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Biosecurity Plan for Invasive Ants in the Pacific Region

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13.1 Introduction

The Pacific Ocean is home to around 30 000 islands, over 22 jurisdictions and the US state of Hawai'i. With a total population of less than 10 million people and a total area of 376 000 mile^2, it is larger than all other land masses on the planet combined. Its large size, relatively small economy, and complex socio-political structure combine to present unique challenges for the region.

In 2004, the Invasive Species Specialist Group of the International Union for the Conservation of Nature published the Pacific Ant Prevention Plan (PAPP) (IUCN/SSC Invasive Species Specialist Group, 2004) in response to regional concerns with the entry and proliferation of invasive ants such as the Red Imported Fire Ant. In the 15 years that followed, these concerns have increased and now include a regional desire to also manage the impacts of existing high impact ant species. This document, The Biosecurity Plan for Invasive Ants in the Pacific Region (BPIAPR), is a logical evolution of the PAPP.

Invasive ants are one group of organisms that have the potential to cause substantial impacts to ecosystems, economies, and human health. Most Pacific islands have not evolved native ant communities, and their ecological environments are naive to invasive ants (Wilson and Taylor 1967a,b). The impacts of invasive ants are often more far-reaching than at other locations, threatening not only delicate and complex island ecosystems, but the livelihoods and well-being of island communities. In the face of climate change, invasive ants will likely further reduce the resilience and food security of subsistence economies.

Some Invasive ants such as the Yellow Crazy Ant (*Anoplolepis gracilipes*) are widespread in the Pacific region. Their impacts elsewhere include complete ecological "meltdown"

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* Retired.

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such as that observed on Christmas Island in the Indian Ocean (Green et al. 2011). Predation on the indigenous red land crab in tandem with mutualisms with sap sucking insects has caused severe canopy decline and large changes to the seedbank. In other locations, such as Johnston Atoll, seabirds are unable to nest and rear young due to continual bites and predation of hatchlings (Peck et al. 2015). Episodic population explosions of Yellow Crazy Ants over-run entire islands, causing massive nuisance to people and animals (Nishida and Evenhuis 2000; Lester and Tavite 2004; Gruber et al. 2018).

The Little Fire Ant (*Wasmannia auropunctata*) is spreading rapidly through the region. This species forms massive three-dimensional supercolonies which blanket the ground layer and the forest canopy (Vanderwoude et al. 2010, 2016; Fasi et al. 2013). They sting residents, cause blindness in domestic and wild animals (Theron 2005), impede agricultural activities, and reduce forest and agricultural productivity. This species continues to spread across the Pacific with little regard for international and domestic borders.

The Red Imported Fire Ant (*Solenopsis invicta*) and the Tawny Crazy Ant (*Nylanderia fulva*), while not yet present in the region, both have the potential to cause devastating impacts to Pacific islands. The threats presented by these species are ever-present. The Red Imported Fire Ant is now present in several countries in the Pacific Rim, including China, the United States, Australia, Korea, and Japan. Some of these countries are significant trading partners with Pacific nations and territories. Even the rigorous biosecurity systems of Australia and New Zealand have been unable to exclude Red Important Fire Ants (Wetterer 2013; Spring and Kompas 2015). The Tawny Crazy Ant is spreading rapidly through south-western USA and threatens to be yet another invader in the region.

The potential threat of invasive ants to the region was highlighted in early 2001 when the Red Imported Fire Ant (*Solenopsis invicta*) was discovered in both Australia and New Zealand. The New Zealand incursion was localized (one large nest), treated, and followed by a comprehensive surveillance effort which confirmed eradication from the country (Harris and Barker 2007). Two subsequent incursions were also eradicated (Ward et al. 2006; Sarty 2009; Christian et al. 2010). A much larger infestation was detected in Brisbane, Australia. AUD 123 million, a five year, AUD $123 million eradication program began in 2001 to combat an infestation that initially covered over 40 000 ha (Vanderwoude et al. 2004). After 19 years, Red Imported Fire Ants are still present in Australia despite an investment of over AUD $300 million, highlighting the difficulty and immense cost of eradication over large areas (Spring and Kompas 2015). During this time, six separate incursions have been documented, with some successful local eradications (Donaldson 2016; Wylie et al. 2016).

These invasions demonstrate how easily invasive ants are able to move into the region, even to countries with world-class biosecurity systems and highlights the importance of surveillance to enable early detection and rapid response while eradication is still feasible and costs to eradicate are relatively low. Smaller nations in the Pacific region currently do not have the same levels of resources to apply to biosecurity. Meetings in the Cook Islands (2002 Global Biodiversity Forum) and Honolulu (2002 Global Invasive Species Program workshop) further highlighted this issue to policy makers in the region.

The IUCN Invasive Species Specialist Group convened a workshop in 2003 with the aim of developing a regional plan to combat the threats of new introductions and to mitigate the impacts of existing invasive ant species in the region. This meeting, held in Auckland during September 2003, resulted in the compilation of a PAPP in 2004 that encompassed

RIFA and other exotic invasive ants with documented negative impacts. This plan was presented and endorsed at a subsequent meeting of the Pacific Plant Protection Organization (PPPO) and the Secretariat of the Pacific Community (SPC) agreed to be the lead agency in implementing the plan. While some elements of the plan have been addressed in the years since, by various groups, these efforts have been largely uncoordinated.

In the years since the original 2004 Pacific Ant Prevention Plan was drafted, the invasive ant species landscape in the Pacific region has changed considerably. The Little Fire Ant (*Wasmannia auropunctata*) has emerged as the most devastating ant species in the region. In 2003, this species was confined to the Solomon Islands, New Caledonia, the outer islands of Vanuatu, and had just been detected on Hawai'i island and Tahiti. From that time to the present (2020), it has spread to Papua New Guinea, French Polynesia (Moorea, Rurutu islands), Vanuatu (Espiritu Santo and Efate), the Federated States of Micronesia, Hawai'i (Oahu, Kauai and Maui), Australia, American Samoa, Fiji, and Guam. Red Imported Fire Ants continue to be detected – on two occasions in New Zealand, and in Australia (Sydney and Gladstone), as well as another new incursion in Brisbane (Donaldson 2016). Impacts from sporadic, eruptive infestations of Yellow Crazy Ants (*Anoplolepis gracilipes*) are often observed around the Pacific, including Tokelau (Lester and Tavite 2004; Gruber et al. 2018), Johnston Atoll (Peck et al. 2015), Hawai'i (Reimer 1994), and elsewhere (O'Dowd and Green 2009). Additionally, Singapore Ants (*Trichomyrmex destructor*) continue to spread within the Republic of Palau (Olsen and Miles 2005; Wetterer 2009) and elsewhere throughout the region. More detailed information on the current distribution of invasive ants may be found online (Gruber et al. 2017)

13.2 What Makes Invasive Ants "invasive"?

Social insects such as bees, wasps, termites, and especially ants are among the most successful invasive organisms. Over 140 ant species have been transported outside their native range (Wetterer 1997; McGlynn 1999). Of these, a dozen or so stand out as species that cause widespread environmental, economic, or social impacts (Holway et al. 2002; Kirschenbaum 2007; Bertelsmeier et al. 2015). It is not surprising therefore that ants feature prominently on the World Conservation Union's (IUCN) selection of 100 of the world's worst invasive species (Lowe et al. 2000). Five of the 18 terrestrial invertebrate species on this list are ants.

Sociality is one of the key factors that contribute to the success of ants as invaders. It bestows a number of unique mechanisms that enhance survival and success. The extent to which sociality assists survival is substantial and includes such benefits as group protection against predators (Holldobler and Wilson 1995), organized resource exploitation (Rowles and O'Dowd 2007), aggressive colony defense (Bertelsmeier et al. 2015), and buffering against environmental changes (Moller 1996). In addition to sociality, invasive ants share a suite of other characteristics which set them apart from non-invasive ant species (Passera 1994). These characteristics enhance their ability to survive and thrive in new habitats and include:

- Polygyny or the presence of multiple queens within a colony (Holldobler and Wilson 1977),
- The formation of large interconnected supercolonies (Chen and Nonacs 2000),
- High levels of aggression toward other ant species (Kirschenbaum and Grace 2007)

- Colony formation by budding instead of nuptial flight (sociotomy) (Holldobler and Wilson 1977);
- Frequent dispersal via human commerce (Mack et al. 2000), and
- Formation of symbiotic relationships with common plant pests such as mealybugs, plant hoppers, and aphids (Way 1962).

13.2.1 Polygyny

Typically, an ant colony consists of a single fertilized female (the queen) attended by her daughters, which are sterile female workers. Winged (alate) males and females with functional ovaries are produced seasonally, and these normally depart the nest to mate and initiate new colonies (Holldobler and 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 mostly pheromone (or odor) derived.

Polygyne or multiple queen colonies are another social form that occurs in a minority of ant species (Moller 1996) and in virtually all invasive ones. The presence of more than one fertile queen in a colony bestows it with competitive and survival advantages including increased production rates 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 (single queen) colonies, because they are not daughters of a common queen. Many invasive ant species are polygyne in their invaded ranges yet monogyne in their native range, suggesting this character is selected by, or a consequence of the invasion process.

An extreme example of polygyny can be found in the case of the Little Fire Ant (*Wasmannia auropunctata*). In its invaded range, this species forms three-dimensional supercolonies with extraordinary densities of more than 220 million individuals per hectare (Souza et al. 2008). The mean worker–queen ratio in these populations is around 400 : 1 (Ulloa-Chacon and Cherix 1990) which means there can be as many as 550 000 queens per hectare. High queen densities confound efforts to control this species because even a small number of surviving queens allows populations to recover from treatment in a few weeks.

13.2.2 Supercoloniality

Invasive ants often form interconnected supercolonies, which may extend for many hectares. This "supercoloniality" is closely associated with the trait of polygyny and the lack of aggression exhibited by worker ants toward neighboring colonies. Often, there are frequent exchanges of individuals, larvae, and food resources between nests (Passera 1994). This offers many advantages to invading ants. The greatest advantage is the reduction in energy expended defending territory. Interconnected colonies only need to defend the outer borders of jointly held territory. The energy saved by this can then be devoted to increased foraging, for example, allowing greater rates of colony expansion. In some cases, for example Argentine Ants (*Linepithema humile*), supercolonies may extend over huge areas of many square kilometers and even entire cities (Suhr et al. 2009).

13.2.3 High Interspecific Aggression

Of the invasion by the Big Headed Ant (*Pheidole megacephala*) in Australia, Tryon (1912) wrote:

> *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)

Invasive ants behave very aggressively toward other species that are found within their foraging territory, including ants of other invasive species. As an example, Argentine ants frequently attack newly mated queens of other ant species and interfere with the establishment of new nests (Human and Gordon 1996). However, the most substantial interactions occur at or near food resources. Argentine ants monopolize food sources, which they actively defend from other ant species (Holway 1999). In California, this causes some native ants to abandon food sources and some species permanently relocate following several aggressive interactions (Human and Gordon 1996). As a result, Argentine ants are able to acquire the majority of resources to the detriment of other species, reduce competition for resources, and weaken any biotic resistance that might be present.

13.2.4 Reproduction by Budding

For many ant species, mating occurs in-flight as part of a synchronized mating flight of winged males and virgin queens, after which newly fertilized queens normally land and attempt to start a new colony. There are substantial risks associated with this activity as the newly inseminated queens are exposed to predatory action, parasitism and attack from enemies (Holldobler and Wilson 1990) in the search for a suitable habitat and their subsequent attempt at producing the first clutch of workers.

For some invasive ant species, mating can occur within or very near the nest and may or may not be in-flight. Newly inseminated queens rejoin the parent nest, sometimes leaving on foot with a small group of attendant workers to form a new locus of the main nest but remaining connected to the parent nest. This process is called budding and carries with it a far lower risk of failure, because many of the causes of mortality, while 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 (Rao et al. 1991). Through this process, the invasion locus can expand and fuse to form a dense population and a continuous invasion front (Porter and Savignano 1990) which is highly resistant to predatory forces.

13.2.5 Dispersal Via Human Commerce

Long range spread of invasive ants is often facilitated by human commerce. Colony fragments containing a fertile queen and enough workers to maintain a functional colony are carried with cargo or in conveyances such as shipping containers, to new locations. This phenomenon is not new and has its origins as early as the 1600s when Spanish galleons traded between the Philippines and Mexico (Gotzek et al. 2015), bringing with them Tropical Fire Ants (*Solenopsis geminata*). The Big Headed Ant *Pheidole megacephala* was carried throughout the Pacific region in the 1800s, including Australia by ships carrying produce. It is no surprise that this species established so readily: as few as 10 workers attending a single inseminated queen are sufficient to start a new invasion of this species (Chang 1985). The Hawaiian archipelago contains no native ants (Reimer et al. 1990), yet over 50 ant species have arrived and established since European contact (Lee et al. 2015).

Not all long-distance dispersal events are accidental or a consequence of shipping. The Little Fire Ant, for example, was deliberately introduced as a biological control of pests in plantations in west Africa (Ndoutoume-Ndong and Mikissa 2007), the Solomon Islands (Ikin 1984), most likely Florida (Wheeler 1929), and New Caledonia. There is also ample evidence that Yellow Crazy Ants were used as biological control in agriculture (Department of Education Papua New Guinea 1988).[1]

13.2.6 Symbiotic Relationships with Plant Pests

Many Hemiptera (scales, mealybugs, whiteflies, aphids, and planthoppers) are serious plant pests. They feed on the sap of target plants and use this as a source of nutrition. Many of these insects benefit from the presence of ants. Some ant species "farm" hemipteran species, protecting them from predators and parasites and moving them to good feeding locations. In return, the ants harvest honeydew from these species, a liquid rich in sugars. The combination of ants and hemipterans can be devastating to plant health.

Although not a trait exclusive to invasive ants, invasive ants are accomplished farmers of Hemiptera (Helms and Vinson 2002), and this contributes to invasive ant populations reaching much higher densities than the ants they replaced (Helms and Vinson 2008), sometimes by a factor of 6 : 1 (Morrison 2016). The Red Imported Fire Ant for example does not often forage on plant foliage; however, it is widely associated with root mealybugs (Helms and Vinson 2002). The Yellow Crazy Ant is able to completely change the structure of forests it has invaded through novel mutualisms. On Christmas Island in the Indian Ocean, this ant feeds on the red land crab (the major detritivore) as well as tending Hemiptera in the forest canopy (Neumann et al. 2016). The combination of two introduced species in a mutualistic relationship is so strong that it caused the "meltdown" of the entire ecosystem (O'Dowd et al. 2003; Green et al. 2011). The Little Fire Ant often tends common plant pests in native forests and agriculture (Delabie and Cazorla 1991; de Souza et al. 1998; Fasi et al. 2013) as does *Pheidole megacephala* (Bach 1991; Jahn and Beardsley 1994; Taniguchi et al. 2005).

13.3 The Biosecurity Plan for Invasive Ants in the Pacific Region

The Biosecurity Plan for Invasive Ants in the Pacific Region is intended for use by all island nations, states, and jurisdictions within the Pacific region: American Samoa, Australia, Cook Islands, Federated States of Micronesia (FSM), Fiji, French Polynesia, Guam, Hawai'i, 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.

The plan has six main objectives:

- Prevent the entry of invasive ants into the Pacific region and prevent their subsequent spread to new locations within the region,
- Implement an efficient and effective early detection and incursion response system for invasive ants that operates at regional, jurisdictional, and island scales,
- Mitigate the impacts of priority invasive ants already present in the region,
- Increase awareness of invasive ant issues and increase the level of public, community and legislative cooperation,
- Enhance capacity for invasive ant biosecurity and management, and
- Develop an active research program that provides practical improvements in detection and management of invasive ants.
  a) Actions needed to prevent the entry and establishment of invasive ants
     i) Legislation
        - Identify existing legislation, policy, and standards which support regulatory activities.
        - Ensure the measures under this Plan fit within existing legislation or are considered during development of new legislation.
     ii) Risk analyses
        - Identify the most appropriate international risk assessment framework and adapt this framework to be appropriate for use in the region.
        - Periodically conduct risk assessments to identify invasive ant species likely to pose the greatest threat in the Pacific.
          - Collate up-to-date biological, ecological, and distribution information to assist with risk identification.
          - Collate up-to-date information on trade pathways and trade volumes into and within the region.
          - Produce a regional and country-specific analysis of factors to estimate risk of establishment.
          - Review information on known and potential economic, environmental and social impacts as they apply to the region.
        - Engage trade support agencies within each jurisdiction and make risk assessments available to them, encourage multilateral negotiators to consider these at regional level.
     iii) Operations
        - Through the adoption of a risk management approach, prioritize invasive ant risks at the border and develop and implement risk reduction practices to address these.
        - Develop best-practice operational systems that are appropriate for jurisdictions within the Pacific region.
        - Assess current capacity (including funding access and needs) for implementation of best-practice operational systems for each jurisdiction and support actions that increase jurisdictional capacity.
        - Review and audit operational systems at regular intervals.

b) Actions needed to implement an efficient and effective early detection and response system.
   i) Early detection
      - Use risk analyses to identify high risk surveillance sites (i.e. arrival entry points and unloading facilities).
      - Collate baseline information on invasive ants currently present in countries and territories.
      - Develop uniform standard operational procedures for surveillance.
      - Identify gaps in capacity, capability and resources and investigate ways to fill them.
      - Develop communication and data sharing protocols and mechanisms.
      - Develop mechanisms to review and modify overall surveillance systems strategy.
      - Define national and regional reporting requirements and protocols for new invasive ant detections.
   ii) Incursion Preparedness
      - Ensure stores of equipment, supplies, and approved chemicals are immediately available for use in the event of an emergency response.
      - Develop a network of persons with expertise both within jurisdictions and the region.
      - Ensure sufficient funding is available in the event of an emergency response.
      - Identify training and capability shortfalls and develop learning packages to fill these gaps.
   iii) Emergency response procedures
      - Develop emergency incursion response plans for priority invasive ant species that are appropriate for jurisdictions within the Pacific region.
      - Establish national and regional reporting protocols for new detections.
      - Conduct regular incursion simulations to test incursion response plans and support systems.
      - Develop a mechanism to review and modify standard operating procedures as new methodologies become available.
   iv) Within-region sources of taxonomic expertise
      - Encourage the development of insect collections, herbaria, and taxonomic personnel within colleges, universities, and biosecurity agencies within the region.
      - Foster taxonomic personnel within the region and provide opportunities for professional development and interaction with colleagues worldwide.

c) Actions needed to mitigate the impacts of invasive ants already present in the region
   i) A prioritized list of species targeted for ongoing management
      - Compile a prioritized list of existing invasive ant species at regional, jurisdictional and island levels.
      - Develop management plans for high-priority species at regional and jurisdictional levels.
   ii) Availability of equipment, supplies, approved chemicals, and trained staff to address ongoing management

- Ensure a supply of equipment and supplies to manage existing species is available to jurisdictions
- Develop and implement training packages for managers.
- Encourage country or island specific mitigation projects that utilize outside expertise to include training components for in-country personnel.

iii) Development of within-region ant management expertise
- Foster the establishment of a regional network of practitioners with ant management skills and capability.
- Develop strong links between practitioners and the applied research community.
- Provide professional development opportunities for within-region practitioners including collaboration interaction with colleagues worldwide.

d) Actions needed to increase awareness of invasive ant issues
  i) Develop a common pool of resource materials for regional/national use (e.g. photos, information, fact sheets, contact lists, school curriculum suggestions).
  ii) Agree on a regional coordinating body/agency.
  iii) Identify links with other successful complementary invasive species awareness programs
  iv) Develop a communication plan.
  v) Identify key contacts (spokesperson) within each country.
  vi) Identify resource requirements and potential sources.
  vii) Ensure awareness materials are developed to most effectively achieve the goal at regional, national, and local levels.

e) Actions needed to enhance capacity for invasive ant management
  i) Establish a network of researchers who focus on invasive ant management.
  ii) Select a regional coordinating person, body/agency.
  iii) Convene regular workshops to disseminate results and prioritize research needs that include practitioners, extension personnel, and policy staff as a mechanism for information dissemination and priority setting.

f) Actions needed to develop an active research program
  i) Develop a list of research needs prioritized by practitioners and stakeholders within the region.
  ii) Identify availability, gaps, and sources of funding for research.
  iii) Establish clear dissemination pathways for research results.
  iv) Facilitate annual publication of research agenda and deliverables.
  v) Convene regular workshops to disseminate results and prioritize research needs that include practitioners, extension personnel, and policy staff as a mechanism for information dissemination and priority setting.

13.4 The Case for a Regional Approach

Pacific island nations and jurisdictions have a common interest in preventing the entry of invasive ants and other invasive species. As demonstrated by the relentless spread of *Wasmannia auropunctata*, invasive ant species that enter the Pacific region will invariably be introduced to nearby jurisdictions through the movement of people and cargo. Thus, it is in every jurisdiction's interest to prevent the entry of new invasive species to the entire region.

Existing control and eradication methodologies for invasive ants, including choice of pesticide, application equipment, schedule, delimiting, and post-treatment monitoring, are often not successful (Hoffman et al. 2011) or untested in island ecosystems (Stanley 2004). Additionally, these methodologies are often species-specific or work in one location but not others. They are also often species-specific and can require a degree of technical ability not easily learned from written instructions. Application equipment can also be costly or not easily procured. The availability of technical specialists and equipment within the region would do much to alleviate these barriers.

One way of addressing this shared stake in the regional status of invasive ants is through collaborating in efforts to prevent and manage the entry of these species. The average per capita gross domestic product (GDP) of small Pacific nations is approximately one tenth of the developed world (International Monetary Fund 2020), and implementing some aspects of this plan would be beyond the economic reach of many jurisdictions individually, but may be possible if jurisdictions worked cooperatively to implement this plan.

Central to implementation of this plan is a broad consensus from Pacific nations to implementation, appointment of a regional coordinator, and funding to ensure the longevity of the program. As several CROP agencies are tasked with coordinating biosecurity and these types of activities in the region, it makes sense that the coordination role is also undertaken by them. Key candidates are SPREP (whose mandate is invasive species), and SPC, whose mandate is biosecurity. Recently, SPREP initiated a permanent Pacific Regional Invasive Species Management Support Service (PRISMSS), with SPC as a founding partner, but which welcomes participation by all parties with the common goal of practical action to prevent and manage invasive species throughout the Pacific.

A regional, coordinated approach to biosecurity focussing on a single taxa group is not new to the region. The Pacific Fruit Fly Programme, for example, was established in 1989 (and ran for more than a decade). This programme was sponsored by the Australian Government, the United Nations Development Programme (UNDP), and New Zealand Government and executed by the SPC and implemented by the Food and Agriculture Organization of the United Nations (FAO), in conjunction with the national governments. The aim of this programme was to enhance production and export of fresh fruits by managing fruit flies and hence, improving farmers' incomes, food security, and rural employment. The programme was successful not only at building in-country capacity for the prevention and management of fruit flies across the region but more importantly getting the countries/territories themselves to take the lead on this issue and institutionalizing best practices for the prevention and management of fruit flies within mandated authorities. This is what we are aiming to achieve for invasive ants through the implementation of the BPIAPR.

Note

1 These attempts at biological control should not be confused with the science of biocontrol where all possible precautions are taken before release of any organism.

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