Pacific Ant Prevention Plan

Pacific Invasive Ant Group (PIAG)

On behalf of the IUCN/SSC Invasive Species Specialist Group (ISSG)

A proposal prepared for the Pacific Plant Protection Organisation and Regional Technical Meeting For Plant Protection

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Cover photo: Fire ant worker. *Photo courtesy of Texas Fire Ant Applied Research and Education Program.*

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Executive Summary

Ants are notorious invaders, particularly those species known as “tramp” ants. They easily disperse worldwide through commerce and other human-assisted avenues, often cause significant economic and environmental damage, and are often extremely difficult or impossible to eradicate or control. Although some species are sometimes considered beneficial for their role as biocontrol agents, the overall impacts of invasive ants are usually overwhelmingly negative. Due to the difficulty and expense of controlling or eradicating these invaders, the most cost-effective approach to addressing the problems they cause is to prevent their establishment.

An excellent example of an ant species for which prevention measures are especially warranted is the red imported fire ant (RIFA) *Solenopsis invicta*. One of the world’s most significant ant pests, RIFA has been extremely successful at spreading around the tropical and sub-tropical world via commerce. Outside of its native range in South America it has caused considerable damage, including millions of dollars in damages to agriculture; injury and death to people, domestic animals and wildlife; and millions of dollars in damage to electrical and communication systems, and other electrical equipment. The history of its invasiveness (see Appendix 1) shows that once established, RIFA is very difficult and costly to eradicate and extremely expensive to control. Consequently, the most efficient and effective option for dealing with this pest is to implement comprehensive preventative measures.

There are a number of other invasive "tramp" ant species, which also cause significant damage and should therefore also be subject to comprehensive preventative measures. These other ants spread using similar pathways to RIFA and require similar measures to prevent their spread and establishment. The most serious threats are from: *Solenopsis geminata* (tropical fire ant), *Anoplolepis gracilipes* (yellow crazy ant), *Pheidole megacephala* (big headed ant), *Monomorium destructor* (Singapore ant), *Tapinoma melanocephalum* (ghost ant), *Solenopsis papuana, Paratrechina longicornis* (crazy ant), *Wasmannia auropunctata* (little fire ant), *Linepithema humile* (Argentine ant), *Monomorium pharaonis* (Pharaoh ant) and *Technomyrmex albipes* (white footed ant).

Prevention of RIFA and other invasive ant species from establishing on Pacific islands is best addressed through a regional approach. This is primarily due to the ease with which these species spread. Should RIFA become established on one island in the Pacific, it would provide a source for it spreading to other islands/countries. Such island invasions in the Pacific are likely to lead to considerable economic and biodiversity loss and hardship for communities. Therefore a regional prevention plan, as offered here, is warranted.

The goal of this prevention plan is to prevent RIFA and other invasive ant species with economic, environmental and social impacts, entering and establishing in or spreading between, or within, countries of the Pacific Region, thereby protecting economic, social and environmental interests in the area.

The Pacific Ant Prevention Plan (PAPP) lays out the recommended procedures, organisation and measures required to achieve the goal. It includes objectives under two broad headings of entry and establishment. In addition, a number of actions have been identified that are likely to be required in order to meet each objective.

Prevention of entry measures required include:

- appropriate legislation, regulations or standards to deal with invasive ants pre-border and at the border;

- risk analysis that covers the region but which can be adapted for implementation to each country or territory;
- regional trade agreements which accommodate risks associated with invasive ants; and
- operational measures which can be applied to each territory and will actually prevent ants gaining entry.

Prevention of establishment measures required include:

- a range of surveillance measures appropriate to quickly identify the presence of a new invasive ant in each territory;
- appropriate incursion response procedures and the capability to enact them;
- a regional public awareness strategy to ensure the ant species concerned have appropriate public profiles so the risks of their establishment are well understood by sections of the community; and
- an active research programme to ensure the measures used to prevent establishment have a sound scientific base and thus will have the greatest likelihood of success.

The Invasive Species Specialist Group (ISSG) of The World Conservation Union (IUCN) is coordinating this project, with support from members of the Pacific Invasive Ant Group.

We recommend that:

- the PPPO and RTMPP acknowledge the threat of RIFA and other invasive ants to the regional economy, trade, plant, animal and human health and biodiversity
- action to prevent RIFA and other invasive ants entering and establishing in the Pacific region is accorded a high priority.
- the intent of/or the proposed plan is included in the SPC work plan
- the SPC models the PAPP on the highly successful Pacific Fruit Fly Program including funding arrangements
- a detailed work plan is compiled including timelines, resources required for each component and responsibility for carrying out each section.

Introduction

Pacific context

The annual meeting of the South Pacific Regional Environment Programme (SPREP) in 1998, recognised the huge threat of invasive species to all Pacific islands and the importance of regional cooperation in mitigating effects of invasive species. The initial desire was for a regional strategy. The New Zealand government subsequently funded an Invasive Species Programme to be managed by SPREP for three years, beginning in September 1998, with the intention of extending funding for another three years after 2001. To facilitate the production of a regional strategy, a SPREP workshop was held in Nadi, Fiji, in September 1999 (with financial support from Australia and the U.S.). SPREP published the resulting regional strategy in 2000: "Invasive Species in the Pacific: A Technical Review and a Draft Regional Strategy". Among many other things, the review recognized the formidable threat of ant invasions to the Pacific region.

In early 2001, both Australia and New Zealand discovered RIFA incursions. New Zealand's incursion was highly localized (one large nest), was treated, and triggered a broad surveillance effort which documented eradication from the country (Pascoe 2002). Australia initiated a $120 million, 5-year eradication program in 2001 (Vanderwoude 2002b) which is currently 50 percent completed.

In January of 2001, Davis *et al.* (2001) documented extensive invasion of RIFA in the Caribbean islands. These incursions demonstrate the ease with which RIFA can spread to, and among, tropical/subtropical islands, and make clear the risk of RIFA invasion to the Pacific.

In July 2002, Loope and Van Gelder of the Hawaiian Ant Group (HAG) made a presentation at a Global Biodiversity Forum held in Rarotonga, Cook Islands, focusing on the threat of RIFA to Pacific Islands and some preliminary ideas for a regional strategy to prevent this invasion. At the same meeting, the Invasive Species Specialist Group (ISSG) of IUCN announced the launching of its Cooperative Islands Initiative.

In October 2002, the Global Invasive Species Program (GISP) convened an Austral-Pacific workshop in Honolulu, Hawaii. Representatives were invited from Ministries of Agriculture and Ministries of the Environment from Pacific Island Countries and Territories (PICTs). Participants were in unanimous agreement that RIFA posed a huge threat to Pacific island biodiversity, island economies and culture, and human health. The group drafted a letter to be sent by ISSG to institutions in the USA and Australia asking for assistance in preventing RIFA establishment in the Pacific. The group also encouraged GISP, ISSG, and the Islands Initiative to hold a workshop aimed at developing a plan for RIFA prevention in the Pacific.

The subsequent ISSG workshop held in Auckland during September 2003, resulted in the compilation of a draft Pacific Ant Prevention Plan (PAPP) that encompassed RIFA and other exotic invasive ants with documented negative impacts. Workshop participants considered that measures developed and implemented for RIFA, would be transferable to all other priority exotic invasive ant species.

The decision of whether or not to address the potential invasion threat of RIFA, and other ants at a regional level, as high priority, rests with the PICTs and Pacific Plant Protection Organisation (PPPO). If they should formally agree on its priority, there would be an unprecedented opportunity for agriculture and conservation entities to work together with international and bilateral aid agencies at regional and country levels. These groups could build much needed quarantine capacity to give the PICTs the protection they need to address RIFA and other invasions which jeopardize both agriculture, human health and biodiversity.

The proposed PAPP outlines a framework on which to build a comprehensive ant prevention plan for the region.

The Plan

GOAL

“To prevent RIFA and other invasive ant species with economic, environmental and/or social impacts, entering and establishing in or spreading between (or within) countries of the Pacific Region.”

SCOPE

- The prevention plan will apply to:
  American Samoa, Australia, Cook Islands, Federated States of Micronesia (FSM), Fiji, French Polynesia, Guam, Hawaii, Kiribati, Marshall Islands, Nauru, New Caledonia, Niue, Northern Mariana Islands (CNMI), New Zealand, Palau, Papua New Guinea (PNG), Pitcairn Islands, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu and Wallis and Futuna
- Actions listed under the objectives may have a local or regional or dual component that will be identified once the details of the plan are finalised
- The plan will focus on RIFA and other invasive ants with economic, environmental and/or social impacts

OBJECTIVES

<u>Prevention of entry:</u>

1. **Legislation (including policy):** *To ensure country or territory specific legislation adequately regulates for invasive ants*

   a. Identify existing legislation, policy and standards which support regulatory activities
   b. Ensure prevention plan fits either into existing legislation or is considered within current biosecurity legislation reviews

2. **Risk analysis:** *To produce a regional risk assessment framework that can be adapted for implementation within individual countries (or territories)*

   a. Identify the most appropriate international risk assessment framework
   b. Identify exotic invasive ant species likely to pose the greatest threat in the Pacific

      This is likely to involve:
      i. Collating biological, ecological and distribution information to assist with hazard identification
      ii. Collating information on trade pathways, and trade volumes into and within the region

iii. Producing a regional analysis of climate and other relevant factors to estimate risk of establishment
iv. Evaluating generic methodologies for estimating risk of establishment
v. Reviewing information on known and potential economic, environmental and social impacts including the Pacific Region

[*Note: The New Zealand ant pest risk assessment currently underway should provide a good basis for assessment*]

c. Identify and evaluate potential risk mitigation measures including, suitability for use

3. **Regional trade agreements:** *To ensure that trade agreements take into account the risks associated with invasive ant species*

Specific actions:

a. Make risk assessment available to trade support teams
b. Make risk management recommendations to the trade support teams
c. Make risk management recommendations for bilateral and multilateral meetings/negotiations

4. **Operations:** *To identify, develop and implement operations or operational programmes that can be used to prevent the entry of invasive ants*

Specific actions:

a. Identify best practice operational systems (including, treatment of high risk commodities) for pre-arrival and at the border
b. Assess current capacity including funding for implementation of best practice operational systems for each country or territory
c. Identify gaps in capacity and capability to implement best practice operational systems for each country or territory and investigate ways to fill them
d. Communicate risks to stakeholders throughout the process of risk analysis
e. Review and audit operational programmes at regular intervals

Container washdown in Papua New Guinea.
Photo courtesy of Ken Glassey, Ministry of Agriculture and Forestry, New Zealand.

Prevention of establishment:

1. **Surveillance:** *To establish and sustain a regionally coordinated surveillance strategy*

   Specific actions:

   a. Use risk analysis to identify high risk surveillance sites (i.e. arrival entry points and unloading facilities) – develop strategic framework
   b. Identify best practice and develop recommendations for surveillance standard operational procedures
   c. Review existing regional/global surveillance programmes
   d. Identify gaps in surveillance programmes, capability and resources and investigate ways to fill them
   e. Agree on regional coordinating body/person/lead agency
   f. Collate baseline information
   g. Confirm surveillance objectives i.e. early detection at regional, country and community levels, updating baseline information
   h. Develop communication and data sharing protocols and mechanisms
   i. Establish key performance indicators
   j. Measure performance against key performance indicators and review accordingly
   k. Develop mechanisms to review and modify overall surveillance strategy[1]
   l. Define national and regional reporting requirements
   m. Identify research needs

2. **Incursion response procedure and capability:** *To ensure the region has procedures and capabilities to undertake incursion response*[1]

   Specific actions:
   a. Review existing response systems globally
   b. Identify best practice and develop recommendations for response standard operational procedures
   c. Review existing regional response systems and capability and resources (includes funding for capability and for undertaking a response)
   d. Identify gaps in procedures and capabilities and investigate ways to fill them
   e. Ensure each country has a response plan based on the response standard operational procedures
   f. Raise awareness within countries/communities to ensure support during a response
   g. Develop recommended key performance indicators for response activities
   h. Establish reporting protocol on key performance indicators
   i. Develop a mechanism to review and modify response plan standard operational procedures and capability
   j. Define national and regional reporting requirements
   k. Identify research needs
   l. Clarify roles and responsibilities (regionally/nationally)

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[1] For the purposes of this prevention plan, incursion response refers to all management activities relating to an incursion, from eradication through to controlling spread on a regional, national or local level.

Jeremiah Kerinaiua spreading Amdro to eradicate *P. megacephala* at Nguiu. Bathurst Islands, Australia, 2003. *Photo courtesy of Ben Hoffman, Commonwealth Scientific & Industrial Research Organisation, Australia.*

3. **Regional public awareness strategy and programme:** *To implement and sustain a regional public awareness strategy and programme (include components of establishment and spread)*

   Specific actions:

   a. Determine the goal(s) and the target audience(s) are (e.g. policy makers, communities, border control staff, trade and tourism industry members, international, schools etc…)
   b. Develop common pool of resource material etc for regional/national use (e.g. photos, information, fact sheets, contact lists, school curriculum suggestions) (must be credible, factually correct and accessible)
   c. Agree on a regional coordinating person, body/agency
   d. Identify links with other successful complementary invasive species awareness programmes
   e. Develop communication plan/strategy (includes media and includes development of priorities at regional/national level, key performance indicators, review, modification of plan)
   f. Identify key contacts (spokesperson) within each country
   g. Identify resource requirements and potential sources
   h. Ensure awareness materials are developed to most effectively achieve the goal at regional, national, local level

4. **Research:** *To establish a regionally coordinated programme for identifying, prioritising and undertaking research*

   a. Establish a Pacific Advisory Group for Invasive Ants (PAGIA)[1]
   b. Establish lines of communication to ensure country research needs are captured by PAGIA
   c. Agree on a regional coordinating person, body/agency
   d. Identify availability, gaps, and sources of funding for research
   e. Define a mechanism by which research results are fed back out to region, individual countries etc (link into public awareness programme)
   f. Promote and facilitate annual publication of research agenda and deliverables
   g. Convene an annual workshop for research, extension and policy as primary mechanism for information dissemination and priority setting
   h. Undertake an annual review and reprioritisation of research needs
   i. Ensure that relevancy of research undertaken
   j. Establish links to the relevant international research networks
   k. Increase and utilise regional/local research capacity

Alapati Tavite examining a scale infested banana plant as a result of *Anoplolepis gracilipes* presence.
Photo courtesy of Phil Lester, Victoria University of Wellington, New Zealand.

5. **Review:** To establish a common regional process for review and revision of the Pacific Ant Prevention Plan and its implementation.

[1] The Pacific Advisory Group for Invasive Ants (PAGIA) will be responsible for reviewing current research, identifying gaps and prioritising needs.

Appendix 1

1. History of Red Imported Fire Ants as invaders

The red imported fire ant (RIFA), *Solenopsis invicta,* is native to the South American Pantanal region and to a lesser extent, the Cerrado (or tropical savanna) that surrounds it (Fowler *et al.* 1990). It is one of several related *Solenopsis* species native to the area (Taber 2000). RIFA's distribution at macro and micro scales appears to be regulated by competition from these related species as well as a suite of endemic predators and pathogens (Porter *et al*. 1997). Colonies of up to 500,000 workers have been recorded although around 150,000 is more usual (Oi *et al*. 1994).

RIFA were inadvertently transported to Alabama USA, perhaps via dumping of ballast soil by cargo ships trading between the two areas during the early 1900s (Lofgren *et al.* 1975; Vinson & Greenberg 1986; Callcott & Collins 1996; Vinson 1997). By 1937 the impact of fire ants on residents in invaded areas around Mobile, Alabama caused them to demand action. The first efforts to control RIFA were conducted the same year (Williams *et al.* 2001) and consisted of topical applications of cyanide and later chlordane. While providing effective local control of individual nests, fire ants continued to spread.

By 1958, quarantine measures were in place to regulate the movement of soil (Callcott & Collins 1996), several state funded research programmes had been established and US Congress had provided funding for a broad-acre eradication program (Williams *et al.* 2001). Initially, this programme consisted of aerial applications of granulated organochlorines (heptachlor and dieldrin). After several years of treatment, it became apparent that these pesticides were accumulating in meat and milk. They were subsequently replaced with a bait formulation containing another organochlorine (mirex), a soya oil attractant and an inert carrier of corn cob grits.

While largely successful at reducing the impacts of fire ants, these broad-acre programs did not eradicate them. Registration of mirex was cancelled on environmental grounds in 1977. A suitable replacement became commercially available in the 1980's. AC217,300 (hydramethylnon) sold as Amdro™, was first registered in 1980 and in the next 20 years became the mainstay of fire ant baits. Recent research has appeared to concentrate on a new class of insecticide, Insect Growth Regulators (IGRs). These generally have no toxic effects, rather they interfere with the reproductive capacity of the queen. Baits containing methoprene, pyriproxyfen fenoxycarb and avermectin have all recently entered the market. New products continue to be developed and formulated. Currently, baits containing fipronil are showing promising results and have recently been registered by the US EPA.

Regardless of the evolution of control methods between 1937 and the present day, RIFA have continued to spread across the USA. No apparent changes in the rate of invasion can be detected in the cumulative area of quarantined counties through time (Callcott & Collins 1996). Recently, RIFA were discovered in California (Williams *et al.* 2001; Klotz *et al.* 2002). They are also spreading through the West Indies (Davis *et al.* 2001), have been discovered in New Zealand (Pascoe 2002) and Australia (Nattrass & Vanderwoude 2001; Vanderwoude 2002a; Vanderwoude 2002b). The invasive potential of this pest within the USA has been obvious for many years but its potential as a global invader is only just becoming apparent.

2. Impacts of RIFA

2.1 Economic impacts of RIFA

In an urban and agricultural context RIFA favours open spaces with access to water (subterranean, rainfall or irrigation) where colonies may be found in densities from hundreds of mounds to thousands of mounds per hectare. In infested areas, they are common in residential lawns, pot plants, golf courses, industrial areas, school sports facilities, pastures and some tree crops. Fire ants also seem to be attracted to electrical fields and are frequently found in switch boxes, pump motors, and other electrical installations. Their presence in these items frequently leads to damage from short circuits.

In urban areas, RIFA are regarded as a nuisance largely due to their predisposition to sting humans and pets when disturbed. As a result, individuals and facility managers (golf courses, schools etc) will prophylactically treat open spaces in order to reduce or remove RIFA colonies. A secondary impact is the damage to external electrical installations such as air conditioners, swimming pool filters etc. In agricultural areas, RIFA mounds are an impediment to harvesting and damage machinery due to the nature of the mound itself. Furthermore they are responsible for stock losses (especially during birth), increased veterinary bills and increased repairs and replacement of electrical and irrigation equipment.

A recent comprehensive economic analysis of impact costs in Texas, USA (population approximately 20 million) concluded that the total annual economic costs to that state alone exceeded US$1.2 billion (Lard *et al.* 2002). Approximately 60 percent of this cost was borne directly by residential households for control and repair costs. Almost US$150 million is spent annually on repair and replacement of electrical and communications equipment, and US$90 million on agricultural losses.

Fire ant feeding on okra bud.
Photo courtesy of Bastiaan Drees, Texas Fire Ant Applied Research and Education Program.

Fire ant damage to base of corn plant.
Photo courtesy of Stewart, Texas Fire Ant Applied Research and Education Program.

A recent study on the potential economic impacts of RIFA in Australia estimated conservatively that the cost of uncontrolled spread of Red Imported Fire Ants in that country would amount to AUD$8.9 billion in the first 30 years (Kompas & Che 2001).

In New Zealand an estimate was undertaken of the potential economic impacts of the red imported fire ant in the North Island and upper South Island of New Zealand under minimal government intervention. Evaluation of selected impacts on households, infrastructure and agriculture suggests that, following range expansion and consolidation, the full annual costs of living with the red imported fire ant would be at least $318 million (New Zealand Ministry of Agriculture and Forestry, 2001).

2.2 Social impacts of RIFA

There are two direct social impacts on humans: a reduction in pleasure derived from outdoor activities and the medical impacts on individuals. In the United States, over 40 million people live in areas infested by *S. invicta*. Annually, 14 million people are stung and one quarter of these are expected to develop some sensitivity to RIFA toxin (Taber 2000). Deaths due to anaphylaxis have been recorded (Bloom & DelMastro 1984; Stablein *et al.* 1985; Rhoades *et al.* 1988; Levy *et al.* 1998; deShazo *et al.* 1999) but are relatively rare.

A survey of 1286 practitioners in South Carolina (USA) (population, four million), where fire ants are well established, estimated that annually over 33,000 people (94 per 10 000 population) seek medical consultation for RIFA stings, and, of these, 660 people (1.9 per 10,000 population) are treated for anaphylaxis (Caldwell *et al.* 1999). Direct extrapolation of these data to the Australian situation for example would suggest that about 140,000 consultations and 3,000 anaphylactic reactions are to be expected annually should Red Imported Fire Ants become established in that country.

Pustules, blisters formed following fire ant sting on arm.
Photo courtesy of Texas Fire Ant Applied Research and Education Program.

2.3 Ecological impacts of RIFA

S. invicta, has the potential to impact on other organisms through three primary pathways: direct predatory action, competition for the same resources, and interference with symbiotic relationships. This is particularly true for the polygenous form, where multiple queens occur within the same nest, due to competitive and survival advantages including increased production of workers and a lower risk of colony death as a consequence of queen mortality (see section 2.1). Within the range of *S. invicta* in southern USA, native ant populations have been replaced by the introduced species at ratios of up to 6:1 (Morrison 2000), with the increase in ant densities diverting resources from other invertebrate groups (Porter & Savignano 1990). The increased numbers of ants in an area is also likely to negatively affect native arthropods through increased predation. RIFA prey upon a wide range of invertebrates, and attack all life stages including eggs, larvae, pupae and adults (Stiles & Jones 2001).

Severe impacts on native vertebrate species have also been observed in the USA. Affected species include small rodents (Holtcamp *et al.* 1997) deer (Allen *et al.* 1997a), ground nesting birds (Allen *et al.* 1995; Giuliano *et al.* 1996; Pedersen *et al.* 1996), alligators (Allen *et al.* 1997b), and even sea turtles (Allen *et al.* 2001). Island ecosystems are likely to be far more vulnerable to biological invasions than mainland USA so it is likely that similar or greater impacts will be seen on Pacific Islands (e.g. crazy ants on Christmas Island).

Tricolor heron chick being attacked by fire ant workers.
Photo courtesy of Bastiaan Drees, Texas Fire Ant Applied Research and Education Program.

3. Impacts of other invasive ant species

3.1 ***Solenopsis geminata*** – tropical fire ant

Solenopsis geminata presents a serious threat to conservation values because it will invade native communities and affect many or all of the animals and plants in that community. Evidence has been presented of *S. geminata* reducing populations of native butterfly eggs and larvae on Guam (Sherley, 2000).

In its native range in the USA it causes injury to humans and domestic animals. *Solenopsis geminata* tend honeydew-producing homoptera, especially mealybugs. This increases the population size of these pests and the incidence of homoptera -vectored disease. It is also one of a number of ant species that damage plastic drip irrigation tubing by chewing new holes and enlarging the existing ones.

Numerous ants may attack a person when a colony is disturbed, and the average victim suffers multiple stings because each ant can administer several stings. The sting produces an immediate, intense pain followed by red swelling.

3.2 ***Anoplolepis gracilipes*** - yellow crazy ant

Anoplolepis gracilipes is a major environmental and agricultural pest, as well as a human nuisance in the tropics and subtropics.

Where densities are high, direct impacts can occur on native 'keystone' species and on species of special conservation value (including endemic reptiles, birds, and mammals). This can alter community structure and species composition, and affect ecosystem processes, including litter decomposition. Deletion of native keystone species by *A. gracilipes* can cause rapid state changes in native communities. Mutualism between *A. gracilipes* and honeydew-secreting homoptera can cause population outbreaks of these generalist herbivores and lead to canopy dieback. On Christmas Island in the Indian Ocean, secondary invasions of giant African landsnails (*Achatina fulica*) and shade-intolerant woody plants can follow invasion by *A. gracilipes*, further degrading native forests.

Red land crabs (*Gecarcoidea natalis*) killed as result of Yellow Crazy ants (*Anoplolepis gracilpes*) infestation on Christmas Island. *Photo courtesy of Dept. of Environment and Heritage, Christmas Island, Australia.*

In agricultural systems impacts are primarily indirect, through increased populations of homoptera insects on crops, although some believe that this ant benefits crop plants by deterring plant pests. *A. gracilipes* commonly nests at the base of plants, sometimes undermining crops such as sugarcane and coffee.

In some instances *A. gracilipes* is a household and village pest. Formic acid sprayed by the ants can cause skin burns and irritate the eyes of fieldworkers. In Tokelau people no longer sleep outside in some locations due to the foraging habits of this species (pers. comm. Lester 2004).

3.3 *Pheidole megacephala* – big headed ant

This ant is a serious threat to biodiversity because it displaces most native invertebrate faunas directly through aggression. Evidence also exists of reductions in vertebrate populations where this ant is extremely abundant.

Effects on plants and horticultural crops can be direct, for example seed harvesting, or indirect, such as harbouring phytophagous insects that reduce plant productivity. *P. megacephala* infestations are known to facilitate the invasion of introduced plant species.

P. megacephala is also known to chew on irrigation pipes, telephone cabling and electrical wires.

3.4 *Monomorium destructor* – Singapore ant

This ant displaces most native invertebrate fauna directly through aggression, and as such is a serious threat to biodiversity.

This ant is known to chew on telephone cabling and electrical wires, causing extensive and expensive damage. In the Tiwi Islands this ant causes damage worth approximately AUD$70,000 per annum, with a number of houses requiring complete rewiring.

It also is commonly associated with food preparation areas. *M. destructor* frequently stings people and the residents of the Tiwi Islands complain about having to co-exist with this species (pers. comm Hoffman 2003).

Singapore ant (*Monomorium destructor*) infested walls on Bathurst Island causing fire hazards.
Photo courtesy of Ben Hoffman, Commonwealth Scientific & Industrial Research Organisation, Australia.

3.5 ***Tapinoma melanocephalum*** – ghost ant

Documented impacts for *T. melanocephalum* are restricted to its effects on human health and its nuisance potential, as it is associated with human habitation and hospitals in particular. It can form very large infestations inside buildings and can be difficult to control.

Disease transmission is a real possibility, with up to 60% of ants carrying pathogenic bacteria (Campos-Farinha *et al.* 1995). In Florida, it is considered one of the worst of such ant pests. *T. melanocephalum* not only invades houses from outside, but they can nest in the house as well. Although the ant feeds upon many household foods it seems to show a preference for sweets, having been observed feeding on sugar, cakes, and syrups (Smith 1965). Outside, the workers scavenge for dead insects and tend sap-sucking insects, collecting honeydew (Ferster *et al.* 2002).

In Florida, USA, *T. melanocephalum* has infested quarantine greenhouses and proven impossible to control due to the restrictions imposed on the use of toxicants in these greenhouses. In Gainesville, USA, the ant preyed upon small beetle larvae and lepidopterous larvae from the cultures of insects in quarantine. In more northern areas, it has become established in heated greenhouses where it can become a problem, especially if it defends honeydew producing plant pests against introduced biological control organisms.

3.6 ***Solenopsis papuana***

Solenopsis papuana is widespread in Hawaii and often very abundant wherever it is established. It can be found from sea level to about 1,000 metres and does best in wet areas (>1250mm precipitation/yr) (pers. comm. Neil Reimer). It has the potential to be a very invasive species but ecosystem impacts are largely unknown. There are suspected deleterious impacts on other invertebrates based on the large numbers of individuals in established sites.

There are no recorded cases in Hawaii where this has been an agricultural or urban pest, but it has been recorded in association with macadamia trees in Hawaii. It appears to be restricted to undisturbed areas, including native forests (pers. comm. Neil Reimer).

3.7 *Paratrechina longicornis* – crazy ant

This ant is a common tramp internationally that often invades houses and heated buildings in temperate areas. It is a relatively large conspicuous species. It can transport pathogenic microbes in hospitals (Fowler *et al*. 1993), and at least in artificial environments is capable of displacing other ants (Wetterer 1999) and probably some other invertebrates.

3.8 *Wasmannia auropunctata* – little fire ant

In the neotropical lowland forests where it is native, *W. auropunctata* is often common, but does not normally dominate the biological community. However, in disturbed areas, such as agricultural and forestry land, and in exotic habitats, *W. auropunctata* commonly shows extreme population explosions. In many areas, *W. auropunctata* can be a significant agricultural pest, both stinging agricultural workers and enhancing populations of homopteran insects.

In addition, *W. auropunctata* has a direct negative impact on many animals, both invertebrates and vertebrates. *W. auropunctata* is blamed for reducing invertebrate species diversity and reducing overall abundance of flying and tree-dwelling insects. In Gabon, Africa, house cats (*Felis catus*) often have *W. auropunctata* in their fur, and several cats developed corneal clouding and blindness. On the Galapagos Islands, the ants attack the eyes and cloacae of the adult Galapagos tortoises (*Geochelone nigra*) and eat the tortoise hatchlings (pers. comm. J. K. Wetterer).

Many locals in the Solomon Islands report that their dogs (*Canis domesticus*) were all gradually blinded by the ants' venom. It has also been reported that hunting of pigs (*Sus scrofa*) in French Polynesia has been adversely affected as, hunting dogs are no longer able to hunt effectively due to vision impairment caused by the ants (pers. comm. Phil Lester)

Due to sting aversion, gardening practices and coco harvesting on the Solomon Islands have also been altered by the presence of *W. auropunctata*, causing gardeners to restrict any gardening activities until dusk when ant activity is minimal (pers. comm. Phil Lester).

3.9 *Linepithema humile* – Argentine ant

The Argentine ant is a pest species for various reasons. When introduced, it is typically predatory toward, and displaces, native invertebrate species, such as in Madeira (Stoll 1898), Australia (Majer 1994) France (Bernard 1983), South Africa (Donnelly, and Giliomee, 1985) the West Indies and Japan (Haskins and Haskins 1965). On the U.S. mainland, it has displaced native ants in Florida, Alabama, Louisiana and California (Newell 1908; Erickson 1972; Ward 1987).

In those areas where the ant infests agriculture, as in California and Florida, crops can be negatively affected due to the ants' habit of tending pest homopteran insect pests, such as Oleander aphids (Bristow 1991), California red scale, black scale and citrus mealybug (Markin 1969).

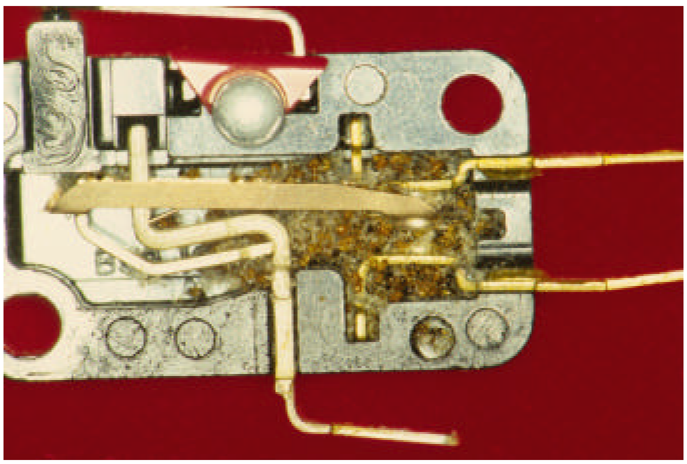
The ants also cause additional direct and indirect damage to crops by reducing predators of insect pests and feeding on the fruits and buds of citrus trees. In South Africa, they hinder beekeeping ventures by preying upon both immature and demoralized adult bees, stealing honey and competing for nectar resources (Buys 1990). Vespid wasps are vulnerable to ant predation as well. One California study found that 22 percent of all wasp nests observed were invaded by ants (Gambino 1990).

Established at high elevations on Mauna Kea, Hawaii, the Argentine ant overlaps its range with the endangered palila, a Hawaiian honeycreeper. It is speculated that the ant could become a potential danger to the bird due to competition for available insect prey and may limit the areas to which it can be successfully reintroduced (Wetterer *et al.* In prep.). Results of a survey of arthropods in ant and non-ant infested areas revealed that *L. humile* negatively impacts native species, including some native plant pollinators (Cole *et al.* 1992). The disastrous effects of ant presence were markedly worse at the higher elevation site, where its prey species exist in lower numbers and a larger percent of them are locally endemic (Cole *et. al.* 1992).

3.10 *Monomorium pharaonis* – Pharaoh ant

The Pharaoh ant is an indoor pest in many countries. This ant has the ability to survive most conventional household pest control treatments, and to establish colonies throughout a building. More than for just the food it consumes or spoils, this ant is considered a serious pest simply due to its ability for "getting into things." Pharaoh ants are reported to have even penetrated the security of recombinant DNA laboratories (Haack and Granovsky 1990).

In some areas, this ant has become a major pest of residences, commercial bakeries, factories, office buildings, apartments, and hospitals, along with other areas where food is handled. Infestations in hospitals have become a chronic problem in Europe (Erdos *et al.* 1977) and the USA. In Texas, Wilson and Booth (1981) reported an extensive infestation throughout a seven-floor medical centre. In ant-infested hospitals, burn victims and newborns are subjected to increased risk because the Pharaoh ant can transmit over a dozen pathogenic pathogens such as *Salmonella* spp., *Staphylococcus* spp., and *Streptococcus* spp. (Beatson 1977, Haack and Granovsky 1990, Smith and Whitman 1992). Pharaoh ants have been observed seeking moisture from the mouths of sleeping infants and from in-use IV bottles (Smith and Whitman 1992).



Pharaoh ants in an electrical switch mechanism. *Photo courtesy of Jim Kalisch, University of Nebraska, Dept. of Entomology.*

This ant infests almost all areas of a building where food is available and infests many areas where food is not commonly found. Pharaoh ants have a wide preference in the types of food consumed. In infested areas, if sweet, fatty, or oily foods are left uncovered for only a short period of time, one can likely find a trail of Pharaoh ants to the food. As a consequence, they cause much food to be discarded due to contamination. Owners have been known to consider selling their homes because of the ravages of this pest (Smith 1965).

3.11 ***Technomyrmex albipes*** – white footed ant

T. albipes is considered by homeowners to be a nuisance pest because it is frequently observed foraging in kitchens, bathrooms, and the exterior of buildings. Colony population estimates vary from 8,000 to 3 million individuals (Tsuji and Yamauchi 1994).

T. albipes feed on plant nectars and honeydew, which is a sweet substance produced by many sap-sucking insects such as aphids, mealybugs, and scale insects. *T. albipes* are known to protect honeydew producers, which has caused problems in agricultural production in some areas of the world. In Sri Lanka *T. albipes* are known to play a major role in spreading the pineapple wilt disease, due to their tending of the pink mealybug, *Dysmicoccus brevis* (Cockerell) (Sulaiman 1997). In South African citrus orchards, *T. albipes* caused localised outbreaks of red scale *Aonidiella aurantii* (Maskell) (Samways *et al.* 1982). Charles (1993) reported *T. albipes* tending mealybugs (*Pseudococcus longispinus*) in citrus and persimmon orchards.

4. Biology of Red Imported Fire Ants and other invasive ant species

Social insects such as bees, wasps, termites and especially ants are among the most successful of invasive organisms. It is not surprising that ants feature prominently on the World Conservation Union's (IUCN) list of the 100 of the world's worst invasive species (Lowe *et al.* 2000). Five of the eighteen terrestrial invertebrates listed are ants. A total of 149 ant species have been transported to parts of the world outside their native range (McGlynn 1999) but not all cause ecological damage.

Sociality is one of the factors that contribute to the success of ants as invaders. It bestows a number of unique mechanisms that enhance survival and invasion success. The extent to which sociality assists survival is substantial and includes such benefits as protection against predators (Hölldobler & Wilson 1990), organised resource exploitation, and buffering against environmental changes (Moller 1996, Davidson 1998).

Aside from sociality, invasive ants share other characteristics including, polygyny, or the tolerance of worker ants for more than a single queen within a colony; unicoloniality or the formation of large inter-connected super-colonies; high interspecific aggression; new colony formation by budding instead of nuptial flight; and dispersal via human commerce (Passera 1994, Jourdan 1997). This last feature has earned them the name "tramp ants" (Holldobler 1990).

4.1 Polygyny

Typically, an ant colony consists of a single reproductive female (the queen) attended by her daughters, which are sterile female workers. From time to time, winged (alate) males and females with functional ovaries are produced and these normally depart the nest to mate and initiate new colonies (Holldobler & Wilson 1990). Worker ants are able to distinguish individuals of their colony from those of other colonies of the same species ("kin recognition"), and will defend their territory from incursion by ants of the same species with the same degree of aggression as they would from incursion of their territory by a different species. This "kin recognition" is most probably pheromone (or odour) derived.

Polygynous or multiple queen colonies are another social form that occurs in a minority of ant species (Holldobler & Wilson 1990). The presence of more than one functional queen in a colony bestows it with competitive and survival advantages including increased production of workers and a lower risk of colony death as a consequence of queen mortality. The workers in these colonies are not all sisters, as is the case for monogyne colonies, because they are not daughters of a common queen. RIFA possesses both social forms. Polygyny in RIFA and other invasive ants appears to contribute to their invasive success. This is thought to be primarily due to higher densities, greater foraging activities and the associated strong interspecific aggression compared to the monogyne form.

The origins and the basis for polygyny are a much-debated topic among researchers in this field. The genetic variability of an invasive species is usually greater in its original home range than in its introduced range. This genetic bottleneck results in homogenisation of the invading population (Tsuitsui and Case 2001) and this may reduce the number of kin recognition cues present. As a result, workers of one colony might no longer regard workers of another colony as different and the barrier preventing the presence of more than one queen would be effectively removed (Porter and Savignano 1990, Davidson 1998). Additional factors contributing to the rise of polygyny for one invasive species include high colony densities achieved by invading ants in their new environment and the skewing of the operational sex ratio through the production of diploid males in polygyne ant populations (Ross *et al.* 1996).

However, in recent years a genetic basis for polygyny has been discovered for RIFA, and it is possible that this trait is genetically determined for other ant species also. RIFA has both monogyne and polygyne forms in both its home range in South America and in its introduced range in USA and Australia. Ross and Keller (1998) discovered that allele frequency differences of a protein-encoding gene (*GP-9*) accurately predict whether a queen is of the monogyne or polygyne type. Monogyne queens all have two “B” alleles and are thus coded $GP\text{-}9^{BB}$ while all polygyne queens possess a unique allele “b” at the same gene and are coded $GP\text{-}9^{Bb}$.

4.2 Unicoloniality

Invasive ants often form interconnected super-colonies, which may extend for many hectares. This unicoloniality is closely associated with the trait of polygyny and the lack of aggression exhibited by worker ants towards neighbouring colonies. Often, there is an exchange of individuals between nests (Passera 1994). In some cases, these super-colonies may extend over huge areas of many square kilometres and even entire states (McFarling 2002).

4.3 High interspecific aggression

While tolerant of neighbouring colonies of the same species, invasive ants behave very aggressively towards other ant species and any other species that are found within their foraging territory. As an example, Argentine ants frequently attack newly mated queens of heterospecifics and interfere with the establishment of new nests (Human & Gordon 1996). However, the most substantial interactions occur at or near food resources. Argentine ants monopolise food sources, which they actively defend from other ant species (Holway and Case 2001). As a result they are generally able to acquire the majority of resources to the detriment of competitors. Native ants in California abandoned food baits in the presence of Argentine ants (Holway 1998). Some ant species may permanently leave a site following several aggressive interactions (Human & Gordon 1996). This behaviour serves to reduce competition for resources and as a result, weaken any biotic resistance that might be present.

4.4 Reproduction by budding

For many ant species, mating occurs in the air as part of a synchronized mating flight of winged males and virgin queens. There are substantial risks associated with this activity and the colony founding process as the newly inseminated queens are exposed to predatory action, parasitism and attack from enemies (Keller 1995) in the search for a suitable habitat and their subsequent attempt at producing the first clutch of workers.

For invasive ant species, mating often occurs within the nest. Newly inseminated queens leave the natal nest on foot with a small group of attendant workers to form a new locus of the main nest. This process is called budding and carries with it a far lower risk of failure, because many of the causes of mortality, whilst in flight and during colony establishment, are eliminated. The queens are provided with the protection of the natal nest and there is a high likelihood that suitable nest sites will be found close to the original nest (Keller 1995). Through this process, the invasion locus can expand and fuse to form a dense population and a continuous invasion front (Porter *et al.* 1988) which is highly resistant to predatory forces.

5. Dispersal via human commerce

Dispersal of all tramp ant species is facilitated by human commerce. Colony fragments containing a fertile queen and enough workers to maintain a functional colony are carried with fresh produce, other cargo or in conveyances such as shipping containers, to new locations. This phenomenon is not new and has been going on for centuries. *Pheidole megacephala* was carried throughout the Pacific region, including Australia by ships carrying produce. It is no surprise that this species established so readily: as few as ten workers attending a single inseminated queen are sufficient to start a new invasion of this species (Chang 1985). In the 1890s, entomologists in Brisbane had observed that areas in the settlement where *P. megacephala* had established were no longer good collection sites for other invertebrates. Indeed,

> "*other kinds of ants vanish before them. They will quite exterminate the large communities of the "meat-ants" - Iridomyrmex and of Lasius spp. as well as of Formicidae, belonging to the genera Camponotus, Polyrhachis, Leptothorax, Crematogaster, Monomorium, etc. Even the "Green Head Ant," Ectatomma metallicum, that stings with such virulence forms no exception in this respect."* (Tryon 1912)

Some islands such as Bermuda, which was invaded by *P. megacephala* in the early 1900s, were subsequently invaded by *Linepithema humile* (the Argentine ant) (Haskins & Haskins 1965) which then displaced the original invader. As commerce and human movement across the globe has increased, so have opportunities for tramp ants to disperse. Further invasions by other tramp species are inevitable but can be minimised by implementation of appropriate biosecurity measures.

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Attending the workshop were international invasive ant specialists, conservationists and policy analysts representing various agencies/organisations (please see list below).

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