mitella*)	V	ne Qld	No.	Moist tall open forests and rainforest interfaces above 600m. Ground dwelling. Feeds on invertebrates, especially arthropods. Oviparous.	Low significance; Low impact. Minimal geographic overlap. Eggs and young potentially vulnerable. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	

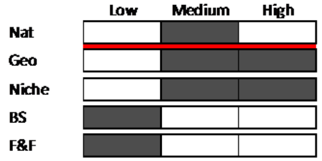
Barnard's snake, Yellow-naped snake (*Furina barnardi*)	Not listed	Qld	No.	Dry woodlands. Nocturnal. Shelters under logs and litter. Feeds on skinks. Oviparous.	Low significance; Low impact. Minimal geographic overlap. Eggs and young potentially vulnerable. Breeding and foraging may be disrupted. Abundance of prey may be reduced.	
Bartle Frere barsided skink (*Eulamprus frerei*)	Not listed	ne Qld	No.	SRE. Cool montane rainforest. Granite boulder fields. Insectivore. Live-bearing.	High significance; No impact. No geographic overlap. Eggs and young potentially vulnerable. Breeding and foraging may be disrupted. Abundance of prey may be reduced.	
Bartle Frere cool-skink (*Bartleia jigurru*) [*Techmarscincus jigurru*]	Not listed	ne Qld	No.	SRE. Cool montane rainforest. Diurnal. On boulders and trees >~1400m. Insectivorous. Oviparous.	Low significance; No impact. No geographic overlap. Eggs and young potentially vulnerable. Breeding and foraging may be disrupted. Abundance of prey may be reduced.	
Black Mountain gecko (*Nactus galgajuga*)	Not listed	ne Qld	No.	SRE. Granite boulder fields, 100 to 500m. Nocturnal. Insectivore. Oviparous.	High significance; Low to medium impact. Eggs and young potentially vulnerable. Breeding and foraging may be disrupted. Abundance of prey may be reduced.	
Black Mountain rainbow-skink (*Liburnascincus scirtetis*)	Not listed	ne Qld	No.	SRE. Granite boulder fields, 100 to 500m. Nocturnal. Insectivore. Oviparous.	High significance; Low to medium impact. Eggs and young potentially vulnerable. Breeding and foraging may be disrupted.	

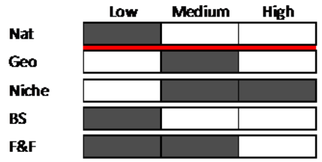
					Abundance of prey may be reduced.	
Boyds forest dragon (*Hypsilurus boydii*)	Not listed	ne Qld	No.	Lowland to montane rainforests. Diurnal. Territorial. Active arboreally and on ground. Feeds on arthropods (including ants) and other invertebrates (such as earthworms) and to lesser extent vertebrates and fruits. Oviparous, eggs laid in shallow burrow.	High significance; Low impact. Eggs and young potentially vulnerable. Breeding and foraging minimally disrupted. Abundance of prey may be reduced.	
Brown tree snake (*Boiga irregularis*)	Not listed	n WA, n NT, n Qld (also New Guinea, nw Melanesia)	No.	Rainforests. Nocturnal. Arboreal, feeds on small mammals, lizards and birds (including eggs and nestlings). Oviparous, eggs laid in log hollows, rock crevices, etc.	Low significance; Low impact. Young potentially vulnerable. Breeding and foraging minimally disrupted. Abundance of some vertebrate prey may be reduced.	
Carpet pythons (*Morelia spilota*)	Not listed	WA, NT, Qld, NSW, Vic, SA (also Indonesia and New Guinea)	No.	Rainforests, woodlands, savannah and grasslands. Semi-arboreal, largely nocturnal. Diet consists mainly of small mammals, bats, birds and lizards. Oviparous, eggs incubated by female.	Low significance; Low impact. Young potentially vulnerable. Breeding and foraging minimally disrupted. Abundance of some vertebrate prey may be reduced.	
Common death adder (*Acanthophis antarcticus*)	Not listed	e NT, Qld, NSW, n Vic, s SA	No.	Rainforests and wet sclerophyll forests, woodlands, grasslands and heaths. In leaf litter. Carnivore, primarily preying on birds and small mammals, but also insects	Low significance; Low impact. Vulnerable as juveniles. Breeding and foraging may be disrupted. Abundance of invertebrate and some vertebrate prey may be	

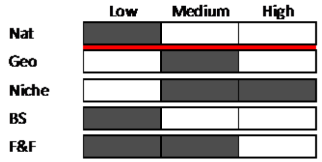
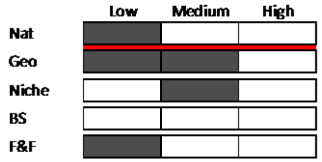
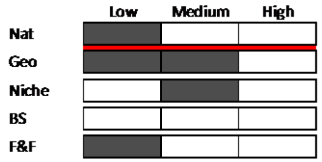
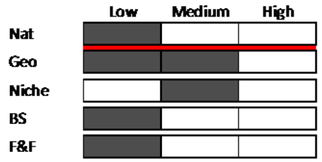
				(ants not included), frogs, and lizards. Produce litters of live young.	reduced.	
Estuarine crocodile, Saltwater crocodile (*Crocodylus porosus*)	Not listed (Marine)	N WA, n NT, n Qld (also India, SE Asia, W Pacific)	No.	Coastal, but also far upstream and in many freshwater swamps and billabongs. Young feed on insects, crabs, prawns and shrimps, but as they grow in size the amount of vertebrate material in the diet increases. Oviparous. Hatchlings carried by female to water.	Low significance; Low impact. Breeding and foraging unlikely disrupted. Abundance of invertebrate and some vertebrate prey may be reduced.	
Faint-striped blind snake (*Ramphotyphlops broomi*)	Not listed	ne Qld	No.	Rainforests. Poorly known. Leaf litter and rotting logs. Believed to feed on earthworms, as well as the larvae and eggs of ants and termites. Oviparous.	High significance; Low to medium impact. All stages vulnerable. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance, but tramp ant unlikely to accept nest intrusion.	
Freshwater crocodile (*Crocodylus johnstoni*)	Not listed (Marine)	n WA, n NT, n Qld	No.	Freshwater rivers, swamps and billabongs, and tidal estuaries. Feeds on fish, insects, crustaceans, small birds, reptiles and frogs, and small mammals. Oviparous.	Low significance; Low impact. Breeding and foraging unlikely disrupted. Abundance of invertebrate and some vertebrate prey may be reduced.	

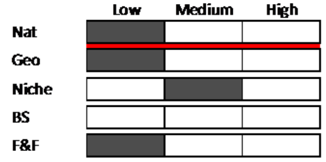
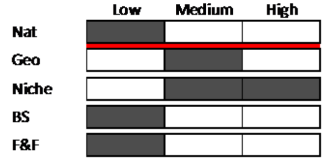
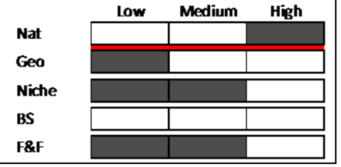
Frilled lizard (*Chlamydosaurus kingii*)	Not listed	e Qld (also New Guinea)	No.	Open forests and woodlands. Primarily arboreal. Feeds on arthropods (including ants) and small vertebrates. Oviparous, nests 5-20cm below ground.	Low significance; Low impact. Breeding and foraging unlikely disrupted. Abundance of invertebrate and some vertebrate prey may be reduced, possibly off-set partially by increased ant abundance.	
Green snake, Common tree snake (*Dendrelaphis punctulata*)	Not listed	WA, NT, Qld, n NSW (also New Guinea)	No.	Rainforests to woodlands, and urban areas, especially near water. Diurnal. Active on ground and arboreally, feeds on frogs, lizards, fish, and frogs. Rest at night in hollow trees, logs, foliage, and rock crevices. Oviparous.	Low significance; Low impact. Breeding and foraging may be disrupted. Abundance of some vertebrate prey may be reduced.	
Green turtle (*Chelonia mydas*)	V (Marine)	WA, NT, Qld, NSW, Vic, SA, LH (tropical and subtropical waters throughout the world)	Yes (2003). Loss of nesting sites to urban development; human disturbance; predation by feral animals.	Marine. Pelagic as young. More inshore as adults, mainly feeds on seagrass and algae. Oviparous. Nests on sandy beaches.	Low significance; No impact. Minimal geographic overlap. Vulnerable in pipping and hatchling stages. Breeding may be disrupted, but nesting not important in Qld.	
Flatback turtle (*Natator depressus*)	V (Marine)	WA, NT, Qld, NSW, CI	Yes (2003). Human activities such as commercial and recreational fishing; coastal development; Indigenous harvest; predation by feral animals.	On continental shelf of northern Australia. Marine. Bays, coral reefs, estuaries and lagoons. Benthic feeding on seagrass, invertebrates including molluscs, jellyfish and shrimp, soft corals and sea cucumbers; and on	Low significance; Low impact. Vulnerable in pipping and hatchling stages. Breeding may be disrupted.	

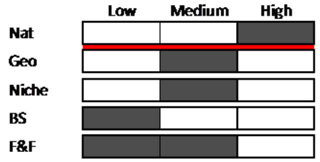
				fishes. Oviparous. Nests on sandy beaches.		
Hawksbill turtle (*Eretmochelys imbricata*)	V (Marine)	WA, NT, Qld, NSW, e Vic, CI, LH, NI (global in subtropical to tropical waters)	Yes (2003). Habitat disturbance; by-catch from fisheries and shark control.	Open ocean to lagoons and mangrove swamps in estuaries. Young entirely pelagic. Adults in-shore, benthic, feeding on sponges, jellyfish, sea anemones and algae. Oviparous. Nests on sandy beaches.	Low significance; Low impact. Vulnerable in pipping and hatchling stages. Breeding may be disrupted, but nesting not important in ne Qld.	
Leathery turtle, Luth (*Dermochelys coriacea*)	E (marine)	All coastal AUS (tropical, subtropical and temperate waters throughout the world)	Yes (2003). Minimal on-shore threats.	Pelagic feeder on soft-bodied creatures such as jellyfish and tunicates. Oviparous. Nesting on sandy beaches. No recent records on nesting in eastern Australia.	Low significance; No impact. Vulnerable in pipping and hatchling stages. Breeding may be disrupted, but nesting not important in ne Qld.	
Loggerhead turtle (*Caretta caretta*)	E (Marine)	ALL AUST (coastal marine) (global distribution throughout tropical, sub-tropical and temperate waters)	Yes (2003). Loss of nesting sites to urban development; predation by feral animals.	Marine. Carnivorous, feeding primarily on marine benthic invertebrates. Oviparous. Nests on beaches.	Medium to high significance; No impact. Vulnerable in pipping and hatchling stages. Breeding and foraging may be disrupted, but nesting not important in ne Qld.	
Limbless snake-tooth skink (*Coeranoscincus frontalis*) [*Anomalopus frontalis*]	Not listed	ne Qld	No.	Rainforests. Shelter under logs. Insectivorous. Reproductive strategy unknown.	High significance; Low impact. Vulnerable in juvenile stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced;	

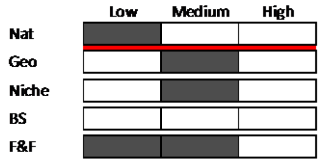
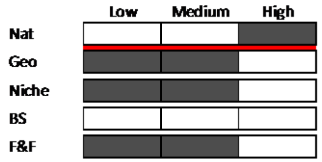
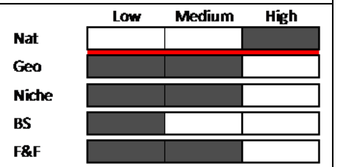
					possibly off-set partially by increased ant abundance.	
Major skink (*Bellatorias frerei*) [*Egernia frerei*]	Not listed	e Qld	No.	Diurnal. Lives in small communities in complex burrow systems; active on ground and arboreally. Feeds on insects, snails, other lizards and vegetable material. Live-bearing.	Medium significance; Low impact. Vulnerable in juvenile stages. Breeding and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Northern leaf-tailed gecko (*Saltuarius cornutus*)	Not listed	ne Qld	No.	Rainforests, 100 to 1300m. Arboreal, forages at night for insects. Oviparous.	High significance; Low impact. Vulnerable in pipping and juvenile stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Northern red-throated skink (*Carlia rubrigularis*)	Not listed	ne Qld	No.	Rainforests, sea level to 1200m, near water margins. Forages for insects and other skinks in leaf litter, fallen logs and tree buttresses. Cannibalistic. Oviparous. Often communal nesting.	High significance; Low to medium impact. Vulnerable in pipping and juvenile stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	

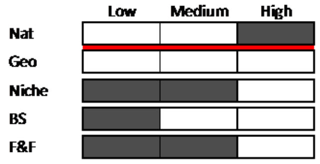
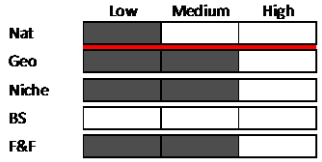
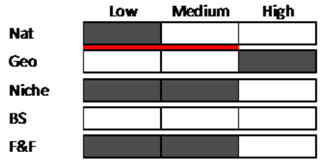
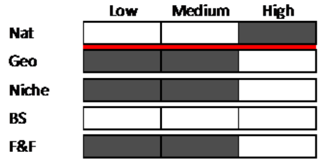
Northern tree snake (*Dendrelaphis calligastra*)	Not listed	ne Qld	No.	Rainforests and open forests; urban and farmed areas. Diurnal. Arboreal. Feeds on frogs and lizards. Oviparous.	High significance; Low impact. Vulnerable in pipping and juvenile stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Pale-flecked garden sunskink (*Lampropholis guichenoti*)	Not listed	Qld, NSW, ACT, Vic, SA	No. Not threatened.	Sclerophyll woodlands, open forests, moist tussock grasslands, and suburban gardens. Leaf litter and rock rubble. Feeds on small invertebrates such as insects (including ants), molluscs and earthworms, and on fruit. Oviparous, often with communal nests.	Low significance; Low to medium impact. Vulnerable, especially pipping and juvenile stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance..	
Prickly forest skink (*Gnypetoscincus queenlandiae*)	Not listed	ne Qld	No.	Rainforests. Nocturnal. Shelters under logs. Insectivore. Live-bearing.	High significance; Low impact. Potentially vulnerable as juveniles. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Rainforest skink, Bar-sided skink (*Eulamprus tigrinus*)	Not listed	ne Qld	No.	Rainforests. Arboreal. Diurnal. Roosts in tree hollows. Feeds on invertebrates. Live young.	High significance; Low impact. Potentially vulnerable as juveniles. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	

Ring-tailed gecko (*Cyrtodactylus louisiadensis*)	Not listed	n Qld (also New Guinea, Solomon Islands)	No.	Open forests and rainforest margins, especially in rocky areas. Insectivorous. Oviparous.	Low significance; Low impact. Vulnerable, especially pipping and juvenile stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Rusty monitor (*Varanus semiremex*)	Not listed	e Qld	No.	Mangroves and coastal to inland Melaleuca swamp forests. Diurnal. Shelters in tree hollows. Forages on ground and arboreally. Feeds on fish, crabs, insects and lizards. Oviparous.	Low significance; Low impact. Breeding and foraging minimally disrupted. Abundance of invertebrate and some vertebrate prey may be reduced.	
Saw-shelled turtle (*Myuchelys latisternum*)	Not listed	ne Qld to n NSW	No.	Coastal rivers and streams. Feeds on aquatic insects, molluscs, crustaceans, fish, tadpoles, frogs and toads. Oviparous.	Low significance; Low impact. Breeding and foraging minimally disrupted. Abundance of invertebrate and some vertebrate prey may be reduced.	
Spotted python, Childrens python (*Liasis maculosus*)	Not listed	e Qld, n NSW	No.	Range of habitat types, especially on rocky hillsides and outcrops with crevices and caves. Predates small mammals. Oviparous.	Low significance; Low impact. Breeding and foraging minimally disrupted. Abundance of invertebrate and some vertebrate prey may be reduced.	

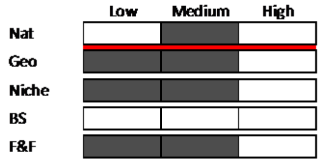
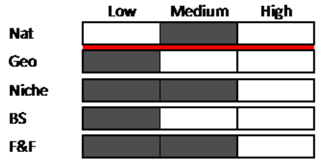
Thornton Peak calyptotis (*Calyptotis thorntonensis*)	Not listed	e Qld	No.	Rainforests, 600 to 700m. Insectivore. Oviparous.	High significance; No impact. Minimal geographic overlap. Vulnerable in pipping and juvenile stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Water python (*Liasis fuscus*)	Not listed	n WA, NT, n-c Qld (also New Guinea) NT	No.	Usually associated with water. Nocturnal, shelters during day in hollow logs, riverbanks and in vegetation. Predates on mammals. Oviparous.	Low significance; Low impact. Foraging minimally disrupted. Abundance of some vertebrate prey may be reduced.	
Yakka skink (*Egernia rugosa*)	V	e Qld	No. Primary threat is habitat loss and degradation through human activities.	Open dry sclerophyll forest, woodland and scrubland. Gregarious. Shelters under rocks, logs, tree stumps, root cavities, abandoned animal burrows, and its own extensive burrows. Omnivorous, consuming soft plant materials and fruits and a wide variety of invertebrates (ants not included). Live-bearing.	Low significance; Low impact. Vulnerable as juveniles, and generally in burrows. Abundance of some vertebrate prey may be reduced.	
Amphibians						
Armoured mistfrog (*Litoria lorica*)	E	ne Qld	Yes (2001). Threats poorly understood.	SRE. Rainforests, generally 640 to 1000m, but present at lower altitudes. In splash zone near turbulent fast flowing water.	High significance; Low impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate	

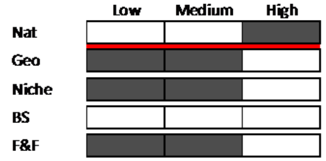
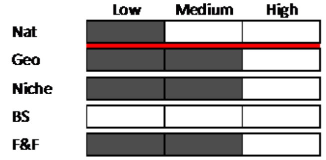
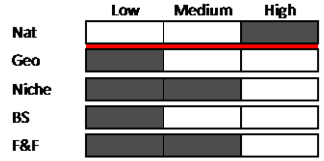
				Breeding aquatic. Insectivore.	prey may be reduced; possibly off-set partially by increased ant abundance.	
Australian wood frog (*Rana daemeli*) [*Hylarana daemeli*]	Not listed	e NT, n Qld (also New Guinea)	No.	Rainforests and mesic woodlands, generally near water. Semi-aquatic, with aquatic breeding. Insectivore.	Low significance; Low impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Bellenden Ker nurseryfrog (*Cophixalus neglectus*)	Not listed	ne Qld	No.	SRE. Rainforests, 900-1500m. Ground dwelling. Insectivore. Eggs laid on ground; attended by an adult; young develop directly into fully formed frogs.	High significance; No impact. No geographic overlap. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Black Mountain boulderfrog (*Cophixalus saxatilis*)	Not listed	ne Qld	No.	Moist lowland forests, rocky areas, and caves. Ground dwelling in granite boulder field. Insectivore. Eggs laid on ground; attended by an adult; young develop directly into fully formed frogs.	High significance; Low to medium impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Buzzing nurseryfrog (*Cophixalus bombiens*)	Not listed	ne Qld	No.	SRE. Rainforests, 900-1300m. Ground dwelling. Insectivore. Eggs laid on ground; attended by an adult; young develop directly into fully formed frogs.	High significance; No impact. No geographic overlap. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by	

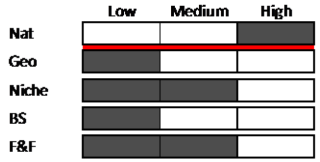
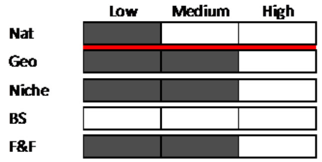
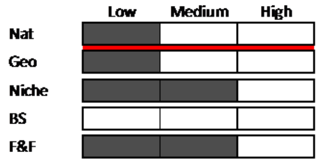
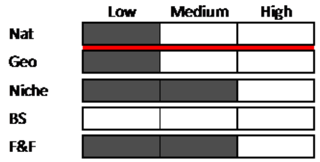
					increased ant abundance.	
Carbine barred frog (*Mixophyes carbinensis*)	Not listed	ne Qld	No.	Rainforests, 700-1300m. Associated with clear, flowing streams and nearby pools. Insectivore. Burrow in the soil. Aquatic breeder. Tadpoles possibly feed on carrion.	High significance; No impact. No geographic overlap. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Common green tree frog (*Litoria caerulea)*	Not listed	n WA, NT, Qld, ne SA (also New Guinea) (introduced to New Zealand)	No.	Rainforests, mesic woodlands, mesic grasslands, and urban areas. Nocturnal. Arboreal. Insectivorous, but also feeds on small mammals and other frogs. Aquatic breeder.	Low significance; Low impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Common mistfrog (*Litoria rheocola*)	E	ne Qld	Yes (2001). Threats poorly understood.	SRE. Rainforests and wet sclerophyll forests, 0 to 1180m. Immature stages aquatic, in fast-flowing streams. Adults forage amongst streamside vegetation. Insectivore.	High significance; Low to medium impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Creaking nurseryfrog (*Cophixalus infacetus*)	Not listed	ne Qld	No.	SRE. Rainforests, up to 900m. Ground dwelling. Insectivore. Eggs laid on ground; attended by an adult; young develop directly into fully formed frogs.	High significance; Low to medium impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	

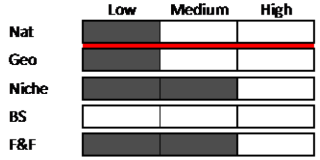
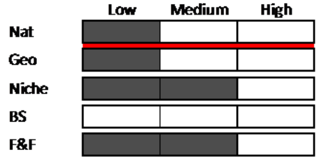
Dainty nurseryfrog (*Cophixalus exiguus*)	Not listed	ne Qld	No.	SRE. Rainforests, ~550 to 620m. Ground dwelling. Insectivore. Eggs laid on ground; attended by an adult; young develop directly into fully formed frogs.	High significance; No impact. No geographic overlap. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Dwarf rocket frog (*Litoria microbelos*)	Not listed	n WA, NT, n & c Qld	No.	Coastal. Long grass surrounding swamps, marshy areas and ponds. Insectivore. Aquatic breeder.	Low significance; Low impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Eastern dwarf tree frog (*Litoria fallax*)	Not listed	ne Qld to NSW	No. Not threatened.	Coastal swamps, lagoons, and other wetlands in forests, wallum heathlands, farmlands and gardens. Lives in reeds and similar situations both near and away from water. Insectivore. Breeding aquatic.	Low significance; Low to medium impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Lace-eyed tree frog, Australian lacelid (*Nyctimystes dayi*)	E	ne Qld	Yes (2001). Threats poorly understood.	SRE. Rainforests and rainforest margins, up to 1200m. Rock soaks, narrow ephemeral streams and rock outcrops in larger watercourses, and fast upland flowing stream. Adults forage amongst streamside vegetation. Insectivore,	High significance; Low to medium impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	

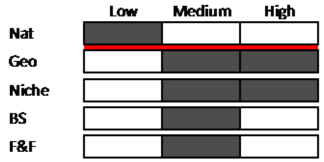
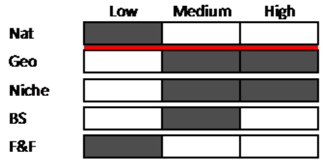
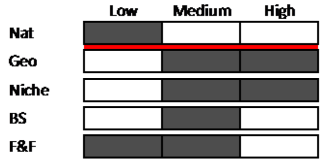
				feeding on terrestrial and aquatic insects. Aquatic breeder.		
Little waterfall frog (*Litoria lorica*)	CE	ne Qld	Yes (2001). Threats poorly understood.	SRE. Rainforests, 640-1000m. Associated with streams. Insectivore. Aquatic breeder.	High significance; No impact. No geographic overlap. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Magnificent brood frog (*Pseudophryne covacevichae*)	V	ne Qld	Yes (2000). Habitat loss and degradation through grazing logging, road construction, etc.	SRE. Seepage areas above 800m, in open eucalypt forests with dense ground cover. Insectivore, adults forage amongst streamside vegetation. Eggs laid on moist soil in or near seepage, usually under vegetation. Tadpoles washed or make their way to first order streams where development is completed.	High significance; No impact. No geographic overlap. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Marbled frog (*Limnodynastes convexiusculus*)	Not listed	n WA, NT, n Qld	No.	Swampy areas among long grass. Ground-dwelling. Insectivore. Aquatic breeder.	Low significance; Low impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	

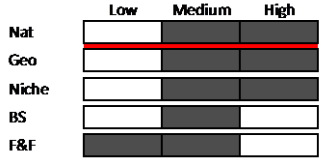
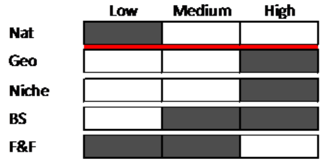
Mottled barred frog (*Mixophyes coggeri*)	Not listed	ne Qld	No.	Rainforests, 100-1500m. Associated with fast-flowing streams and nearby ponds. Burrow in the soil. Insectivore. Aquatic breeder.	Medium significance; Low impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Mountain mistfrog (*Litoria nyakalensis*)	CE	ne Qld	Yes (2001). Threats poorly understood.	SRE. Upland rainforests and wet sclerophyll forests. Immature stages aquatic, in fast-flowing streams. Adults forage amongst streamside vegetation. Insectivore.	High significance; No impact. No geographic overlap. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Mountain nurseryfrog (*Cophixalus monticola*)	Not listed	ne Qld	No.	SRE. Rainforests above 1100m. Ground dwelling, in crevices of fallen trees, dry creek beds, and under fallen palm fronds. Insectivore. Eggs laid on ground; attended by an adult; young develop directly into fully formed frogs.	High significance; No impact. No geographic overlap. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Northern barred frog (*Mixophyes schevilli*)	Not listed	ne Qld	No.	Rainforests, 100-1500m. Around fast-flowing streams and nearby pools. Burrow in the soil. Eggs laid on ground and around the roots of plants at water level beside streams and pools. Tadpoles aquatic.	Medium significance; Low to medium impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	

Northern stoney creek frog (*Litoria jungguy*)	Not listed	ne Qld	No.	Rainforests. Ground dwelling. Insectivore. On exposed sandy banks where sunlight penetrates the canopy, constructs water-filled basins for oviposition and where larvae are reared through metamorphosis.	High significance; Low to medium impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Ornate burrowing frog (*Platyplectrum ornatum*)	Not listed	n WA, NT, Qld, n NSW	No.	Seasonally inundated habitats. Found in dry sandy watercourses some distance from permanent water. Ground-dwelling. Insectivore. Shelter and aestivate in burrows. Breeding aquatic.	Low significance; Low impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Peeping whistlefrog (*Austrochaperina fryi*)	Not listed	ne Qld	No.	SRE. Rainforests, up to 1300m. On forest floor under fallen timber and leaf litter. Insectivore. Eggs deposited in moist soil and tended by an adult; development direct.	High significance; Low to medium impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Rattling nurseryfrog (*Cophixalus hosmeri*)	Not listed	ne Qld	No.	SRE. Rainforest at 800-1370m. On forest floor and low vegetation. Insectivore. Eggs deposited in moist soil and tended by an adult; development direct.	High significance; No impact. No geographic overlap. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	

Robust whistlefrog (*Austrochaperina robusta*)	Not listed	ne Qld	No.	SRE. Rainforests above 360m. Shelters beneath logs, rocks and leaf litter on the forest floor. Insectivore. Eggs deposited in moist soil; development direct.	High significance; Low impact. Minimal geographic overlap. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Striped rocket frog (*Litoria nasuta*)	Not listed	n WA, NT, Qld, me NSW	No.	Coastal. Open forests and forested edges of permanent swamps. Forages among leaf litter of t forest floor and open flats exposed by receding waters. Insectivore. Aquatic breeder.	Low significance; Low impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Superb collared frog (*Cyclorana brevipes*)	Not listed.	Qld, ne NSW	No.	Open grassland and lightly forested areas. Insectivore. Burrows in soil during dry season. Breeding aquatic.	Low significance; Low impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Tapping green-eyed frog (*Litoria genimaculata*)	Not listed	ne Qld (also New Guinea)	No.	Rainforests up to 1500m. Streams and rocky creek beds. Insectivore. Breeding aquatic.	Low significance; Low impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	

Tapping nurseryfrog (*Cophixalus concinnus*)	Not listed	ne Qld	No.	SRE. Montane rainforests, 560-1300m. In leaf litter and on low vegetation. Insectivore. Terrestrial breeder, eggs laid in a string under rocks and logs in moist soil; development direct.	High significance; No impact. No geographic overlap. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Tinkling frog, Northern tinker frog (*Taudactylus rheophilus*)	E	ne Qld	Yes (2001). Threats poorly understood.	SRE. Montane, 940 to 1400m (formerly also at lower elevations). Under rocks and logs beside fast-flowing streams - prefers seepage and trickle areas. Insectivore. Breeding assumed to be aquatic.	High significance; No impact. No geographic overlap. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Waterfall frog, Torrent tree frog (*Litoria nannotis*)	E	ne Qld	Yes (2001). Threats poorly understood.	SRE. Lowland to montane rainforests and wet sclerophyll forests, 180-1300m. All life stages stream dwelling, but nocturnally venturing away from the water to forage among streamside vegetation . Insectivore.	Low significance; Low impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
White-lipped tree frogs (*Litoria infrafrenata*)	Not listed	ne Qld (also New Guinea, Indonesia and East Timor)	No.	Rainforests, wet sclerophyll forests, cultivated and suburban habitats. Insectivore. Breeds in forest pools, deep and slow streams, and in ditches and pools in disturbed areas.	Low significance; Low impact. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	

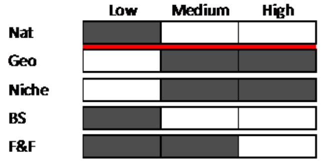
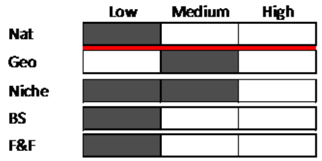
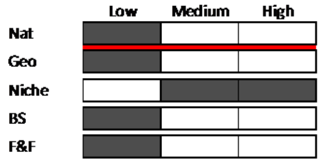
Whirring treefrog (northern population) (*Litoria revelata*)	Not listed	ne Qld	No.	Coastal swamps and ponds to montane rainforests. Insectivore. Aquatic breeder.	High significance; Low impact. Minimal geographic overlap. Vulnerability in non-aquatic stages unknown. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Invertebrates						
Apollo jewel butterfly (*Hypochrysops apollo apollo*)[1, 2]	Not listed	e Qld	No. Habitat loss.	Larvae live within bulbs of *Myrmecodia beccarii* and *M. tuberose* (Rubiaceae) - epiphytic on various coastal trees, particularly *Melaleuca viridifolia*. Larvae emerge nocturnally to feed also on the foliage. Generally larvae are associated with the ant *Iridomyrmex cordatus*, which feed on honeydew from the butterfly larvae.	Low significance; Medium impact. Highly vulnerable, especially in immature stages, through both direct predation and possible displacement of the native ant associate. However, a further tramp ant, *Pheidole megacephala*, has evidently not lead to displacement.	
Australian beak butterfly (*Libythea geoffroy*)	Not listed	n WA, n NT, ne Qld (also Asia to Melanesia)	No.	Dry river beds and gullies. Larvae feed on new leaves of *Celtis* spp. (Ulmaceae). Pupae suspended from host plant. Adults visit flowers of host plants.	Low significance; Low to medium impact. Highly vulnerable, especially in immature stages. Foraging may be disrupted.	
Moth butterfly (*Liphyra brassolis*)[2]	Not listed	n WA, NT, n Qld (also Asia)	No.	Rainforests, woodlands and shrublands. Occur in nests of ants, especially of tree ants (*Oecophylla smaragdina*). Larvae are predatory on ant larvae.	Low significance; Medium impact. Highly vulnerable, especially in immature stages, through both displacement of the native	

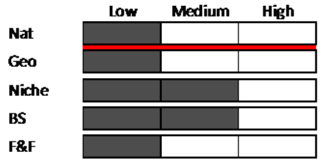
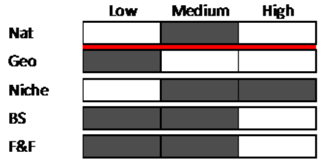
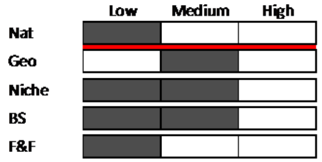
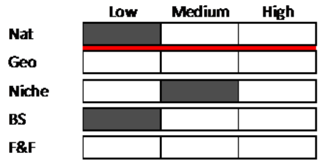
					ant associate and direct predation.	
Purple dusk-flat (*Chaetocneme porphyropis*)	Not listed	ne Qld	No.	Rainforests. Larvae feed on various Lauraceae species. Nocturnal, shelters by day between leaves bound by silk. Adults feed at flowers.	Medium to high significance; Medium impact. Highly vulnerable, especially in immature stages. Foraging may be disrupted.	
Weaver ant, Green tree ant (*Oecophylla smaragdina*)[2]	Not listed	n WA, n NT, n Qld (also India to SE Asia and Orient)	No. Not threatened.	Rainforests, vine thickets, closed forests, and heaths. Nests arboreal, built by stitching living tree and shrub leaves together with silk produced by special glands in the larvae. Forage on ground and arboreally. Predate arthropods and other invertebrates; also tend aphids, scale insects, and the caterpillars of some butterfly species that produce honeydew.	Low significance; Medium to high impact. Nest brood and foraging ants vulnerable. Abundance of invertebrate prey and nectar may be reduced.	

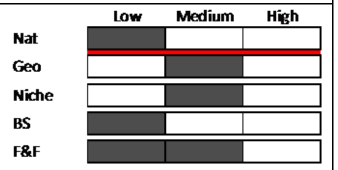
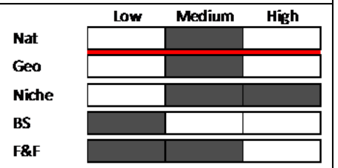
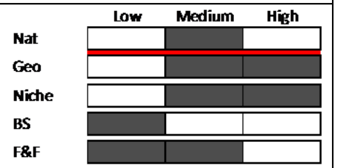
Appendix 3 References

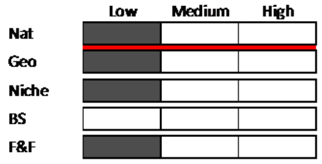
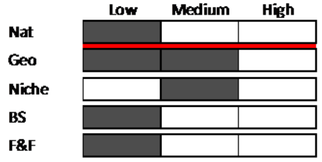
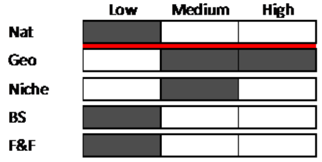
1. McNicol, C. 2008. Queensland Electric Ant (*Wasmannia auropunctata*) Program Plan, Department of Primary Industries and Fisheries.
2. Royer, J. 2006. Impacts of Wasmannia auropunctata (Roger) on native and local fauna in Smithfield, Queensland--A baseline survey, Electric Ant Control Centre, Cairns.
3. National Electric Ant Eradication Program. 2010. National Environmental Biosecurity Response Agreement (NEBRA), Biosecurity Queensland, Department of Primary Industries and Fisheries.
4. National Electric Ant Eradication Program. 2011. Response Plan: Eradication of electric ant in Queensland, Biosecurity Queensland, Department of Employment Development and Innovation.

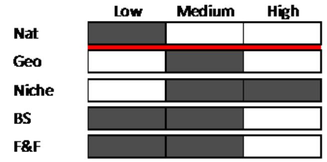
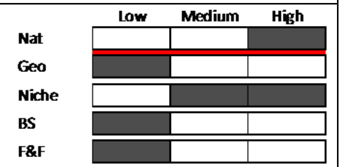
Appendix 4 Rapid assessment of native species potentially at risk from Yellow crazy ant in the Arnhem Coast Bioregion

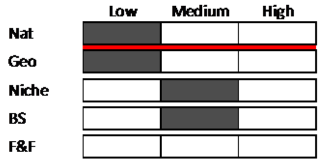
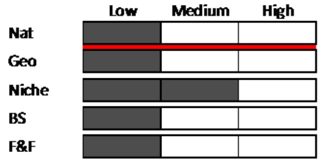
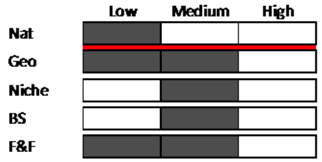
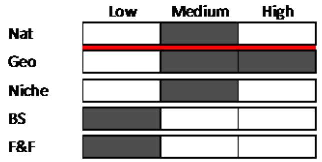
Common Name (scientific name)	EPBC Act listing status	Range	Recovery Plan	Habitat and behaviour	Potential or presumed level of impact and mechanisms for Yellow crazy ant effect	
Birds						
Australian bustard (*Ardeotis australis*)	Not listed	(also New Guinea)	No. Not threatened.	Grasslands, woodlands and open agricultural areas. Nomadic. Omnivorous, feeds on leaves, buds, seeds, fruit, centipedes, insects, molluscs, lizards, young birds and small rodents. Nests on open ground or on grass.	Low significance; Low to medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced. On-site effects off-set in part by nomadic activity.	
Azure kingfisher (*Ceyx azurea*) [=*Alcedo azurea*]	Not listed	WA, NT, Qld, NSW, Vic, e SA, Tas (also New Guinea, Moluccas)	No. Degradation of wetland waters.	Near water - ponds, rivers, lakes and mangroves. Diet mostly fish and insects. Roosts arboreal. Nests in burrows in earth banks and cliffs.	Low significance; Low impact. Nesting attempts and fledgling success may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced.	
Banded fruit dove (*Ptilinopus cinctus alligator*)	Not listed	NT	No. Fire.	Monsoonal rainforests. Diurnal. Often gregarious. Feeds on fruit from forest trees, especially figs. Roosts, nests and rests in trees; nests an open platform.	Low significance; Low impact. Nesting attempts, fledgling success, and foraging may be disrupted.	

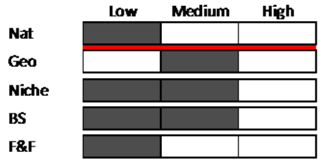
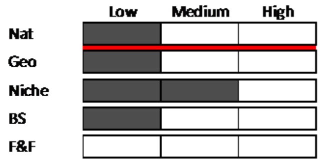
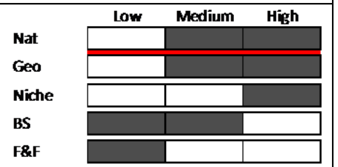
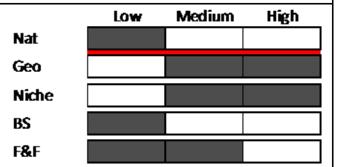
Beach stone-curlew (*Esacus neglectus*)	Not listed (Marine)	n WA, n NT, Qld, (NSW)	No. Habitat loss; human disturbance; predation by feral animals.	Wader. Occurs on open, undisturbed beaches, islands, reefs and estuarine intertidal sand and mudflats. Nest a scrape on ground.	Low significance. Low impact. Nesting and fledgling success may be disrupted. Minimal disruption of foraging and food resources.	
Black-tailed treecreeper (*Climacteris melanurus*)	Not listed	n WA, n NT, nw Qld	No.	Woodlands and shrublands. Forages arboreally and on ground for insects, including ants, and nectar. Nests in trees hollows or forks.	Medium significance; Low to medium impact. Nesting attempts, fledgling success, and foraging may be disrupted. Abundance of invertebrate prey and nectar may be reduced, but possibly off-set by increased ant abundance.	
Black bittern (Australasian) (*Ixobrychus flavicolllis australis*)	Not listed	n WA, n NT, n Qld to s NSW	No. Habitat loss; disturbance by livestock; predation by feral ants.	Lowland terrestrial and estuarine wetlands, generally in areas of permanent water and dense vegetation. Nocturnal. Forages for reptiles, fish and invertebrates. Roosts in trees or on the ground amongst dense reeds. Nests on branch overhanging water.	Low significance; Low impact. Nesting attempts and fledgling success may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced.	
Bridled tern (*Onychoprion anaethetus*)	Not listed (Marine, Migratory)	WA, NT, Qld, SA (widespread globally)	No. Threats to breeding colonies include predation by feral animals; human disturbances.	Forages primarily in offshore, continental shelf waters for pelagic fish and cephalopods; also feeding inshore on crustacean molluscs, insects etc. Breeding on off-shore islands, in rocky areas	Low significance; No impact. Minimal geographic overlap. Nesting attempts and fledgling success, potentially disrupted Not breeding or feeding on mainland.	

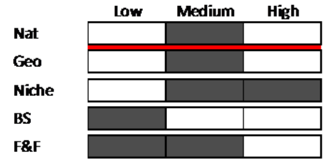
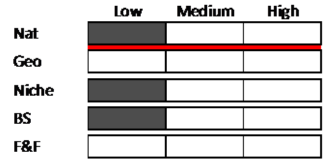
				concealed in crevices or caves up to 1.5m deep, under rocks, among talus or coral rubble, on ledges of cliffs, and on ground beneath low vegetation.		
Bush stone-curlew (*Burhinus grallarius*)	Not listed	WA, NT, Qld, NSW, Vic, SA (also New Guinea)	Yes (2006). Habitat disturbance through human activity, livestock grazing, cultivation, and wildfires; predation by feral animals.	Lightly timbered, open forests, woodlands and pastures. Nocturnal. Feeds on invertebrates (including ants), frogs, reptiles and some vegetation. Nests and forages on ground.	Low significance; Low to medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced, but possibly off-set by increased ant abundance.	
Chestnut-breasted button-quail (*Turnix castanotus*)	Not listed	n WA, n NT	No.	Short grass in eucalypt woodlands, particularly on stony or rocky hills. Feeds on seeds and invertebrates (especially arthropods). Nest a dome of grass on ground.	Medium significance; Low to medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced, but possibly off-set by increased ant abundance.	
Crested shrike-tit (northern), Northern shrike-ti) (*Falcunculus frontatus whitei*)	V	n WA, n NT	Yes (2004). Wildfires.	Eucalypt open woodlands. Forages by probing or tearing bark, and gleaning branches, foliage and buds, for arthropods. Nests in vertical fork in the uppermost leaves and branch of shrubs and trees.	Medium significance; Low to medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced, but possibly off-set by increased ant abundance.	

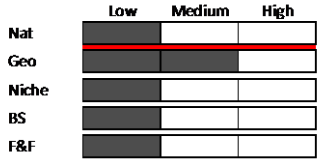
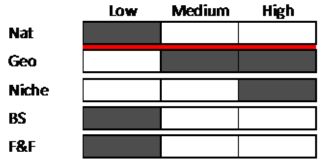
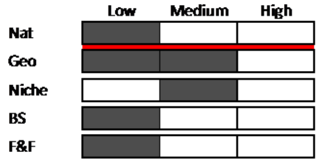
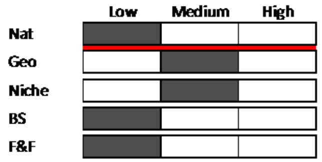
Eastern curlew (*Numenius madagascariensis*)	Not listed (Marine)	All Aus; LH, NI (breeds in Russia and north-eastern China)	No. Human disturbance; habitat degradation.	Sheltered coasts, especially estuaries, bays, harbours, inlets and coastal lagoons. Migratory. Roosts terrestrially in salt-marshes, behind mangroves, and on sandy beaches. Forages on soft intertidal sand- and mud-flats.	Low significance. Low impact. Roosting and foraging minimally affected. Not breeding in Australia.	
Emu (mainland) (*Dromaius novaehollandiae novaehollandiae*)	Not listed	WA, NT, Qld, NSW, Vic, SA	No. Population fragmentation; loss of habitat; predation by feral animals; road kills and illegal hunting/poisoning.	Lowland grasslands, heathlands, shrublands, open and shrubby woodlands, forests, and swamp and sedgeland communities, and farmland. Diurnal. Nomadic. Feeds on fruits, seeds, arthropods, and small vertebrates (mammals, amphibians, reptiles). Nests on ground.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced.	
Grey goshawk (*Accipiter novaehollandiae*)	Not listed	WA, NT, Qld, NSW, Vic, Tas. (also the Lesser Sunda Islands, Moluccas, New Guinea, Solomon Islands)	No. Habitat loss and fragmentation.	Tending coastal. Forests, tall woodlands, and timbered watercourses. Feeds on small vertebrates and insects. Nests arboreally.	Low significance. Low impact. Nesting, roosting and foraging minimally affected.	

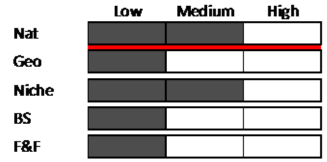
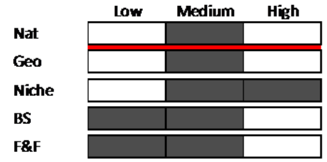
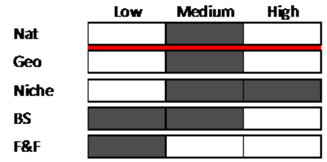
Gouldian finch (*Erythrura gouldiae*)	E	n WA, n NT, n Qld	Yes (2006). Loss and degradation of habitat due to livestock grazing, fire; predation by feral animals. Potential predation by Red imported fire ant.	Open woodlands with grass ground cover. Feeds almost entirely on grass seeds, but will take arthropods and honeydew. Nests on ground.	Low significance; Low to medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey and honeydew may be reduced, but off-set partially by increased ant and homopteran abundance.	
Grass owl (eastern) (*Tyto capensis longimembris*)	Not listed	n WA, NT, Qld, NSW, SA (also s Asia, Orient, W Pacific)	No. Not threatened.	Tall grasslands, but also heaths, swamps, coastal dunes, treelined creeks, treeless plains, grassy gaps between trees and crops. Nocturnal. Roosts, forages and nests on ground. Feeds predominantly on small rodents.	Low significance; Low impact. Nesting, fledgling success, and foraging may be disrupted. Abundance of vertebrate prey may be reduced.	
Great-billed heron (*Ardea sumatrana*)	Not listed	n WA, n NT, n Qld (also se Asia/Orient)	No. Not threatened.	Largely coastal, coral reefs, mangroves, large rivers deltas, estuaries. Wader. Foraging largely aquatic, on fish, small mammals, birds, snakes, lizard, frogs, crabs, molluscs and insects. Nests generally large twig platforms built on trees.	Low significance; Low impact. Nesting and fledgling success may be disrupted. Abundance of invertebrate and vertebrate may be reduced in non-aquatic part of foraging range.	
Hooded parrot (*Psephotus dissimilis*)	Not listed	NT	No. Habitat disturbance/degradation by grazing and fires.	Semi-arid open woodlands and savannahs. Diet consists mainly of seeds, berries and vegetation. Nests in termite mounds.	High significance; Low impact. Nesting, fledgling success, and foraging may be disrupted.	

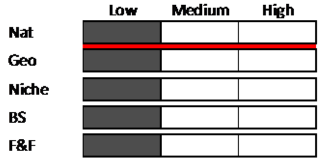
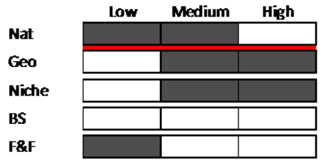
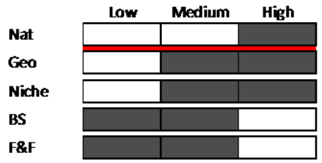
Little tern (*Sterna albifrons*)	Not listed (Marine)	Widespread globally. Coastal Qld, NSW, Vic, SA, WA, NT	Yes (2003). Habitat loss; human disturbances; predation and disturbance by feral animals. Mentions ant effects on nesting success.	Migratory. Ground-nesting on sandy beaches and close to the high-tide mark. Estuarine feeder.	Low significance; Low to medium impact. Nesting attempts and fledgling success likely disrupted.	
Major Mitchell's cockatoo (*Cacatua leadbeateri*)	Not listed	NT, Qld, NSW, Vic, SA, WA	No. Habitat loss, including removal of nesting trees in agricultural areas.	Primarily semi-arid open woodland, but utilizing a range of other habitats, including agricultural fields. Nests in tree hollows. Forages on ground and in foliage of trees and tall shrubs for seeds, fruits, and tubers.	Low significance; Low impact. Very low geographic overlap. Nesting attempts, fledgling success, and foraging may be disrupted.	
Masked lapwing (*Vanellus miles*)	Not listed	NT, Qld, NSW, Vic, SA, Tas (also Indonesia; New Zealand; Papua New Guinea; Timor-Leste, Singapore)	No. Habitat disturbance through human activity, livestock grazing, cultivation and wildfires; predation by feral animals.	Wetlands and in other moist, open habitats, including parks and pastures. Insectivore, feeds on insects (including ants) and earthworms. Nests on ground.	Low significance; Medium impact. Nesting and fledgling success may be disrupted. Abundance of invertebrate prey may be reduced, but possibly off-set by increased ant abundance.	
Masked owl (*Tyto novaehollandiae kimberli*)	V	n WA, n NT, ne Qld	Yes (2004).	Forests and woodlands. Sedentary, territorial. Nocturnal. Forages widely, in woodlands, and adjoining grasslands and agricultural fields, for small mammals. Roosts and nests in tree hollows.	Medium significance; Low impact. Nesting and fledgling success may be disrupted. Abundance of some vertebrate prey may be reduced.	

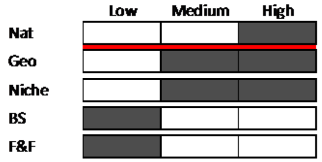
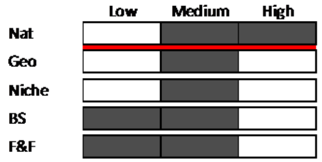
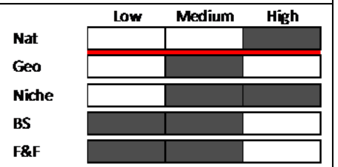
Painted honeyeater (*Grantiella picta*)	Not listed	NT, Qld, NSW, Vic, SA	No. Loss and fragmentation of habitat; removal of large, old trees with heavy mistletoe infestations; heavy grazing of grassy woodlands.	Forests and woodlands. Nomadic, at low densities throughout range. Arboreal, foraging exclusively on mistletoes, mainly in upper canopy. Nests 3-20 m from the ground.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted.	
Painted snipe (*Rostratula benghalensis*)	Not listed	Qld, NSW, Vic, SA, WA, NT, Tas, LH	No. Habitat loss and modification through hydrological changes; predation by feral animals; disturbance by grazing livestock.	Inhabits inland and coastal shallow freshwater wetlands. Forages nocturnally on mud flats and in shallow water for seeds and invertebrates. Nest a scrape in the ground.	Low significance; Low impact. Nesting attempts and fledgling success may be affected. Foraging minimally affected.	
Partridge pigeon (eastern) (*Geophaps smithii smithii*)	V	ne WA, n NT	Yes (2004). Fire.	Woodlands, shrublands and grasslands. Diurnal. Somewhat gregarious. Foraging, roosting and nesting on ground. Granivore, taking a variety of seeds; also preying on arthropods.	Medium to high significance; Low to medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Rainbow bee-eater (*Merops ornatus*)	Not listed (Marine)	All Aus (also New Guinea, Solomon Islands, Indonesia, SE Asia, Japan)	No. Not considered threatened.	Migratory over part of Australian range. Open forests and woodlands, shrublands, and in various cleared or semi-cleared areas. Insectivore, feeds on insects (primarily on bees and wasps, but including ants, beetles, etc.) in flight and on ground. Nests in burrows in banks.	Low significance; Medium impact. Nesting and fledgling success, and ground foraging may be disrupted. Abundance of invertebrate prey may be reduced, but possibly off-set by increased ant abundance. May compete directly for nest sites in banks.	

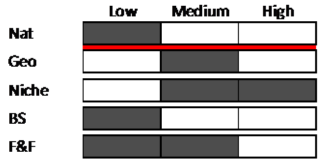
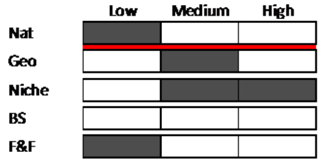
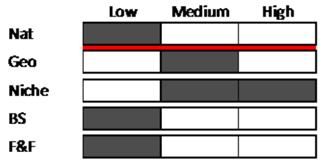
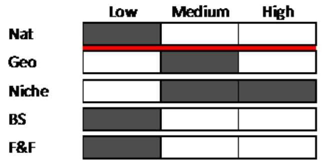
Rainbow pitta (*Pitta iris*)	Not listed	n WA, NT	No. Not threatened.	Monsoonal forests. Forages among leaf litter for invertebrates (especially earthworms in wet season) and small vertebrates. Nesting on ground to 20m in tree forks.	Medium significance; Low to medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced.	
Red goshawk (*Erythrotriorchis radiatus*)	V	NSW, Qld, NT, WA	Yes (2012). Habitat loss.	Coastal and sub-coastal woodlands and forests. Predatory on other birds and to lesser extent other vertebrates. Arboreal nesting.	Low significance; Low impact. Nesting and fledgling success may be disrupted. Minimal affect on prey abundance.	
Roseate terns (*Sterna dougallii*)	Not listed (Marine)	WA, NT, Qld (widespread globally)	No.	Migratory. Pelagic, feeds on fish and molluscs; also exhibits kleptoparasitic behaviour, stealing fish from other seabirds. Colonial nesting on sand-dunes, sand-spits, shingle beaches, reefs, salt-marshes, and rocky, sandy or coral islands, with or without vegetative cover.	Low significance; No impact. Nesting and fledgling success potentially disrupted, but breeding not occurring on Arnhem Land mainland.	
Sacred kingfisher (*Todiramphus sanctus*)	Not listed (Marine)	WA, NT, Qld, NSW, ACT, Vic, SA, Tas, LH, NI (also New Zealand, New Guinea, Indonesia, n and w Melanesia; vagrant CI, nw Pacific)	No. Not threatened.	Mangroves, woodlands, forests, and disturbed open area. Migratory over part of range. Forages mainly on land, only occasionally capturing prey in water. Feeds on invertebrates, fish and small vertebrates. Nest in burrows in earth banks, tree hollows, etc.	Low significance. Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of some invertebrate and vertebrate prey may be reduced. May compete directly for nest sites.	

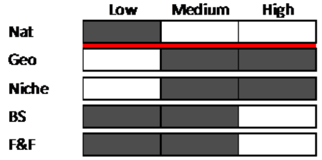
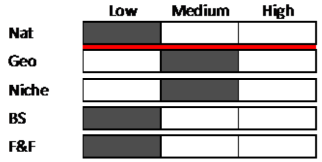
Square-tailed kite (*Lophoictinia isura*)	Not listed	e Qld, NSW, Vic, SA, WA, NT	No. Habitat loss; illegal hunting.	Open country, including open woodlands and heaths. Specialist hunter of passerines. Arboreal nesting.	Low significance; Low impact. Nesting and fledgling success unlikely affected. Abundance of prey may be indirectly reduced through effects on invertebrates.	
Varied lorikeet (*Psitteuteles versicolor*)	Not listed	n WA, NT, nw Qld	No.	Lowland. Dense eucalypt, paperbark and swamp woodlands, savanna woodlands, grasslands and mangroves. Gregarious. Diet includes pollen, fruits, seeds, and arthropods. Nests in tree hollows.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of some invertebrate prey and nectar may be reduced.	
White-faced heron (*Ardea novaehollandiae*)	Not listed	WA, NT, Qld, NSW, ACT, Vic, SA, Tas, CI, LH, NI (also New Guinea, Indonesia, New Caledonia, New Zealand; vagrant se Asia, Cocos Islands, Solomon Islands)	No. Not threatened.	Mainly diurnal. Forages in wet grasslands, wetlands, estuaries and lagoons. Locally nomadic, and dispersive in non-breeding season. Diet highly varied – invertebrates and small vertebrates. Nests in trees.	Low significance. Low impact. Nesting and fledgling success may be disrupted. Abundance of some invertebrate and vertebrate prey may be reduced.	
Mammals						
Agile Wallaby (*Macropus agilis*)	Not listed	n WA, NT, n Qld (also New Guinea)	No. Not threatened.	Coastal. Along river banks and open forests. Gregarious. Grazes native grasses, and digs for succulent roots.	Low significance; Low impact. Breeding and foraging minimally disrupted.	

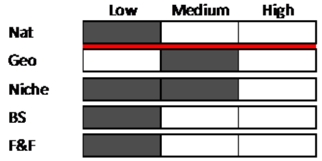
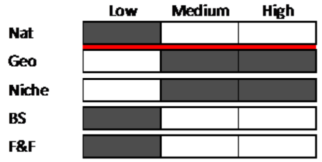
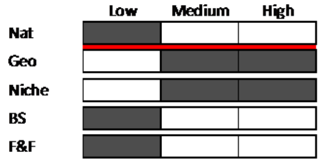
Arnhem sheathtail-bat (*Taphozous kapalgensis*)	Not listed	n WA, n NT	No. Weed invasion, including replacement of floodplain vegetation with introduced grasses.	Floodplains, mangroves, patchy monsoon forests, and nearby woodlands. Probably roosting in tree hollows and *Pandanus*. Diet comprises insects, caught in flight over forest canopies, grasslands and open water bodies.	Low to medium significance (range of species poorly known); Low impact. Roosting and fledgling success may be disrupted. Abundance of some invertebrate prey may be reduced.	
Black-footed tree-rat (*Mesembriomys gouldii*)	Not listed	n WA, NT, n Qld	No. Loss, fragmentation and degradation of habitat; predation by feral animals.	Lowland to lower montane, in eucalypt forests and woodlands, rainforests, and open coastal forests. Nocturnal, often terrestrial, but forages and nests in trees. Folivore and frugivore, diet supplemented by nectar, invertebrates such as termites and molluscs.	Medium significance; Low to medium impact. Breeding and foraging may be disrupted. Abundance of invertebrate prey and nectar may be reduced.	
Black wallaroo (*Macropus bernardus*)	Not listed	n WA, n NT, n Qld	No. Grazing by introduced ungulates; changes in fire regimes.	Tall open eucalypt forests and woodlands, up to ~700m. Nocturnal, sheltering during day in tree hollows and *Pandanus*. Feeds on fruits and seeds, and invertebrates such as termites and molluscs.	Medium significance; Low impact. Juveniles vulnerable. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Brush-tailed rabbit-rat, Brush-tailed tree-rat (*Conilurus penicillatus*) (Australia subspecies)	V	n WA, n NT, n Qld	No. Habitat loss; inappropriate fire regimes; grazing by livestock; predation by feral animals.	Mixed eucalypt open forests and woodlands, and dunes with *Casuarina*, with grassy ground cover. Nocturnal, shelters in tree hollows, hollow logs and	Medium significance; Low to medium impact. Juveniles vulnerable. Breeding and foraging may be disrupted. Abundance of invertebrate prey may	

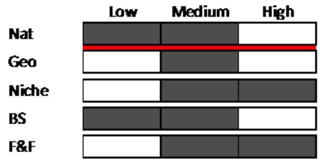
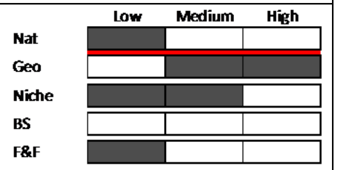
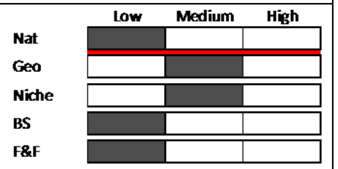
				Pandanus. Granivorous, with diet of grass seed supplemented by other plant material and invertebrates.	be reduced.	
False water-rat, Water mouse (*Xeromys myoides*)	V	n WA, n NT, Qld, ne NSW (also New Guinea)	Yes (2010). Habitat loss and degradation; predation by feral animals.	Coastal. Mangroves and the associated salt-marshes, sedgelands, heathlands and freshwater wetlands. Nesting in mounds and mud ramps. Carnivorous, feeding on estuarine/wetland invertebrates such as crabs, worms and molluscs.	Low significance; Low impact. Nesting and foraging may be minimally disrupted.	
Ghost bat (*Macroderma gigas*)	Not listed	n WA, NT, n Qld	No. Loss of habitat, especially roost sites; predation by feral animals.	Rainforests, monsoonal and vine scrublands, mangroves, and savannah woodlands. Carnivore, commonly feeds on mice, other bats, small birds, legless lizards, geckos, snakes, and invertebrates. Hunting nocturnal, by sit and wait technique. Roosts in caves, mines, etc. Females aggregate in breeding season.	Low to medium significance; Low impact. Roosting and breeding minimally disrupted. Foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced.	
Golden bandicoot (mainland) (*Isoodon auratus auratus*)	V	n WA, n NT	Yes (2003). Threats poorly understood, but likely include predation by feral animals and in appropriate fire regimes.	Rainforest margins, vine thickets, eucalypt woodlands, and heaths. Primarily insectivorous, feeding on arthropods (including ants); also eating plant material,	High significance; Low to medium impact. Juveniles vulnerable. Breeding and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be	

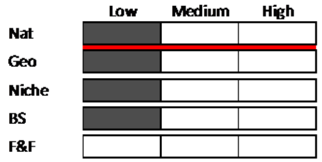
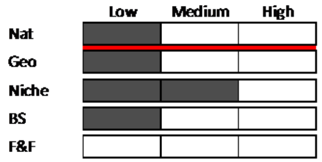
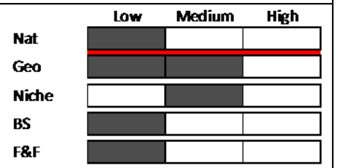
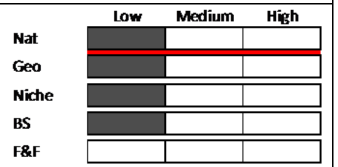
				bird's eggs and reptiles.	reduced.	
Nabarlek, Pygmy rock-wallaby (*Petrogale concinna*)	Not listed	n WA, n NT	No. Yes (2003). Threats poorly understood, but likely include predation by feral animals and in appropriate fire regimes.	Monsoon rainforests, vine thickets, savannah woodlands and hummock grasslands, often associated with rocky hills, cliffs and gorges. Nocturnal, shelters in caves and crevices. Semi-gregarious grazer of grasses and other vegetation.	High significance; Low impact. Breeding and foraging may be minimally disrupted.	
Northern hopping-mouse (*Notomys aquilo*)	V	n NT, n Qld	Yes (2004). Predation by feral animals; habitat disturbance by grazing livestock; mining.	Monsoonal tropics. Prefers coastal sand dunes and sand sheets with a cover of tussock grass or heath. Also found in shrublands, eucalypt open forests, and the margins of coastal rainforest thickets. Forages on ground, for seeds of grasses, herbs and shrubs, but also arthropods. Communal in burrows.	Medium to high significance; Low to medium impact. Juveniles vulnerable. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Northern brush-tailed phascogale (*Phascogale pirata*)	V	n NT	No. Loss of habitat; predation by feral animals; wildfires.	Eucalypt forests. Solitary. Active on ground and arboreally. Nocturnal carnivore, feeds on smaller mammals, birds, lizards, and insects; also nectar from flowering trees. Roosts and nests in hollow trees.	High significance; Low impact. Breeding and foraging may be disrupted. Abundance of invertebrate and some vertebrate prey may be reduced.	

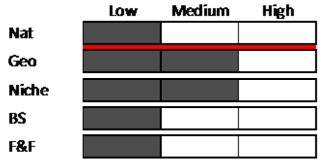
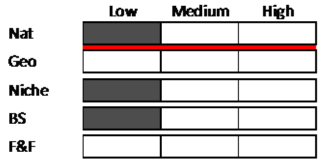
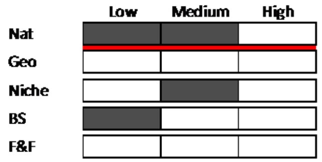
Northern quoll (*Dasyurus hallucatus*)	E	WA, NT, Qld	Yes (2010). Lethal toxic ingestion caused by Cane toad; loss and degradation of habitat; inappropriate fire regimes; predation by feral animals.	Range of habitats including eucalypt forests and woodlands, rainforests, sandy lowlands and beaches, shrublands, grasslands and deserts; especially on rocky ground. Omnivores, feeds on invertebrates, fruits, nectar, bird's eggs, small vertebrates, and carrion.	Low significance; Low to medium impact. Breeding and foraging may be disrupted. Abundance of invertebrate prey and nectar may be reduced.	
Orange leaf-nosed bat (*Rhinonicteris aurantius*)	Not listed	n WA, n NT, n Qld	No. Loss of roost sites; human disturbance of roosts.	Dry season roosts communally in caves. Disperse in wet season, use a diversity of roosts including caves, buildings, and probably tree hollows. Forages in nearby open woodland, catching insects in flight (including ants).	Low significance; Low impact. Roosting may be disrupted. Abundance of invertebrate prey may be reduced.	
Pale field-rat (*Rattus tunneyi*)	Not listed	n WA, n NT, n & e Qld	No. Predation by feral animals; habitat disturbance by grazing livestock; displacement by *Rattus rattus*.	Woodlands, tall grasslands, wallum swamps, and agricultural fields. Nocturnal. Feeds on grass stems, seeds and roots. Rests and dens in shallow burrows.	Low significance; Low impact. Breeding and foraging may be disrupted.	
Pygmy long-eared bat (*Nyctophilus walker*)	Not listed	n WA, n NT, nw Qld	No. Not threatened.	Associated with watercourses through rocky areas surrounded by melaleuca, pandanus, gallery rainforests or Livistona palms. Roosts in trees, especially palms and Pandanus. Insectivore,	Low significance; Low impact. Breeding and roosting may be disrupted. Abundance of invertebrate prey and nectar may be reduced.	

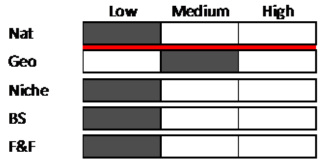
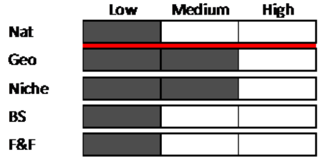
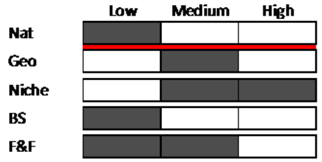
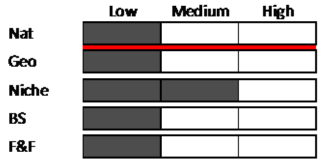
				capturing insects in flight often within 1-2 m of the ground or water surface.		
Short-beaked echidna (*Tachyglossus aculeatus*)	Not listed	ALL AUST (also New Guinea)	No. Not threatened.	Rainforests, open woodlands, semi-arid and arid savannahs, grasslands and heathlands; also agricultural areas. Semi-fossorial, digging for hibernation cover and to construct nursery burrows. Lay a single egg directly into pouch. Young evicted from the pouch (when they start to develop spines) and are left in the burrow; young defenceless. Forages on ants, termites and other invertebrates.	Low significance; Medium impact. Young in nursery burrows highly vulnerable. Abundance of prey may be reduced. Given importance of ants in diet the species may benefit from increased ant abundance. Possibly displaced by ant activity.	
Spectacled hare-wallaby (mainland) (*Lagorchestes conspicillatus leichardti*)	Not listed	n WA, NT, n Qld	No. Predation by feral animals; competition with grazing livestock.	Open forests and woodlands, tall shrublands, tussock grasslands and hummock grasslands. Solitary, nocturnal herbivore.	Low significance; Low impact. Roosting, breeding and foraging may be disrupted.	
Reptiles						
Arnhem land skink (*Bellatorias obiri*)	E	n NT	No. Threats poorly understood.	Largely restricted to sandstone outcrops, typically with extensive fissures and cave systems. Ground-dwelling. Probably at least partly nocturnal or crepuscular. Insectivore. Oviparous.	High significance; Low impact. Minimal geographic overlap. Young potentially vulnerable. Breeding and foraging may be disrupted. Abundance of prey may be reduced, but possibly off-set in part by increased	

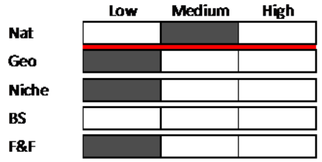
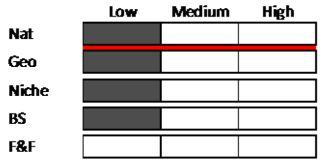
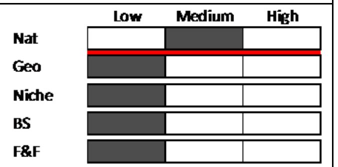
					ant abundance. Rare	
Arafura snake-eyed skink (*Cryptoblepharus gurrmul*)	Not listed	n NT	No. Restriction to three small islands presents a substantial risk.	SRE. Littoral habitats, including beach sands, rocks and coral rubble. Forages amongst rocks in intertidal zone, and retreats to fringing vegetation when confronted by an incoming tide; feeds on both terrestrial and marine small invertebrates. Oviparous.	High significance; Medium impact. Young potentially vulnerable. Breeding and foraging may be disrupted. Abundance of prey may be reduced, but possibly off-set in part by increased ant abundance. Restricted to several islands	
Beach snake-eyed skink, Supralittoral shinning-skink (*Cryptoblepharus litoralis*)	Not listed	n NT, e Qld (also New Guinea)	No.	Coastal, rocky outcrops on beaches and headlands. Diurnal. Insectivore. Oviparous.	Low significance; Low impact. Young potentially vulnerable. Breeding and foraging may be disrupted. Abundance of some invertebrate prey may be reduced.	
Brown tree snake (*Boiga irregularis*)	Not listed	n WA, n NT, n Qld (also New Guinea, nw Melanesia)	No.	Rainforests. Nocturnal. Arboreal, feeds on small mammals, lizards and birds (including eggs and nestlings). Oviparous, eggs laid in log hollows, rock crevices, etc.	Low significance; Low impact. Young potentially vulnerable. Breeding and foraging minimally disrupted. Abundance of some vertebrate prey may be reduced.	
Carpet pythons (*Morelia spilota*)	Not listed	WA, NT, Qld, NSW, Vic, SA (also Indonesia and New Guinea)	No.	Rainforests, woodlands, savannah and grasslands. Semi-arboreal, largely nocturnal. Diet consists mainly of small mammals,	Low significance; Low impact. Young potentially vulnerable. Breeding and foraging minimally	

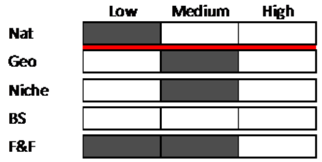
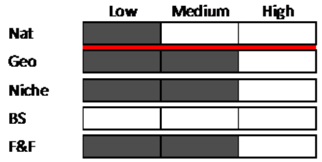
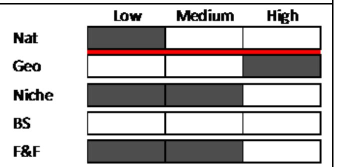
				bats, birds and lizards. Oviparous, eggs incubated by female.	disrupted. Abundance of some vertebrate prey may be reduced.	
Chameleon dragon (*Chelosania brunnea*)	Not listed	n WA, n NT, nw Qld	No. Wildfires; predation by feral animals.	Monsoonal rainforests, eucalypt forests and woodlands. Arboreal but frequently on ground; females descend to dig nest holes. Insectivorous, with Green ants *Oecophylla smaragdina* evidently important diet items. Oviparous.	Low to medium significance; Medium impact. Potentially vulnerable, especially at pipping and juvenile stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey, especially /green ants, likely reduced.	
Estuarine crocodile, Saltwater crocodile (*Crocodylus porosus*)	Not listed (Marine)	n WA, n NT, n Qld (also India, SE Asia, W Pacific)	No.	Coastal, but also far upstream and in many freshwater swamps and billabongs. Young feed on insects, crabs, prawns and shrimps, but as they grow in size the amount of vertebrate material in the diet increases. Oviparous. Hatchlings carried by female to water.	Low significance; Low impact. Breeding and foraging unlikely disrupted. Abundance of invertebrate and some vertebrate prey may be reduced.	
Green snake, Common tree snake (*Dendrelaphis punctulata*)	Not listed	WA, NT, Qld, n NSW (also New Guinea)	No.	Rainforests to woodlands, and urban areas, especially near water. Diurnal. Active on ground and arboreally, feeds on frogs, lizards, fish, and frogs. Rest at night in hollow trees, logs, foliage, and rock crevices. Oviparous.	Low significance; Low impact. Breeding and foraging may be disrupted. Abundance of some vertebrate prey may be reduced.	

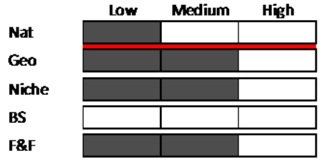
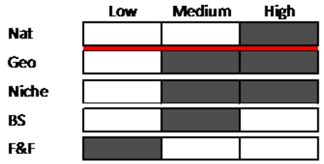
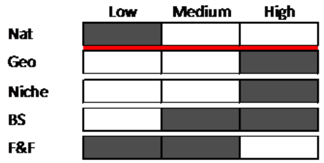
Green turtle (*Chelonia mydas*)	V (Marine)	WA, NT, Qld, NSW, Vic, SA, LH (tropical and subtropical waters throughout the world)	Yes (2003). Loss of nesting sites to urban development; human disturbance; predation by feral animals.	Marine. Pelagic as young. More inshore as adults, mainly feeding on seagrass and algae. Oviparous. Nests on sandy beaches.	Low significance; Low impact. Vulnerable in pipping and hatchling stages. Breeding may be disrupted.	
Flatback turtle (*Natator depressus*)	V (Marine)	WA, NT, Qld, NSW, CI	Yes (2003). Human activities such as commercial and recreational fishing; coastal development; Indigenous harvest; predation by feral animals.	On continental shelf of northern Australia. Marine. Bays, coral reefs, estuaries and lagoons. Benthic feeding on seagrass, invertebrates including molluscs, jellyfish and shrimp, soft corals and sea cucumbers; and on fishes. Oviparous. Nests on sandy beaches.	Low significance; Low impact. Vulnerable in pipping and hatchling stages. Breeding may be disrupted.	
Floodplain monitor, Argus monitor (*Varanus panoptes*)	Not listed	WA, NT, Qld (also New Guinea)	No. Poisoning by cane toads.	Diverse habitats, including beaches, dunes, woodlands and shrublands, around permanent water. Primarily ground-dwelling, with extensive burrowing; but will forage arboreally. Carnivore, preying on fish, crabs, small birds, rodents, insects and other reptiles and their eggs. Oviparous.	Low significance; low impact. Potentially vulnerable in pipping stage. Breeding and foraging minimally disrupted. Abundance of some invertebrate and vertebrate prey may be reduced.	
Hawksbill turtle (*Eretmochelys imbricata*)	V (Marine)	WA, NT, Qld, NSW, e Vic, CI, LH, NI (global in subtropical to tropical	Yes (2003). Habitat disturbance; by-catch from fisheries and shark control.	Open ocean to lagoons and mangrove swamps in estuaries. Young entirely pelagic. Adults in-shore, benthic, feeding on	Low significance; Low impact. Vulnerable in pipping and hatchling stages. Breeding may be disrupted.	

		waters)		sponges, jellyfish, sea anemones and algae. Oviparous. Nests on sandy beaches.		
King brown snake, Mulga snake (*Pseudechis australis*)	Not listed	WA, NT, Qld, NSW, ACT, SA	No. Not threatened.	Woodlands, hummock grasslands, chenopod scrublands and sparsely vegetated gibber or sandy deserts. Nocturnal; usually shelters under woody debris, burrows and deep soil cracks. Carnivorous, preys on lizards, snakes, birds, mammals and frogs. Oviparous.	Low significance; Low impact. Potentially vulnerable in pipping stage. Breeding and foraging minimally disrupted. Abundance of some vertebrate prey may be reduced.	
Leathery turtle, Luth (*Dermochelys coriacea*)	E (marine)	All coastal AUS (tropical, subtropical and temperate waters throughout the world)	Yes (2003). Minimal on-shore threats.	Pelagic feeder on soft-bodied creatures such as jellyfish and tunicates. Oviparous. Nesting on sandy beaches. No recent records on nesting in eastern Australia.	Low significance; No impact. Vulnerable in pipping and hatchling stages, but nesting not important in Northern Territory.	
Loggerhead turtle (*Caretta caretta*)	E (Marine)	ALL AUST (coastal marine) (global distribution throughout tropical, sub-tropical and temperate waters)	Yes (2003). Loss of nesting sites to urban development; predation by feral animals.	Marine. Carnivorous, feeding primarily on marine benthic invertebrates. Oviparous. Nests on beaches.	Low to medium significance; Low impact. Vulnerable in pipping and hatchling stages. Breeding and foraging may be disrupted, but nesting not important in Northern Territory.	

Mertens' water monitor (*Varanus mertensi*)	Not listed	n WA, n NT, n Qld	No.	Coastal and inland waters. Semi-aquatic, only climbing onto rocks or tree-trunks lying at the shore for sunbasking. Opportunistic predator in aquatic and riparian habitats, feeding on fish, crabs, frogs, small mammals, and insects. Oviparous.	Low significance; Low impact. Abundance of non-aquatic invertebrate and some vertebrate prey may be reduced, but effect likely minimal.	
Mitchell's water monitor (*Varanus mitchelli*)	Not listed	n WA, NT	No.	Around swamps, lagoons, inland rivers and other water bodies. Arboreal. Shelters in tree hollows and under bark. Carnivorous, foraging terrestrially and aquatically on lizards, small mammals, nestling birds, reptile eggs, terrestrial invertebrates crabs, frogs and fish.	Low significance; Low impact. Potentially vulnerable in pipping stage. Breeding and foraging minimally disrupted. Abundance of some invertebrate and vertebrate prey may be reduced.	
Northern death adder (*Acanthophis praelongus*)	Not listed	n WA, n NT	No.	Woodlands and scrublands. In leaf litter. Carnivore, primarily taking birds and small mammals, but also insects (ants not included), frogs, and lizards as prey. Produce litters of live young.	Low significance; Low impact. Vulnerable as juveniles. Breeding and foraging may be disrupted. Abundance of invertebrate and some vertebrate prey may be reduced.	
Northern ridge-tailed monitor (*Varanus primordius*)	Not listed	n NT	No.	Savannah woodlands, on stony ground. Shelters under rocks, and in crevices and burrows. Predatory, feeds on small	Low significance; Low impact. Minimal geographic overlap. Potentially vulnerable in pipping	

				arthropods (including ants), geckos and skinks. Oviparous.	stage. Breeding and foraging minimally disrupted. Abundance of some invertebrate and vertebrate prey may be reduced, but possibly off-set in part by increased ant abundance.	
Oenpelli python (*Morelia oenpelliensis*)	Not listed	NT	No. Land use changes; inappropriate fire regimes; illegally collection.	Woodlands, heathlands, open rocky plains, and sparsely wooded sandstone outcrops. Nocturnal. Territorial. Shelters in caves, rock crevices, and trees. Arboreal and terrestrial carnivore, preying on birds and small to medium sized mammals. Oviparous.	Medium significance; Low impact. Minimal geographic overlap. Foraging minimally disrupted. Abundance of some vertebrate prey may be reduced.	
Olive ridley, Pacific ridley (*Lepidochelys olivacea*)	E (Marine)	n WA, n NT, Qld, CI (widespread globally)	Yes (2003).	Inshore benthic and pelagic foraging. Migratory. Feeds on various invertebrates and algae.	Low significance; Low impact. Vulnerable in pipping and hatchling juvenile stages. Breeding may be disrupted.	
Pig-nosed turtle (*Carettochelys insculpta*)	Not listed	NT (also New Guinea)	No.	Freshwater river systems; prefers large, still bodies of water and sandy riverbeds. Wholly aquatic, except for nesting on river banks. Forages on plant material, insects and molluscs.	Medium significance; Low impact. Vulnerable in pipping and hatchling juvenile stages. Breeding may be disrupted. Abundance of some invertebrate prey may be reduced.	

Yellow-snouted gecko (*Lucasium occultum*)	E	n NT	No. Inappropriate fire regimes; spread of exotic pasture grasses.	Open eucalypt forests. Ground dwelling, in leaf litter and grass. Insectivorous. Oviparous.	High significance; Low impact. Very low geographic overlap. Vulnerable in all life stages. Breeding and foraging may be disrupted. Abundance of invertebrate prey may be reduced, but possibly off-set by increased any abundance..	
Amphibians						
Australian wood frog, Water frog (*Rana daemeli*) [*Hylarana daemeli*]	Not listed	e NT, n Qld (also New Guinea)	No.	Rainforests and mesic woodlands, generally near water. Semi-aquatic, with aquatic breeding. Insectivore.	Low significance; Low impact. Vulnerability in non-aquatic stages unknown. Foraging may be disrupted. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Marbled frog (*Limnodynastes convexiusculus*)	Not listed	n WA, NT, n Qld	No.	Swampy areas among long grass. Ground-dwelling. Insectivore. Aquatic breeder.	Low significance; Low impact. Vulnerability in non-aquatic stages unknown. Foraging may be disrupted. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Northern dwarf tree Frog (*Litoria bicolor*)	Not listed	n WA, n NT, n Qld (possibly also Indonesia)	No.	Woodlands, grasslands and marshy areas. Arboreal. Aquatic breeder in permanent and semi-permanent water bodies.	Low significance; Low impact. Vulnerability in non-aquatic stages unknown. Foraging may be	

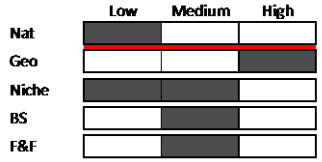
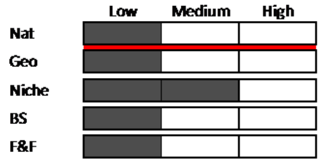
					disrupted. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance	
Ornate burrowing frog (*Platyplectrum ornatum*)	Not listed	n WA, NT, Qld, n NSW	No.	Seasonally inundated habitats. Found in dry sandy watercourses some distance from permanent water. Ground-dwelling. Insectivore. Shelters and aestivates in burrows. Breeding aquatic.	Low significance; Low impact. Vulnerability in non-aquatic stages unknown. Foraging may be disrupted. Abundance of invertebrate prey may be reduced; possibly off-set partially by increased ant abundance.	
Invertebrates						
Gove crow butterfly (*Euploea alcathoe enastri*)[1, 3]	E	n NT	Yes (2008). YCA listed as a threatening process.	SRE. Rainforests (evergreen monsoon vine-forest) associated with permanent groundwater seepages. Adults feed at blossoms of *Melaleuca* sp., *Tylophora benthamii* and possible other plants. Larval hosts *Gymnanthera oblonga* and *Parsonsia alboflavescens*.	High significance; Medium impact. Immature stages vulnerable. Breeding and foraging may be disrupted. Abundance of nectar may be reduced	
Weaver ant, Green tree ant (*Oecophylla smaragdina*)[2]	Not listed	n WA, n NT, n Qld (also India to SE Asia and Orient)	No. Not threatened.	Rainforests, vine thickets, closed forests, and heaths. Nests arboreal, built by stitching living tree and shrub leaves together with silk produced by special glands in the larvae. Forage on ground and arboreally. Predate	Low significance; Medium to high impact. Nest brood and foraging ants vulnerable. Abundance of invertebrate prey and nectar may be reduced.	

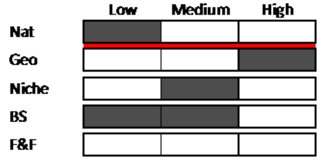
				arthropods and other invertebrates; also tend aphids, scale insects, and the caterpillars of some butterfly species that produce honeydew.		

Appendix 4 References

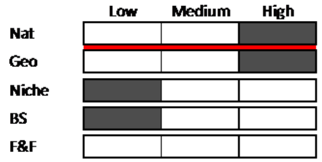
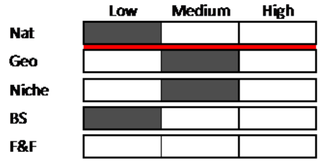
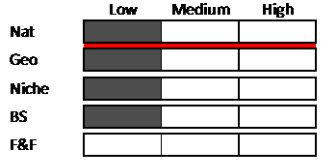
1. Braby, M. 2007. National Recovery Plan for the Gove Crow Butterfly *Euploea alcathoe enastri*, Department of Natural Resources, Environment and the Arts, Northern Territory.
2. Hoffmann, B.D. and W.-C. Saul. 2010. Yellow crazy ant (*Anoplolepis gracilipes*) invasions within undisturbed mainland Australian habitats: no support for biotic resistance hypothesis. *Biological Invasions*.
3. Commonwealth of Australia. 2006. Background document for the threat abatement plan to reduce the impacts of tramp ants on the biodiversity in Australia and its territories, Department of the Environment and Heritage: Canberra.

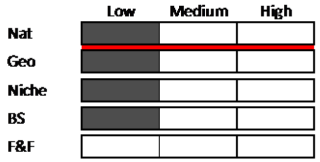
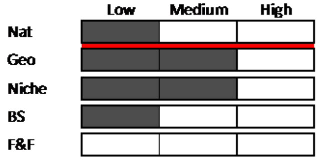
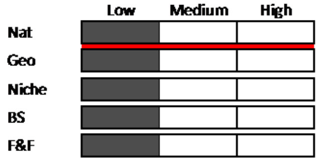
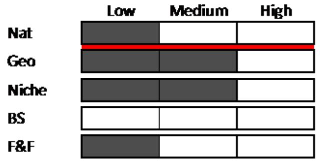
Appendix 5 Rapid assessment of native species potentially at risk from Yellow crazy ant in the Indian Territory Islands Bioregion (Christmas Island)

Common Name (scientific name)	EPBC Act Listing Status	Range	Recovery Plan	Habitat and behaviour	Potential or presumed level of impact and mechanisms for Yellow crazy ant effect	
Birds						
Abbott's booby (*Papasula abbotti*)[1, 3, 4, 19]	E (Marine)	CI (formerly other Indian Ocean islands)	Habitat loss and degradation through mining	SRE. Feeds in warm, low salinity waters, taking squid and fish. Nests in emergent and canopy rainforest trees. Productivity extremely low, with a pair needing nearly 30 years to replace themselves.	High significance; Low impact. Nesting and fledgling success may be disrupted.	
Australian kestrel, Nankeen kestrel (*Falco cenchroides*)	Not listed	WA, NT, Qld, NSW, ACT, Vic, Tas, SA, CI (also New Caledonia; Norfolk Island, Lord Howe; Papua New Guinea; vagrant New Zealand, Cocos (Keeling) Islands)	No. Not threatened.	Woodlands. Partially migratory. Forages mostly in open habitat, feeding on insects, and small birds, reptiles and mammals. Nests in tree hollows, cliff ledges, etc., and occasionally on the ground.	Low significance; Medium impact. Nesting and fledgling success may be disrupted. Abundance of invertebrate and vertebrate prey likely reduced.	
Azure kingfisher (*Ceyx azurea*) [=*Alcedo azurea*]	Not listed	WA, NT, Qld, NSW, Vic, e SA, Tas (also New Guinea, Moluccas)	No. Degradation of wetland waters.	Near water - ponds, rivers, lakes and mangroves. Diet mostly fish and insects. Roosts arboreal. Nests in burrows in earth banks and cliffs.	Low significance; Low impact. Nesting attempts and fledgling success may be disrupted. May compete with ants for nest sites. Abundance of invertebrate and vertebrate prey may be reduced.	

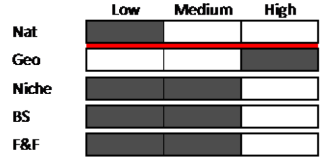
Brown booby (*Sula leucogaster*)	Marine	WA, NT, Qld, CI (also Indian and Pacific oceans)	No.	Tropical oceans, feeding on fish, squid and some other cephalopods. Nests on ground.	Low significance; Low to medium impact. Nesting and fledgling success may be disrupted.	
Christmas Island emerald dove (*Chalcophaps indica natalis*)[1, 3, 4, 19]	E	CI	Yes (2000). Yellow crazy ant listed as a threat.	SRE. Rainforest. Feeds on seeds and fruit on forest floor. Nests in tops of rainforest trees and other dense vegetation.	High significance; Medium impact. Nesting and fledgling success, and foraging may be disrupted.	
Christmas Island frigatebird (*Fregata andrewsi*)[1, 3, 4, 7, 19]	V (Marine)	CI	Yes (2004). Yellow crazy ant listed as a threat.	SRE. Migratory. Foraging in low densities over the Indian Ocean and throughout the Indo-Malay Archipelago. Feeds predominately on flying fish, squid and other marine species, and stealing food from other birds on the wing. Nests in rainforest trees. Productivity low.	High significance; Low to medium impact. Nesting and fledgling success may be disrupted.	
Christmas Island glossy swiftlets (*Collocalia esculenta natalis*)3	Not listed	CI	No. Not threatened.	SRE. Rainforests and shrublands. Diurnal. Nests in caves and feeds over most habitats, including settlements, secondary forest and primary rainforests. Aerial insectivore, with flying ants predominant diet.	High significance; Low impact. Nesting and fledgling success may rarely be disrupted. Abundance of invertebrate prey likely be reduced.	
Christmas Island goshawk (*Accipiter hiogaster natalis*)[1, 3, 4, 5, 19]	E	CI	Yes (2004). Yellow crazy ant listed as a threat.	SRE. Range of forest types. Diurnal. Feeds on invertebrates and small vertebrates (birds, mammals, reptiles), either gleaned from ground or caught in flight. Nests in canopy.	High significance; Medium impact. Nesting and fledgling success may rarely be disrupted. Abundance of invertebrate and vertebrate prey likely reduced.	

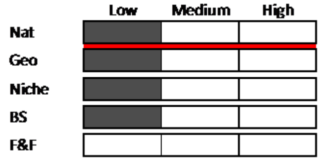
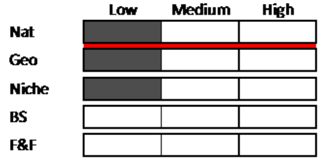
Christmas Island hawk-owl (*Ninox natalis*)[1, 3, 4, 6, 19]	V	CI	Yes (2004). Yellow crazy ant listed as an extreme threat.	SRE. Rainforest. Nests in tree hollows. Mostly active in forest subcanopy. Feeds on invertebrates and some vertebrates.	High significance; Medium to high impact. Nesting and fledgling success may rarely be disrupted. Abundance of invertebrate and vertebrate prey likely reduced.	
Christmas Island imperial-pigeon (*Ducula whartoni*)[1, 4, 14]	Not listed	CI	Not threatened.	SRE. Rainforests. Active in canopy and subcanopy. Frugivore, feeding on fruit, and occasionally buds and leaves in the canopy.	High significance; Low impact. Nesting and fledgling success, and foraging may rarely be disrupted.	
Christmas Island thrush (*Turdus poliocephalus erythropleurus*)[1, 3, 4, 19]	E	CI	No. Yellow crazy ant considered primary threat.	SRE. Rainforests and shrublands. Omnivore, forages primarily on the forest floor, but also in understory vegetation for invertebrates, small vertebrates, and fruits. Nests in canopy to subcanopy.	High significance; Medium to high impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate and vertebrate prey likely reduced.	
Christmas Island white-eye (*Zosterops natalis*)[1, 3, 4]	Not listed	CI	No. Not threatened.	SRE. Rainforests and shrublands. Insectivore, nectarivore, and frugivore foraging in the forest understory and canopy, and rarely on the forest floor. Nests in forest canopy and subcanopy.	High significance; Low impact. Nesting and fledgling success, and foraging may rarely be disrupted. Abundance of invertebrate prey likely reduced, but off-set by increase in ant and Homoptera numbers.	

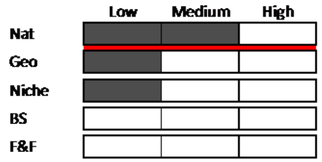
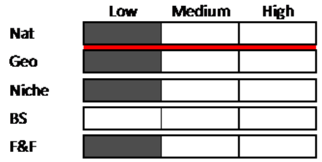
Christmas Island white-tailed tropicbird, Golden bosunbird (*Phaethon lepturus fulvus*)[1, 4]	Marine	CI	No. Not threatened.	SRE. Forages in warm waters, feeding on fish and various marine molluscs. Roosts at sea, except when nesting. Nests in tree hollows and inland cliffs, and occasionally on ground.	High significance; Low impact. Nesting and fledgling success may rarely be disrupted.	
Common noddy (*Anous stolidus*)[4]	Marine	WA, NT, Qld, CI, LH, NI (widespread globally)	No. Not threatened.	Migratory. Forages inshore waters and up to 50 km out to pelagic zone. Diet of small fish, as well as pelagic molluscs, medusae and insects. Nest sites variable, in tree hollows, low vegetation, inland cliffs, and on open ground and amongst rocks.	Low significance; Low impact. Nesting and fledgling success may rarely be disrupted.	
Eastern reef egret (*Egretta sacra*)	Marine	(also widely distributed Asia, Pacific)	No. Not threatened.	Beaches, rocky shores, tidal rivers and inlets, mangroves, and exposed coral reefs. Diet primarily marine fish, crustaceans and molluscs. Nests arboreally.	Low significance; Low impact. Nesting and fledgling success may rarely be disrupted.	
Great frigatebird (*Fregata minor*)	Marine	n WA, n NT, n Qld, CI (Pacific, Indian and Atlantic Oceans)	No. Not threatened.	Feed on fish and squid in pelagic waters within 80 km of breeding colonies or roosting areas. Migratory. Nesting colonial, in bushes and trees (and on the ground in the absence of vegetation).	Low significance; Low impact. Nesting and fledgling success may rarely be disrupted.	
Lesser frigatebird (*Fregata ariel*)	Marine	n WA, n NT, n Qld, CI (Pacific, Indian and Atlantic Oceans)	No. Not threatened.	Diet mainly squid and flying fish; also feeds on seabird eggs and chicks, carrion and fish scraps. Kleptoparasitic. Migratory. Nesting colonial, in bushes and trees.	Low significance; Low impact. Nesting and fledgling success may rarely be disrupted.	

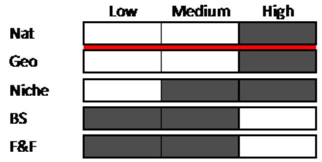
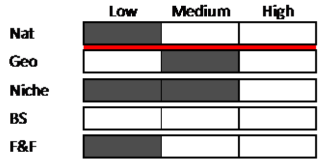
Red-footed booby (*Sula sula*)[4]	Marine	n WA, n Qld, CI (Pacific, Indian and Atlantic Oceans)	No. Not threatened.	Migratory. Pelagic, up to 150 km from nearest breeding island, foraging on fish and squid. Nesting colonial, on beaches, ridges of atolls and cays, and slopes of mountainous islands; generally at low elevations. Nests in forest canopy.	Low significance; Low impact. Nesting and fledgling success may rarely be disrupted.	
Red-tailed tropic bird (*Phaethon rubricauda*)[3]	Marine	WA, NT, Qld, CI, LH, NI (widespread Indian and Pacific Oceans)	Yes (2010).	Pelagic, foraging on squid, fish and crustaceans. Non-migratory but nomadic. Nests a scrape on ground in inaccessible cliffs.	Low significance; Low impact. Nesting and fledgling success may be disrupted.	
White-breasted water-hen (*Amaurornis phoenicurus*)	Not listed	CI (also Southeast Asia and the Indian Subcontinent)	No. Not threatened.	Usually near freshwater, but also found near brackish water and seashore. Forages on the ground and low vegetation, feeding on insects, small fish, aquatic invertebrates and seeds. Nest on the ground.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted.	
White-faced heron (*Ardea novaehollandiae*)	Not listed	WA, NT, Qld, NSW, ACT, Vic, SA, Tas, CI, LH, NI (also New Guinea, Indonesia, New Caledonia, New Zealand; vagrant se Asia, Cocos Islands, Solomon Islands)	No. Not threatened.	Mainly diurnal. Forages in wet grasslands, wetlands, estuaries and lagoons. Locally nomadic, and dispersive in non-breeding season. Diet highly varied – invertebrates and small vertebrates. Nests in trees.	Low significance; Low impact. Abundance of some invertebrate and vertebrate prey may be reduced.	
Mammals						

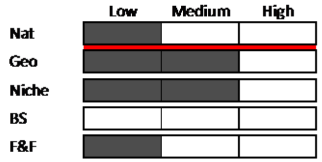
Christmas Island flying fox (*Pteropus melanotus natalis*)[1, 4, 19]	Not listed	CI	No.	SRE. Range of forested habitats, primarily semi-deciduous and evergreen rainforests. Diurnal. Roosts in canopy, often communally. Feeds on fruit, flowers, leaves and pollen.	High significance; Low to medium impact. All life stages vulnerable. Breeding success and foraging may be disrupted.	
Christmas Island pipistrelle (*Pipistrellus murrayi*)[1, 2, 4, 8, 9, 19]	CE	CI	Yes (2004). Threats remain poorly understood, but include loss of roost sites; predation by feral animals; and invasive species. Yellow crazy ant mentioned as possible threat.	SRE. Roost in trees, in hollows and under bark of dead trees, and in *Pandanus*. Torpid state during day-roosting. Nocturnal. Insectivore, taking prey in flight and gleaned from foliage and branches (includes ants). Young left unattended in the roost.	High significance; Medium to high impact. Roosting may be disrupted, and loss of young at roost sites. Abundance of invertebrate prey may be reduced.	
Christmas Island shrew (*Crocidura attenuata trichura*)[1, 4, 13, 19]	E	CI	Yes (2004). Yellow crazy ant identified as a threat.	SRE. Rainforests. Likely burrowing and sheltering in leaf litter, woody debris and under rocks and tree roots on forest floor. Insectivorous. Breeding in nests/dens.	High significance; Medium to high impact. Breeding success and foraging may be disrupted. Abundance of invertebrate prey likely reduced.	
Reptiles						
Blue-tailed skink, Blue-tailed snake-eyed skink (*Cryptoblepharus egeriae*)[4, 10, 11, 19]	Not listed [nomination for listing as CE in review]	CI	No.	SRE. Rainforests. Diurnal. Most active on forest floor and lower vegetation tiers, particularly in canopy gaps and tree-falls; extends to canopy. Burrowing for shelter and breeding. Carnivore, preying on insects, earthworms and probably	High significance; Medium to high impact. Breeding success and foraging may be disrupted. Abundance of invertebrate prey likely reduced.	

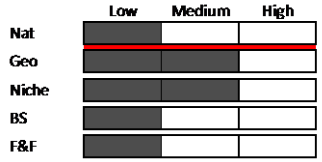
				other invertebrates. Oviparous.		
Christmas Island blind snake (*Ramphotyphlops exocoeti*)[1, 4, 10, 12, 15]	V	CI	Yes (2006). Predation by and competition with feral/introduced species; habitat loss, fragmentation and degradation. Yellow crazy ant identified as a threat.	SRE. Rainforests. Fossorial, in soil and leaf litter. Probably preying on the eggs, larvae and pupae of ants and termites.	High significance; Medium impact. Breeding success and foraging may be disrupted. Abundance of invertebrate prey likely reduced. Suitability of Yellow crazy ant as prey is unknown.	
Christmas Island gecko (*Lepidodactylus listeri*)[1, 4, 10, 12, 15, 19]	V	CI	Yes (2006). Predation by and competition with feral/introduced species; habitat loss, fragmentation and degradation. Yellow crazy ant identified as a threat.	SRE. Rainforests and secondary forested areas. Nocturnal. Active on tree trunks from near ground to upper canopy. Shelters in the day under bark of living or dead trees. Predator, feeding on invertebrates. Oviparous, eggs deposited under bark and on trunks.	High significance; Medium to high impact. Breeding success and foraging may be disrupted. Abundance of invertebrate prey likely reduced.	
Coastal skink, Mangrove skink (*Emoia atrocostata*)[10, 11]	Not listed [nomination of CI population for listing is in review]	CI (also southeast Asia/ Oceania and Pacific)	No.	Specialist forager of intertidal zone of rocky coasts and adjacent fringing limestone rock outcrops, feeding on insects (including ants) and small crabs. Able swim well, but prefer to retreat to higher ground at high tide. Oviparous.	Low significance; Low to medium impact. Breeding success and foraging may be disrupted. Abundance of some invertebrate prey likely reduced, but possibly off-set in part by increased ant abundance.	

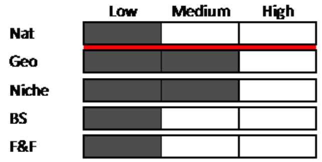
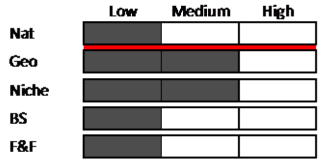
Forest skink (*Emoia navitatus*)[10, 11, 16, 19]	Not listed	CI	No.	SRE. Rainforests, associated with forest clearings, usually in leaf litter but occasionally on low vegetation and tree buttresses. Predator, feeding on invertebrates. Oviparous.	High significance; Medium to high impact. Breeding success and foraging may be disrupted. Abundance of invertebrate prey likely reduced.	
Giant gecko, Christmas Island giant gecko (*Cyrtodactylus sadlieri*)[10, 19]	Not listed [nomination for listing as Vulnerable in review]	CI	No.	SRE. Rainforest. Nocturnal, active on ground and in trees and shrubs well below forest canopy. Feeds on invertebrates. Oviparous, eggs deposited under logs and other debris on forest floor.	High significance; Low to medium impact. Breeding success and foraging may be disrupted. Abundance of invertebrate prey likely reduced.	
Green turtle (*Chelonia mydas*)[1]	V (Marine)	WA, NT, Qld, NSW, Vic, SA, LH (tropical and subtropical waters throughout the world)	Yes (2003). Loss of nesting sites to urban development; human disturbance; predation by feral animals.	Marine. Pelagic as young. More inshore as adults, mainly feeds on seagrass and algae. Oviparous. Nests on sandy beaches.	Low significance; Low impact. Vulnerable in pipping and hatchling stages. Breeding may be disrupted.	
Hawksbill turtle (*Eretmochelys imbricata*)[1]	V (Marine)	WA, NT, Qld, NSW, e Vic, CI, LH, NI (global in subtropical to tropical waters)	Yes (2003). Habitat disturbance; by-catch from fisheries and shark control.	Open ocean to lagoons and mangrove swamps in estuaries. Young entirely pelagic. Adults in-shore, benthic, feeding on sponges, jellyfish, sea anemones and algae. Oviparous. Nests on sandy beaches.	Low significance; No impact. Vulnerable in pipping and hatchling stages, but no breeding at CI.	
Leatherback turtle (*Dermochelys coriacea*)	E (Marine)	All coastal AUS (tropical, subtropical and temperate waters throughout the	Yes (2003). Minimal on-shore threats.	Pelagic feeder on soft-bodied creatures such as jellyfish and tunicates. Oviparous. Nesting on sandy beaches.	Low significance; No impact. Vulnerable in pipping and hatchling stages, but breeding not important at CI.	

		world)				
Loggerhead turtle (*Caretta caretta*)	E (Marine)	ALL AUST (coastal marine) (global distribution throughout tropical, sub-tropical and temperate waters)	Yes (2003). Loss of nesting sites to urban development; predation by feral animals.	Marine. Carnivorous, feeding primarily on marine benthic invertebrates. Oviparous. Nests on beaches.	Low to medium significance; No impact. Vulnerable in pipping and hatchling stages, but not breeding at CI.	
Invertebrates						
Blue crab (*Discoplax celeste*) [formerly as *Discoplax hirtipes*][4, 19]	Not listed	CI	No.	SRE. Moist areas with water seepages. Diurnal. Leaf litter, in water-filled burrows. Feeds on fallen leaves and fruits; also on other crabs. Females migrate to spawning in the ocean; marine larval development. Young migrate up freshwater streams to the forest.	High significance; Low impact. Breeding migrations and foraging may be disrupted.	
Brown crab (*Epigrapsus politus*)	Not listed	CI (widely distributed Indo-Pacific)	No.	Beach sand/rubble boundary on forest soil, usually under rocks. Omnivores. Spawning in ocean; marine planktonic larval development.	Low significance; Low impact. Foraging may be disrupted.	
Jackson's crab (*Karstarma jacksoni*) [formerly *Sesarmoides jacksoni*]	Not listed	CI	No.	SRE. Cool moist areas on lower terraces, in caves and deep crevices. Spawning in ocean; marine planktonic larval development.	High significance; Low impact. Foraging may be disrupted.	

Little nipper (*Geograpsus grayi*)[19]	Not listed	CI (also Indian and Pacific Oceans)	No	Distributed from shore terrace to plateau. Diurnal. Does not burrow - lives under rocks, tree roots. Omnivore, feeding on insects, decaying plant matter and carrion. Spawning in ocean; marine planktonic larval development.	Low significance; Low to medium impact. Breeding migrations and foraging may be disrupted.	
Mottled crab (*Metasesarma rousseauxi*)	Not listed	CI (also East Africa to Pacific)	No.	Leaf litter above beaches. Spawning in ocean; marine planktonic larval development.	Low significance; Low impact. Foraging may be disrupted.	
Purple crab (*Gecarcoidea lalandii*) [Possibly conspecific with Red land crab]	Not listed	CI (also South East Asia; Western Pacific)	No.	Rainforests. Diurnal. In burrows in moist soil. Largely herbivorous, but also scavenging on carrion and predaceous on invertebrates). Annual migration to coast to mate in burrows and females spawn in the sea. Marine planktonic larval development.	Low significance; High impact. Breeding migrations and foraging may be disrupted. Abundance of some invertebrate prey likely reduced.	
Purple hermit crab (*Coenobita brevimana*)	Not listed	CI (also Indo-Pacific)	No.	Beaches, and shore terraces, including rainforests close to source of empty shells. Mostly nocturnal. Fills shell with fresh or brackish water. Omnivorous scavengers, feeding on plant and animal matter, including fallen fruit, rotting wood and carrion. Spawning in ocean; marine planktonic larval development.	Low significance; Low impact. Foraging may be disrupted.	

Red hermit crab, Strawberry hermit crab (*Coenobita perlata*)	Not listed	CI (widespread in Indo-Pacific)	No.	Beaches and upper-littoral cliffs. Nocturnal. Returns to the sea at night to refresh its water reservoir in the shell. Omnivorous scavengers, feeding on plant and animal matter, including fallen fruit, rotting wood and carrion. Spawning in ocean; marine planktonic larval development.	Low significance; Low impact. Foraging may be disrupted.	
Red land crab (*Geocarcoidea natalis*)[1, 4, 11, 18, 19]	Not listed	CI and the Cocos (Keeling) Islands	No.	SRE. Rainforests. Diurnal. Burrowing in moist soil. Annual migration to coast to mate in burrows and females spawn in the sea. Marine planktonic larval development. Mass recruitment of 'crablings' from ocean highly variable among years. Largely herbivorous, but also scavenging on carrion and predaceous on invertebrates).	High significance; High impact. Breeding migrations and foraging may be disrupted. Abundance of some invertebrate prey likely reduced.	
Red nipper (*Geograpsus stormi*)	Not listed	CI (also East Africa to Pacific)	No.	Supralittoral, under shoreline rocks and in crevices on the seacliff near water. Nocturnal. Spawning in ocean; marine planktonic larval development. Scavenger on crustacean and other carrion.	Low significance; Low impact. Foraging may be disrupted.	
Robber crab, Coconut crab (*Birgus latro*)[4, 17, 18, 19]	Not listed	CI (widespread Indo-Pacific Oceanic islands)	No.	Diurnal to circadian. Terrestrial, but good climber. Omnivorous, feeds on coconuts and other fruits, as well as smaller crabs, and	Medium to high significance; High impact. Breeding migrations and foraging may be	

				carrion. Mating on land; females retain the fertile eggs under their abdomen for several months; once hatched, females deposit nymphs in the ocean. Planktonic larval development. Following metamorphosis to hermit crab form, emerge onto the shore and inhabit progressively larger mollusc shells before assuming an adult form.	disrupted. CI important breeding pop	
Tawny hermit crab (*Coenobita rugosa*)	Not listed	CI (also Indo-Pacific)	No.	Beaches and dune systems. Forage for food along the strandline. Nocturnal. Shelters by day in leaf litter. Omnivorous scavengers, feeding on plant and animal matter, including algae, fallen fruit, rotting wood and carrion. Spawning in ocean; marine planktonic larval development.	Low significance; Low impact. Foraging may be disrupted.	
White-striped crab (*Labuanium rotundatum*)	Not listed	CI (also Indo-west Pacific)	No.	Rainforests and other wooded areas above beaches. Mostly nocturnal. Arboreal on trees to about 5m from ground, and on rocks. Sheltering in tree-holes and other crevices. Feeds on algae and plant debris. Spawning in ocean; marine planktonic larval development.	Low significance; Low impact. Breeding migrations and foraging may be disrupted.	

Yellow-eyed crab (*Chiromantes obtusifrons*)	Not listed	CI (also Indo-west Pacific)	No.	Crevices high in seacliffs beyond tidal or salt spray, around coast. Spawning in ocean; marine planktonic larval development.	Low significance; Low impact. Breeding migrations and foraging may be minimally disrupted.	
Yellow nipper (*Geograpsus crinipes*)	Not listed	CI (also Indo-west Pacific)	No.	Lower terraces, seacliffs and beaches. Diurnal. Spawning in ocean; marine planktonic larval development. Active predatory of crabs and myriapods; also feeding on carrion.	Low significance; Low impact. Breeding migrations and foraging may be minimally disrupted.	

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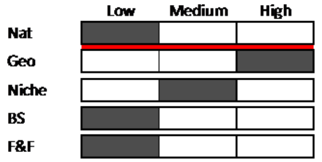
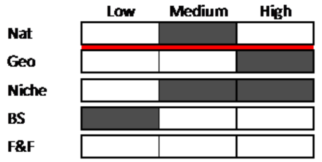
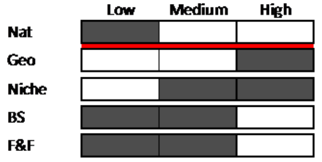
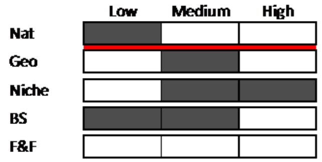
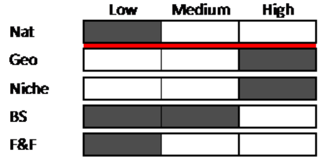
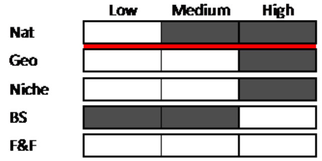
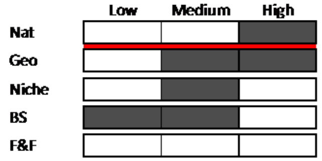
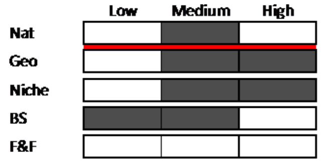
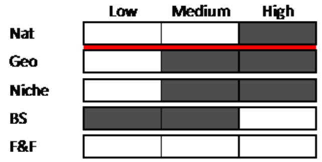
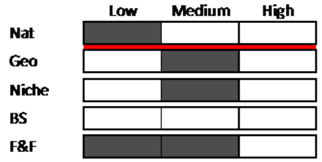
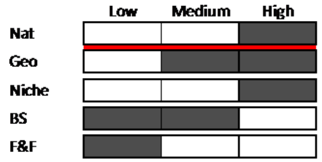
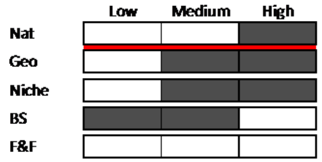
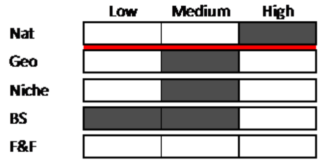
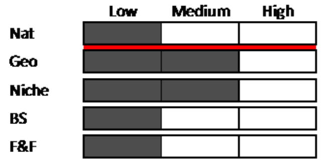
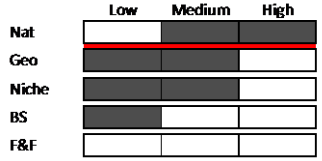
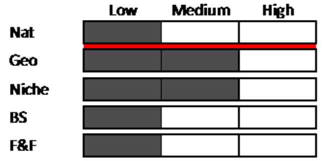
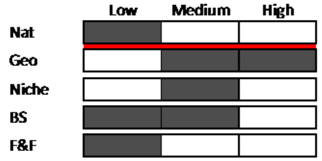
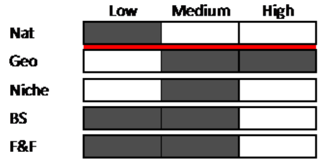
Appendix 6 Rapid assessment of native species potentially at risk from African big-headed ant in the Pacific Territory Islands Bioregion (Lord Howe Island)

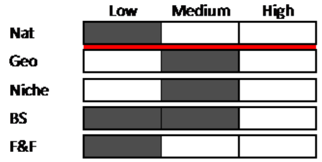
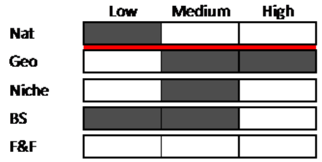
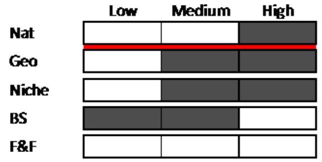
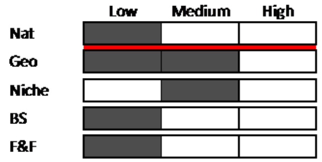
Common Name (scientific name)	EPBC Act Listing Status	Range	Recovery Plan	Habitat and behaviour	Potential or presumed level of impact and mechanisms for African big-headed ant effect	
Birds						
Australian kestrel, Nankeen Kestrel (*Falco cenchroides*)	Not listed	WA, NT, Qld, NSW, ACT, Vic, Tas, SA, CI, LH, NI (also New Caledonia; Papua New Guinea; vagrant New Zealand, Cocos (Keeling) Islands)	No. Not threatened.	Woodlands. Partially migratory. Forages mostly in open habitat, feeding on insects, and small birds, reptiles and mammals. Nests in tree hollows, cliff ledges, etc., and occasionally on the ground.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate, and some vertebrate, prey may be reduced.	
Black-winged Petrel (*Pterodroma nigripennis*)	Not listed	s Qld, e NSW, LH, NI (widespread in Pacific)	No. Predation by feral animals.	Pelagic, foraging on squid, fish and crustaceans. Migrates to central Pacific Ocean in non-breeding season. Breeding grounds vegetated coastal slopes and rugged terrain inland. Nests in shallow burrow.	Medium significance; Low impact. Nesting and fledgling success may be disrupted.	
Buff banded rail (*Gallirallus philippensis*)	Not listed [*Gallirallus philippensis macquariensis*, Macquarie Island, Extinct]	WA, NT, Qld, NSW, ACT, Vic, SA, Tas, LH, NI (also Philippines, Indonesia, New Guinea, Cocos (Keeling) Islands, w Pacific, New Zealand)	No.	Rainforests and woodlands, and adjoining grasslands. Omnivorous scavenger, feeds on invertebrates and small vertebrates, seeds, fallen fruit and other vegetable matter, as well as carrion. Nests on ground in dense grassy or reedy vegetation close to water.	Low significance. Medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced.	

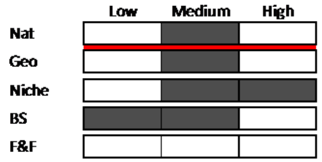
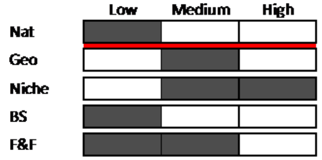
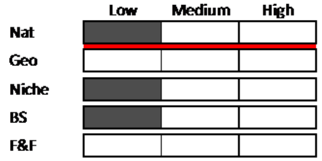
Common noddy (*Anous stolidus*)	Marine	WA, NT, Qld, CI, LH, NI (widespread globally)	No. Not threatened.	Migratory. Forages in inshore waters and up to 50 km out to pelagic zone. Diet of small fish, as well as pelagic molluscs, medusae and insects. Nest sites variable, in tree hollows, low vegetation, inland cliffs, and on open ground and amongst rocks.	Low significance; Low impact. Nesting and fledgling success may be disrupted.	
Emerald ground-dove (*Chalcophaps indica chrysochlora*)	Not listed	Qld, NSW, LH, NI	No.	Lowland rainforests and semi-urban areas. Roosts in trees. Forages on ground and low vegetation for seeds and fruit. Nests in trees.	Low significance; low to medium impact. Nesting and fledgling success, and foraging may be disrupted.	
Flesh-footed shearwater (*Puffinus carneipes*)	Marine	s WA, s SA, Vic, Tas, NSW, se Qld, LH (Indian and Pacific Oceans, including NI as vagrant)	No. Disturbance of breeding sites; predation by feral animals.	Pelagic, foraging on squid, fish and crustaceans. Migratory in non-breeding season. Breeding on sloping ground in coastal forests, shrublands and grasslands. Nests in burrows.	Medium to high significance; Low to medium impact. Nesting and fledgling success may be disrupted.	
Grey ternlet (western Pacific) (*Procelsterna cerulea albivitta*)	Not listed	LH, NI (also New Zealand)	No. Predation by feral animals.	SRE. Pelagic, nest and roost in coastal regions, usually on steep cliff faces, and forage over waters close to shore, feeding on small fish and crustaceans. Nests a scrape, on the ground, in a niche under a boulder or on a cliff ledge.	High significance; Low to medium impact. Nesting and fledgling success may be disrupted. Breeds LH, NI, NZ	
Kermadec petrel (*Pterodroma neglecta neglecta*)	V	Qld, NSW, LH, NI (also SW Pacific)	Yes (2010).	Pelagic, foraging on squid and crustaceans. Breeding in rainforests. Nests in crevices among rocks and vegetation.	Medium significance; Low to medium impact. Nesting and fledgling success may be disrupted. (breeds only Ball's Pyramid)	

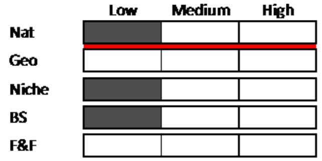
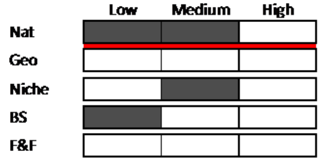
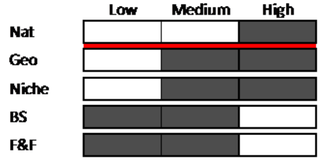
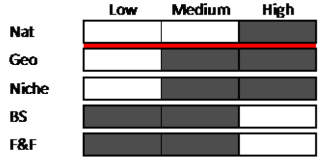
Little shearwater (*Puffinus assimilis assimilis*)	Marine	LH, NI [species widespread globally]	No.	Pelagic, foraging on squid, fish and crustaceans. Non-migratory. Breeding on sloping ground in coastal forests and shrublands. Nests in burrows.	High significance; Low to medium impact. Nesting and fledgling success may be disrupted. Ssp. Breeds only on LH, NI	
Long-tailed cuckoo (*Eudynamys* [= *Urodynamis*] *taitensis*)	Not listed	NT, LH, NI (also eastern Papuasia through Melanesia and Micronesia to Polynesia and New Zealand)	No.	Forests and woodlands. Migratory. Solitary. General predator, foraging on insects, small reptiles, and eggs and nestlings of birds. Brood parasite.	Low significance; Low to medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced. [Not breeding in LH, NI]	
Lord Howe Island currawong, Pied currawong (*Strepera graculina crissalis*)	V	LH	No. Illegal shooting; predation by feral animals.	SRE. Primarily rainforests and palm forests, but also disturbed urban areas. Omnivore, feeding on fruits, seeds, invertebrates and small vertebrates. Breeds in uplands. Nests in canopy.	High significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced.	
Lord Howe Island golden whistler (*Pachycephala pectoralis contempa*)	Not listed	LH	No.	SRE. Rainforests. Insectivore, foraging arboreally and on ground. Nests in trees.	High significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced, possibly off-set by increased ant and homopteran abundance.	

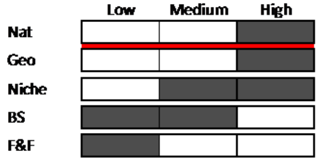
Lord Howe silvereye (*Zosterops lateralis tephropleura*)	Not listed	LH	No.	SRE. Rainforests and shrublands. Insectivore, nectarivore, and frugivore foraging in the forest understory and canopy, and rarely on the forest floor. Nests in canopy and subcanopy.	High significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced, possibly off-set by increased ant and homopteran abundance.	
Lord Howe woodhen (*Gallirallus sylvestris*)	V	LH	Yes (2002). Predation by humans and feral animals.	SRE. Primarily in closed forest. Ground foraging, with diet comprising earthworms, molluscs and other invertebrates, and small vertebrates. Nests on ground.	High significance; Low to medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be reduced.	
Masked booby (*Sula dactylatra fullagari*)	Not listed	LH, NI (also Kermadec Islands, New Zealand)	No.	Pelagic, foraging on squid and fish. Nests in scrape on open ground.	High significance; Low impact. Nesting and fledgling success may be disrupted.	
Providence petrel (*Pterodroma solandri*)	Marine	LH, NI	No. Threats not well understood.	SRE. Pelagic, foraging on squid, fish and crustaceans. Migratory in non-breeding season. Breeds in forested uplands. Nests in burrows.	High significance; Ledium impact. Nesting and fledgling success may be disrupted.	
Purple swamphen (*Porphyrio porphyrio melanotus*)	Not listed	s Qld, NSW, ACT, Vic, SA, Tas, NI, (also eastern Indonesia, the Mollucas, Aru and Kai Islands, Papua New	No. Not threatened.	Freshwater wetlands and wet grasslands. Feeds on vegetation, but also takes eggs and young birds, small fish, and invertebrates such as snails. Nests on reeds over or near water.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate and	

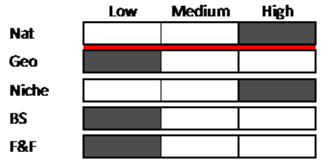
		Guinea, New Zealand)			vertebrate prey may be reduced.	
Red-tailed tropic bird (*Phaethon rubricauda*)	Marine	WA, NT, Qld, CI, LH, NI (widespread Indian and Pacific Oceans)	Yes (2010, LH).	Pelagic, foraging on squid, fish and crustaceans. Non-migratory but nomadic. Nests a scrape on ground in inaccessible cliffs.	Medium to high significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. LH important breeding site	
Sacred kingfisher (*Todiramphus sanctus*)	Marine	WA, NT, Qld, NSW, ACT, Vic, SA, Tas, LH, NI (also New Zealand, New Guinea, Indonesia, n and w Melanesia; vagrant CI, nw Pacific)	No. Not threatened.	Mangroves, woodlands, forests, and disturbed open area. Migratory over part of range. Forages mainly on land, only occasionally capturing prey in water. Feeds on invertebrates, fish and small vertebrates. Nest in burrows in earth banks, tree hollows, etc.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of some invertebrate and vertebrate prey may be reduced.	
Silver-eye (*Zosterops lateralis*)	Marine	WA, Qld, NSW, ACT, Vic, SA, Tas, LH, NI (also New Caledonia, Vanuatu, Fiji, New Zealand)	No. Not threatened.	Rainforests and shrublands, and wooded urban areas. Insectivore, nectarivore, and frugivore foraging in the forest understory and canopy, and rarely on the forest floor. Nests in canopy and subcanopy.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of some invertebrate prey may be reduced, but partially offset by increased ant and homopteran abundance.	
Shining bronze-cuckoo (*Chrysococcyx lucidus*)	Marine	WA, NT, Qld, NSW, ACT, Vic, SA, Tas, LH, NI (also Indonesia, New Caledonia, New Zealand,	No.	Forests. Migratory. Insectivore, feeding predominately on caterpillars and beetles. Brood parasite of birds nesting in subcanopy.	Low significance; Low to medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of some	

		Papua New Guinea, Solomon Islands, and Vanuatu)			invertebrate prey may be reduced.	
Sooty tern (*Sterna fuscata*)	Marine	WA, SA, Vic, NSW, Tas, LH, NI (widespread globally)	Yes (2010). Predation by feral animals.	Pelagic, with nocturnal and diurnal foraging for squid, fish and crustaceans. Also feeds on insects (e.g. hawking cicadas over forest). Dispersive and migratory. Gregarious. Nests a scrape in sand or soft soil.	Low significance; Low to medium impact. Nesting and fledgling success may be disrupted. Abundance of some invertebrate prey may be reduced.	
Wedge-tailed shearwater (*Puffinus pacificus*)	Marine	WA, SA, Qld, NSW, LH, NI (Indian and Pacific Oceans)	No.	Pelagic, foraging on squid, fish and crustaceans. Migratory. Breeds colonially. Nests in deep burrows, usually under vegetation.	Low significance; Low impact. Nesting and fledgling success may be disrupted. Breeding NI, LH	
White-bellied storm petrel (Australasian) (*Fregetta grallaria grallaria*)	V	Qld, NSW, Vic, Tas, LH, NI (also Kermadec Islands, New Zealand; Pacific)	No.	Pelagic, foraging on squid and crustaceans. Migratory in non-breeding season. Nests in chamber amongst large rocks and in burrows.	High significance; Low impact. Nesting and fledgling success may be disrupted. Breeds only on off-shore islands of LH Group.	
White-faced heron (*Ardea novaehollandiae*)	Not listed	WA, NT, Qld, NSW, ACT, Vic, SA, Tas, CI, LH, NI (also New Guinea, Indonesia, New Caledonia, New Zealand; vagrant se Asia, Cocos Islands, Solomon Islands)	No. Not threatened.	Mainly diurnal. Forages in wet grasslands, wetlands, estuaries and lagoons. Locally nomadic, and dispersive in non-breeding season. Diet highly varied – invertebrates and small vertebrates. Nests in trees.	Low significance; Low impact. Nesting and fledgling success may be disrupted. Abundance of some invertebrate and vertebrate prey may be reduced.	

White tern (*Gygis alba*)	Marine	LH, NI (widespread Atlantic, India, Pacific Oceans)	No. Not threatened.	Pelagic, foraging on small fish, squid and crustaceans. Migratory over part of its range. Breeding in trees or cliff ledge; no nest – egg laid on the horizontal branch or ledge.	Medium significance; Low impact. Fledgling success may be disrupted. breeding on Norfolk Island, Lord Howe Island and the Cocos Keeling Islands. also Atlantic ids.	
Mammals						
Large forest bat (*Vespadelus darlingtoni*) [formerly *Eptesicus sagittula*]	Not listed	se Qld, e NSW, Vic, Tas, LH	No.	Rainforests, wet and dry eucalypt forests, subalpine woodlands, and alpine moors; also in urban areas and in remnant farmland vegetation. Insectivorous. Roosting communal, in caves and hollow limbs of trees.	Low significance; low to medium impact. Roosting and breeding may be disrupted. Abundance of insect prey may be reduced.	
Reptiles						
Green turtle (*Chelonia mydas*)	V (Marine)	WA, NT, Qld, NSW, Vic, SA, LH (tropical and subtropical waters throughout the world)	Yes (2003). Loss of nesting sites to urban development; human disturbance; predation by feral animals.	Marine. Pelagic as young. More inshore as adults, mainly feeds on seagrass and algae. Oviparous. Nests on sandy beaches.	Low significance; No impact. Vulnerable in pipping and hatchling stages. Breeding may be disrupted, but nesting not important in LH.	
Hawksbill turtle (*Eretmochelys imbricata*)	V (Marine)	WA, NT, Qld, NSW, e Vic, CI, LH, NI (global in subtropical to tropical waters)	Yes (2003). Habitat disturbance; by-catch from fisheries and shark control.	Open ocean to lagoons and mangrove swamps in estuaries. Young entirely pelagic. Adults in-shore, benthic, feeding on sponges, jellyfish, sea anemones and algae. Oviparous. Nests on sandy beaches.	Low significance; No impact. Vulnerable in pipping and hatchling stages. Breeding may be disrupted, but no nesting in LH.	

Leathery turtle, Luth (*Dermochelys coriacea*)	E (marine)	All coastal AUS (tropical, subtropical and temperate waters throughout the world)	Yes (2003). Minimal on-shore threats.	Pelagic feeder on soft-bodied creatures such as jellyfish and tunicates. Oviparous. Nesting on sandy beaches. No recent records on nesting in eastern Australia.	Low significance; No impact. Vulnerable in pipping and hatchling stages. Breeding may be disrupted, but nesting not important in LH.	
Loggerhead turtle (*Caretta caretta*)	E (Marine)	ALL AUST (coastal marine) (global distribution throughout tropical, sub-tropical and temperate waters)	Yes (2003). Loss of nesting sites to urban development; predation by feral animals.	Marine. Carnivorous, feeding primarily on marine benthic invertebrates. Oviparous. Nests on beaches.	Low to medium significance; No impact. Vulnerable in pipping and hatchling stages. Breeding and foraging may be disrupted, but not breeding LH.	
Lord Howe Island skink (*Oligosoma lichenigera*)	V	LH, NI	Yes (2010). Predation by feral animals; loss and degradation of habitat.	SRE. Closed rainforests, low open woodlands, tussock grasslands, littoral complexes and rocky isolates. Nocturnal. Insectivorous, forages in leaf litter. Oviparous.	High significance; Medium impact. Breeding and foraging may be disrupted. Abundance of invertebrate prey likely reduced, but may be off-set partially by increased abundance of ants. Extinct on NI but still present on Phillip Id	
Lord Howe Island southern gecko (*Christinus guentheri*)	V	LH, NI	Yes (2010). Predation by feral animals; loss and degradation of habitat.	SRE. Rainforests. Nocturnal. Insectivorous, forages in trees and on ground; also takes nectar. Oviparous.	High significance; Low to medium impact. Breeding and foraging may be disrupted. Abundance of invertebrate prey likely reduced, but may be off-set partially by increased abundance of ants and	

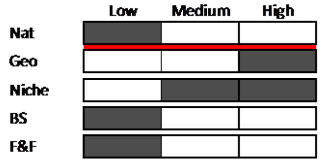
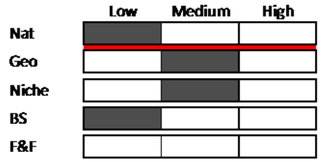
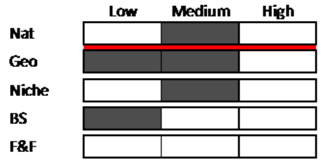
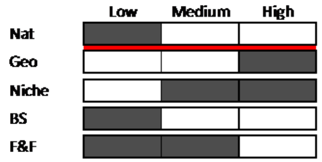
					increased availability of honeydew.	
Invertebrates						
Lord Howe Island earthworm (*Pericryptodrilus nanus*)	Not listed	LH	No.	SRE. Montane rainforests. Deep leaf litter in moist environments close to streams. Detritivore.	High significance; Low impact. Minimal geographic overlap. Vulnerable in all post-cocoon stages. Breeding and foraging may be disrupted.	
Lord Howe Island phasmid (*Dryococelus australis*)	CE	LH (now only Balls Pyramid)	No. Predation by feral animals.	SRE. Rainforests and coastal shrublands. Nocturnal. Flightless. Burrows in damp leaf litter, under bark, and in tree hollows by day. Feeds on *Melaleuca*. Oviparous.	High significance; Low to medium impact. Vulnerable, especially in egg and early instar stages. Breeding and foraging may be disrupted. Now only on off-shore island at one site	
Lord Howe Island placostylus, Lord Howe flax Snail (*Placostylus bivaricosus*)	E	LH	Yes (2001). Habitat loss and disturbance; predation by feral animals.	SRE. Lowland to lower montane rainforests and palm forests. Leaf litter. Detritivore. Oviparous.	High significance; Low to medium impact. Vulnerable, especially in egg and early hatchling stages. Breeding and foraging may be disrupted.	
Lord Howe Island wood-feeding cockroach (*Panesthia lata*)	Not listed	LH (now only Blackburn and Roach Islands)	No. Predation by feral animals.	SRE. Rainforests. Flightless. Burrows in soil under rocks and logs. Detritivore and scavenger, feeds on leaf litter and rotting wood. Oviparous.	High significance; Low impact. Vulnerable in egg and early instar stages. Breeding and foraging may be disrupted. Now only on off-shore islands	

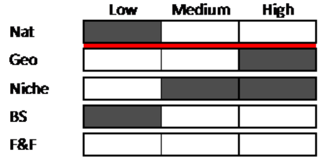
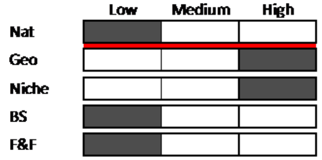
Magnificent heliocarionid land snail (*Gudeoconcha sophiae magnifica*)[1]	CE	LH	No. Predation by feral animals, especially rats. African big-headed ant mentioned as potential threat in SPRAT profile.	SRE. Montane rainforest. Detritivore, feeds on leaf litter and rotting wood. Oviparous.	High significance; Low impact. Minimal geographic overlap. Vulnerable, especially in egg and early hatchling stages. Breeding and foraging may be disrupted.	
Masters' charopid land snail (*Mystivagor mastersi*)[2]	CE	LH	No. Predation by feral animals, especially rats. African big-headed ant mentioned as potential threat in SPRAT profile.	SRE. Lowland to montane rainforests. Possibly arboreal. Detritivore. Oviparous.	High significance; Low to medium impact. Vulnerable, especially in egg and early hatchling stages. Breeding and foraging may be disrupted.	
Mount Lidgbird charopid land snail (*Pseudocharopa lidgbirdi*)[3]	CE	LH	No. Predation by feral animals, especially rats. African big-headed ant mentioned as potential threat in SPRAT profile.	SRE. Lowland to montane rainforests. Associated with wet rock surfaces and possibly woody debris. Detritivore. Oviparous.	High significance; Low to medium impact. Vulnerable, especially in egg and early hatchling stages. Breeding and foraging may be disrupted.	
Whitelegge's land snail (*Pseudocharopa whiteleggei*)[4]	CE	LH	No. Predation by feral animals, especially rats. African big-headed ant mentioned as potential threat in SPRAT profile.	SRE. Montane rainforests, associated with mossy woody debris. Detritivore. Oviparous.	High significance; Low impact. Minimal geographic overlap. Vulnerable, especially in egg and early hatchling stages. Breeding and foraging may be disrupted.	

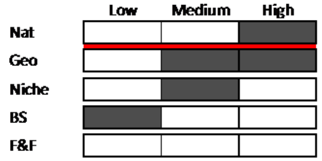
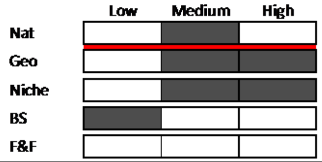
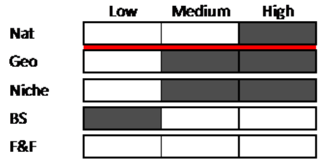
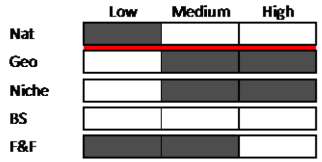
Appendix 6 References

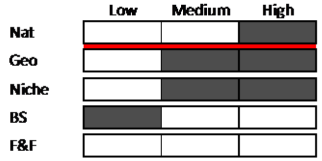
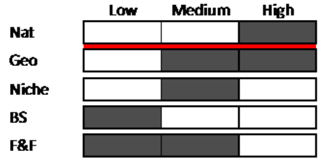
1. Department of Sustainability Environment Water Population and Communities. *Gudeoconcha sophiae magnifica* — Magnificent Heliocarionid Land Snail. Biodiversity: Species Profile and Threats Database. Accessed 20 May 2012; http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=81249.
2. Department of Sustainability Environment Water Population and Communities. *Mystivagor mastersi* — Masters' Charopid Land Snail. Biodiversity: Species Profile and Threats Database. Accessed 20 May 2012; http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=81247.
3. Communities, D.o.S.E.W.P.a. *Pseudocharopa lidgbirdi* — Mount Lidgbird Charopid Land Snail. Biodiversity: Species Profile and Threats Database. Accessed 20 May 2012; http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=81248.
4. Department of Sustainability Environment Water Population and Communities. *Pseudocharopa whiteleggei*— Whitelegge's Land Snail. Biodiversity: Species Profile and Threats Database. Accessed 20 May 2012; http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=81249.

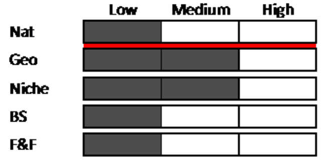
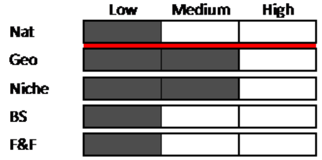
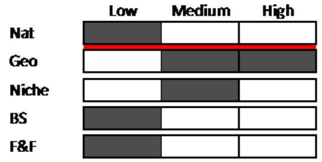
Appendix 7 Rapid assessment of native species potentially at risk from Argentine ant in the Pacific Territory Islands (Norfolk Island) Bioregion

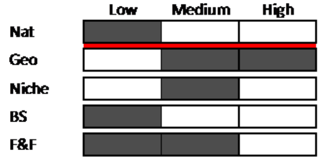
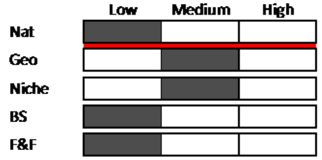
Common Name (scientific name)	EPBC Act Listing Status	Range	Recovery Plan	Habitat and behaviour	Potential or presumed level of impact and mechanisms for Argentine ant effect	
Birds						
Australian kestrel, Nankeen kestrel (*Falco cenchroides*)	Not listed	WA, NT, Qld, NSW, ACT, Vic, Tas, SA, CI, LH, NI (also New Caledonia, Papua New Guinea; vagrant New Zealand, Cocos (Keeling) Islands)	No. Not threatened.	Woodlands. Partially migratory. Forages mostly in open habitat, feeding on insects, and small birds, reptiles and mammals. Nests in tree hollows, cliff ledges, etc., and occasionally on the ground.	Low significance. Low impact. Nesting and fledgling success may be disrupted. Abundance of invertebrate may be reduced.	
Black noddy (*Anous minutus*)	Not listed (Marine)	WA, Qld, LH, NI (widespread globally)	No. Not threatened.	Pelagic, diurnal foraging mainly for small fish and squid. Returns to land to roost at night. Nest in trees.	Low significance; Low impact. Nesting and fledgling success, and roosting may be disrupted.	
Black-winged Petrel (*Pterodroma nigripennis*)	Not listed	s Qld, e NSW, LH, NI (widespread in Pacific)	No. Predation by feral animals.	Pelagic, foraging on squid, fish and crustaceans. Migrates to central Pacific Ocean in non-breeding season. Breeding grounds vegetated coastal slopes and rugged terrain inland. Nests in shallow burrow.	Medium significance; Low impact. Nesting and fledgling success may be disrupted.	
Buff-banded rail (*Gallirallus phillippensis*)	Not listed [*Gallirallus philippensis macquariensis*, Macquarie Island, Extinct]	WA, NT, Qld, NSW, ACT, Vic, SA, Tas, LH, NI (also Philippines, Indonesia, New Guinea, Cocos (Keeling) Islands, w Pacific, New	No.	Rainforests and woodlands, and adjoining grasslands. Omnivorous scavenger, feeds on invertebrates and small vertebrates, seeds, fallen fruit and other vegetable matter, as well as carrion. Nests on ground in dense grassy or	Low significance; Low to medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	

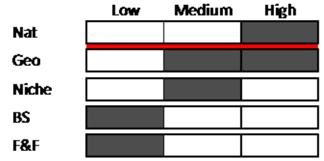
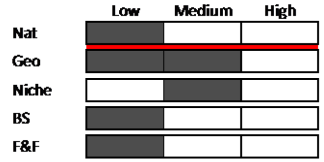
		Zealand)		reedy vegetation close to water.		
Common noddy (*Anous stolidus*)	Not listed (Marine)	WA, NT, Qld, CI, LH, NI (widespread globally)	No. Not threatened.	Migratory. Forages in inshore waters and up to 50 km out to pelagic zone. Diet of small fish, as well as pelagic molluscs, medusae and insects. Nest sites variable, in tree hollows, low vegetation, inland cliffs, and on open ground and amongst rocks.	Low significance; Low impact. Nesting and fledgling success may be disrupted.	
Eastern curlew (*Numenius madagascariensis*)	Not listed (Marine)	All Aus; LH, NI (breeds in Russia and north-eastern China)	No. Human disturbance; habitat degradation.	Sheltered coasts, especially estuaries, bays, harbours, inlets and coastal lagoons. Migratory. Roosts terrestrially in salt-marshes, behind mangroves, and on sandy beaches. Forages on soft intertidal sand- and mud-flats.	Low significance; Low impact. Roosting and foraging minimally affected.	
Emerald ground-dove (*Chalcophaps indica chrysochlora*)	Not listed	Qld, NSW, LH, NI	No.	Lowland rainforests and semi-urban areas. Roosts in trees. Forages on ground and low vegetation for seeds and fruit. Nests in trees.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted.	
Flesh-footed shearwater (*Puffinus* [= *Ardenna*] *carneipes*)	Not listed (Marine)	s WA, s SA, Vic, Tas, NSW, se Qld, LH, NI (Indian and Pacific Oceans)	No. Disturbance of breeding sites; predation by feral animals.	Pelagic, foraging on squid, fish and crustaceans. Migratory in non-breeding season. Breeding on sloping ground in coastal forests, shrublands and grasslands. Nests in burrows.	Medium significance; Low impact. Nesting and fledgling success may be disrupted.	
Grey fantail (*Rhipidura fuliginosa pelzelni*) [= *Rhipidura albiscapa pelzelni*]	Not listed	NI	No.	SRE. Forests and shrublands. Insectivore, feeds on insects, mostly caught in flight but sometimes gleaned off the ground and vegetation. Nests	High significance; Low impact. Nesting and fledgling success, and foraging may be disrupted.	

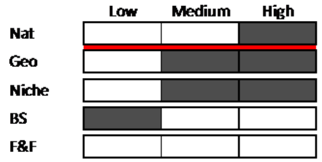
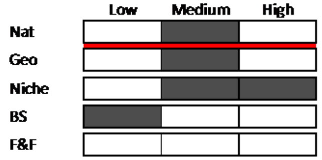
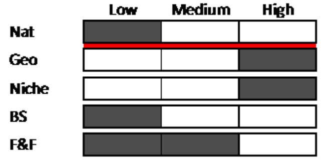
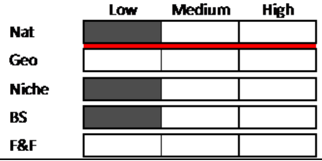
				in subcanopy.	Abundance of invertebrate prey may be reduced.	
Grey gerygone (*Gerygone modesta*)	Not listed	NI	No. Not threatened.	SRE. Forests and shrublands, and urban areas. Insectivore, nectarivore, and frugivore foraging in the forest understory and canopy, and rarely on the forest floor. Nests in canopy and subcanopy.	High significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Grey ternlet (western Pacific) (*Procelsterna cerulea albivitta*)	Not listed	LH, NI (also New Zealand)	No. Predation by feral animals.	SRE. Pelagic, nest and roost in coastal regions, usually on steep cliff faces, and forage over waters close to shore, feeding on small fish and crustaceans. Nests a scrape, on the ground, in a niche under a boulder or on a cliff ledge.	High significance; Low impact. Nesting and fledgling success may be disrupted.	
Kermadec petrel (*Pterodroma neglecta neglecta*)	V	Qld, NSW, LH, NI (also SW Pacific)	Yes (2010).	Pelagic, foraging on squid and crustaceans. Breeding in rainforests. Nests in crevices among rocks and vegetation.	Medium significance; Low impact. Nesting and fledgling success may be disrupted.	
Little shearwater (*Puffinus assimilis assimilis*)	Marine	LH, NI [species widespread globally]	No.	SRE. Pelagic, foraging on squid, fish and crustaceans. Non-migratory. Breeding on sloping ground in coastal forests and shrublands. Nests in burrows.	High significance; Low mpact. Nesting and fledgling success may be disrupted.	
Long-tailed cuckoo (*Eudynamys* [= *Urodynamis*] *taitensis*)	Not listed	NT, LH, NI (also eastern Papuasia through Melanesia and Micronesia to	No.	Forests and woodlands. Migratory. Solitary. General predator, foraging on insects, small reptiles, and eggs and nestlings of birds. Brood	Low significance; Low impact. Foraging may be disrupted. Abundance of invertebrate and vertebrate prey may be	

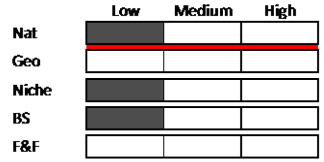
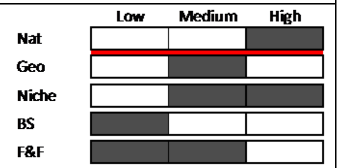
		Polynesia and New Zealand)		parasite.	reduced.	
Masked booby (*Sula dactylatra fullagari*)	Not listed	LH, NI (also Kermadec Islands, New Zealand)	No.	Pelagic, foraging on squid and fish. Nests in scrape on open ground.	High significance; Low impact. Nesting and fledgling success may be disrupted.	
Norfolk Island green parrot (*Cyanoramphus cookii*)	E	NI	Yes (2002/2010). Habitat loss and degradation; predation by feral animals; competition for nest sites	SRE. Forests and adjacent disturbed areas. Diet of seeds, fruits, flowers and leaves. Nests in hollows of live trees, ~ 2 m above ground.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted.	
Norfolk Island boobook owl, Morepork (*Ninox novaeseelandiae undulata*) (hybrid)	E	NI	Yes (2010).	SRE. Forests. Nocturnal predator, feeds on small vertebrates, especially birds and mammals, as well as invertebrates. Nests in tree hollows.	High significance; Medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Norfolk Island golden whistler, Tamey (*Pachycephala pectoralis xanthoprocta*)	V	NI	Yes (2005/2010).	SRE. Forests. Diet of insects and some fruit; often ventures to ground to forage in leaf litter. Nests in small trees and hanging masses of vines.	High significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Norfolk Island scarlet robin (*Petroica multicolour multicolor*)	V	NI	Yes (2002/2010).	SRE. Forests. Feed on invertebrates, mainly insects, foraging on the ground or using low branches from which to pounce on prey. Nests in upper subcanopy.	High significance; Low to medium impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of	

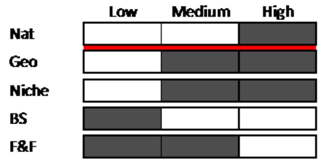
					invertebrate prey may be reduced.	
Providence Petrel (*Pterodroma solandri*)	Not listed (Marine)	LH, NI	No. Threats not well understood.	SRE. Pelagic, foraging on squid, fish and crustaceans. Migratory in non-breeding season. Breeds in forested uplands. Nests in burrows.	High significance; Low impact. Nesting and fledgling success may be disrupted.	
Purple swamphen (*Porphyrio porphyrio melanotus*)	Not listed	s Qld, NSW, ACT, Vic, SA, Tas, NI, (also eastern Indonesia, the Mollucas, Aru and Kai Islands, Papua New Guinea, New Zealand)	No. Not threatened.	Freshwater wetlands and wet grasslands. Feeds on vegetation, but also takes eggs and young birds, small fish, and invertebrates such as snails. Nests on reeds over or near water.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of invertebrate prey may be reduced.	
Red-tailed tropic bird (*Phaethon rubricauda*)	Not listed (Marine)	WA, NT, Qld, CI, LH, NI (widespread Indian and Pacific Oceans)	Yes (2010).	Pelagic, foraging on squid, fish and crustaceans. Non-migratory but nomadic. Nests a scrape on ground in inaccessible cliffs.	Medium significance; Low impact. Nesting and fledgling success, and foraging may be disrupted.	
Sacred kingfisher (*Todiramphus sanctus*)	Not listed (Marine)	WA, NT, Qld, NSW, ACT, Vic, SA, Tas, LH, NI (also New Zealand, New Guinea, Indonesia, n and w Melanesia; vagrant CI, nw Pacific)	No. Not threatened.	Mangroves, woodlands, forests, and disturbed open area. Migratory over part of range. Forages mainly on land, only occasionally capturing prey in water. Feeds on invertebrates, fish and small vertebrates. Nest in burrows in earth banks, tree hollows, etc.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of some invertebrate prey may be reduced.	
Silver-eye (*Zosterops lateralis*)	Not listed (Marine)	WA, Qld, NSW, ACT, Vic, SA, Tas, LH, NI (also New Caledonia, Vanuatu, Fiji,	No. Not threatened.	Rainforests and shrublands, and wooded urban areas. Insectivore, nectarivore, and frugivore foraging in the forest understory and canopy,	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted.	

		New Zealand)		and rarely on the forest floor. Nests in canopy and subcanopy.	Abundance of some invertebrate prey may be reduced, but partially offset by increased homopteran abundance.	
Slender-billed white-eye (*Zosterops tenuirostris*)	Not listed	NI	No. Habitat loss, fragmentation and degradation; predation by feral animals; competition from introduced birds.	SRE. Forests. Gregarious. Probes fissures in bark and leaf litter for insects. Also eats fruit. Nests in subcanopy.	High significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of some invertebrate prey may be reduced, but possibly offset by increased homopteran abundance.	
Shining bronze-cuckoo (*Chrysococcyx lucidus*)	Not listed (Marine)	WA, NT, Qld, NSW, ACT, Vic, SA, Tas, LH, NI (also Indonesia, New Caledonia, New Zealand, Papua New Guinea, Solomon Islands, and Vanuatu)	No.	Forests. Migratory. Insectivore, feeding predominately on caterpillars and beetles. Brood parasite of birds nesting in subcanopy.	Low significance; Low impact. Nesting and fledgling success, and foraging may be disrupted. Abundance of some invertebrate prey may be reduced.	
Sooty tern (*Sterna fuscata*)	Not listed (Marine)	WA, SA, Vic, NSW, Tas, LH, NI (widespread globally)	Yes (2010). Predation by feral animals.	Pelagic, with nocturnal and diurnal foraging for squid, fish and crustaceans. Also feeds on insects (e.g. hawking cicadas over forest). Dispersive and migratory. Gregarious. Nests a scrape in sand or soft soil.	Low significance; Low impact. Nesting and fledgling success may be disrupted. Abundance of some invertebrate prey may be reduced.	

Wedge-tailed shearwater (*Puffinus pacificus*)	Not listed (Marine)	WA, SA, Qld, NSW, LH, NI (Indian and Pacific Oceans)	No.	Pelagic, foraging on squid, fish and crustaceans. Migratory. Breeds colonially. Nests in deep burrows, usually under vegetation.	Low significance; Low impact. Nesting and fledgling success may be disrupted.	
White-bellied storm petrel (Australasian) (*Fregetta grallaria grallaria*)	V	Qld, NSW, Vic, Tas, LH, NI (also Kermadec Islands, New Zealand; Pacific)	No.	Pelagic, foraging on squid and crustaceans. Migratory in non-breeding season. Nests in chamber amongst large rocks and in burrows.	Low significance; No impact. Nesting and fledgling success may be disrupted.	
White-breasted white-eye, Norfolk island silver-eye (*Zosterops albogularis*)	Extinct	NI	No. Habitat loss; predation by feral animals.	SRE. Forests. Active in canopy. Insectivore, gleaning insects from foliage and twigs; also feeds on fruit. Nests in subcanopy.	High significance; Low impact. and fledgling success, and foraging may be disrupted. Abundance of some invertebrate prey may be reduced, but partially offset by increased homopteran abundance.	
White-faced heron (*Ardea novaehollandiae*)	Not listed	WA, NT, Qld, NSW, ACT, Vic, SA, Tas, CI, LH, NI (also New Guinea, Indonesia, New Caledonia, New Zealand; vagrant se Asia, Cocos Islands, Solomon Islands)	No. Not threatened.	Mainly diurnal. Forages in wet grasslands, wetlands, estuaries and lagoons. Locally nomadic, and dispersive in non-breeding season. Diet highly varied – invertebrates and small vertebrates. Nests in trees.	Low significance; Low impact. Nesting and fledgling success may be disrupted. Abundance of some invertebrate prey may be reduced.	

White-necked petrel (*Pterodroma cervicalis*)	Not listed (Marine)	NI (also Pacific, with breeding Kermadecs, New Zealand)	No.	Pelagic, migrates to North Pacific when not breeding. Feed on small squid and crustaceans. Nests in burrows, generally on high, gently sloping areas with sedges and grass; also amongst boulders under vegetation.	High significance; Low impact. Nesting and fledgling success may be disrupted.	
White tern (*Gygis alba*)	Not listed (Marine)	LH, NI (widespread Atlantic, India, Pacific Oceans)	No. Not threatened.	Pelagic, foraging on small fish, squid and crustaceans. Migratory over part of its range. Breeding in trees or cliff ledge; no nest – egg laid on the horizontal branch or ledge.	Medium significance; Low impact. Fledgling success may be disrupted.	
Mammals						
Gould's wattled bat (*Chalinolobus gouldii*)	Not listed	WA, NT, Qld, NSW, ACT, Vic, SA, Tas, NI (also New Caledonia)	No.	Wooded and urban areas. Roosts in tree hollows, bird nests and other cavities. Often gregarious. Nocturnal. Insectivorous, feeding on a range of insects and life stages, including ants. Grass seeds and twig fragments are occasionally ingested.	Low significance; Low impact. Roosting and breeding success, and foraging may be disrupted. Abundance of some invertebrate prey may be reduced, but possibly offset partially by increased ant abundance.	
Reptiles						
Green turtle (*Chelonia mydas*)	V (marine)	WA, NT, Qld, NSW, Vic, SA, LH (tropical and subtropical	Yes (2003). Loss of nesting sites to urban development;	Marine. Pelagic as young. More inshore as adults, mainly feeds on seagrass and algae. Oviparous. Nests on	Low significance; No impact. Vulnerable in pipping and hatchling stages.	

		waters throughout the world)	human disturbance; predation by feral animals.	sandy beaches.	Breeding may be disrupted, but nesting not important in NI.	
Hawksbill turtle (*Eretmochelys imbricata*)	V (Marine)	WA, NT, Qld, NSW, e Vic, CI, LH, NI (global in subtropical to tropical waters)	Yes (2003). Habitat disturbance; by-catch from fisheries and shark control.	Open ocean to lagoons and mangrove swamps in estuaries. Young entirely pelagic. Adults in-shore, benthic, feeding on sponges, jellyfish, sea anemones and algae. Oviparous. Nests on sandy beaches.	Low significance; No impact. Vulnerable in pipping and hatchling stages. Breeding may be disrupted, but no nesting in NI.	
Leathery turtle, Luth (*Dermochelys coriacea*)	E (marine)	All coastal AUS (tropical, subtropical and temperate waters throughout the world)	Yes (2003). Minimal on-shore threats.	Pelagic feeder on soft-bodied creatures such as jellyfish and tunicates. Oviparous. Nesting on sandy beaches. No recent records on nesting in eastern Australia.	Low significance; No impact. Vulnerable in pipping and hatchling stages. Breeding may be disrupted, but nesting not important in LH.	
Loggerhead turtle (*Caretta caretta*)	E (Marine)	ALL AUST (coastal marine) (global distribution throughout tropical, sub-tropical and temperate waters)	Yes (2003). Loss of nesting sites to urban development; predation by feral animals.	Marine. Carnivorous, feeding primarily on marine benthic invertebrates. Oviparous. Nests on beaches.	Low to medium significance; No impact. Vulnerable in pipping and hatchling stages. Breeding may be disrupted, but not breeding NI.	
Lord Howe Island skink (*Oligosoma lichenigera*)	V	LH, NI	Yes (2010). Predation by feral animals; loss and degradation of habitat.	SRE. Closed rainforests, low open woodlands, tussock grasslands, littoral complexes and rocky isolates. Nocturnal. Insectivorous, forages in leaf litter for insects, including ants, and other invertebrates. Oviparous.	High significance; Low to medium impact. Breeding and foraging may be disrupted. Abundance of invertebrate prey likely reduced, but may be off-set partially by increased	

					abundance of ants.	
Lord Howe Island southern gecko (*Christinus guentheri*)	V	LH, NI	Yes (2010). Predation by feral animals; loss and degradation of habitat.	SRE. Rainforests. Nocturnal. Insectivorous, forages in trees and on ground; also takes nectar. Oviparous.	High significance; Low to medium impact. Breeding and foraging may be disrupted. Abundance of invertebrate prey and nectar likely reduced, but may be off-set partially by increased abundance of ants and increased availability of honeydew.	
Invertebrates						
Endemic centipede (*Cormocephalus coynei*)	Not listed	NI	No.	SRE. Forests and shrublands. In leaf litter and associated with woody debris and rock rubble. Predatory, feeds on invertebrates and small vertebrates. Oviparous.	High significance; Low to medium impact. Breeding and foraging may be disrupted. Abundance of invertebrate prey likely reduced.	
Campbell's helicarionid land snail (*Advena campbellii campbellii*)	CE	NI	No. Habitat loss and degradation; predation by feral animals.	SRE. Forests, under rocks and woody debris. Detritivore. Oviparous.	High significance; Low to medium impact. Vulnerable, especially in egg and hatchling stages. Breeding and foraging may be disrupted.	
Gray's helicarionid land snail (*Mathewsoconcha grayi*)	CE	NI	No. Habitat loss and degradation; predation by feral animals.	SRE. Forests and shrublands. In leaf litter. Detritivore. Oviparous.	High significance; Low to medium impact. Vulnerable, especially in egg and hatchling stages. Breeding and foraging may be disrupted.	

Helicarionid land snail (*Mathewsoconcha suteri*)	CE	NI	No. Habitat loss and degradation; predation by feral animals.	SRE. Forests and shrublands. In leaf litter and woody debris. Detritivore. Oviparous.	High significance; Low to medium impact. Vulnerable, especially in egg and hatchling stages. Breeding and foraging may be disrupted.	
Phillip Island helicarionid land snail (*Mathewsoconcha phillipii*)	CE	NI	No. Habitat loss and degradation; predation by feral animals.	SRE. Forests and shrublands. Under rocks. Detritivore. Oviparous.	High significance; Low to medium impact. Vulnerable, especially in egg and hatchling stages. Breeding and foraging may be disrupted.	
Stoddart's helicarionid land snail (*Quintalia stoddartii*)	CE	NI	No. Habitat loss and degradation; predation by feral animals.	SRE. Forests and shrublands. Under rocks. Detritivore. Oviparous.	High significance; Low to medium impact. Vulnerable, especially in egg and hatchling stages. Breeding and foraging may be disrupted.